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ECONOMIC AND COMMUNITY BENEFITS OF LOCAL BUS TRANSIT SERVICE (PHASE ONE)

Final Report

August 4, 2009

HDR | Decision Economics

ECONOMIC AND COMMUNITY BENEFITS OF LOCAL BUS TRANSIT SERVICE (PHASE ONE)

FINAL REPORT

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1. INTRODUCTION

In its continuous effort to foster better governmental decision making and planning for public transportation, the Michigan Department of Transportation (MDOT) has commissioned HDR Decision Economics (HDR) to develop a model to estimate the economic and community benefits of local bus transit service. This model will be used by various stakeholders at the local, regional and state levels.

The study relies on a comprehensive literature review, and a detailed methodology developed by HDR on behalf of the Federal Transit Administration (FTA) and other state agencies. Overall, the benefits of public transportation stem from: *(i)* its ameliorative effects on traffic congestion and transportation costs; *(ii)* its significant effect on improving people's mobility; and *(iii)* its positive impact on regional economic development. In addition to these benefits, the re-spending of out-of-pocket savings by transit riders, and the on-going operation of transit systems contribute to the economy activity.

This report contains the following elements: key findings of the literature review on the benefits of public transportation; the methodological framework for estimating these benefits; and a discussion of the model characteristics requested by MDOT.

1.1 Study Objectives and Process

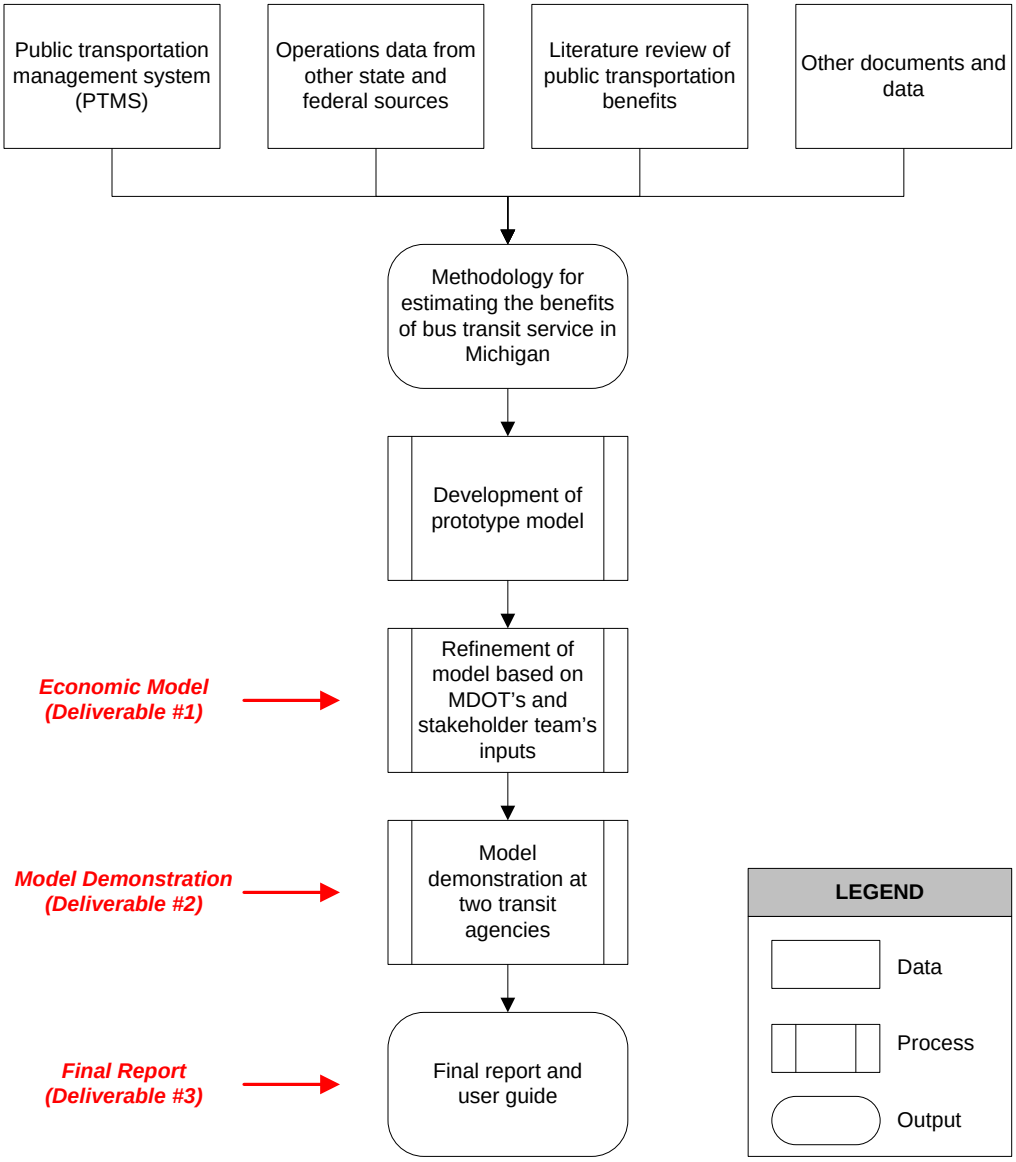
The study consists of two phases: Phase One focuses on the development of an economic model to measure the economic and community benefits of local bus transit service in Michigan; Phase Two deals with the implementation of the model at a sample of representative agencies in Michigan, and the actual assessment of benefits at the local, regional and state levels.

More specifically, Phase One comprises six key objectives:

- Identify the various benefits of public transportation based on a review of the literature;
- Design a methodology to estimate the various benefits of providing local bus transit service in Michigan;
- Use operations data reported by Michigan transit agencies in the Public Transportation Management System (PTMS);
- Develop a spreadsheet-based model capable of estimating transit benefits that can be used and updated independently by various decision makers at the local, regional and state levels (Deliverable Number One);
- Test the model in two transit agencies, one urban and one non-urban (deliverable Number Two); and
- Document the study findings in a final report (Deliverable Number Three).

Figure 1, on the following page, illustrates the general process followed by HDR for Phase One of the study. The flowchart shows both the deliverables mandated by MDOT, and the different steps to arrive at these deliverables.

Figure 1: Study Process (Phase One)



1.2 Guiding Principles

HDR's approach to developing a model capable of assessing the transit benefits recognizes a number of principles, or pillars, upon which the accuracy, credibility, and usefulness of any economic assessment rest. These guiding principles are summarized below.

- *Account for all positive and negative effects of public transportation* – Positive effects are treated as benefits (or cost savings), while negative effects are treated as costs in the

model. For instance, diesel powered buses are known for emitting more nitrogen oxides than cars.

- *Assess the "incrementality" of benefits* – In accordance with this principle, the model measures the incremental cost savings associated with individuals switching from personal vehicles (and other less affordable transportation modes) to public transit.

- *Avoid double-counting* – Benefits should not be estimated more than once. This is important because the economic value of some effects can arise in more than one category.

- *Acknowledge the uncertainty surrounding model assumptions* by constructing the model within a risk analysis framework, and thereby providing model users with the full spectrum of potential outcomes in lieu of single point estimates.

1.3 Plan of the Report

Five chapters, including this introduction, form the basis of this report. Chapter 2 presents the findings of a comprehensive literature review on the benefits of public transportation. The methodology employed for estimating the benefits of local bus transit in Michigan is discussed in Chapter 3. The economic model developed by HDR is described in detail in Chapter 4.

The report also includes a number of appendices. Appendix A and Appendix B contain the preliminary model results for the Interurban Transit Partnership and the Isabella County Transportation Commission, respectively. A primer on risk analysis is provided in Appendix C. References and data sources used during the course of the study are listed in Appendix D.

2. LITERATURE REVIEW

This chapter presents the findings of the literature review on the benefits of providing public transportation services. After a brief introduction, the materials reviewed are divided into four sections: mobility and cross-sector benefits (Section 2.2.1), congestion management benefits (Section 2.2.2), economic development benefits (Section 2.2.3), and methodologies (Section 2.2.4).

2.1 Overview

Public infrastructure, in general, provides a basic foundation for economic activity. The location and level of public investments can enhance both the well being of a community as a whole, and the opportunities available to its members. There are, however, costs and benefits to any investment in public transportation. To better direct the magnitude, timing, and location of public transportation investments it is necessary to understand the social, economic, and environmental costs and benefits of these investments on different industries, and segments of the population.

There are many testimonies supporting the growth of demand for public transportation, and the supply of funding for these projects. According to research conducted by the American Public Transportation Association (APTA), public transportation ridership increased by 25 percent from 1995 to 2005 (APTA, 2007); this growth is higher than the 11 percent increase in the U.S. population and greater than the 22 percent growth in use of the nation's highways over the same period. As William Millar, president of APTA, stated: *"More and more people are riding buses, commuter trains, subways and trolleys, and America's changing demographics means this trend will continue."* He added, *"We must make the necessary investment in state-of-the-art transit technology today, if we hope to meet the increasing demand tomorrow."*[1]

Safe, reliable and cost-effective public transportation is important for all citizens across the nation, not just for those who live in big cities. Transit systems help relieve the pressure on highway and road systems, reducing congestion and travel time. Intermodal linkages among different transportation modes also provide more choices for riders.

2.2 Transit Benefit Studies

From federal government agencies to local community organizations, many institutions sponsor or conduct transit benefit studies. Many of the studies highlight the benefits of reduced traffic and low-cost mobility effects that enable people to move from welfare to work.

In a 2002 report prepared for the National Cooperative Highway Research Program (NCHRP), Cambridge Systematics, Inc. (Cambridge, 2002) identifies a range of benefits associated with public transportation. These benefits include:

- Increase mobility and access;
- Provide a greater choice of travel modes;

[1] American Public Transportation Association, *News Releases*, "Transportation Secretary Mineta Proposes Increased Funding for Public Transit Infrastructure," October 2, 2002.

- Improve safety;
- Enhance the visual appearance of communities, cities, and natural landscapes; and
- Bolster community cohesion.

Local community organizations also take the initiative to publicize the transportation needs of lower-income segments of the population. For instance, a study led by the Transportation and Land Use Coalition (2002) document the poor state of the public transportation system in Southern California and the need for immediate action.

For the most part, research focuses on the following three benefit categories:

- **Low-Cost Mobility Benefits** – These are the benefits of providing low-cost mobility to "transit-dependent" as well as "choice" riders.[2] The benefits include: *(i)* income from employment, which is made at minimum more convenient by transit; *(ii)* the economic value of access to services, such as healthcare, education, shopping, and attractions; and *(iii)* budget savings for welfare and social services due to the presence of transit.
- **Congestion Management Benefits** – These are the benefits resulting from a reduction in vehicle ownership and operating cost (VOC), shorter travel time, fewer accidents, and lower environmental emissions due to less congestion and fewer miles traveled by personal vehicles. These resource savings mean greater disposable household income for other purposes.
- **Economic Development Benefits** – Proximity to rail transit can have a positive effect on residential property values and commercial activities due to the increased availability of travel opportunities and ease of accessing residential and commercial centers by transit.

Some studies attempt to measure the different benefits listed in all three categories, while other studies focus on one or a few of the benefits within a category. Each of these benefits plays an important role in magnitude, location, and timing of transit sector investments. Different types of benefits, however, require different evaluation methods. Some of the most pronounced benefits are relatively difficult to measure. As a result, conventional planning practices may undervalue public transit by considering just a portion of total potential benefits.

2.2.1 Low-Cost Mobility Benefits

Though the goals of public transportation are many and may differ from one area to another, they typically boil down to maximizing the mobility of a community. Public transportation provides mobility for millions of Americans to access jobs, health care, education, and other social services. It is a vital link for seniors, the disabled and children. Public transportation brings to the table a choice of travel modes, increased economic opportunities, and savings for human services programs. These services have an effect on public health in ways that are not necessarily obvious by reducing energy consumption, reducing deaths and injuries from accidents, and protecting the

[2] "Transit-dependent" riders are people who either cannot drive due to age, physical condition, or other factors, do not have access to an automobile, or cannot afford to use one. "Choice" riders are people who have access to an automobile but elect to use transit instead.

environment by reducing air, water, and groundwater pollution, greenhouse gas emissions, and traffic noise.

2.2.1.1 Access to Healthcare

Inadequate transportation is one of the primary reasons that low-income families miss or forego medical appointments. Hence, public transportation helps agencies reduce medical institutionalization of the poor. This, in turn, reduces demand for more expensive and oversubscribed paratransit services, and provides an alternative to the use of costly ambulance and emergency services. Public transportation also relieves other public agencies from transportation responsibility.

The Transportation and Land Use Coalition (TLUC) study, *Roadblocks to Health: Transportation Barriers to Healthy Communities* (2002), drew attention to the socio-economic problems of inadequate public transportation services for low-income communities. The TLUC report clearly demonstrates that the Bay Area's most disadvantaged communities face significant transportation barriers to healthy activities. In low-income communities, where car-ownership rates are low, inadequate public transportation limits access to job centers, hospitals, supermarkets, and recreational parks. Low-income people are disproportionately injured and killed on unsafe streets, a health crisis in itself that contributes to fears of walking and bicycling. The U.S. Department of Health and Human Services affirms that there is compelling evidence that race and ethnicity correlate with persistent, and often increasing, health disparities among communities.

The aging of the population is another issue to consider. In a report published in 2002 the American Public Transportation Association and the Public Transportation Partnership for Tomorrow emphasize that as people age, isolation becomes a growing problem, and access and mobility become increasingly critical needs. Kleffman (2002) also argues that for many low-income residents without cars, access to healthcare and healthful food could be a frustrating, and time-consuming experience.

