A. Travel Time Value Literature Review Findings

A.1 AUTOMOBILES AND COMMERCIAL VEHICLES

Objective

This appendix provides background information on the valuation of user travel time and travel-time reliability, as reported in the relevant literature; and explores the various market segmentations and monetary values that could be applied to the calculation of user travel-time costs for the Southeast Florida Road and Transit User Costs Study. Previously, all values in this appendix were expressed in 2004 dollar values. These values are adjusted to 2010 dollar values using historical Consumer Price Index (CPI) data.

Format

This evaluation included a review of the following:

- Scholarly research from peer-reviewed journals;
- User benefit applications developed and/or used by the Federal Highway Administration (FHWA) and some state departments of transportation (DOT); and
- Implied values of time from a review of numerous mode-split models.

Literature Review Findings

The references cited in this literature review are organized into the following categories, based on content:

- **State of the Practice,** which include historic or refreshed TTVs applied to established market segmentations;
- **New Markets,** which include a list of relevant available sources identifying relatively new market segmentations and concomitant TTVs; and
- **TTVs Based on Review of Mode-Split Models**, which employ logit coefficients from previously developed models to compute TTVs.

Following is a list of the reviewed articles.

State of the Practice

- The Per-Mile Costs of Operating Automobiles and Trucks

- Highway Economic Requirements System (HERS-ST) Version 2.0: State Version (Draft Version);
- User Benefit Analysis for Highways;
- California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C);
- Departmental Guidance for the Valuation of Travel Time in Economic Analysis;
- The Value of Travel Time: Estimates of the Hourly Value of Time for Drivers, Passengers, and Cargo in Oregon, 1997;
- MicroBENCOST;
- Procedures and Technical Methods for Transit Project Planning;
- Transportation Cost Analysis: Techniques, Estimates, and Implications (on-line version);
- Perceived Value of Time for Truck Operators;
- The Value of Travel Time Savings in Evaluation; and
- Choice Models of Route, Occupancy, and Time of Day With Value-Priced Tolls.

New Markets

- The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990 to 1991 Data;
- The National Cooperative Highway Research Program (NCHRP) Report 463: Economic Impacts of Congestion;
- The Day Activity Schedule Approach to Travel Demand Analysis;
- Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User-Cost Estimation;
- Some Evidence of Travelers with Zero Value of Time;
- Market Segmentation for Ridership Forecasting (Draft Working Paper/PowerPoint presentation);
- The Value of Time and Reliability: Measurement from a Value Pricing Experiment;
- Uncovering the Distribution of Motorists' Preferences for Travel Time and Reliability: Implications for Road Pricing; and
- The Florida Reliability Method in Florida's Mobility Performance Measures Program.

Market Segmentations for Travel Time Values

The scholarly and applications-oriented literature on travel time values show a considerable range of travel markets, or market segmentations for which TTVs have been developed. Some general metrics regarding market segmentations are shown in Table A.1 for the sources presented in this literature review. Many of the sources examined provided results based on more than one market segmentation.

From this table, it can be seen that the highest instance of market segmentation occurs in the "Purpose of Travel" category. The table indicates that eight of the examined sources provided TTVs that reflect the purpose of the trip (e.g., business or personal). Additionally, seven of the entries provided segmentations based on the type of vehicle, or "Vehicle Class," which included, for example, automobiles, light-duty trucks, and heavy trucks. Other common segmentations for the articles reviewed here are income, mode, and type of travel. A significant number of the sources (three) provided no market segmentation, but instead present a unified average value of travel time or no TTV at all.

Table **A.2** illustrates the range of TTVs exhibited in the literature reviewed, also expressed as the percentage of the annual average wage. These ranges do not include some outlying values that were determined to be irrelevant to the Southeast Florida project, such as time spent telecommuting ($0.00 per hour) or time spent in school buses ($0.94 per hour). Table **A.2** also shows the number of relevant entries for a particular segmentation (which corresponds to the "number of sources" listed in Table A.1); some factors that influence the low and/or high numbers in the range, and a row showing ranges for reliability values, which does not appear in Table A.1.

Table **A.2** shows that the low-high range for a given segmentation is larger when more than one relevant source is referenced, which we feel reflects differences in methodology and underlying assumptions. In addition, some segmentation types, such as vehicle class, exhibit considerable within-group variability, simply because of the range of trip purposes or types of activities they consider. Ranges exceeding 100 percent of the average hourly wage reflect the additional weight given to higher-wage occupations/industries, the inclusion of fringe benefits, and, in the case of commercial vehicle travel, the inclusion of an inventory cost. Overall, the number of different market segmentations shown in Table A.1 demonstrates the variety of applications for which TTVs may be used.

Table A.1 Summary of Market Segmentations

Segmentation Type	Sample Segmentation Details	Number of Sources Using This Segmentation
Age	15-24, 25-34, 35-44, 45-54, 55 and over	1
Attitudinal Characteristics of Traveler	Sensitivity to pricing, time savings, stress, etc.	1
Gender	Male, Female	2
Income	Personal, Household	3
Industry	Private, Government, etc.	2
Level of Employment	Full-time, Part-time, Unemployed, Self-Employed, Housewife, Student, Retired	1
Mode	Bus, Truck, Auto, Transit, In/Out-Vehicle	5
Occupation	Sales, Professional, Clerical, Precision Production and Crafts, etc.	2
Purpose of Travel	Business, Personal, Commute, Home-to-Work, Home-to-Other	9
Time of Day	Peak, Off-Peak	1
Travel Time		1
Trip Distance		2
Truck – Driver Payment Method	Hourly, Other	1
Truck – Fleet Type	For-Hire, Private	1
Truck – Load	Truckload, Less-than-Truckload	1
Type of Development	Urban, Rural	1
Type of Travel	Local, Intercity, Carpool, Alone, Passenger, Driver	3
Vehicle Class	Small Auto, Light Truck, Heavy Truck, 4-Axle Combination, etc.	7
No Segmentation		5

Note: The number of sources using a given segmentation, as given in this table, is higher than the total number of citations in this document because multiple segmentations occur in most studies.

Table A.2 Travel Time Value Range by Market Segmentations

Segmentation	Range (in 2010 Dollars) Low	High	Number of Studies	Influencing Factors
Income	$2.50 (10%)	$37.16 (142%)	3	Purpose of travel, type of travel, mode
Mode	6.23 (24%)	26.20 (100%)	4	
Purpose of Travel	6.38 (24%)	27.43 (105%)	9	Mode, vehicle class, trip length
Truck – Driver Payment Method	21.02 (80%)	35.36 (135%)	1	
Truck – Fleet Type	24.51 (94%)	32.58 (124%)	1	
Truck – Load	25.68 (98%)	34.80 (133%)	1	
Type of Travel	9.60 (37%)	24.01 (92%)	3	Mode, vehicle class, purpose of trip
Vehicle Class	9.60 (37%)	43.69 (167%)	7	Purpose and type of travel
No Segmentation	3.39 (13%)	34.13 (130%)	5	
Value of Reliability	4.81 (18%)	47.22 (180%)	3	Gender

Travel Time Values of Managed Lane Users

On top of regular travel time values, managed lane users choose to pay certain amount of toll for time saving, reliability, potential safety benefit, or even comfort of the trip. Several studies, shown below, have been review to identify additional travel time value components for managed lane users and proposed methodologies to estimate these components.

- Synthesis of Research on Value of Time and Value of Reliability, FDOT, 2009
- Improving Value of Travel Time Savings Estimation for More Effective Transportation Project Evaluation, FDOT, 2011
- Managed Lane Travelers – Do They Pay for Travel as They Claimed They Would, TTI, 2011
- The Value of Travel Time and Reliability – Evidence from a Stated Preference Survey and Actual Usage, Devarasetty, et al., 2012
- 95 Express Phase 3&4 Stated Preference Survey Report, RSG, 2013

Devarasetty's study found that two major additional travel time values components of managed lane users are value of travel time savings (VTTS) and travel time reliability (VOR). A case study was compared with what was found from a stated preference survey. The results indicated agreement between the two approaches. The FDOT study of "Improving Value of Travel Time Savings Estimation for More Effective Transportation Project Evaluation" used a survey on the 95 Express corridor found that a mean VTTS of around 49% of hourly income. The other FDOT study conducted by CUTR concluded that value of time to ranges from 25% to 175% of income level depending on travel mode and conditions, while VOR ranges from 80%-300% of value of time depending on constraints of department and arrival time. The TTI study also applied VTTS and VOR as key components of managed lane user travel time values. The study indicated that VTTS is about 65% of income while VOR is 108%. The SP survey report from RSG measures VOR in the term of travel time entropy, or unpredictability. The report indicated that "respondents who are delayed by unexpected traffic congestion would be willing to pay approximately of $0.45 on average for a more reliable travel time on I-95."

Truck Driver Travel Time Values by Commodity Types

Due to natural of different commodities, some good tends to have higher time sensitivity than others. For instance, fresh flower is very time-sensitive for its delivery, while house furniture tends to be less time sensitive. In order to reflect such variation, a review of studies and researches was conducted targeting at time sensitivities of different types of goods.

- The Value of Freight Travel Time Saving and Reliability Improvements – Recent Evidence from Great Britain, Fowkes and Whiteing, 2006
- Cost Per Hour and Value of Time Calculations for Passenger Vehicles and Commercial Trucks for Use in the Urban Mobility Study, TTI, 2008
- The Valuation of Travel Time Saving and Predictability in Congested Conditions for Highway User Cost Estimation, NCHRP Report 431, 1999
- Monetizing Truck Freight and the Cost of Delay for Major Truck Routes in Georgia, Gillett, 2011
- Assessing the Value of Delay for Truckers and Carriers, TTI, 2011
- Value of Time for Road Commercial Vehicles, Fowkes, 2011

These studies looked at truck drivers and travel time values by commodity types grouped by time sensitivity, unit type, and bulk or dry. The NCHRP report recommended that commodities to be grouped as high time sensitive (agriculture/fresh produce), medium time sensitive (building material, minerals, bulk product, etc), and low time sensitive (household goods). Gillett further expanded the grouping into each two-digit Standard Classification of Transported Goods (SCTG) group. Fowkes's study in 2011 presented value of time for several sampled commodity types. Blending with time sensitivity grouping, time sensitivity factors, a group of multiplication factors applied on regular truck driver travel time values, were developed as shown in Table A.4 below.

Table A.3 Commodity Group Time Sensitivity Factors

Commodity	SCTG Class	Time Sensitivity Group	Factor
Alcohol beverages	8	Medium	1.00
Animal Feed	4	High	1.66
Articles-Base metal	33	Medium	1.00
Base metals	32	Medium	1.00
Basic chemicals	20	Medium	1.00
Building stone	10	Medium	1.00
Cereal Grains	2	High	1.66
Chemical products	23	Medium	1.00
Coal	15	Medium	1.00
Coal-n.e.c.	19	Medium	1.00
Crude petroleum	16	Medium	1.00
Electronics	35	Low	0.75
Fertilizers	22	Medium	1.00
Fuel Oils	18	Medium	1.00
Furniture	39	Low	0.75
Gasoline	17	Medium	1.00
Gravel	12	Medium	1.00
Life animals/fish	1	High	1.66
Logs	25	Medium	1.00
Machinery	34	Low	0.75
Meat/seafood	5	High	1.66
Metallic ores	14	Medium	1.00
Milled grain products	6	High	1.66
Misc. mfg. prods.	40	Low	0.75
Mixed freight	43	High	1.66
Motorized vehicles	36	Low	0.75
Natural sands	11	Medium	1.00
Newsprint/paper	27	Low	0.75
Nonmetallic minerals	13	Medium	1.00
Non-metallic mineral products	31	Medium	1.00
Other agricultural products	3	High	1.66
Other food stuffs	7	High	1.66
Paper articles	28	Low	0.75
Pharmaceuticals	21	Medium	1.00
Plastics/rubber	24	Medium	1.00
Precision instruments	38	Low	0.75
Printed products	29	Low	0.75
Textiles/leather	30	Low	0.75
Tobacco products	9	Medium	1.00
Transport equipment	37	Low	0.75
Unknown	42	Low	0.75
Waste/scrap	41	Low	0.75
Wood products	26	Medium	1.00

A.2 TRANSIT VEHICLES

Objective

This section summarizes the findings of a literature review conducted to establish the value of travel time for transit users is Southeast Florida. The purpose of this review is to provide an overview on existing work to date on transit TTV in the United States and internationally. Additionally, the literature review will be used to help develop a methodology for computing TTV for transit users in Southeast Florida.

Literature Review Findings

Travel time is one of the largest components of transport costs; and time savings are often the greatest benefit of transport projects, such as new and expanded roadways and public transit improvements.[1] TTV varies depending on trip purpose, income level, travel condition, traveler preference, travel time variability and uncertainty, different parts of a trip, etc.[1] Business trips tend to have higher TTVs than commuting or leisure trips. People with higher income probably have higher TTVs than people with lower income. Transit riders sitting in a crowded bus may have higher TTVs than those riding an empty bus. TTV increases when travel time is longer than normally expected. Time spending on walking to a transit station has a higher value than in-vehicle time.

There has been a wide variation in the methodologies applied by different agents studying travel time value of transit users. Considering the main objective of this task is to assess local travel time values for Southeast Florida, results from agents within the United States are given more attention. Therefore, studies conducted by U.S. DOT, AASHTO, and two studies from Boston, Massachusetts, and Portland, Maine, are mainly used to develop the travel time values and market segmentation applied in tasks later on, as summarized in Table A.4. While different segmentation values have been used in the various studies reviewed, they tend to converge on the values selected for presentation in Table A.4.

Table A.4 Travel Time Values and Market Segmentations Applied

Local Transit				Intercity Transit				
Personal		Business		Personal		Business		
Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Notes
57%	43%	100%	100%	85%	65%	100%	100%	of total Income

[1] Litman, T., *Transportation Cost and Benefit Analysis – Travel Time Costs*, Victoria Transport Policy Institute, June 2002.

The literature review included 13 references from published sources. For each entry in the review, a summary was compiled. Each summary includes a title and source citation; a brief synopsis of the source; a summary of the market segmentations for which travel-time and/or reliability values are given; and, if applicable, calculation methodologies and monetary figures for the value of user travel time and reliability. It is important to note that no single study was found to cover all the factors affecting TTV for transit users.

The references cited in this literature review are organized into the following categories, based on content: TTVs in the United States and TTVs in other countries. Table A.5 illustrates the key findings on TTVs for transit users in the United States and globally.

Summaries are presented as follows: first, studies related to TTVs of transit users in the United States are presented; second, studies about those of Europe, Australia, and North America are summarized; and third, a summary of the study about other countries in South America, Asia, and Africa is provided, where the economies and resulting TTVs tend to vary significantly from North American conditions.

Table A.5 Literature Review Findings of TTVs of Transit Users ($2010 in "()")

	Local Transit				Intercity Transit				
	Personal		Business		Personal		Business		
Source/Country	**Peak**	**Off-Peak**	**Peak**	**Off-Peak**	**Peak**	**Off-Peak**	**Peak**	**Off-Peak**	**Notes**
United States									
U.S. DOT	35-60%		80-120%		60-90%		80%-120%		of total wage rate
ECONorthwest & PBQD	50%		100%		50%		100%		of total wage rate
VTPI	$5.40 (6.40)								in 2003 dollars
Boston, MA	$5.9-7.8 (8.68-11.48)	$4.2-6.1 (6.18-8.98)	$5.9-7.8 (8.68-11.48)	$4.2-6.1 (6.18-8.98)	$5.9-7.8 (8.68-11.48)	$4.2-6.1 (6.18-8.98)	$5.9-7.8 (8.68-11.48)	$4.2-6.1 (6.18-8.98)	in 1994 dollars, medium density
Portland, ME	$6.39 (9.40)	$5.03 (7.40)	$6.39 (9.40)	$5.03 (7.40)	$6.39 (9.40)	$5.03 (7.40)	$6.39 (9.40)	$5.03 (7.40)	in 1994 dollars, medium density
AASHTO	50%		100%		50%		100%		of total wage rate
Texas DOT	$17.88 (21.19)								in 2003 dollars
Federal Transit Administration (FTA)	25-50%								of total wage rate
Delucci's Study	$9.82-15.63 (11.64-18.52)								in 2003 dollars
Bowman's Study	$2.17-15.76 (2.57-18.68)								depending on income level
European Countries									
Austria	3.31 (7.30)		11.23-12.38 (24.76-27.25)		3.31 (8.01)		11.23-12.38 (24.76-27.25)		in Jan 98 U.K. pounds
Belgium	2.88-3.38 (6.34-7.43)		–		2.88-3.38 (6.34-7.43)		–		in Jan 98 U.K. pounds
Finland	11.02 (24.32)		–		11.02 (24.32)		–		in Jan 98 U.K. pounds