2.2.1.2 Access to Education

School districts, educators, and concerned parents are finding that greater reliance on expanded public transportation services helps improve educational systems. About 12 percent of public transportation users are en route to schools of various types (APTA, 2007). Across the country, "Unlimited Access" transit pass programs at many universities provide free, system-wide transportation service to college students, faculty and staff, expanding access, reducing auto-related expenditures, and saving universities millions of dollars. Below are a few examples:

- Salt Lake City's University TRAX serves 46,000 students and faculty, relieving campus congestion and reducing university parking costs;

- The Milwaukee County Transit System's UPASS program includes four schools; during the first two years of the program, the percent of students traveling by transit to the University of Wisconsin-Milwaukee doubled;

- The Worcester Regional Transit Authority connects 26 training facilities and two General Educational Development (GED) test centers, as well as 26 major employers and 24 child-care facilities; and

- In Duluth, MN the UPASS program allows access to the Duluth Transit Authority, lowering parking costs and congestion at three area colleges and universities.

It is evident that many cities and educational institutions throughout the country are recognizing the benefits of public transportation. Given the low-income nature of many students, they stand to reap large benefits from affordable transportation.

2.2.1.3 Welfare Recipients

Public transportation is key to moving former welfare recipients into the workforce as permanent wage earners. An estimated 94 percent of welfare recipients attempting to move into the workforce do not own cars and rely on public transportation. In 2002, the $75 million federal Job Access and Reverse Commute (JARC) initiative provided grants to transit service providers to help low-income residents get to work where existing transit was unavailable, inappropriate, or insufficient.[3] JARC and other programs have impacted the lives of thousands of welfare recipients and low-income families.

Contrary to the common belief that if people have low-cost access to jobs they will move out of welfare to paying jobs, Blumenberg and Hess (2002) argue that this is not always the case. Using data from three California counties, their study examines welfare recipients' spatial access to employment. The study finds that the traditional notion of the spatial mismatch is less relevant to welfare recipients, many of whom live in counties in which the urban structure does not fit the simple model of poor, central-city neighborhoods and distant, job-rich suburbs. Many welfare recipients live in job-rich areas, while others live in neighborhoods that are spatially isolated from employment. They argue that, to be effective, transportation policies must be tailored to the diverse characteristics of the neighborhoods in which welfare recipients live.

Wachs and Taylor (1997) also observe that while inadequate access to employment clearly contributes to unstable work histories, poverty, and dependency on programs like Aid to Families with Dependent Children (AFDC), it is by no means the only barrier to steady work for most welfare recipients. Programs that seek to increase employment access (either by locating jobs and workers near one another or by improving the transportation linkages between jobs and workers) can help to move people into steady employment and reduce welfare usage, but they are not a comprehensive remedy.

2.2.2 Congestion Management Benefits

Public transportation also helps to alleviate our nation's crowded roadways by providing transportation choices. Without these choices, in areas with populations over 1 million, there would be an additional 493 million hours of delays if travelers used their personal vehicles instead (TTI, 2007). The average urban traveler spent 38 hours stuck in traffic in 2005, an

[3] Surface Transportation Policy Partnership, *Transportation and Jobs*, http://www.transact.org/library/factsheets/transportation and jobs.doc

increase from 14 hours in 1982. Half the drivers spent the same amount of time stuck in traffic as they did on vacation.

A study conducted by Hickling Lewis Brod, Inc. (2000) for the Transportation Research Board (TRB) points out that the transit profession focused on cost control for many years, neglecting the benefits of transit. Much transit policy analysis, premised upon a transit cost crisis, overlooked the cost to modernize transit organizations, equipment, and deployment. During the 1970s, transit managers wrestled to forge local and fragmented transit services into regional mobility institutions. They not only succeeded in increasing transit's share of suburb to downtown commutes, they did so while simultaneously improving transit's cost structure.

The HLB study points to a pattern of policy preferences that recur throughout the U.S. transit industry. The greatest focus of large transit systems, both old and new, has been the relief from traffic congestion. This function attracts the financial support of suburban jurisdictions with residents who must commute in severely congested travel corridors. Owing to a relatively fixed budget since the early 1980s, the expansion of commuter services has been accomplished by squeezing the budgets of services that support pedestrian-oriented neighborhoods and affordable mobility services.

In their book, *Policy and Planning as Public Choice*, Lewis and Williams (1999) attempt to quantify the benefits of public transit nationwide. Benefits include reduced energy consumption and air pollution associated with lower motor vehicle use, budgetary savings from not having to add more highway capacity, low-cost mobility to access jobs, and thus reduced welfare and unemployment rolls. They argue that the concentration of population in large cities is not possible without public transit services. Lewis and Williams estimate that annual transit benefits easily outpace costs. During the 1990s public transit returned:

- $15 billion per year, increasing to $19.4 billion per year in 1999, in reduced congestion delays for rush-hour passengers and motorists;

- $10 billion per year in reduced vehicle ownership costs for residents of livable neighborhoods; and

2.2.2.1 Impacts on the Environment

Public transportation helps to promote cleaner air by reducing automobile use, which can in turn reduce smog and public health problems. According to the U.S. Environmental Protection Agency (EPA), asthma attacks lead to 2 million emergency room visits and 5,000 deaths per year in the U.S. Asthma account for more than 14 million missed school days. In terms of related healthcare costs and lost productivity, asthma costs are estimated $14 billion annually.[4]

For each mile traveled, fewer pollutants are emitted by transit vehicles than by a single-passenger automobile. On average, buses emit 80 percent less carbon monoxide than cars. According to the Sierra Club (2001), seven of the twelve cities with the highest grades for low car and truck smog per person (New York, Chicago, Los Angeles, San Diego, San Francisco, Sacramento and Washington, D.C.) are located in states that spend the most on clean

[4] U.S. Environmental Protection Agency, *Asthma and Indoor Environments: About Asthma*, 2006.

transportation choices, demonstrating the power of public transit as a tool to combat air pollution.

Litman (2007) states that even though a variety of strategies are utilized to reduce congestion or vehicle miles on roads, conventional transportation planning has a tendency to undervalue the full emission reduction benefits. His paper provides a guide to standardizing comprehensive impact assessments of transportation planning, including the effects on energy conservation.

2.2.2.2 Energy Conservation

Public transportation can significantly reduce dependency on fuel, with an average of 26 gallons of gasoline "wasted" per traveler in 2005 due to congestion (TTI, 2007). Many U.S. transit systems are continuing to invest in compressed natural gas, low-sulfur burning buses or diesel-electric hybrid buses.

A study by Shapiro, Hassett and Arnold (2002) focuses on the environmental and resource management side of transit sector investments. They assert that the role of transportation in our nation's energy consumption and environmental quality is immense. Americans use more energy and generate more pollution in their daily lives than they do in the production of all the goods in the economy, or the operations of all commercial enterprises. Any serious effort to reduce our dependence on foreign oil and make significant environmental progress must address the way Americans travel. Their study demonstrates that traveling by transit uses significantly less energy per person and per mile, and produces substantially less pollution than comparable travel by private vehicles. The findings provide clear and indisputable evidence that public transportation is saving energy and reducing pollution in America today – and that increased usage could have an even greater impact in the future.

2.2.3 Economic Development Benefits

Communities that invest in public transportation realize enhanced development and prosperity in the form of more jobs, revitalized business and activity centers, and an expanded tax base. Employers throughout the U.S. are taking advantage of public transportation to attract larger and more reliable work forces and save on employee time lost to delay, accident and injury on the road.

Public transportation facilities and corridors are natural focal points for economic and social activities. These activities help create strong neighborhood centers that are more economically stable, safe and productive. Studies have shown that the ability to travel in an area conveniently, without a car, is an important component of a community's livability. Public transportation provides opportunity, access, choice and freedom, all of which contribute to improved quality of life.

Public transportation fuels local development and in turn has a positive impact on local property values. Hedonic analyses in particular have shown greater increases in the value of properties located near public transportation systems than in similar properties not located near public transportation. A sample of studies in which this added value, or premium, is measured is presented in Table 1 below.

Table 1: Economic Development Premiums – A Sample of Recent Studies

Location *Reference*	**System**	**Type of Transit**	**Type of Property**	**Relevant Findings**	**Comments**
Atlanta, GA *Bowes and Ihlanfeldt, 1997*	MARTA	Heavy Rail	Residential	Properties within a 1/4 mile from a rail station sell for 18.7% more than properties beyond a 3 mile radius; though if a property is within a 2 or 3 mile radius of a rail station, it sells for 3.5% more than those beyond a 3 mile radius.	The effects of a property being within a 1/2 mile or 1 mile radius of a rail station are both positive, though statistically insignificant and therefore the estimates cannot be utilized.
Boston, MA *Armstrong, 1994*	MBTA	Commuter Rail	Residential	Increase in single-family home value of 6.7%. Loss of value of approximately 20% for properties within 400 ft of commuter or freight rail right of way.	
Buffalo, NY *Hess and Almeida, 2007*	NFTA-Metro	Light Rail	Residential	Homes that are located within a 1/4 mile radius of a station can earn a premium of $1,300-$3,000, or 2%-5% above the city's median home value. Moreover, for every foot closer to a metro station, homes located within the study area exacted an additional $2.31 (using geographical straight-line distance) and $0.99 (using network distance) over the average property value.	Geographical straight-line distance is the equivalent of looking at a map and drawing a circle around a transit station for a given radius; network distance uses accessible routes from a transit station by way of streets, simulating the distance one would walk from a given property.
Dallas, TX *Clower, Weinstein and Seman, 2007*	DART	Light Rail	Residential and Commercial	The total fiscal impact of projects that are attributable to the presence of LRT is $4.26 billion.	
Eastern Massachusetts *Armstrong and Rodriguez, 2006*	MBTA	Commuter Rail	Residential	Properties within a 1/2 mile buffer of a rail station are 10.1% higher in value than those outside of this buffer. Also, an additional one minute of driving time from the station results in a 1.6% decrease in property values.	Proximity to commuter rail right-of-way has a significant negative impact on property values.
Portland, OR *Al-Mosaind et al., 1993*	TriMet	Light Rail	Residential	On average, a house sells for $663 more for every 100 ft closer to a light rail station (within a 1/4 mile radius).	

Location *Reference*	**System**	**Type of Transit**	**Type of Property**	**Relevant Findings**	**Comments**
Portland, OR *Lewis-Workman and Brod, 1997*	TriMet	Light Rail	Residential	Within a 2,500 ft to 5,280 ft distance of a MAX station, average property values increase by about $0.76 for every foot closer to a station. Within the 2,500 ft radius, average property values decrease by $1.41 for every foot closer to a station*.	*The negative effect is primarily attributed to the proximity of highways, which have been shown to have a similar effect in other studies.
San Francisco, CA *Lewis-Workman and Brod, 1997*	BART	Heavy Rail	Residential	On average, property values increase by approximately $15.78/ft closer to a BART rail station. Moreover, a 1% increase in distance from a BART station results in a 0.22% reduction in home prices.	
Santa Clara, CA *Cervero and Duncan, 2001*	Caltrain	Light Rail and Commuter Rail	Commercial	For commercial properties within ¼ mile distance of a LRT station, land value is higher by $4/sf (or 23%) than those of comparable properties away from stations. For properties within a ¼ mile radius of a Caltrain station and within a business district, there is a value increase of $25/sf (or 120%) compared to properties outside of this radius.	Analysis was conducted at the parcel-level.
Washington, D.C. *Hickling Lewis Brod, 2002*	WMATA	Heavy Rail	Commercial	On average, if the distance of a commercial property to a metro station is reduced by 1,000 ft (or 3 blocks), the value to the property will increase by $2.30/sf or 2%.	

2.2.3.1 Impact on Households

American families spend about 18 percent of household spending on transportation, making it the second largest household expenditure after housing.[5] Public transportation can significantly reduce the amount of money a family spends getting to work, school and other activities. The high cost of driving, insuring and parking a car results in a reduction in individual economic opportunities. It can make it hard for many to access high quality and high paying jobs. Public transportation provides an affordable and, for many, necessary alternative to driving.

According to APTA (2005), it is estimated that a sustained program of transit capital investment would generate an increase of $800,000 in personal income for each $10 million in the first year. After 20 years, these benefits would increase to $18 million in personal income.[6]

[5] U.S. Department of Labor, Bureau of Labor Statistics, *2006 Consumer Expenditure Survey*.

[6] American Public Transportation Association, *News Releases*, "«We Make Communities Go» Campaign To Highlight Transit's Benefits To National And Local Economies," February 17, 2005.

2.2.3.2 Job Creation

Transit capital investment is a significant source of job creation. According to a study led by Cambridge Systematics, Inc. (1999), each $10 million invested in transit yields 314 jobs, and more than 570 jobs are created for each $10 million in the short run. On average, a typical state/local government could realize a 4 to 16 percent gain in revenues due to the increases in income and employment generated by investments in transit.

Business output is positively affected by transit investment. The 1999 study by Cambridge Systematics, Inc. also finds that a sustained program of transit capital investment would generate an increase of $2 million in business output. After 20 years, these benefits would increase to $31 million.

2.2.3.3 Suburban Communities

Public transportation also provides valuable options for suburban commuters who work in the city. In fact, the average annual income of rail commuters is more than $50,000 and most own two cars.

The Camph study (1997) discusses how public transportation contributes to the economic vitality of small towns as well as sprawling cities. He argues that while transit is clearly a blessing to the people who use it, even larger benefits accrue to motorists, businesses, and society in general. More and more central cities, suburbs, and smaller towns and villages are choosing to make public transit an essential component of their strategic transportation investment portfolio. In those areas where such strategic investments in transit have been made, ridership has grown, and the economic benefits to those communities have risen accordingly. The market for transit is there, but the nation's transportation strategies must be geared to tap into that market. Public transportation investments should be designed to reduce the economic, social and human costs of the lack of personal mobility. These costs show up in unemployment, lower tax revenue, and welfare and medical costs.