	Local Transit				Intercity Transit				
	Personal		Business		Personal		Business		
Source/Country	**Peak**	**Off-Peak**	**Peak**	**Off-Peak**	**Peak**	**Off-Peak**	**Peak**	**Off-Peak**	**Notes**
France	6.41-16.27 (14.13-35.88)		–		6.41-16.27 (14.13-35.88)		–		in Jan 98 U.K. pounds
Germany	45.43 (100.10)		–		45.43 (100.10)		–		in Jan 98 U.K. pounds
Ireland	1.15-7.34 (2.54-16.17)		–		1.15-7.34 (2.54-16.17)		–		in Jan 98 U.K. pounds, by modes, see Table A.14
Moldova	0.22-1.73 (0.47-3.81)		–		0.22-1.73 (0.47-3.81)		–		in Jan 98 U.K. pounds, per bus, see Table A.14
Netherlands	3.82-4.68 (8.44-10.34)		13.18-13.25 (29.10-29.22)		3.82-4.68 (8.44-10.34)		13.18-13.25 (29.10-29.22)		in Jan 98 U.K. pounds
Norway	2.59-4.32 (5.71-9.52)		9.58 (21.15)		4.32-4.9 (9.52-10.80)		6.77-10.44 (14.95-23.03)		in Jan 98 U.K. pounds, by modes, see Table A.14
Sweden	0.72-0.94 (1.59-2.07)		3.02-10.87 (6.67-24.93)		0.72-0.94 (1.59-2.07)		3.02-10.87 (6.67-24.93)		in Jan 98 U.K. pounds, by modes, distance, see Table A.14
Other Countries									
Australia	$8.8-9.3 (6.96-7.32)	$6.9-7.9 (5.46-6.25)	$8.8-9.3 (6.96-7.32)	$6.9-7.9 (5.46-6.25)	$6.9-8.7 (5.46-6.88)	$5.9-7.5 (4.66-5.93)	$6.9-8.7 (5.46-6.88)	$5.9-7.5 (4.66-5.93)	in 2003 Australian dollars
Canada	35-70% if seated; 50-100% if standing								of total wage rate, based on Level of Service (LOS)
New Zealand	$5.25-10.55 (3.74-7.53)		$21.3 (17.55)		$5.25-10.55 (3.74-7.53)		$21.3 (17.55)		in 1998 New Zealand dollars

*Values in “()” are equivalent 2010 dollars of the updated 1997 source data.

**Conversion factors between different currencies are from Bank of Canada: http://www.bankofcanada.ca/en/rates/exchform.html.

***Inflation factors between different years are from U.S. Department of Labor Bureau of Labor Statistics: http://www.bls.gov/data/home.htm

.

TTVs of Transit Users in United States

1. Department Guidance for the Valuation of Travel Time in Economic Analysis

<u>Source</u>

U.S. DOT, April 1997/Update, 2002/Update, 2011, *Departmental Guidance on the Evaluation of Travel Time in Economic Analysis*, memorandum, U.S. DOT; used in STEAM software**.**

<u>Synopsis</u>

This memorandum from U.S. DOT provides an overall guideline for TTVs of all travelers, including surface travel, air travel, and truck travel. According to U.S. DOT, the value of saving time may vary, depending on both the purpose of travel, which affects the possible alternative uses of time, and the conditions under which it occurs. When a trip is undertaken during work or when the traveler is free to vary his or her work hours, an important measure of the value of time is the wage paid for the productive work that is sacrificed to travel. When evaluating time saved for personal activities, travelers are likely to regard some fraction of their wage rate as an approximate standard of what they are willing and able to pay for time. Note that since the focus of this study is about TTVs of transit users, only surface travel has been taken into consideration in this summary.

<u>Market Segmentation</u>

- Mode (surface, including all combinations of in-vehicle and other transit time, air, truck);
- Travel type (local, intercity); and
- Travel purpose (personal, business).

<u>TTV Calculation Methodologies</u>

As shown in Table A.6, the recommended TTVs of roadway users (including transit users) are a fraction of their wage rate based on their trip purpose. Acceptable TTV ranges also are given based on certain percentages.

TTVs

Table A.6 TTVs of Roadway Users
In 2010 Dollars

Category	Percentage of Wage*	Acceptable Range of Percentage**	Average Hourly Income	Recommended TTVs	Acceptable TTV Ranges
Local Travel					
Personal	50%	35-60%	$24.29 (household)	$12.20	$8.54 - $14.53
Business	100%	80-120%	$23.28 (personal)	$23.28	$18.60 - $27.95
All Purposes***				$12.71	$9.05 - $15.14
Intercity Travel					
Personal	70%	60-90%	$24.29 (household)	$16.97	$14.53 - $21.85
Business	100%	80-120%	$23.28 (personal)	$23.28	$18.60 - $27.95
All Purposes***				$18.30	$15.45 - $23.17

* Walk access, waiting, and transfer time should be valued at 100 percent of the wage rate when actions affect only these elements of transit time.

** Walk access, waiting, and transfer time should be valued at $19.41 - $29.17 per hour.

*** Distribution for local travel: 95.4 percent personal and 4.6 percent business; and for intercity travel: 78.6 percent personal, 21.4 percent business.

2. Estimating the Benefits and Costs of Public Transit Projects

<u>Source</u>

ECONorthwest and PBQD (2002), *Estimating the Benefits and Costs of Public Transit Projects*, TCRP Report 78, http://gulliver.trb.org/publications/tcrp/tcrp78/index.htm, TRB.

<u>Synopsis</u>

This paper summarizes the findings of numerous research projects. Travel time is typically valued as a percentage of the wage rate. Most research suggests that noncommercial travelers generally value their travel time at a substantial fraction of their wage, but that the actual value can vary with the type and length of trip and other factors. A reasonable estimate of the value of in-vehicle time is 50 percent of the gross wage rate of the traveler, with waiting, walking, and transfer time being valued at two to three times that level (i.e., even higher than the wage rate).

<u>Market Segmentation</u>

- Trip Segment (in-vehicle, waiting, walking, transferring); and

- Trip purpose (personal, business).

TTV Calculation Methodologies

TTVs are calculated as a proportion of the wage rate. Table A.7 shows TTVs of different time component in percentages of wage rate. This table is based on the estimation from the previously summarized document (*Department Guidance for the Valuation of Travel Time in Economic Analysis*).

TTVs

Table A.7 Value of Transit Travel for Various Time Elements

Time Component	Value of Time as Percentage of Wage or Total Compensation
In-Vehicle Personal (Local)	50%
In-Vehicle Personal (Intercity)	70%
In-Vehicle Business	100%
Excess (waiting, walking, or transfer time) Personal	100%
Excess (waiting, walking, or transfer time) Business	100%

Source: Aithers, from U.S. DOT, as reported in the Federal Register, 1997.

3. Transportation Cost and Benefit Analysis – Techniques, Estimates, and Implications

Source

Victoria Transport Policy Institute (VTPI), June 2003.

Synopsis

Prepared by the Canadian Victoria Transport Policy Institute, this guidebook provides research and reference information on transportation costing, and provides guidelines for the preparation of planning and policy analyses. The report gives a synopsized literature review regarding both the factors that affect TTVs and the recommended values for use in costing of transportation projects. Various studies from around both the U.S. and other countries about estimate of travel time values for different user types and travel conditions had been reviewed in this study.

Market Segmentation

- Mode;
- Time of day traveled (peak or off-peak); and
- Type of development (urban or rural).
- Trip segment (in-vehicle, waiting, walking, transferring); and
- Trip purpose (personal, business).