A study by Cambridge Systematics, Inc. and Apogee Research, Inc. (1996) categorizes and describes transit benefits and costs. The study presents the dimensions of transit's economic impact, addresses the links between increased transit investment and use, notes changes in long-term, regional economic conditions that can be measured with current analytic methods, and provides examples of transit benefits and costs. The study states that an integrated transportation and economic modeling approach to assess the economic consequences of significant additions to regional transit capacity has not been attempted to date.

Similarly, the Gwilliam study (2002) aims to understand the nature and magnitude of urban transport problems, particularly with respect to the poor, and to articulate a strategy by which the World Bank and other agencies can assist national and city governments to address these problems.

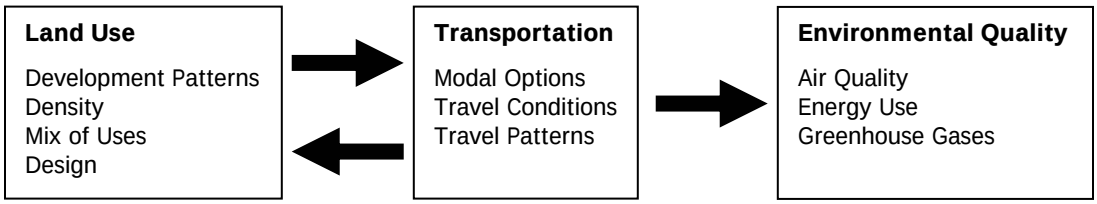
2.2.3.4 Land Use Policies

Land use and transportation are inter-related. On the one hand, land uses affect transportation by physically arranging the activities that people want to access. Changes in the location, type, and density of land uses change people's travel choices. This, in turn, changes transportation patterns. On the other hand, transportation affects land uses by providing a means of moving

goods, people, and information from one place to another. Changes in transportation networks make some places more accessible and, therefore, more attractive to development. Transportation changes can have the paradoxical effect of facilitating either dispersion or concentration. As the cost of travel has declined, people and activities have been dispersed. At the same time, transportation facilities have supported concentrated development in places where they confer the greatest accessibility.

Given land use's role in affecting transportation patterns, and the fact that motor vehicles are a major cause of air pollution and a primary factor in energy consumption, it is relatively easy to see how land use affects air quality and energy consumption. Figure 2 shows these interrelationships of transportation, land use, and environmental quality.

Figure 2: Diagram of Land Use, Transportation, and Air Quality Interactions



The effects of past transportation decisions and investments are evident in today's development patterns, with the United Nations predicting an average annual increase of 105 people for every 10,000 in North American urban areas from 2005 to 2030, and an average annual decline in rural populations of 73 people for every 10,000 over the same time period and area.[7] This means that populations are expected to become more concentrated in urban areas and less in rural. Thus, the transportation – land use connection is one that cannot be ignored and must be addressed for effective planning by local agencies.

There are two important concepts that are central to understanding the land use – transportation connection: accessibility and mobility. Accessibility refers to the number of opportunities, also called activity sites, available within a certain distance or travel time. Due to the low-density development patterns that we see today in most communities, the distances between activity sites such as home, school, and grocery store are increasing. As a result, accessibility has become increasingly dependent on mobility.

On the one hand, mobility can be seen as the consequence of spatial segregation of different types of land uses; on the other hand, it can be seen as contributing to increased separation of land uses. Improvements in the transportation field have enabled people to travel longer distances in the same amount of time, which has resulted in the growing segregation of activity sites, especially those between home and work. In today's urban scenario, the value of land is heavily dependent on the transportation network providing access to it. Or, in other words, the location of a place within the transportation network determines its value and use.

[7] United Nations, Department of Economic and Social Affairs, Population Division, *World Urbanization Prospects: The 2005 Revision*, Working Paper No. ESA/P/WP/200, 2006.

The most significant role that transportation plays in land transportation or land use development is its effect on access to land. Transportation systems have the potential to indirectly affect land development either by inducing new development or by altering the pattern of development. Even though a transportation improvement may not bring growth to a region in terms of number of households or square feet of developed area, it may affect the location pattern of land uses. However, due to the large number of factors affecting land use patterns, transportation may be considered just one part of a complicated process of land development.[8]

Some studies also show that public transit investments play a significant role in successful land use policies. The Kenworthy and Newman (1999) study, *Sustainability and Cities*, examines the urban aspect of sustainability issues, arguing that cities are a necessary focus for that global agenda. The authors make the case that the essential character of a city's land use results from how it manages its transportation, and that only by reducing our automobile dependence will we be able to successfully accommodate all elements of the sustainability agenda.

In another study that considers the effect on mode choice resulting from a transportation system change, Boarnet and Sarmiento (1996) argue that empirical evidence does not support the claim that land use can be manipulated to influence travel behavior. The effect of land use on travel behavior within the context of a consumer demand framework is measured by means of a regression model. They point out that planners are increasingly viewing land use policies as a way to manage transportation demand. Yet, the evidence of the link between land use and travel behavior is inconclusive. This paper uses travel diary information for Southern California residents to examine the demand for non-work travel. Both non-work automobile trips and non-work miles traveled by car are modeled as a function of individual socio-demographic variables and land use characteristics near the person's place of residence. The land use variables are rarely statistically significant, and diagnostic tests suggest that land use (and thus residential location choice) is endogenous to non-work travel. The implications are twofold. The link between land use and non-work travel is weak at best, at least for the sample studied here, and future research should treat residential location and thus nearby land use characteristics as endogenous in models of travel behavior.

2.2.4 Methodologies

HLB (1997) has developed a transit investment decision methodology and related requirements for the Federal Transit Administration (FTA). This procedure compares several options for each proposed transit corridor – for example, light rail vs. dedicated bus lanes and the "no build" option. It considers costs and benefits in both monetary and other measures, and evaluates each option in a fair and consistent manner against pre-established evaluation criteria. This methodology was successfully implemented on numerous occasions, most notably for the Wisconsin Department of Transportation (WisDOT) and the Pennsylvania Department of Transportation (PennDOT).

Other studies have attempted to streamline the cost-benefit analysis methodologies for public transportation projects. The ECONorthwest study (2002) for the Transit Cooperative Research Program provides a guidebook to support transit planners in state, regional, and local

[8] Wisconsin Department of Transportation, *Land Use in Environmental Documents: Indirect and Cumulative Effects Analysis for Project-Induced Land Development Technical Reference Guidance Document*, 1996.

government who evaluate transit investments. Benefits and costs include impacts on travel, on the environment and safety, land use and land development, economic impacts, and the distribution of impacts.

Litman (2008) also developed methods for evaluating public transit benefits, costs and equity impacts. These include financial subsidies, improved mobility, reduced traffic congestion, road and parking facility cost savings, consumer cost savings, reduced pollution emissions, and support for land use, economic development, and equity objectives. Conventional transportation planning often overlooks some of these positive impacts and so undervalues transit. More comprehensive evaluation practices, such as transportation demand management, tend to justify more policies and programs that support transit.

3. METHODOLOGICAL FRAMEWORK

For more than a decade HDR has worked extensively with federal, state and local agencies in developing methodologies to accurately measure the benefits of public transportation. This chapter introduces the methodology used for assessing such benefits in the State of Michigan, based on the literature review findings. Section 3.1 discusses the framework used to evaluate the socio-economic benefits of transit. Section 3.2 describes the computation of economic impacts resulting from transit operation and maintenance expenses, and vehicle ownership and operating cost savings accruing to transit riders.

3.1 Economic Benefits of Transit

3.1.1 Overview

Public transportation benefits local communities in various ways, from reducing vehicle traffic on the roadway network, to providing low-cost mobility to those with limited financial resources and contributing to economic growth.

One of the core functions of public transportation is to help alleviate traffic congestion, especially in metropolitan areas during peak periods. The use of transit contributes to reduce personal vehicle trips thus directly saving resources, which can be more productively spent elsewhere in the economy. Moreover, fewer personal vehicle trips result in reduced roadway congestion that benefits all travelers. This also yields resource savings and their redirection to better and more efficient uses.

Public transportation also provides low-cost transportation opportunities to many lower-income households. Individuals with access to public transportation can enjoy the benefits of social interaction, entertainment and education, which in turn influence their contribution to the economy. Also, low-cost mobility extends the opportunities for employment to individuals who may otherwise be unemployed. In the end, low-cost mobility reduces the need for costly social services, thus resulting in a direct reduction in welfare and social service budgets.

In addition, for many residents, living near transit stops provides an array of benefits. These benefits arise from lower transportation expenses, changing development patterns and other non-user benefits. As a consequence, the presence of transit stops can increase the value of properties located nearby. In other words, there is a direct benefit of transit on household income for properties located near transit stops.

Taken together, all the attributes of public transportation make a positive contribution to the regional economy. More specifically, the benefits of public transportation fall into three main categories that can be defined as follows:

- **Transportation Cost Savings** – These are the savings in vehicle ownership and operating cost (purchase/lease, insurance, fuel consumption, etc.), travel time, accidents and environmental emissions (such as carbon monoxide, nitrogen oxides and volatile

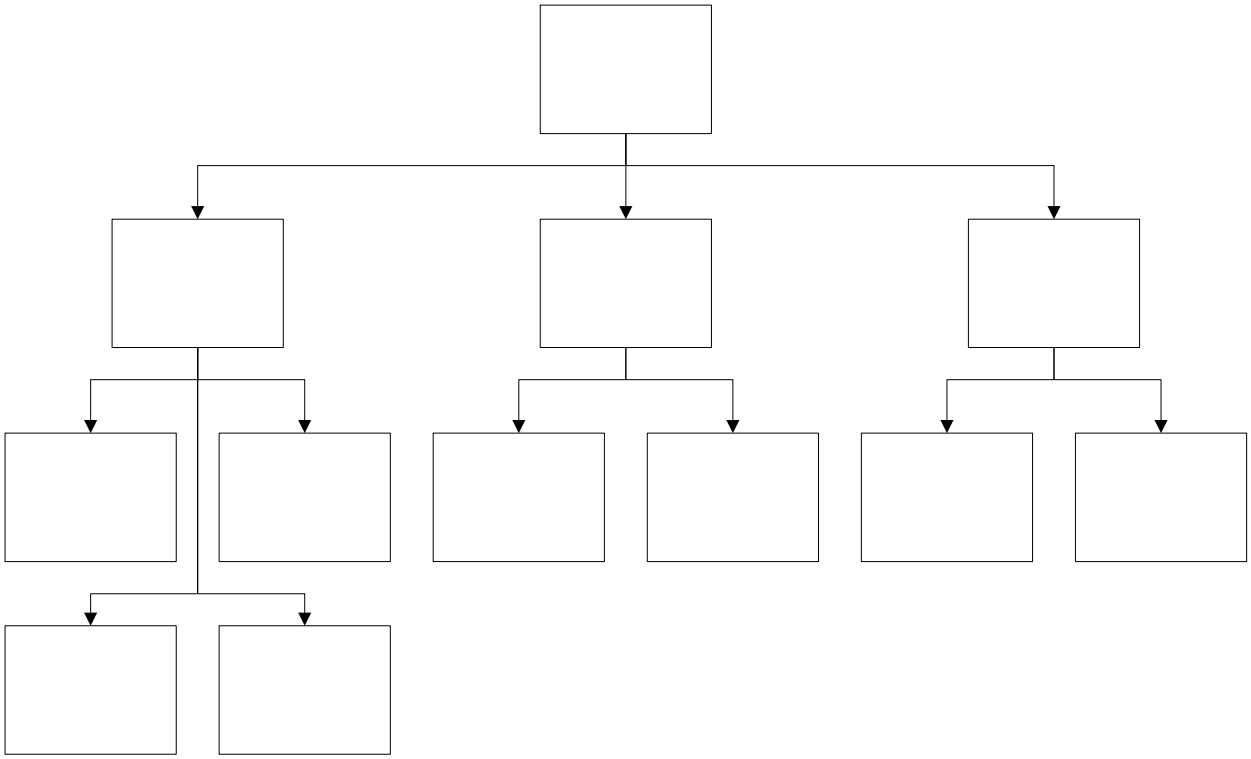
organic compounds)[9] due to less congestion and fewer miles traveled by personal vehicles in the presence of transit. These savings in resources imply greater disposable household income for other purposes. The two main benefits are the reduction in travel for personal vehicles, and travel in less congested conditions for vehicles remaining on the roadway network.

- **Low-cost Mobility Benefits** – These are the benefits from providing low-cost mobility to transit-dependent households. The benefits include: *(i)* the economic value to access services such as healthcare, education, retail, and attractions (affordable mobility benefits), and *(ii)* budget savings for welfare and social services, such as unemployment and homecare, due to the presence of transit (cross-sector benefits).

- **Economic Development Benefits** – Proximity to transit can have a positive effect on residential property values and commercial activities due to the increased availability of travel opportunities, and the ability of others to access the residence and commercial centers by transit. Economic development benefits are mainly found in corridors with rail transit systems.

Figure 3 illustrates the benefits of public transportation described above.

Figure 3: Overview of Transit Benefits



[9] Transportation accounts for about 80 percent of carbon monoxide emissions, 50 percent of nitrogen oxides emissions, 50 percent of volatile organic compounds emissions and 30 percent of carbon dioxide emissions.

It is noteworthy that these benefit categories can be estimated for each key socioeconomic sector impacted by public transportation (work, healthcare, education, etc.).

3.1.2 Methodology for Estimating Transportation Cost Savings

The starting point of the analysis is to model the decisions made by transit riders if transit service were not available. Transportation costs are then estimated under two scenarios: in the presence of transit, and in the absence of transit. In other words, the methodology followed for this study evaluates the incremental costs associated with individuals switching from transit to alternative transportation modes.

The calculation of transportation cost savings is performed in six steps, as follows:

1. For each transit system, passenger trips are allocated by trip purpose (work; medical; shopping; school; and other).

2. Assuming that transit service is not available, the number of trips foregone and the number of trips diverted from transit to other transportation modes (private vehicle, taxi, etc.) are calculated.

3. The remaining trips are translated into vehicle miles traveled (VMT) based on the average trip length.

4. The various transportation costs associated with VMT generated in the absence of transit are subsequently estimated:

   - **Vehicle ownership and operating costs** are calculated for private vehicle trips and taxi trips;

   - **Travel time costs** are calculated based on the relationship between traffic volume (measured in vehicle miles) and congestion delays (measured in hours), and the value of time;

   - **Safety costs** are assessed by accident severity (fatality accidents, injury accidents, and property damage only accidents);

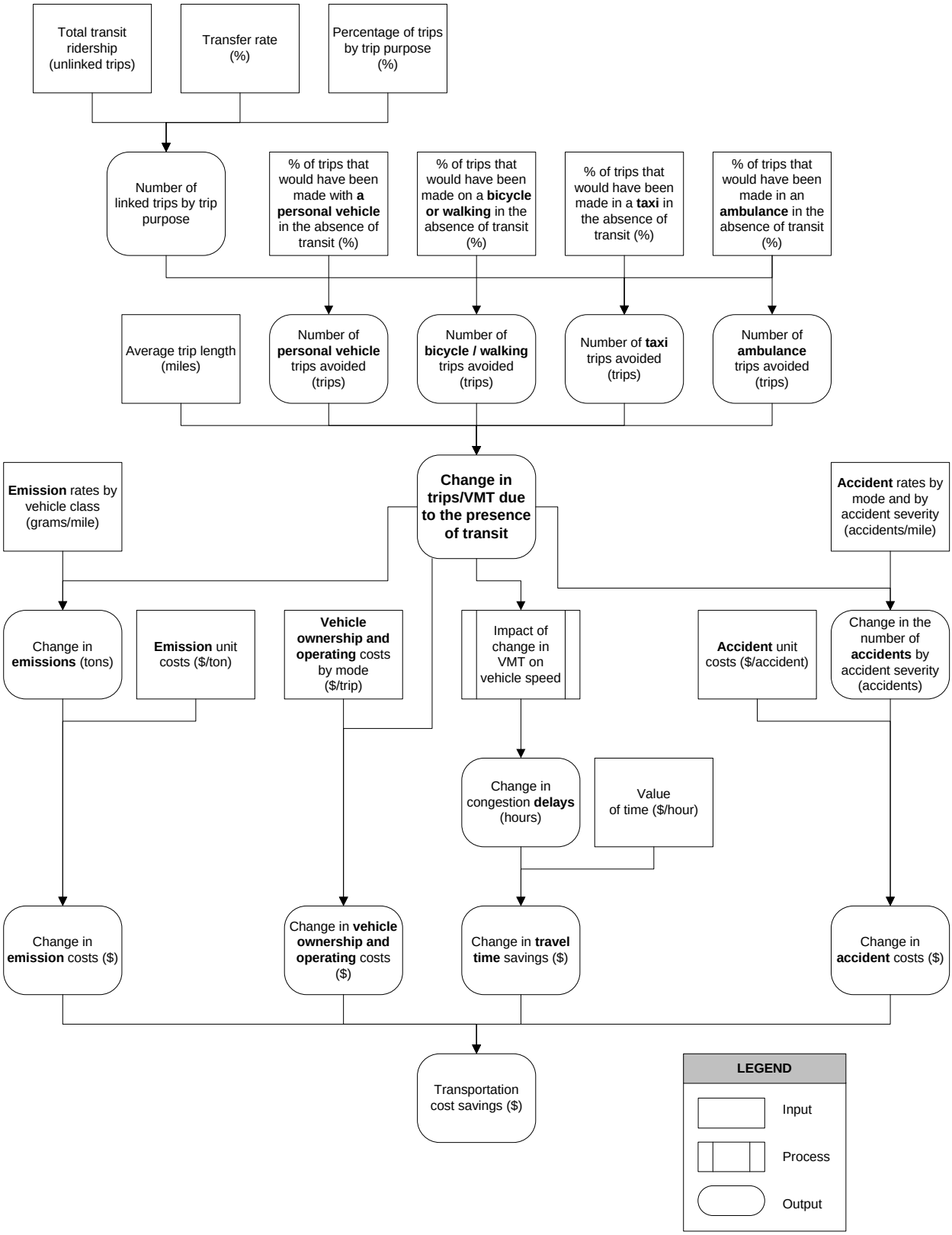
   - **Environmental emission costs** are assessed for all major vehicle emission factors (hydrocarbons, carbon monoxide, nitrogen oxides, sulfur dioxide, particulate matter, and carbon dioxide).

5. In the same way, transportation costs are estimated in the presence of transit service.

6. Transportation cost savings are simply the difference between transportation costs in the absence of transit (step 4) and transportation costs in the presence of transit (step 5).

Figure 4 illustrates, in a simplified way, the methodology used to estimate transportation cost savings in the presence of transit. The structure and logic diagram identifies all of the model inputs and the relationships between these inputs.

Figure 4: Structure and Logic Diagram for Transportation Cost Savings



3.1.3 Methodology for Estimating Affordable Mobility Benefits

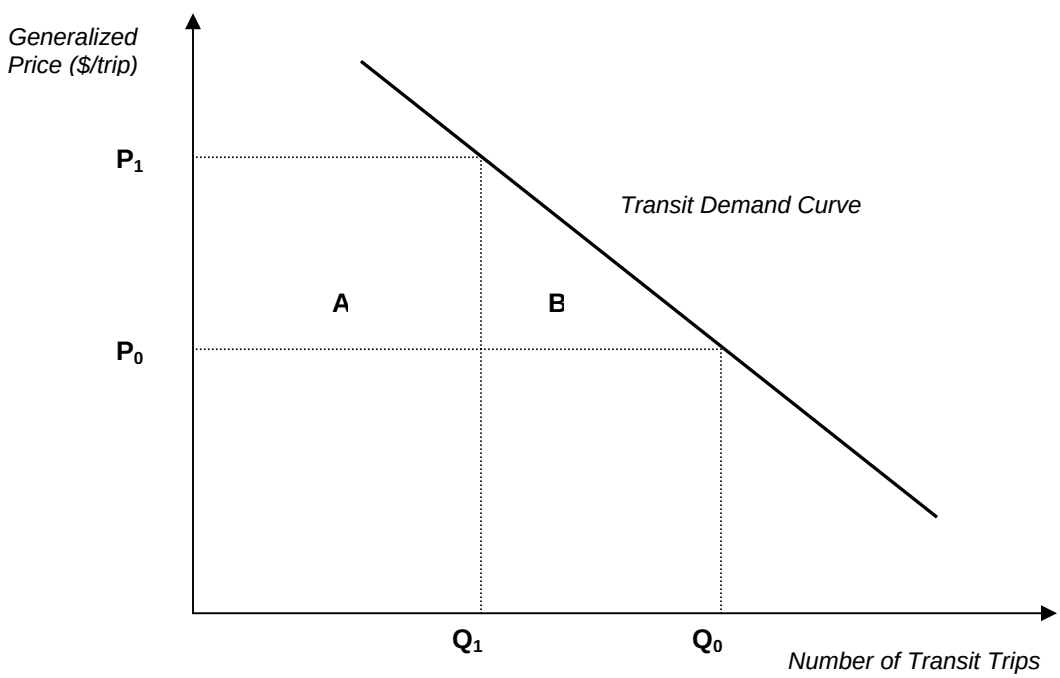
Affordable mobility benefits are estimated by means of the consumer surplus. Economists call the difference between the amount people actually pay for something, and the amount they would pay for the next most costly alternative, "consumer surplus." Consumer surplus is a monetary quantity that equates to the economic value (EV) of the mobility afforded to people by the availability of a transit system. Formally, it can be expressed in the following way:

$$EV = (P^{t}_{1} - P^{t}_{0}) * Q^{t}_{2} + ½ [(P^{t}_{1} - P^{t}_{0}) * (Q^{t}_{0} - Q^{t}_{1})]$$

Where:
- P^{t}_{0} is the expected fare to be paid by transit riders;
- Q^{t}_{0} is the expected number of passenger trips;
- P^{t}_{1} is the (weighted average) fare that people pay to use other travel modes (personal vehicle, taxi, etc.); and
- Q^{t}_{1} is the number of passenger trips using other modes.

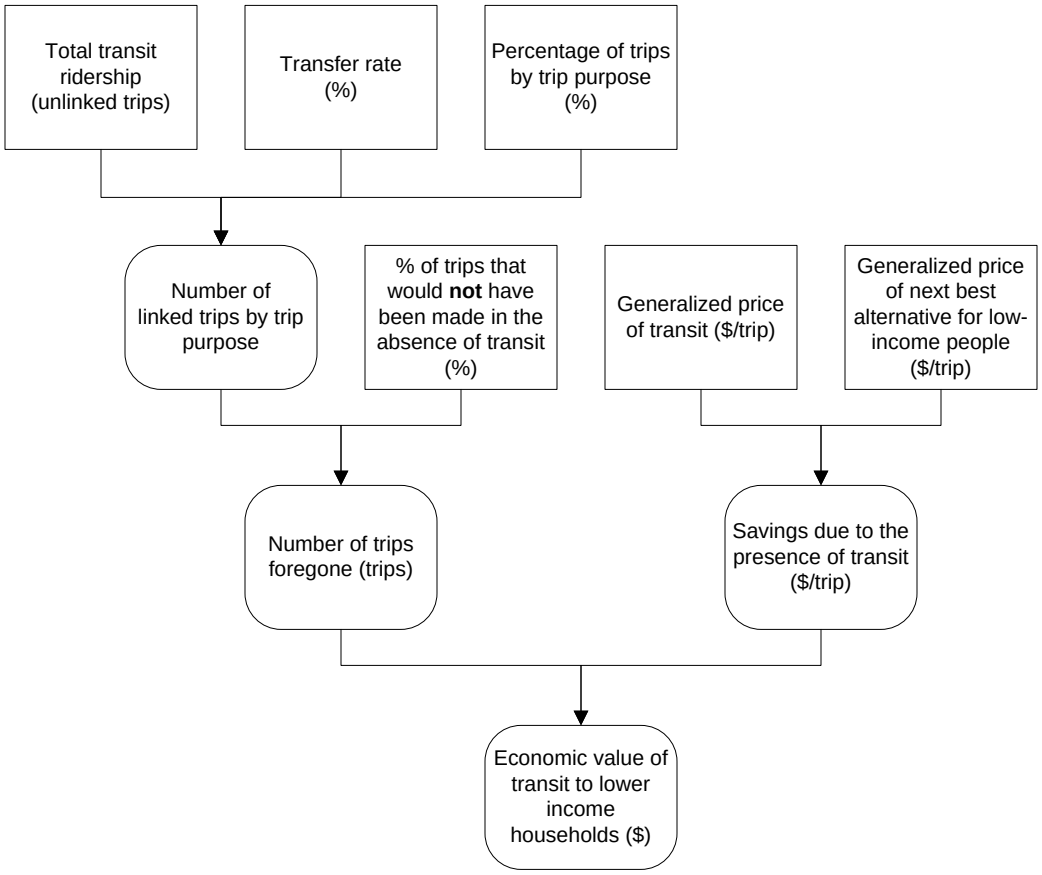
The level of demand for transit and the price difference between transit and other transportation modes measure the consumer surplus, or affordable mobility benefits of transit. This is illustrated in Figure 5 below. In the presence of transit, riders pay P_0 and demand Q_0 number of trips. When transit services are eliminated, low income riders have no choice but to forego their trips while other riders shift to more costly transportation modes. P_1 is the new fare per trip using other modes and Q_1 is the corresponding trip demand. The difference between P_1 and P_0 is the increase in fare, while the difference between Q_0 and Q_1 is the number of foregone trips. The economic value of transit is represented by areas A and B: rectangle area A represents the benefits accruing to travelers switching to transit (i.e., vehicle operating cost savings) and **triangle area B represents the benefits accruing to low-income people who depend on transit**.

Figure 5: The Concept of Consumer Surplus



The methodology used to derive the net economic value from affordable mobility is illustrated in Figure 6 below.