TTV Calculation Methodologies

Recommended values appear in 1996 U.S. dollars per passenger mile, and are easily convertible to dollars per passenger hour. The following assumptions are given in the guidebook:

> *For automobile (car, van, and light truck) modes and motorcycles, drivers' TTV is 50 percent of the average wage of $12.00; passenger time is valued at 35 percent of the average wage, at $4.20 per hour. Urban peak speeds are estimated to average 30 mph with a 16.5 percent congestion cost premium; urban off-peak and rural travel have no added associated congestion costs, and are assumed to average 35 and 40 mph, respectively. Passengers accrue no congestion premiums. Rideshare passengers increase trip times by 20 percent. Diesel buses and electric buses/trolleys travel at an average speed of 12, 15, and 18 mph in urban peak, urban off-peak, and rural settings. Walking and cycling is valued at $3.00 per hour, and are assumed to average three and 10 mph, respectively. Cycling incurs the 16.5 percent congestion premiums for urban peak conditions.*

TTVs

Table A.8 shows the TTVs of various kinds of roadway users.

Table A.8 User Travel-Time Costs
In 2010 Dollars

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	$10.63	$9.17	$9.25	$9.49
Compact Car	$10.63	$9.17	$9.25	$9.49
Electric Car	$10.64	$9.17	$9.25	$9.49
Van/Light Truck	$10.64	$9.17	$9.25	$9.49
Rideshare Passenger	$8.32	$8.31	$8.32	$8.31
Diesel Bus	$6.48	$6.48	$6.45	$6.45
Electric Bus/Trolley	$6.48	$6.48	$6.45	$6.45
Motorcycle	$10.63	$9.17	$9.25	$9.49
Bicycle	$5.39	$4.62	$4.62	$4.78
Walk	$4.68	$4.62	$4.62	$4.62
Telework	$0.00	$0.00	$0.00	$0.00

Note: Values are adjusted for inflation using CPI. Source data are valued in 1996 dollars.

As part of the review done by VTPI, it was found that Apogee Research estimated travel time costs per passenger mile for urban peak and urban off-peak travel at high, medium, and low densities in two U.S. cities, as shown in Table A.9.[2] Time values were based on 50 percent of average local wages for commuting and 25 percent for other travel. Original data was given in cent per passenger mile, which was translated into dollar per passenger hour.

Table A.9 Travel Time Cost in Two Cities
1994 Dollar Per Passenger Hour

	Commuter Rail		Rail Transit		Bus		Bicycle		Walk	
Density	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
Boston, MA										
High	$8.67 (12.76)	$6.81 (10.02)	$9.62 (14.15)	$6.86 (10.09)	$7.58 (11.15)	$5.97 (8.78)	$7.27 (10.70)	$5.74 (8.45)	$7.29 (10.72)	$4.77 (7.08)
Medium	$5.94 (8.74)	$4.2 (6.18)	$6.74 (9.92)	$6.07 (8.93)	$7.58 (11.15)	$5.97 (8.78)	$7.27 (10.70)	$5.74 (8.45)	$7.29 (8.33)	$4.77 (7.08)
Low	$5.7 (8.39)	$3.99 (5.88)	n/a	n/a	$7.58 (11.15)	$5.97 (8.78)	$7.27 (10.70)	$5.74 (8.45)	$7.29 (8.33)	$4.77 (7.08)
Portland, ME										
High	n/a	n/a	n/a	n/a	$6.39 (9.40)	$5.03 (7.40)	$5.98 (8.80)	$4.7 (6.91)	$4.98 (7.33)	$3.93 (5.78)
Medium	n/a	n/a	n/a	n/a	$6.39 (9.40)	$5.03 (7.40)	$5.98 (8.80)	$4.7 (6.91)	$4.98 (7.33)	$3.93 (5.78)
Low	n/a	n/a	n/a	n/a	$4.53 (6.66)	$3.57 (5.25)	$5.98 (8.80)	$4.7 (6.91)	$4.98 (7.33)	$3.93 (5.78)

*Values in "()" are equivalent 2010 dollars of the updated 1994 source data.

4. User Benefit Analysis for Highways

Source

AASHTO, August 2003.

Synopsis

This document provides guidelines for the assessment of user benefits associated with highway improvements. According to the AASHTO, user benefits comprise four components: value of time; operating costs; accident costs; and project management, which addresses the impacts on user benefits during the construction phase of an improvement.

Market Segmentation

[2] Conservation Law Foundation (www.clf.org), *The Costs of Transportation*, pp. 119-120, 1994.

- Mode (bus, truck, or auto);
- Type of travel (local or intercity, carpool or alone, and passenger or driver);
- Purpose of travel (personal, commute, or business); and
- Vehicle class (truck or auto).

TTV Calculation Methodologies

Value of time for the purposes of this study is represented as a function of wage or total compensation, percentage of wage or total compensation, and average vehicle occupancy. The report does not specify guidelines for input of segmentations more specific than "auto" and "truck," and appears to recommend using the national average hourly wage for autos, and average hourly compensation for trucks, as an input to the model.

The document cites and follows guidelines regarding valuation of travel time as a percentage of wage rate, set forth in the 1997 U.S. DOT report, *The Value of Travel Time: Departmental Guidance for Conducting Economic Evaluations*. It is noteworthy that the guidance was updated in 2002, and some recommended percentages adjusted. The 2002 update is discussed in this literature review.

To determine wage and compensation rates, this document departs from the guidance recommendations and takes its data from the U.S. National Income and Product Accounts (NIPA) for 2000.

Hourly Wage Values

Note: Source data are given in 2000 dollars. The values given here are inflated to 2004 equivalent dollars, as shown in Table A.10.

- National Average Hourly Wage = $24.65 (2010 equivalent); and
- National Average Hourly Compensation = $26.90 (2010 equivalent).

TTVs

Table A.10 AASHTO TTVs
In 2010 Dollars

Transportation Mode and Trip Purpose	Percentage		Wage or Total Compensation Rate (Dollar Per Hour)	Travel-Time Cost (Dollar Per Hour)
	Percent	Of		
Transit Bus				
In-vehicle commute	50	Wage rate	$24.93	$12.48
In-vehicle personal	50	Wage rate	$24.93	$12.48
Excess (waiting, walking, transfer), nonbusiness	100	Wage rate	$24.93	$24.93

Transportation Mode and Trip Purpose	Percentage		Wage or Total Compensation Rate (Dollar Per Hour)	Travel-Time Cost (Dollar Per Hour)
	Percent	Of		
Business (all time)	100	Total compensation	$27.22	$27.22
Auto				
Drive alone commute	50	Wage rate	$24.93	$12.48
Carpool driver commute	60	Wage rate	$24.93	$14.96
Carpool passenger commute	40	Wage rate	$24.93	$9.97
Personal (local)	50	Wage rate	$24.93	$12.48
Personal (intercity)	70	Wage rate	$24.93	$17.45
Business	100	Total compensation	$27.22	$27.22
Truck				
In-vehicle business	100	Total compensation	$27.22	$27.22
Excess (waiting time) business	100	Total compensation	$27.22	$27.22

Note: Values are adjusted for inflation using CPI. Source data are valued in 1997 dollars.

5. MicroBENCOST

Source

Daniels, G., D. R. Ellis, and W. R. Stockton, *Techniques for Manually Estimating Road User Costs Associated with Construction Projects*, Construction Division, Texas DOT, December 1999.

Description of Program

MicroBENCOST is a set of two software programs, developed by the Texas Transportation Institute (TTI), for the calculation of benefits and costs of highway improvement projects.

Market Segmentation

- Vehicle class (passenger car, bus, truck, etc.).

TTV Calculation Methodologies

According to TTI personnel, the default TTVs in MicroBENCOST are based on data collected in 1986 for passenger vehicles, and 1975 for commercial vehicles. The current values have been updated to the 1990s using the consumer price index (CPI) for passenger vehicles and producer price index (PPI) for commercial vehicles. TTI personnel recommend the continued use of CPI and PPI to inflate values to the current year. For simplicity, the CPI was used to inflate all values shown here.

TTVs

Table A.11 shows the TTVs used in MicroBENCOST. A specific item identifies that the TTV of bus is about $10.64 in 1990 dollar, which is equivalent to $21.10 in 2010 dollars.