Figure 6: Structure and Logic Diagram for Affordable Mobility Benefits



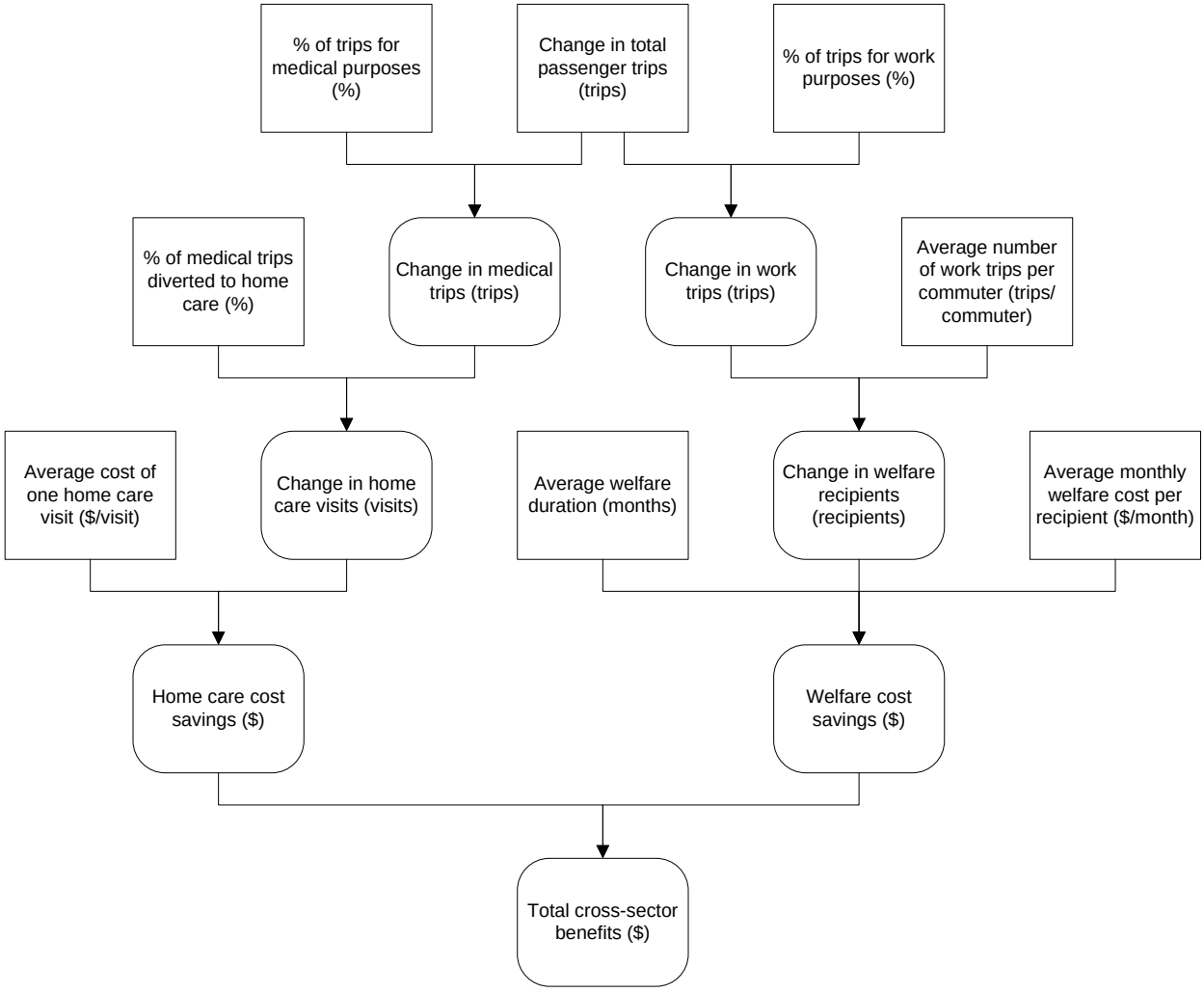
3.1.4 Methodology for Estimating Cross-Sector Benefits

The model also measures the impact of a reduction in the level of mobility on the level of social services. In quantifying the resulting increase in costs, such as increased homecare costs (for people on dialysis, for instance), the benefits of transit can be estimated. These costs would not exist if transit services were provided, and thus are qualified as cross-sector benefits of transit.

Figure 7 on the next page provides a graphical illustration of the methodology used for estimating cross-sector benefits. The starting point assumes a level of passenger trips eliminated due to a lack of transit service. These trips are translated into trips by purpose to estimate social spending impacts. The percentage of lost medical trips leading to homecare and the average number of work trips per commuter generates estimates of the number of added homecare visits and welfare recipients (or job losses). The average cost of a homecare visit is multiplied by the number of added visits to estimate the monetary value of these trips. Likewise, the added welfare costs per recipient are multiplied by the number of welfare recipients and the average welfare

duration to arrive at estimates of the monetary value of lost employment. The total spending impact of transit on social services is simply the sum of home care spending and welfare spending.

Figure 7: Structure and Logic Diagram for Cross-Sector Benefits



3.2 Economic Impacts of Transit

In addition to these benefits, the presence of transit contributes to the economic activity in two ways:

- Firstly, the on-going operation of transit systems requires inputs (purchases) of labor, materials, equipment, and services, which are supplied by local (and non-local) producers. This is normally measured by operation and maintenance expenses.[10]

[10] Capital expenses are not considered for two main reasons: *i)* though operation and maintenance expenses are typically incurred locally (they mainly consist of wages and salaries), that is not necessarily the case for capital

- Secondly, people who use transit instead of more expensive alternative modes make substantial cost savings (i.e., vehicle ownership and operating cost savings). A majority of these savings is re-directed toward other household expenses such as housing or healthcare.[11]

3.2.1 Types of Economic Impact

Traditionally, economic impact analysis involves the estimation of three distinct types of expenditure/production activity, commonly referred to as direct effects, indirect effects, and induced effects. The total economic impact is the sum of these direct, indirect and induced effects for the project being evaluated.

- **Direct impacts** refer to the financial transactions (output, income, and employment) occurring as the result of direct spending by economic agents. Direct spending results in the employment of workers, sales of locally produced goods and services, and generation of local tax revenue. In the case of transit operation and maintenance expenses, all direct effects originate from transit systems.

- **Indirect impacts** refer to off-site economic activities that are directly attributable to the operation of transit systems. For instance, they can be the result of purchases by local firms who are the direct suppliers to the transit system. The spending by these supplier firms for labor, goods and services necessary for the production of their product or service creates output from other firms further down the production chain, thus bringing about additional employment, income and tax revenue.

- **Induced impacts** represent the increase in economic activity over and above the direct and indirect impacts, generated by successive rounds of spending (often referred to as re-spending). Induced impacts are changes in business output, employment, income, and tax revenue that are the result of personal (or household) spending for goods and services – including employees of the transit agency, employees of direct supplier firms, and employees of all other firms comprising the indirect impact.

Indirect and induced impacts are often referred to as "multiplier effects," since they can make the overall economic impacts substantially larger than the direct effects alone. In reality, though indirect and induced impacts do always occur, the net impact on the total level of economic activity in an area may or may not be increased by multiplier effects. That outcome depends on the definition of the study area and the ability of the area to provide additional workers and capital resources, or attract them from elsewhere.

Multipliers can be expressed in terms of output or employment/jobs. An output multiplier is the total overall increase in dollars of business output (sales) for all industries, per dollar of additional final demand (purchases) of a given industry in that area. A job multiplier is the total overall increase in jobs for all industries, per new job created in a given industry.

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expenses (e.g., purchase of buses); *ii)* the model estimates the benefits associated with local bus transit for a given year, whereas transit capital projects can have a life cycle of up to 40 years.

[11] The portion of household savings that is actually re-spent in the State of Michigan (48 percent) is determined by the Social Accounting Matrix.

3.2.2 Economic Impact Analysis Methodology

To measure the effects of transit operations (as well as vehicle ownership and operating cost savings accruing to transit riders) on the economy of Michigan, HDR utilizes IMPLAN Professional®, an economic impact assessment modeling system structured as an input-output model[12] – originally developed by the U.S. Forest Service and now maintained by the Minnesota IMPLAN Group, Inc.[13] The IMPLAN data files include transaction information (intra-regional and import/export) on 440 industrial sectors (corresponding to four and five digit North American Industry Classification System (NAICS) codes), and data on 21 different economic variables – including employment, output, and employee compensation. For this study, the IMPLAN software system is populated with the most recent (2007) data available for the State of Michigan.

In the course of the analysis, several adjustments are made to help ensure that all impact estimates are truly incremental and specific to the study area:

- Since the original IMPLAN data is for 2007, it is adjusted for inflation to express the results in current dollars;[14]
- Social Accounting Matrix (SAM)[15] multipliers used for estimating indirect and induced effects are modified with Regional Purchase Coefficients (RPC)[16] to ensure that imports to Michigan are not accounted for; and
- Households are the only institutions considered when building type SAM multipliers. As a result, induced effects are based on the income of Michigan residents solely.

Figure 8 below presents a structure and logic diagram for estimating the economic impacts of transit operating expenses in Michigan. The economic impacts resulting from the re-spending of transit riders' vehicle ownership and operating cost savings are estimated in a similar manner.

[12] An input-output ("I-O") approach has been followed in this study, drawing on an extensive body of research and experience with successful applications to transportation project analysis. An I-O model calculates impact multipliers, which are then used to compute direct, indirect, and induced effects – output, value added, employment, and tax revenue generated per dollar of direct spending.

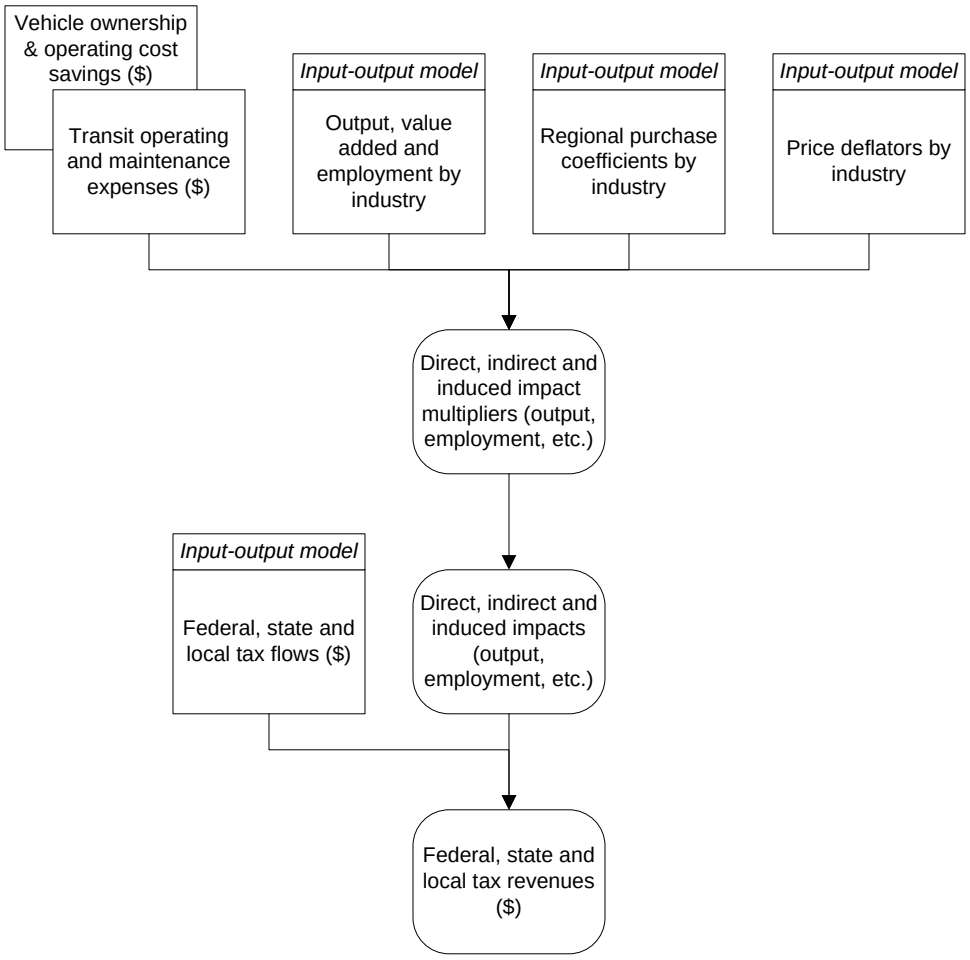
[13] For further information on the IMPLAN system, go to http://www.implan.com/.

[14] Deflators derived from the most current Bureau of Labor Statistics (BLS) Growth Model are used to convert the cash flows to current dollars. These deflators are applied at the commodity level and vary for different goods and services.

[15] Type SAM multipliers are the direct, indirect and induced effects where the induced effect is based on social accounting matrix information. Type SAM multipliers capture inter-institutional transfers (in addition to all commodity flows).

[16] RPCs are ratios indicating what fraction of total demand for goods and services within a region (both by business and household) is satisfied from within the region; all remaining demand is satisfied by imports, which provide no direct economic benefit to the region. In other words, they filter-out economic leakages from the region.

Figure 8: Structure and Logic Diagram for Economic Impacts of Transit Operations and Vehicle Ownership and Operating Cost Savings



4. ECONOMIC MODEL

HDR was tasked by Michigan DOT to demonstrate how the economic model would be used independently by local, regional, and state government decision makers and planners to estimate the benefits of public transit. To this end, two transit agencies, one urban and one non-urban, were selected to test and validate the model in the field. This chapter presents the findings of the model demonstration. It includes both a discussion of the model's performance in meeting all of the characteristics required by MDOT (Section 4.1), and the model results for the two test agencies (Section 4.2).

4.1 Key Model Characteristics

MDOT required that the economic model developed by HDR contain a number of key characteristics to ensure that it can be used independently by local, regional, and state government decision makers and planners.[17]

4.1.1 The Model is Scalable

One of the key features of the economic model is that the assessment of transit benefits can be conducted at different geographical or jurisdictional levels. More precisely, the model estimates the benefits of local bus transit service at the agency level, at the agency type level, or at the state level (i.e., all agencies combined). Transit agencies are aggregated into seven agency types based on the classification currently used in the Public Transportation Management System (PTMS): urban metro, urban large, urban medium, urban small, nonurban county, nonurban city, and nonurban township. In addition, at MDOT's request, the model can calculate benefits for all urban agencies or for all nonurban agencies.

The selection of the level of analysis in the model is a two-step process:

- On the worksheet named 'CONTROL PANEL', first choose 'Level of Analysis (1)'. Click on cell C3 and using the drop down menu, select 'State', 'Transit Agency Type', 'Urban/Non-Urban' or 'Agency'.

- Next, on the 'CONTROL PANEL' sheet, click on cell E3. Using the drop down menu that appears, select 'Level of Analysis (2)'. If 'State' was selected in Step 1, 'State' must be selected here as well. If 'Transit Agency Type' was selected, choose one of the seven transit agency types. If 'Urban/Non-Urban' was selected, choose 'Urban' or 'Non-Urban'. If 'Agency' was selected, choose one of the 85 agencies.

Note that the model inputs used to estimate the cost savings associated with public transit are divided into two blocks: inputs that are specific to each transit agency (passengers, vehicle miles, etc.) are provided in the 'OPERATIONS' sheet; and inputs that are specific to the agency type (e.g., percentage of work trips foregone) or common to all agencies (e.g., nitrogen oxide emissions cost per metric ton) are provided in the 'OTHER DATA' sheet.

[17] The requirements are also listed on page 5 of the Request for Proposal.

4.1.2 The Model Uses Operations Data from the Public Transportation Management System (PTMS)

The Public Transportation Management System is an online database administered by the Michigan DOT. It provides quantitative and qualitative data on the financial and operational characteristics of the transit agencies in the state. Key functions of PTMS include the collection and reporting of performance indicator data (e.g., passengers per vehicle hour) as well as the facilitation of asset replacement forecasts to name a few. In addition, the financial database is used for both budgeting and the procurement of funding. Transit agencies in Michigan are required to upload their data to the system on an annual basis. The information is then audited before it is reconciled.

Whenever possible, HDR used transit operations data specific to each agency available from PTMS. In particular, the following variables are included in the model:

- Population (of the service area);
- Total passengers (regular, elderly, persons with disabilities, and elderly persons with disabilities);
- Vehicle miles (including deadhead miles and purchased transportation service miles);
- Fare revenue (passenger fares and contract fares);
- Total expenses (eligible and ineligible); and
- Accidents (collision, non-collision, and station accidents resulting in a fatality, personal injury, or property damage).

Note that the most recent complete data (FY 2007) was used to calculate the benefits of transit for the two test agencies.

4.1.3 All Model Inputs not in PTMS Are Publicly Available

HDR identified a number of data sources and references for all model variables not available in PTMS (in particular, non-operating data such as value of time, and emission costs per ton). All data sources and references are listed in the worksheet 'SOURCES'. Whenever possible, the hyperlink to the webpage where the data was found is provided to make future updates easier (e.g., Michigan Traffic Crash Facts).

Some data was not readily available from the public domain and was directly uploaded into the model. This is the case only for the economic multipliers (see 'I-O RESULTS' sheet) used to estimate the impacts associated with: *(i)* transit operation and maintenance expenses; and *(ii)* vehicle ownership and operating cost (VOC) savings accruing to transit riders. Multipliers for the State of Michigan were obtained from IMPLAN® (for more information, see Section 3.2.2) for the following impact metrics: industry output (i.e., total volume of sales), value added (equivalent to the Gross State Product), employment (or number of jobs), and tax revenue (at the Federal and State/Local levels separately). The multipliers are available for different years (2009

through 2012), so that that the economic impacts can be expressed in nominal or current dollars up to 2012.

4.1.4 The Assessment of Transit Benefits is Comprehensive

HDR conducted a comprehensive review of the economic literature to identify the different economic and community benefits of public transportation (see Section 3.1). Based on the findings of the literature review, the following benefits are assessed in the economic model:

- **Transportation Cost Savings (or Congestion Management Benefits in Urban Areas)** – These are the savings in vehicle ownership and operating cost (purchase/lease, insurance, fuel consumption, etc.), travel time, accidents, and environmental emissions (carbon monoxide, nitrogen oxides, etc.) due to less congestion and fewer vehicle miles traveled in the presence of public transit.

- **Low-Cost Mobility Benefits (Affordable Mobility and Cross-Sector Benefits)** – These are the benefits from providing low-cost mobility to transit-dependent households. The benefits include: *(i)* the economic value to access services such as healthcare, education, retail, and attractions (transit fare is typically lower than taxi fare and vehicle ownership and operating cost); and *(ii)* budget savings for welfare and social services (such as unemployment and homecare) due to the presence of public transit.

Note that these cost savings are estimated for all key socioeconomic sectors based on a breakdown of ridership by trip purpose: work; healthcare; education; shopping, recreation, and tourism; and other. Note, also, that transit benefits do not accrue only to transit riders or highway users, but also to the community at large (e.g., emission cost savings).

In addition to these cost savings, the model estimates the statewide economic impacts (direct, indirect, and induced) resulting from: *(i)* transit operation and maintenance expenses; and *(ii)* the re-spending of vehicle ownership and operating cost (VOC) savings accruing to transit users (see Section 3.2). Economic impacts are measured in terms of industry output (i.e., total volume of sales), value added (equivalent to the Gross State Product), employment (or number of jobs), and tax revenue (at the Federal and State/Local levels separately).

4.1.5 The Model Can Be Used Independently by Policy Makers at the Local, Regional and State Levels

The economic model is a “stand alone” spreadsheet-based model. In other words, it is not linked to external files and contains all the model inputs. All data sources and references used to derive the model inputs are listed in the worksheet ‘SOURCES’. Whenever possible, the hyperlink to the webpage where the data was found is provided to make future updates easier (e.g., Michigan Traffic Crash Facts).

The model was also designed so that it requires minimal proficiency in Excel. The end user needs only be familiar with the ‘CONTROL PANEL’ sheet. Key instructions for using the Control Panel are provided in the ‘INSTRUCTIONS’ sheet. The selection of the level of analysis (agency, agency type, state, and urban/non-urban) is a simple two-step process (described in Section 4.1.1 above).

The results are automatically updated when a model input is changed. Some sheets, in particular the sheets where all the calculations are made ('CALCUL-BEN', 'CALCUL-IMP', and '@RISK'), are protected so that the formulae can be viewed but not changed by the user.

4.1.6 The Model Accounts for Uncertainty

The economic model is built within a risk analysis framework to account for uncertainty surrounding all model assumptions (e.g., percentage of trips for work purposes), thereby providing decision makers with the full spectrum of potential outcomes in lieu of single point estimates. **Note that this feature is not required by MDOT and is optional in the model.** Users who wish to conduct a risk analysis need to install the @RISK application (a MS Excel add-in) on their machines.[18]

Confidence in the model results is maximized when risk analysis is applied. Risk analysis involves recognizing the probability range of error in each and every assumption that enters into the benefit estimation process. It also involves being transparent about these probability ranges and permitting enough scrutiny by experts and opinion leaders beyond the study team to assure their confidence that risk is properly taken into account.

The result of a risk analysis is a forecast of future events and the probability, or odds, of their occurrence. Not unlike modern weather forecasting, in which the likelihood of rain is projected with a statement of probability ("there is a 20 percent chance of snow tomorrow"), risk analysis is intended to provide a sense of perspective on the likelihood of future events. Risk analysis is an easily understandable, but technically robust method that allows planners and decision-makers to select the level of risk within which they are willing to plan and make commitments.

4.2 Agencies' Feedback on the Economic Model

The Interurban Transit Partnership (The Rapid) and the Isabella County Transportation Commission (ICTC) were selected by MDOT and HDR to test and validate the model in the field. The Rapid is the fourth largest public transit agency in Michigan, by the number of riders, and operates a fixed-route bus service along with paratransit and vanpool services in a large urban area. By comparison, ICTC is a small demand response system operating in a rural area.

The model testing sessions took place in Grand Rapids on March 17th, 2009 and in Mount Pleasant on April 2nd. A follow-up call with each agency's management representatives was made more than a week after the session to receive additional comments on the model. The preliminary model outputs for both agencies are available in Appendix A and Appendix B.

4.2.1 Interurban Transit Partnership

The Rapid had four key comments.

Overall, *they were pleased with the general appearance, scope, and capabilities of the model. They stressed its usefulness for marketing purposes, but asked for some guidance as to how to present the results*, especially when dealing with a non-technical audience (general public or elected officials). From that perspective, it seems that a documented case study (Phase Two)

[18] The '@RISK' sheet should be unhidden if the user has chosen 'Yes' to the 'Risk Analysis' option in the 'CONTROL PANEL' sheet.

would be helpful for transit managers to understand both the meaning and the usage of the model results.

However, *The Rapid pointed out the lack of connectivity between the model and the Public Transportation Management System (PTMS)*. PTMS is an online database administered by the Michigan Department of Transportation that provides quantitative and qualitative data on the financial and operational characteristics of transit agencies operating in the state. The data can be viewed or downloaded by means of a simple query system. In its current version, nearly all output files are only available in PDF or HTML format, and thus cannot be directly linked to the spreadsheet-based economic model. As a result, PTMS data must be manually entered in the model at this time.

The Rapid also commented on the fact that when the @RISK application is not installed or launched, all cells linked to @RISK functions display the "#NAME?" error because MS Excel does not recognize those functions. To avoid any confusion, HDR suggest hiding the "@RISK" sheet in the model. The User Guide, included as a separate document, advises model users who are using the @RISK software to unhide the worksheet if they want to view the complete risk analysis results.

Finally, *The Rapid noticed that economic development benefits are not estimated in the model*. As explained above, the study focuses on bus transit only and economic development benefits arise chiefly in rail corridors. HDR suggest that these benefits be estimated separately or that the model be modified in the future to accommodate this feature.

4.2.2 Isabella County Transportation Commission

ICTC had four major comments as well.

Firstly, *they found it was difficult to understand and update the model without the help of a user guide*. In particular, *they were uncertain what information should be updated by the user and how the benefits of public transportation are calculated*. The methodological framework is graphically represented by means of flow charts in the presentation document that HDR created for the model demonstration. It is also explained in detail in Chapter 3. And the User Guide outlines what data should be updated.

ICTC also pointed out that PTMS, in its current version, does not separate line haul operations data from demand response operations data, which could be a problem when updating the model in the future. However, the model offers the option to estimate the benefits for all services combined if such data is not available. In addition, MDOT mentioned that PTMS might be updated to show the breakdown of operations data by transit mode in the future.

Like The Rapid, *ICTC stated that the model results would be useful to get support from local officials and show the benefits of transit to the community*.

Lastly, *one of the conference call participants mentioned that transit vehicles could be used to evacuate the disabled and the elderly in case of emergency (e.g., flood) and asked whether the model could estimate any related benefits*. Beyond the humanitarian aspects of the question, which are more qualitative in nature, HDR pointed out that the model could be used to estimate

the cost savings associated with the use of transit vehicles vs. the use of ambulances. Since then, HDR has modified the model to include EMS vehicles as an alternative mode of transportation.

APPENDIX A: PRELIMINARY RESULTS FOR INTERURBAN TRANSIT RIDERSHIP

Table 2: Transportation Cost Savings (The Rapid)

Benefit Sub-Category	
Vehicle ownership & operating cost savings	$27.6
Travel time savings	$5.0
Accident cost savings	$4.3
Emissions cost savings	$0.4
TOTAL	**$37.2**

Note: All dollar estimates are expressed in millions.

Table 3: Low-Cost Mobility Benefits (The Rapid)

Benefit Sub-Category	
Affordable mobility benefits	$0.8
Cross-sector benefits	$0.7
TOTAL	**$1.5**

Note: All dollar estimates are expressed in millions.

Figure 9: Benefits by Socioeconomic Sector (The Rapid)

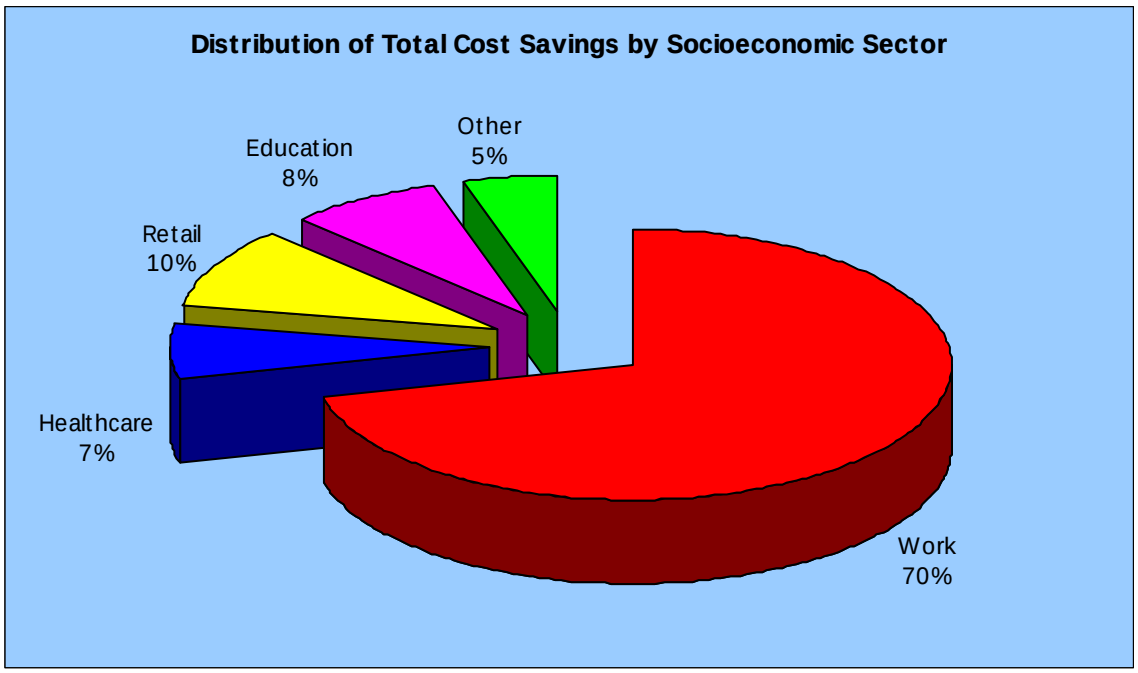


Table 4: Economic Impacts (The Rapid)

Impact Category	VOC Savings	Transit Expenses
Output	$29.0	$54.8
Value added	$16.1	$16.0
Employment	235	463
Tax revenue	$4.2	$4.6

Note: All dollar estimates are expressed in millions.