Table A.11 TTVs from MicroBENCOST

	TTVs ($/Hour)	
Vehicle Type	**1990 Equivalent**	**2010 Equivalent***
Small passenger car	$9.75	$16.26
Medium/large passenger car	$9.75	$16.26
Pickup/van	$9.75	$16.26
Bus	**$10.64**	**$17.75**
2-axle single-unit truck	$13.64	$22.75
3-axle single-unit truck	$16.28	$27.16
2-S2 semi truck	$20.30	$33.87
3-S2 semi truck	$22.53	$37.59
2-S1-2 semi truck	$22.53	$37.59
3-S2-2 semi truck	$22.53	$37.59
3-S2-4 semi truck	$22.53	$37.59

Note: Conversions based on CPI.

6. Procedures and Technical Methods for Transit Project Planning

Source

Ryan, J. M., et al., prepared for the FTA, U.S. DOT, 1986 to 2003.

Synopsis

The FTA serves as a resource for agencies conducting alternatives analysis for a major capital investment in transit. Alternatives analysis is the second phase of process of planning for a major capital investment in transit. The guidance provides an overview of the major capital investment planning process, and provides guidance for the technical analysis and the environmental review and project-selection processes.

Market Segmentation

The report recommends, at minimum, that the value of travel time be disaggregated according to at least two categories: in-vehicle time and out-of-vehicle time (i.e., walking, waiting, etc.). Finer disaggregation, such as TTV by mode, are implied in the recommended procedures for TTV calculation (see the forthcoming section) in the literature, but not specifically recommended.

TTV Calculation Methodologies and TTVs

The literature indicated that the value of travel time is the ratio of the in-vehicle-time coefficient and the cost coefficient, as given by a calibrated transit impendence equation from a mode-choice model. The passage on TTVs also mentions that, historically, TTVs have been valued at one-quarter to one-half of household income expressed as a wage rate. This is somewhat lower than many other sources reviewed here, which tend to use one-half of the wage rate as the lower boundary for TTVs.

7. The Annualized Social Cost of Motor-Vehicle Use in the United States, Based on 1990 to 1991 Data

Source

Delucci, M. A., Institute of Transportation Studies at University of California at Davis, September 1998.

Synopsis

In a series of reports entitled, *The Annualized Social Cost of Motor-Vehicle Use in the United States*, based on 1990 to 1991 data, Delucci, et al., examine the costs associated with motor vehicle use in the United States. The series of reports addresses multiple issues, including delay and travel time, emissions and other environmental concerns, noise pollution, health costs, politics and international conflict, taxation and transportation finance, etc.

Delucci, through a series of analyses described in several reports, details the methodology for deconstructing total travel-time costs. Although not all of the reports have been reviewed here, analysis of the fourth report, *Personal Nonmonetary Costs of Motor-Vehicle Use*, suggests that several different econometric models were used to derive total annual costs for four disaggregated categories comprising total travel time.

In Delucci's framework, the term "personal" refers to costs imposed by an individual as a result of the decision to travel (e.g., value of foregone activities); "private," as used here by Delucci, has the same meaning as "personal"; "external" refers to costs imposed on individuals by factors outside of their control (e.g., delay because of other vehicles); "monetary" costs are those that are priced (i.e., that involve a monetary exchange between a buyer and a seller); and "nonmonetary" costs are those that are not priced. Each term is followed by relevant examples of a cost in that category.

- Personal (or private) nonmonetary costs (i.e., value of unpaid activities forgone to engage in travel; pain and suffering because of accidents which cause involves no other actors).
- Private monetary (or priced) costs (i.e., value of paid activities foregone to engage in travel; cost of liability insurance).
- External monetary costs (i.e., time spent in delay caused by other vehicles that replaces compensated work time; vehicle repair costs for accidents caused by uninsured motorists).

- External nonmonetary costs (i.e., time spent in delay caused by other vehicles that replaces unpaid, rather than paid, work time; costs for pain and suffering inflicted by others and not covered by user payments).

Delucci calculates TTVs based on the four aforementioned cost categories for multiple market segmentations, which are listed below and detailed in Table A.12. His calculations are based on 1990 data; and his models include considerations for person-hours of travel time and delay, vehicle occupancy, ratio of passengers to drivers, fraction of travel time that replaces unpaid and paid activities, opportunity cost, hedonic cost, speed with and without delay, etc. He concludes that personal nonmonetary costs, associated with motor vehicle use, cost the U.S. public between $527.3 billion and $968.2 billion per year (in 1991 dollars). Total time costs (in dollars per person-hour) were computed for this review by dividing Delucci's calculated Total Time Cost (in billions of dollars) by his calculated Total Person-Hours of Travel.

Market Segmentation

- Purpose of trip (business or personal);
- Vehicle class (light- and heavy-duty auto, light- and heavy-duty trucks, with and without paid drivers, and public vehicle classes);
- Mode (buses: intercity, transit, and school);
- Industry (government or civilian); and
- Trip Length.

TTVs

Table A.12 Value of Travel Time from Delucci Study
In 2010 Dollars

Travel In		Low	High
Private vehicles, personal purposes	Daily travel	$10.79	$18.15
	Long trips	$9.66	$17.02
Private vehicles, business purposes	Light-duty autos	$23.24	$35.23
	Light-duty trucks, drivers not paid	$22.96	$34.41
	Light-duty trucks, drivers paid	$22.60	$22.60
	Heavy-duty trucks, drivers paid	$31.04	$31.04
Buses	**Intercity and transit**	$11.76	$18.75
	School	$1.43	$1.69
Public (government) vehicles	Federal civilian	$52.73	$65.91
	Federal military	$0.00	$0.00
	State, local civilian	$22.02	$28.10
	State, local police	$17.57	$19.45
All vehicles		**$11.12**	**$12.67**

8. The Day Activity Schedule Approach to Travel Demand Analysis

Source

Bowman, J. L., Ph.D. Dissertation, Massachusetts Institute of Technology, May 1998.

Synopsis

An integrated set of discrete choice models was developed to forecast urban travel demand based on people's day activity schedules (i.e., an activity pattern and a set of tours). Stated-preference survey data were captured in a survey. Various models were used to identify daily travel structure, priority, purpose, timing, location, and access modes. It was found that, when travel and activity conditions change, relative preference for the associated travel and activity patterns changes as well, because of expected changes in tour utility. An empirical implementation in Portland, Oregon, confirms the significance of activity and travel accessibility in pattern choice.

Market Segmentation

- Annual household income;
- Type of travel (transit in-vehicle, drive alone, etc.); and
- Purpose of travel (home-to-work or home-to-other).

TTV Calculation Methodologies

TTVs were estimated from stated-preference data. Precise procedures are not explained in the document.

TTVs

TTVs are as presented in Table A.13.

Table A.13 Values of Time Estimated from Stated-Preference Data
2010 Equivalent Dollars Per Hour

	Home-to-Work Travel Annual Household Income			Home-to-Other Travel Annual Household Income		
Type of Travel Time	Less Than $30,000	$30,000-$60,000	More Than $60,000	Less Than $30,000	$30,000-$60,000	More Than $60,000
Drive alone, in-vehicle	$14.49	$20.04	$28.82	$19.87	$19.87	$38.60
Drive with passenger, in-vehicle	$15.31	$21.34	$30.62	$12.86	$12.86	$24.91
Transit in-vehicle	$9.44	$13.18	$18.90	$2.60	$2.60	$5.04
Transit walk	$35.02	$48.37	$69.70	$47.88	$47.88	$92.66

Values are adjusted for inflation using CPI. Source data are valued in 1994 dollars.

TTVs of Transit Users in Other Countries

1. Europe

Source

R. Balcombe, et al., *The Demand for Public Transport: A Practical Guide*, Transport Research Laboratory 593, 2004.

Synopsis

The report provides detailed elasticity and cross-elasticity estimates for different travel modes and conditions, based on numerous European studies. Chapter 7 of this report introduces the time factors affecting the quality of service of transportation facilities. TTVs among 13 European countries have been reported, as shown in Table A.14. The project found that for public transportation, TTVs were between 0 and £3.60 per hour in 1998, which is about $7.87 per hour in 2010 U.S. dollars. Also for business trips, TTVs of transit users are between £7.20 and £14.40 per hour in 1998, which are about between $15.75 and $31.50 per hour in 2010 U.S. dollars.