Figure 10: Output Impact from VOC Savings, by Type of Effect (The Rapid)

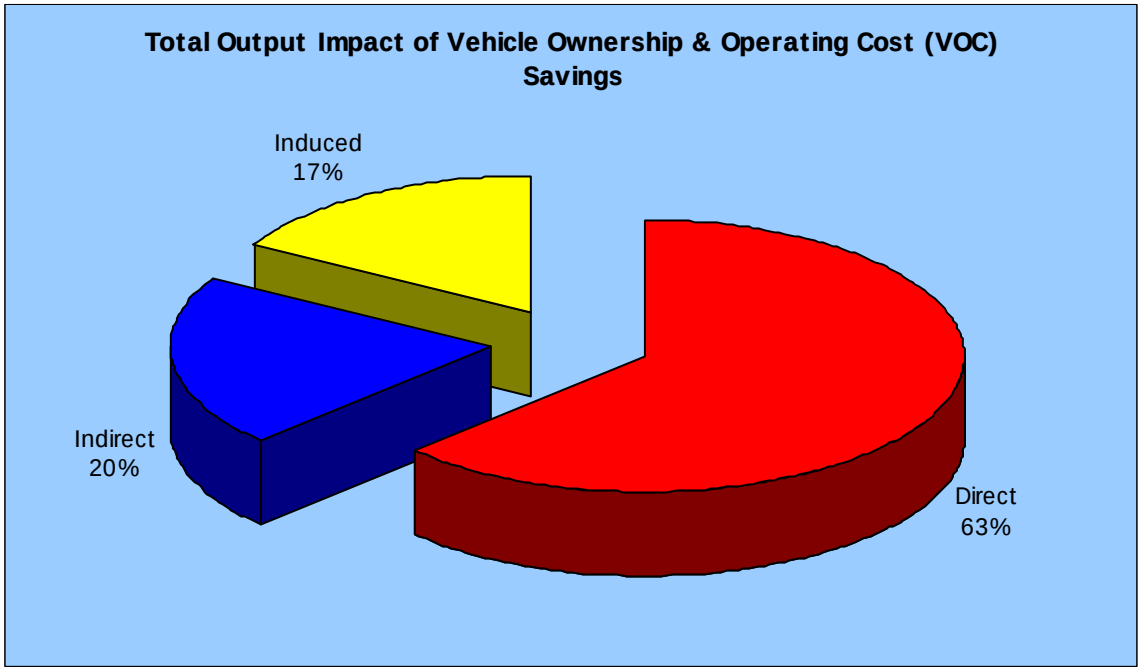
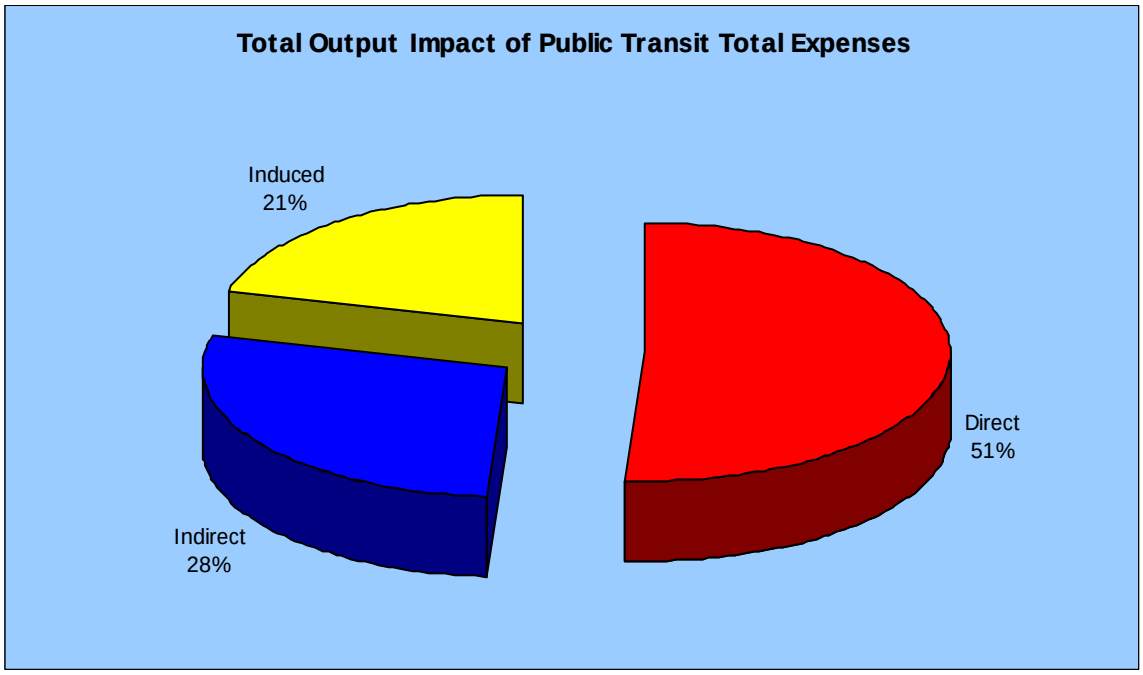


Figure 11: Output Impact from Public Transit Total Expenses, by Type of Effect (The Rapid)



APPENDIX B: PRELIMINARY RESULTS FOR ISABELLA COUNTY TRANSPORTATION COMMISSION

Table 5: Transportation Cost Savings (ICTC)

Benefit Sub-Category	
Vehicle ownership & operating cost savings	$1.2
Travel time savings	$0.0
Accident cost savings	$0.1
Emissions cost savings	$0.0
TOTAL	**$1.3**

Note: All dollar estimates are expressed in millions.

Table 6: Low-Cost Mobility Benefits (ICTC)

Benefit Sub-Category	
Affordable mobility benefits	$0.0
Cross-sector benefits	$0.2
TOTAL	**$0.2**

Note: All dollar estimates are expressed in millions.

Figure 12: Benefits by Socioeconomic Sector (ICTC)

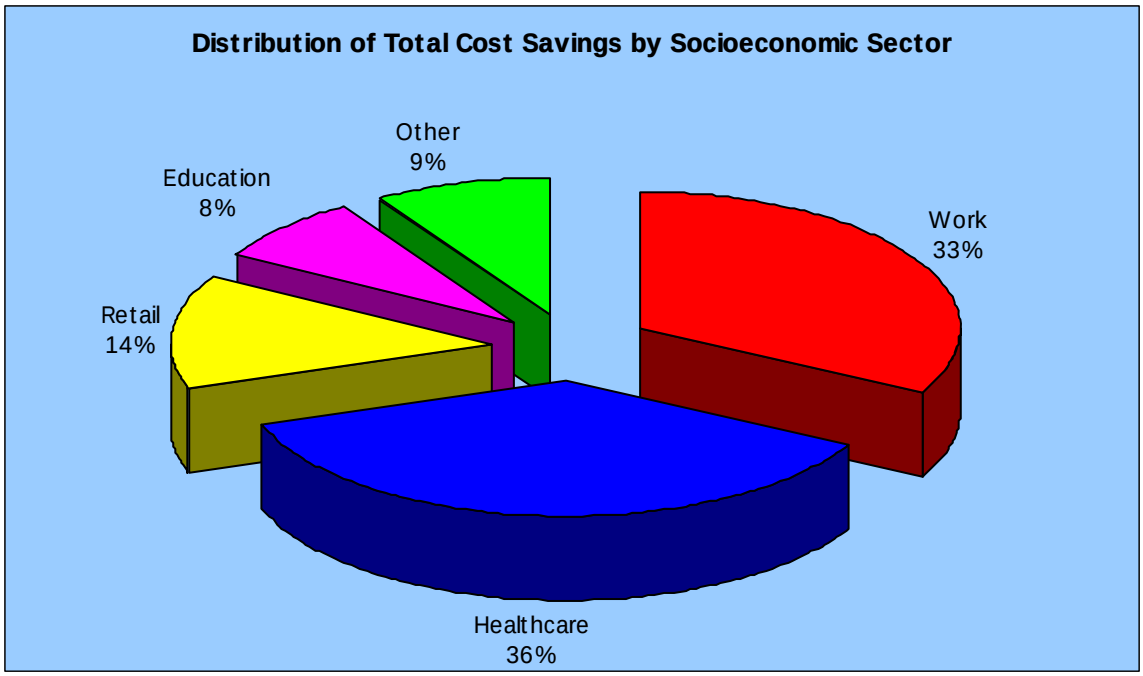


Table 7: Economic Impacts (ICTC)

Impact Category	VOC Savings	Transit Expenses
Output	$1.2	$7.4
Value added	$0.7	$2.2
Employment	10	63
Tax revenue	$0.2	$0.6

Note: All dollar estimates are expressed in millions.

Figure 13: Output Impact from VOC Savings, by Type of Effect (ICTC)

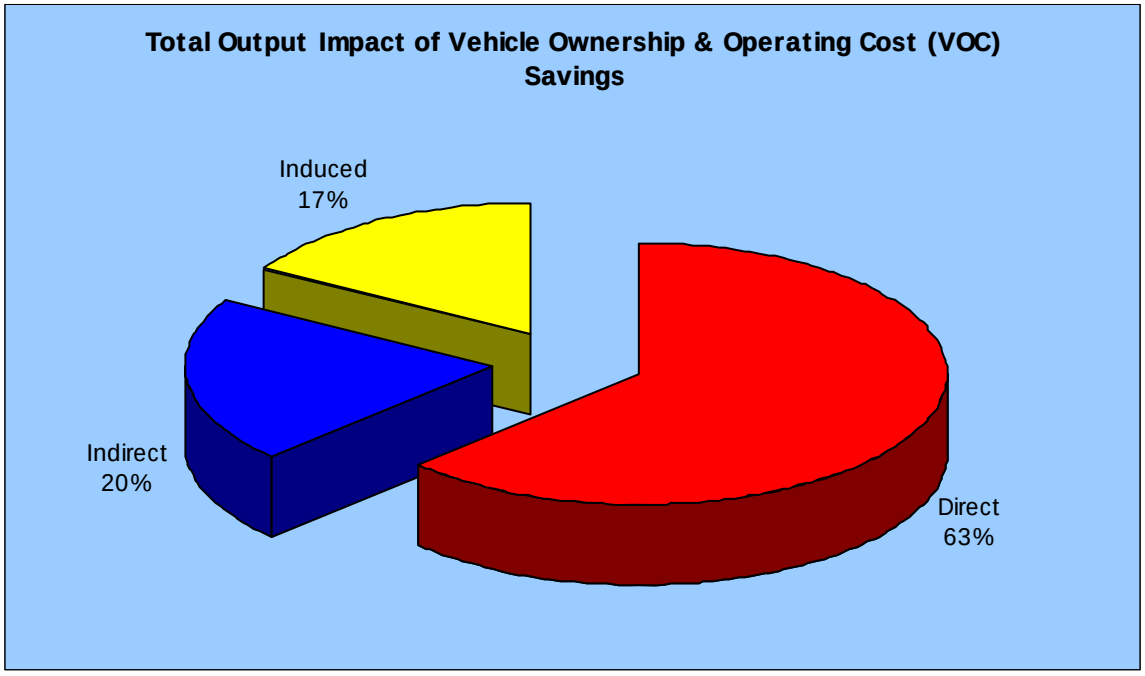
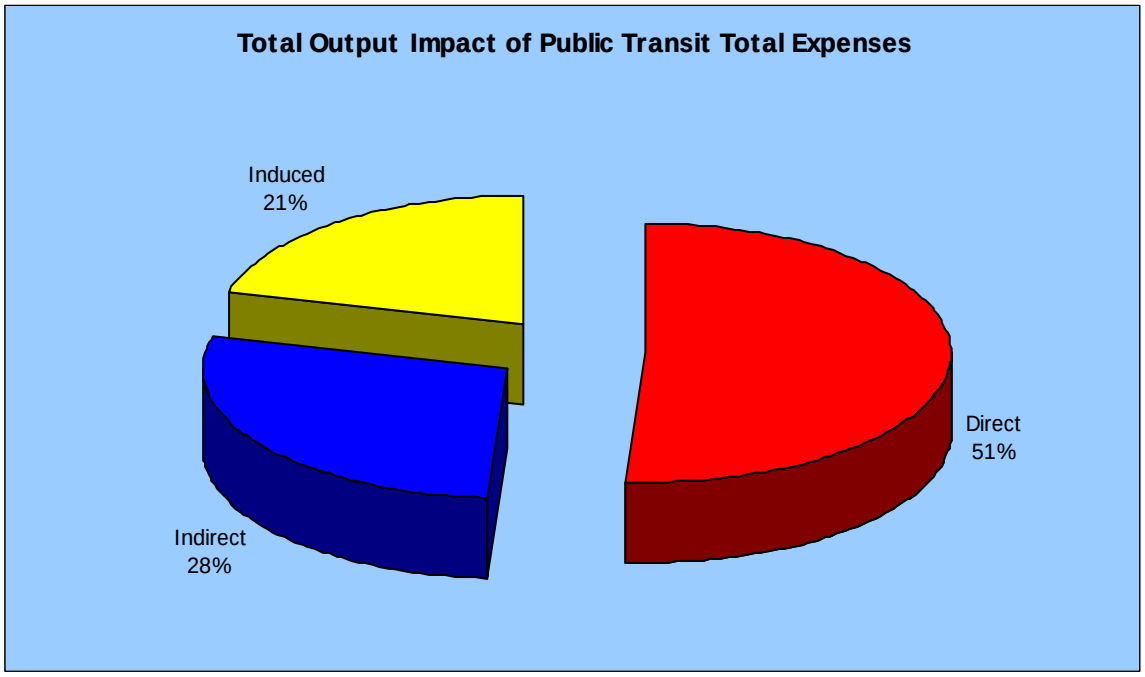


Figure 14: Output Impact from Public Transit Total Expenses, by Type of Effect (ICTC)



APPENDIX C: PRIMER ON RISK ANALYSIS

Economic forecasts traditionally take the form of a single "expected outcome" supplemented with alternative scenarios. The limitation of a forecast with a single expected outcome is clear – while it may provide the single best statistical estimate, it offers no information about the range of other possible outcomes and their associated probabilities. The problem becomes acute when uncertainty surrounding the forecast's underlying assumptions is material.

A common approach is to create "high case" and "low case" scenarios to bracket the central estimate. This scenario approach can exacerbate the problem of dealing with risk because it gives no indication of likelihood associated with the alternative outcomes. The commonly reported "high case" may assume that most underlying assumptions deviate in the same direction from their expected value, and likewise for the "low case." In reality, the likelihood that all underlying factors shift in the same direction simultaneously is just as remote as that of everything turning out as expected.