In addition, the TRACE project found that most car driver values of time are generally higher than those of public transportation user. This difference is partly attributed to a "selection" effect: a person for whom time is of high value tends to choose fast modes. It also is confirmed by this report that values of time for business trips are higher than for all other purposes, particularly for transit users.

Market Segmentation

- Mode (car, public transit, etc.); and
- Trip purpose (business, commuting, other).

TTV

Table A.14 Travel Time Value in Europe
In 2010 Dollars

Country	Study Year	Mode	Trip Purpose		
			Business	**Commuting**	**Other**
Austria	1996	All Modes	24.76-27.25	7.30	
Belarus	1996	Train Passenger	1.59		
Belgium	1983	Car or Public Transit User		6.34-7.43	
Finland	1993	All Modes		24.32	
Finland	1996	All Modes	33.86	5.71	3.32
Finland	1996	Urban Bus Passenger		2.68-5.39	
France	1996	Rail Passenger		14.13-35.88	
Germany	1996	Bus		100.10	
Ireland	1998	PT Passenger		2.54-8.08	
		Slow Modes		5.25-16.17	
Moldova	1996	Train Passenger		0.47-3.81	
Netherland	1998	Train Passenger	29.24	10.33	
		Bus/Train Passenger	29.09	8.44	4.91
Norway	1997	Rail Interurban	23.03		10.80
		Bus Interurban	14.95		9.52
		Rail Urban	21.15		9.52
		Bus/Light-Rail Urban	21.15		5.71
Russia	1996	Train Passenger		1.59-2.38	
Sweden	1994	Public Transit User		1.59-2.07	
Sweden	1996	IC Train > 50 km	23.99		13.82
		X2000 Train > 50 km	24.93		18.91
		Regional Train < 50 km		6.67	7.94
		Regional Train > 50 km			13.02
		Long Distance bus < 50 km		8.74	5.26
		Long Distance bus > 50 km			12.06
		Regional Bus < 50 km		7.94	5.26
		Regional Bus > 50 km			9.38
Ukraine	1996	Train Passenger		1.10	

Note: Values are converted into U.S. dollar and adjusted for inflation using CPI. Source data are valued in January 1998 United Kingdom pounds.

2. Australia

<u>Source</u>

N. J. Douglas, L. J. Franzmann, and T. W. Frost, 2003, *Estimation of Demand Parameters for Primary Public Transport Service*, Australian Transport Research Forum (www.Douglaseconomics.co.nz).

<u>Synopsis</u>

Booz Allen Hamilton used stated-preference survey data to estimate own and cross-elasticities for various costs (fares, travel time, waiting time, transit service frequency, parking fees); modes (automobile, transit, taxi); and trip types (peak, off-peak, work, education, other) in the Canberra, Australia region. They developed generalized costs and travel time cost values, including estimates of the relative cost of walking and waiting time for transit users. The travel time cost values from a similar study in Brisbane, Australia, are summarized in Table A.15.

<u>Market Segmentation</u>

- Mode (bus, rail, ferry, and car);
- Travel duration (under 30 minutes, and 30 to 45 minutes);
- Time of day (peak hours and nonpeak hours); and
- Travel region (CBD and non-CBD).

<u>TTV</u>

Table A.15 TTVs in Brisbane, Australia
In 2010 Dollars

	Short (Under 30 Minutes)				Medium (30-45 Minutes)			
	Peak		Off-Peak		Peak		Off-Peak	
Mode	**CBD**	**Non-CBD**	**CBD**	**Non-CBD**	**CBD**	**Non-CBD**	**CBD**	**Non-CBD**
Bus	7.17	6.00	5.85	4.59	7.17	6.79	5.92	5.85
Rail	7.25	5.38	5.38	4.68	6.86	6.00	6.15	5.22
Ferry	8.33	-	6.46	-	-	-	-	-
Car	8.25	6.46	6.46	5.53	7.86	6.23	7.02	4.99

Note: Values are converted into U.S. dollar and adjusted for inflation using CPI. Source data are valued in January 1998 United Kingdom pounds.

3. New Zealand

Source

TransFund (2007), *Economic Evaluation Manual, Volume 1*, TransFund New Zealand.

Synopsis

TransFund New Zealand uses standard TTVs summarized in Table A.16. Their Economic Evaluation Manual has detailed instructions for applying these values.

Market Segmentation

- Mode (car, motorcycle, commercial vehicle, bus, pedestrian, and bicycle);
- Driver/passenger; and
- Trip purpose (work and nonwork).

TTV Calculation Methodologies

The manual suggested that travel time benefits for a project option shall be calculated as the difference between the minimum and option travel time costs. Total travel time savings should be the summation of base travel time benefits for improved flow, travel time benefits for reduced congestion (if applicable), and travel time benefits for improved trip reliability (if applicable). Table A.16 shows the adjusted values. Congestion increment was considered for car, motorcycle, commercial vehicle drivers, and passengers only, therefore, not indicated here.

TTV

Table A.16 Base Values for Vehicle Occupant Time
In 2010 Dollars Per Hour

Mode	Work Travel Purpose	Commuting To/From Work	Other Nonwork Travel Purpose
Car, motorcycle driver	14.26	4.66	4.12
Car, motorcycle passenger	12.96	3.5	3.12
Light commercial driver	14.01	4.66	4.13
Light commercial passenger	12.96	3.5	3.12
Medium/heavy commercial driver	12.01	4.66	4.12
Medium/heavy commercial passenger	12.01	3.5	3.12
Seated bus and train passenger	12.96	2.81	1.82
Standing bus and train passenger	12.96	3.95	2.54
Pedestrian and cyclist	12.96	3.95	2.54

Note: Values are converted into U.S. dollar and adjusted for inflation using CPI. Source data are valued in January 1998 United Kingdom pounds.

4. Canada

Source

William Waters, *Value of Time Savings for the Economic Evaluation of Highway Investments in British Columbia*, BC Ministry of Transportation, 1992.

Synopsis

This report investigates the value travelers place on qualitative factors, such as comfort and convenience; and practical ways to incorporate these factors into TTVs for planning and project evaluation. This report recommends specific TTV adjustments to account for factors, such as travel and waiting comfort, travel reliability, and real time transit vehicle arrival information. It also describes how service quality improvements can increase transit ridership and reduce automobile travel.

Market Segmentation

- Travel type (commercial and personal);
- Type of traveler (passenger and driver);
- Mode (bus, car, bicycle, and walk);
- Trip Segment (in-vehicle and waiting); and
- Travel condition (LOS A~C, LOS D, LOS E, and LOS F).

TTV Calculation Methodologies

Time spent walking to and waiting for transit vehicles generally has unit costs averaging two to five times higher than in-vehicle time, or 70 percent to 175 percent of prevailing wages. Improved walking and waiting conditions, such as transit area pedestrian improvements and improved transit stop area cleanliness and security, reduce these relatively high-unit costs, such as from 175 percent down to 70 percent of wage rates (from the higher to the lower end of the typical estimated cost range of these activities) or even lower to 50 percent of wage rates if conditions are particularly pleasant, such as at an attractive transit station with real-time information, shops and services, and other convenience features. Transfers are estimated to impose penalties equivalent to 5 to 15 minutes of in-vehicle time.

TTV

Table A.17 TTVs Relative to Prevailing Wages

Category	LOS A-C	LOS D	LOS E	LOS F	Waiting Good	Waiting Average	Waiting Poor
Commercial vehicle driver	120%	137%	154%	170%		170%	
Commercial vehicle passenger	120%	132%	144%	155%		155%	
City bus driver	156%	156%	156%	156%		156%	
Personal vehicle driver	50%	67%	84%	100%		100%	
Adult car passenger	35%	47%	58%	70%			
Adult bus passenger – seated	**35%**	**47%**	**58%**	**70%**	**35%**	**50%**	**125%**
Adult bus passenger – standing	**50%**	**67%**	**83%**	**100%**	**50%**	**70%**	**175%**
Child (< 16 years) – seated	25%	33%	42%	50%	25%	50%	125%
Child (< 16 years) – standing	35%	46%	60%	66%	50%	70%	175%
Pedestrians and cyclists	50%	67%	84%	100%	50%	100%	200%
Transit Transfer Premium					5-min	10-min	15-min

5. Other Countries

Source

Kenneth Gwilliam, 1997, *The Value of Time in Economic Evaluation of Transport Projects; Lessons from Recent Research*, World Bank, Washington, D.C.

Synopsis

Based on an extensive review of international studies, World Bank economist Kenneth Gwilliam also recommends that TTVs could be valued at wages and benefits. This study compares TTVs of travelers using different transportation modes and within different countries, as shown in Table A.18.

Market Segmentation

- Mode (car, bus, bicycle, etc.); and
- Purpose of travel.

TTV Calculation Methodologies

At a default level, TTVs of adult personal travel (including commuting) should be between 30 percent and 150 percent of household income per hour, unless better local data are available, as summarized in Table A.18.

TTVs

Table A.18 TTVs in Other Countries
In 2010Dollars

Year	Country	Motorcycle	Car	Pick-Up	Bus	Truck	Rail
92	Venezuela		4.26	3.36	**2.6**		
96	Uruguay	0	1.54	1.54	**0.42**	0	
96	Ukraine				**0.21**		
93	Tunisia		1.63		**0.74**		0.74
83	Tunisia	0.73	0.73	0.73	**0.73**	0.73	
75	Thailand	4.07	6.12		**2.04**		
90	Sri Lanka	0.69	1.37		**0.28**	0.28	
91	Sierra Leone	0	0	0	**0**	0	
93	St. Lucia		1.73	2.27	**1.39**	1.69	
94	Russia		0		**0.52**		
93	Perú	1.05	1.05	1.05	**1.05**	1.05	1.05
95	Lebanon		2.48	3.73	**1.79**	0	
95	Latvia		0		**2.6**		
94	Korea (S)		3.81		**2.53**		
87	Korea (S)	**1.06 to 3.19 per passenger/hour for work-related trips**					
84	Korea (S)		3.49		**0.95**	1.9	
95	Kenya		1.79	0.35	**0.35**	0	
83	Jordan	2.78	2.78	2.78	**2.78**		
85	Indonesia		4.2	4.2	**0.85**		
96	India		1.4	0	**1.05**		
94	India	0.87	0.91		**1.84/ 0.45**	0	
91	Honduras		0.97	0.97	**0.22**		
92	Guatemala		1.25	1.57	**0.44**		
96	Dominican		1.02	0	**0.22**	0	
81	Côte d'Ivoire	1.62	1.62	1.62	**1.62**	1.62	
95	Colombia		2.48		**0.46**	0.46	
96	China	0.17	0.17	0.17	**0.17**	0.17	
93	China	0.51	0.51	0.51	**0.51**	0.51	
90	China	**Working time at 0.33/hr and nonpaid time at 0.08/hr**					
89	China	0.36	0.36	0.36	**0.36**	0.36	
87	Cameroon		2.84		**2.84**		
89	Burkina		1.12		**1.12**		
95	Brazil		6.43		**1.84**		1.12
79	Brazil		2.15		**0.45**		0.66

Note: Values are adjusted for inflation using CPI. Source data are valued in 1997 dollars.

B. Travel Time Value Survey Findings

As part of the original SEFRTUC study, a survey was conducted between December 2004 and January 2005 to verify localized TTVs. The 2014 update did not include any survey study. The following content of Appendix B keeps original 2004/2005 survey findings and values. All dollar values in this section are in 2004 dollars.

Introduction

This section presents the results and findings of a survey used to validate the localized travel time values developed for this study. This survey and the analysis that accompanies it support a broader effort to develop travel time values for transportation investment analysis purposes. The main findings from the survey are the following:

1. Travel time values for all trips fall in the range of $8.00 to $12.00, which is quite consistent with previous findings from national sources that have been adjusted for use in Southeast Florida;
1. Respondents attach a higher value to work trips than nonwork trips ($12.00 versus $8.00, when unweighted or $7.40 and $10.30 when weighted by age distribution in the population);
2. Higher-income respondents have a higher value of time than lower-income residents ($7.80 versus $16.70 unweighted by age distribution, and $7.90 and $11.20 when weighted by age distribution in the population); and
3. These results can be applied to the SEFRUC study to develop TTV factors that could be used for analyses using high-/low-income markets, or market stratifications, based on age, trip length, or possibly other stratifications.

Survey Design

The Southeast Florida value of time telephone survey was administered to a random sampling of 5,000 households in the six-county SEFRUC region. This pool of households was drawn upon until the target of 200 completed surveys was achieved. To ensure that as large a proportion of the working population as possible was contacted, calls were only made only during the early evening during the week and all day and evening during the weekends. Only 10 percent of all households contacted were not able to complete the survey once the survey got underway. The survey was administered during the time period between December 1, 2004 to December 13, 2004, and January 8, 2005 to January 30, 2005.

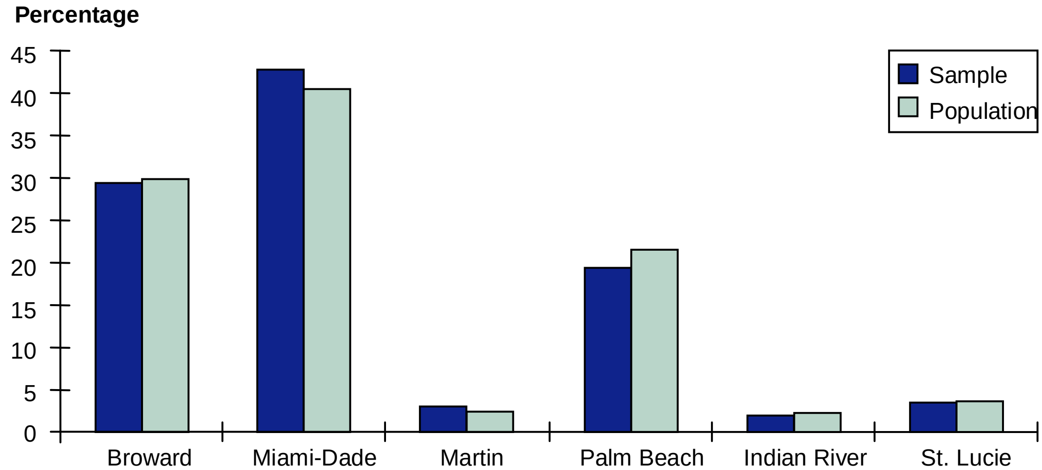
The survey instrument consisted of a set of questions on socioeconomic and current trip-making characteristics and a set of stated-preference questions from which the values of time were to be derived. Employed respondents were asked to report the travel time of their latest work trip and to indicate whether, as employees, they had flexibility in the time they reported to work. Both employed and nonworking individuals also were asked to report the travel time of their most recent nonwork trip. Using these most recent work and nonwork trips as points of reference, the stated-preference survey questions asked respondents whether they would, if they had the choice, continue to make their trip as they do now, or would be willing to pay a toll or tax to save varying amounts of time as given in the survey. The work and nonwork sections each presented respondents with four choice experiments. In all, there were 308 usable work trip choice experiments and 762 nonwork choice experiments.

Socioeconomic/Demographic Characteristics

Figure B.1 shows the distribution of respondents 20 years or older as compared to the distribution in the general population. As shown in the figure, the sample distribution is very close to the population distribution. Figure B.2 shows the distribution of respondents by employment status. Workers make up a little less than one-half of all respondents. The rest of the respondents are students, retired, or not working for pay. Figure B.3 shows the distribution of the population 16 years or older in the study area using Census 2000 data. The proportion of workers in the sample is underrepresented compared to the Census distribution. For example, while 52 percent of the general population is employed on a full-time basis, only 38 percent of survey respondents indicated that they work full-time. Figure B.4 shows the distribution of respondents and population of the study area by age category. The categories "50s" and "over 60" are relatively overrepresented. While 28 percent of the general population in the study area is over 60 years of age, nearly 45 percent of survey respondents report being over 60. This result reflects the likelihood that older and nonworking adults probably have fewer demands on their time and can more readily respond to surveys of this sort. Figure B.5 shows the distribution of respondents and population by household income. The proportion of respondents in low and high-income groups is slightly larger than that found in the general population, and is lower then the general population's proportion for medium-income groups.