Another common approach to providing added perspective on reality is "sensitivity analysis." Key forecast assumptions are varied one at a time in order to assess their relative impact on the expected outcome. A problem here is that the assumptions are often varied by arbitrary amounts. A more serious concern with this approach is that, in the real world, assumptions do not veer from actual outcomes one at a time. It is the impact of simultaneous differences between assumptions and actual outcomes that is needed to provide a realistic perspective on the riskiness of a forecast.

Risk Analysis provides a way around the problems outlined above. It helps avoid the lack of perspective in "high" and "low" cases by measuring the probability or "odds" that an outcome will actually materialize. This is accomplished by attaching ranges (probability distributions) to the forecasts of each input variable. The approach allows all inputs to be varied simultaneously within their distributions, thus avoiding the problems inherent in conventional sensitivity analysis. The approach also recognizes interrelationships between variables and their associated probability distributions.

The Risk Analysis Process involves four steps:

Step 1: Define the structure and logic of the forecasting problem;

Step 2: Assign estimates and ranges (probability distributions) to each variable and forecasting coefficient in the forecasting structure and logic;

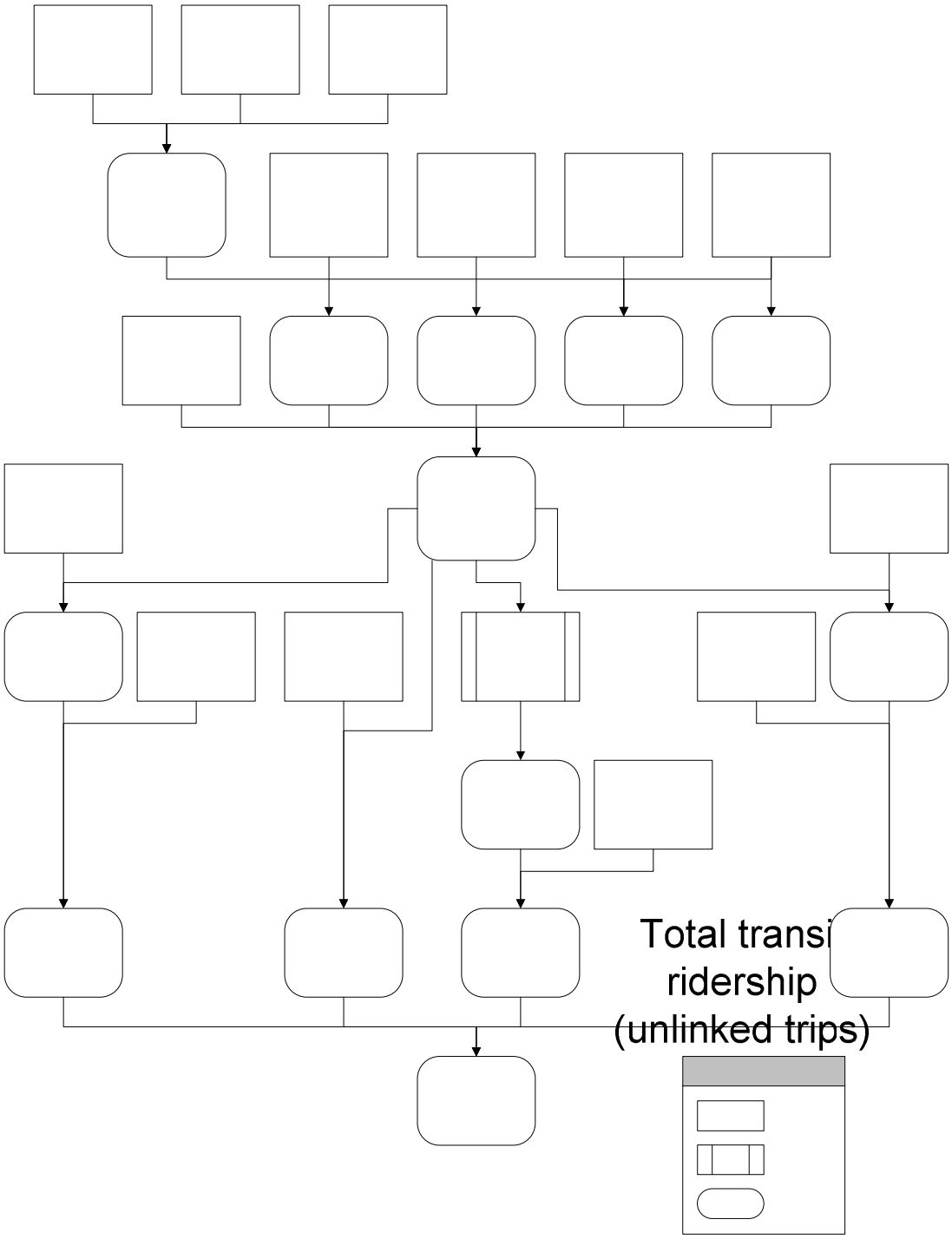
Step 3: Engage experts and stakeholders in assessment of model and assumption risks (the "RAP Session"); and

Step 4: Issue forecast risk analysis.

Step 1: Define Structure and Logic of the Forecasting Problem

A "structure and logic model" depicts the variables and cause and effect relationships that underpin the forecasting problem at-hand (Figure 15). Although the structure and logic model is written down mathematically to facilitate analysis, it is also depicted diagrammatically in order to permit stakeholder scrutiny and modification in Step 3 of the process (see below).

Figure 15: Example of Structure and Logic Model



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Step 2: Assign Central Estimates and Conduct Probability Analysis

Each variable is assigned a central estimate and a range (a probability distribution) to represent the degree of uncertainty. Special data sheets are used (see Table 8) to record the estimates. The first column gives an initial median while the second and third columns define an uncertainty range representing an 80 percent confidence interval. This is the range within which there exists an 80 probability finding the actual outcome. The greater the uncertainty associated with a forecast variable the wider the range.

Table 8: Example of Data Sheet, Percentage of Trips for Healthcare Purposes

Variable	Median	Lower 10%	Upper 10%
Percentage of trips for medical purposes (%)	10%	7%	13%

Probability ranges are established on the basis of both statistical analysis and subjective probability. Probability ranges need not be normal or symmetrical – that is, there is no need to assume the bell shaped normal probability curve. The bell curve assumes an equal likelihood of being too low and being too high in forecasting a particular value. It might well be, for example, that if a projected percentage deviates from expectations; circumstances are such that it is more likely to be higher than the median expected outcome than lower.

The RAP computer program transforms the ranges as depicted above into formal probability distributions (or "probability density functions"). This liberates the non-statistician from the need to appreciate the abstract statistical depiction of probability and thus enables stakeholders to understand and participate in the process whether or not they possess statistical training.

From where do the central estimates and probability ranges for each assumption in the forecasting structure and logic framework come? There are two sources. The first is an historical analysis of statistical uncertainty in all variables and an error analysis of the forecasting "coefficients." "Coefficients" are numbers that represent the measured impact of one variable (say, income) on another (such as retail sales). While these coefficients can only be known with uncertainty, statistical methods help uncover the magnitude of such error (using diagnostic statistics such as "standard deviation," "standard error," "confidence intervals" and so on).

The uncertainty analysis outlined above is known in the textbooks as "frequentist" probability. The second line of uncertainty analysis employed in risk analysis is called "subjective probability" (also called "Bayesian" statistics, for the mathematician Bayes who developed it). Whereas a frequentist probability represents the measured frequency with which different outcomes occur (i.e., the number of heads and tails after thousands of tosses) the Bayesian probability of an event occurring is the degree of belief held by an informed person or group that it will occur. Obtaining subjective probabilities is the subject of Step 3.

Step 3: Conduct Expert Evaluation: The RAP Session

Step 3 involves the formation of an expert panel and the use of facilitation techniques to elicit, from the panel, risk and probability beliefs about:

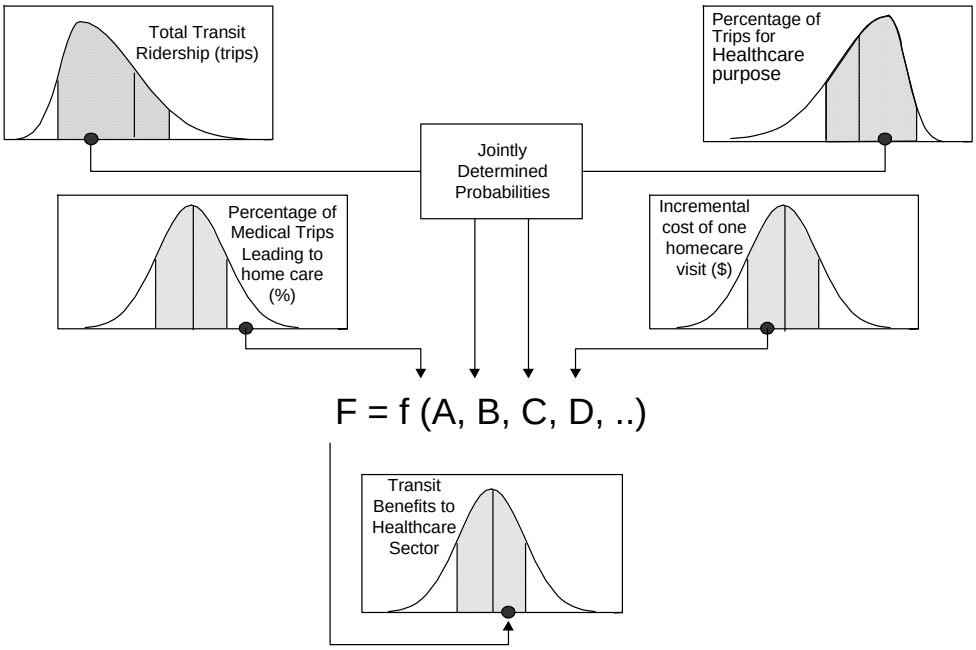
- The structure of the forecasting framework; and
- The degree of uncertainty attached to each variable and forecasting coefficient within the framework.

In (1), experts are invited to add variables and hypothesized causal relationships that may be material, yet missing from the model. In (2), panelists are engaged in a discursive protocol during which the frequentist-based central estimates and ranges, provided to panelists in advance of the session, are modified according to subjective expert beliefs. This process is aided with an interactive "groupware" computer tool that permits the visualization of probability ranges under alternative belief systems.

Step 4: Issue Risk Analysis

The final probability distributions are formulated by the risk analyst (HDR) and represent a combination of "frequentist" and subjective probability information drawn from Step 3. These are combined using a simulation technique (Monte Carlo analysis) that allows each variable and forecasting coefficient to vary simultaneously according to its associated probability distribution (see Figure 16 below).

Figure 16: Combining Probability Distributions



The end result is a central forecast, together with estimates of the probability of achieving alternative outcomes given uncertainties in underlying variables and coefficients (see Figure 17 and Table 9 below).

Figure 17: Risk Analysis of Homecare Cost Savings, an Illustration

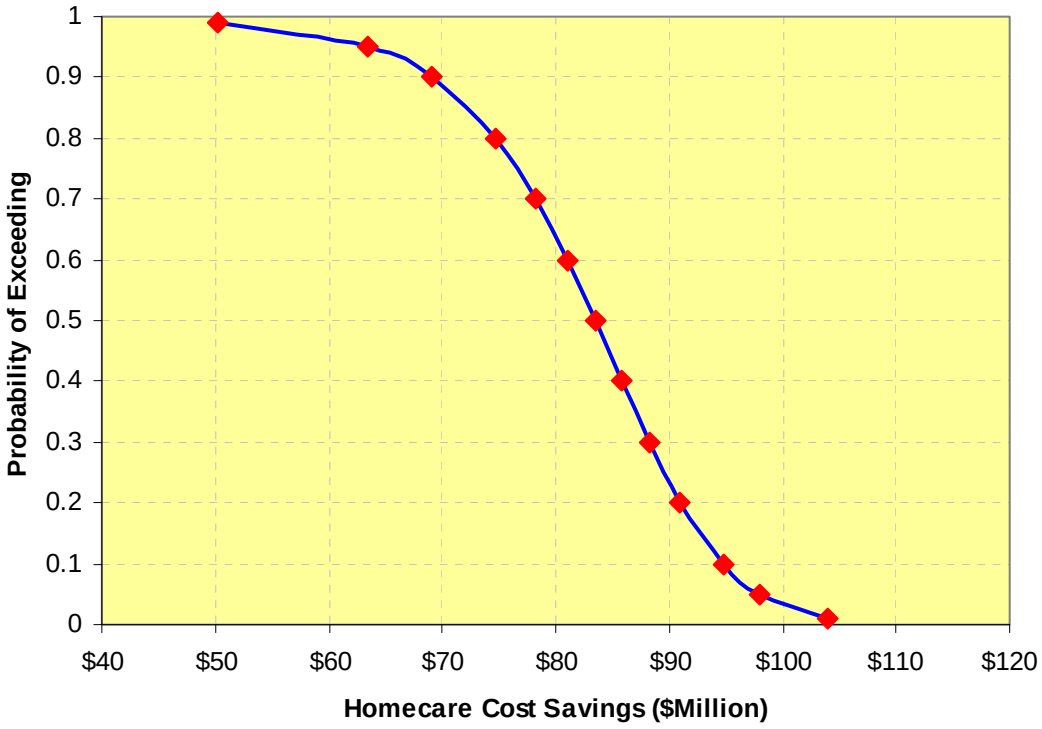


Table 9: Risk Analysis of Homecare Cost Savings, an Illustration

Homecare Cost Savings (in Millions of Dollars)	Probability of Exceeding Value Shown at Left
$50.2	0.99
$63.4	0.95
$69.0	**0.90**
$74.7	0.80
$78.3	0.70
$81.1	0.60
$83.5	**0.50**
$85.8	0.40
$88.2	0.30
$91.0	0.20
$94.8	**0.10**
$98.0	0.05
$104.0	0.01
$82.3	**Mean Expected Outcome**

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