Figure B.1 Distribution by County

Number of Observations in Sample = 201



Source: Census 2000.

Figure B.2 Distribution of Respondents by Employment Status

Number of Observations = 201

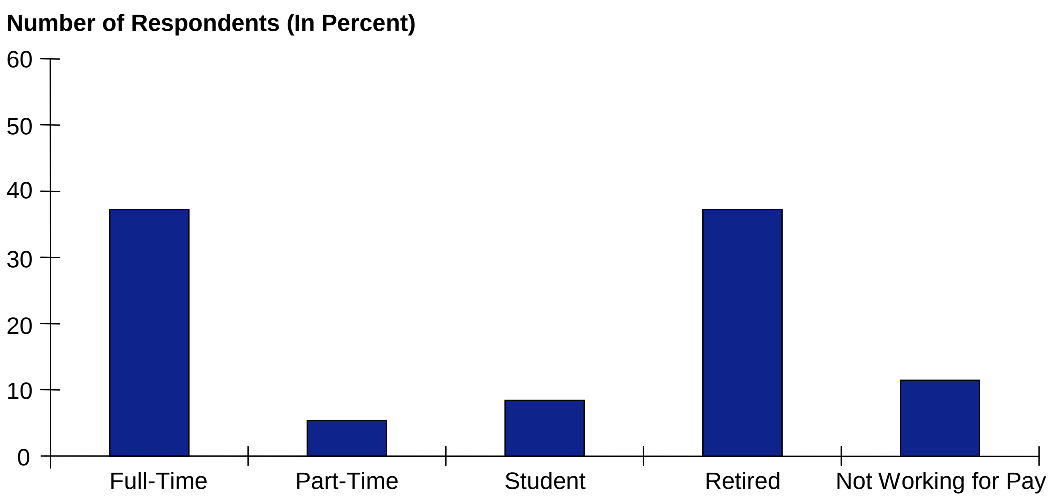
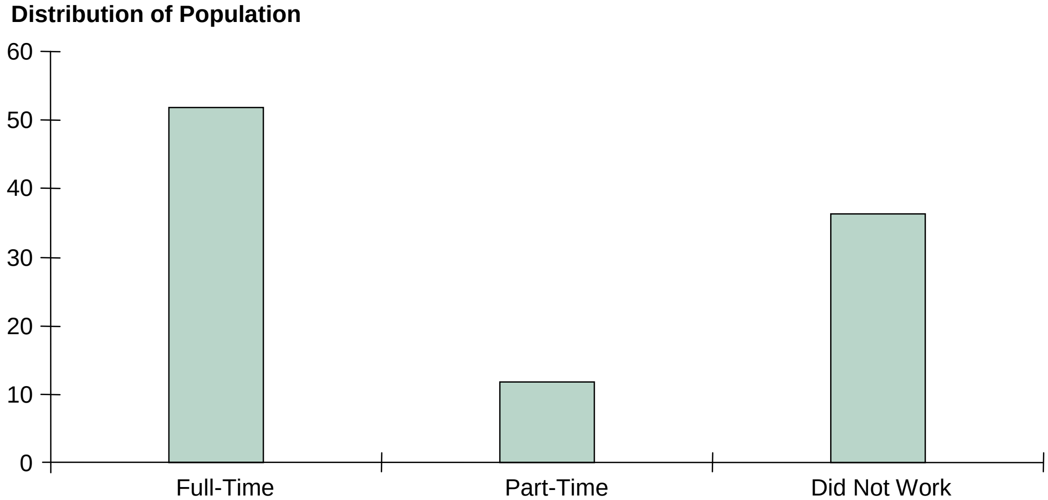


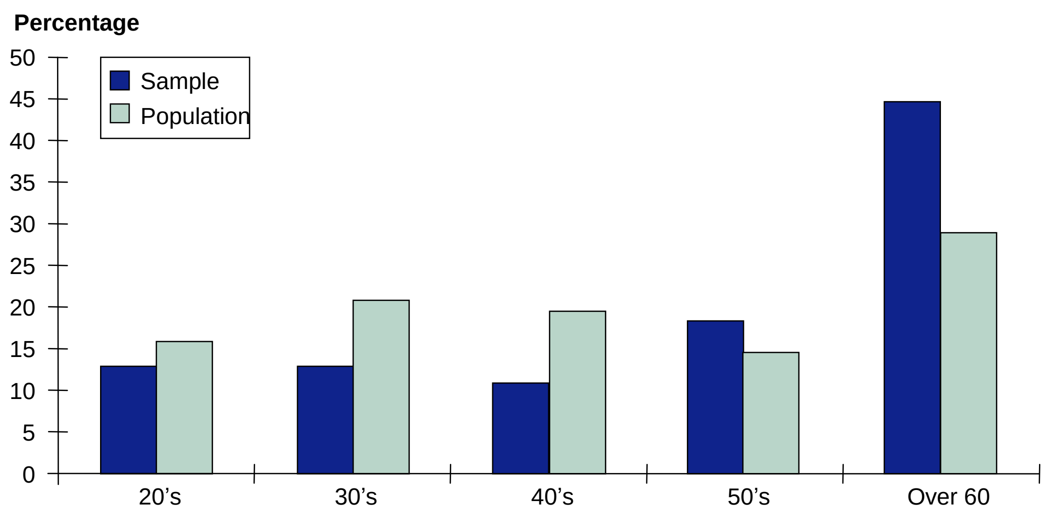
Figure B.3 Distribution of the Population 16 Years or Older by Employment Status



Source: Census 2000.

Figure B.4 Distribution by Age Category

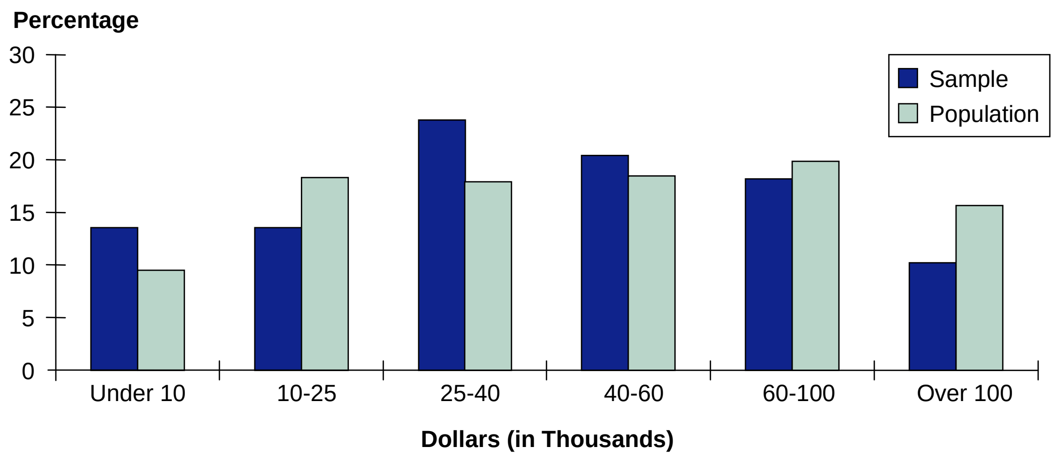
Number of Observations in Sample = 201



Source: Census 2000.

Figure B.5 Distribution by Household Income

Number of Observations in Sample = 176



Source: Census 2000 inflated by nine percent to obtain 2004 figures.

Overall, the survey captured a higher proportion of the lower-income, nonworking, and older segment of the population. This may indicate that the TTV results will biased downward somewhat, based on the assumption that values of time are positively correlated with income, work status, and working age.

Work Trip Characteristics

Figure B.6 shows the distribution of respondents by work time flexibility. Workers without work time flexibility constitute about 46 percent of all workers sampled, with the remaining having either full or partial flexibility. Figure B.7 shows the distribution of respondents by travel mode to work, with the majority of workers driving alone to work. Figure B.8 shows the distribution of respondents by departure time to work. The majority of work trips depart in the one-half-hour period 8:00 a.m. to 8:30 a.m., and over 70 percent of work trips depart between 6:30 a.m. and 9:00 a.m. Figure B.9 shows the distribution of respondents by travel time to work. The average travel time is 36.8 minutes.

Figure B.6 Distribution of Respondents by Work Time Flexibility

Number of Observations = 85

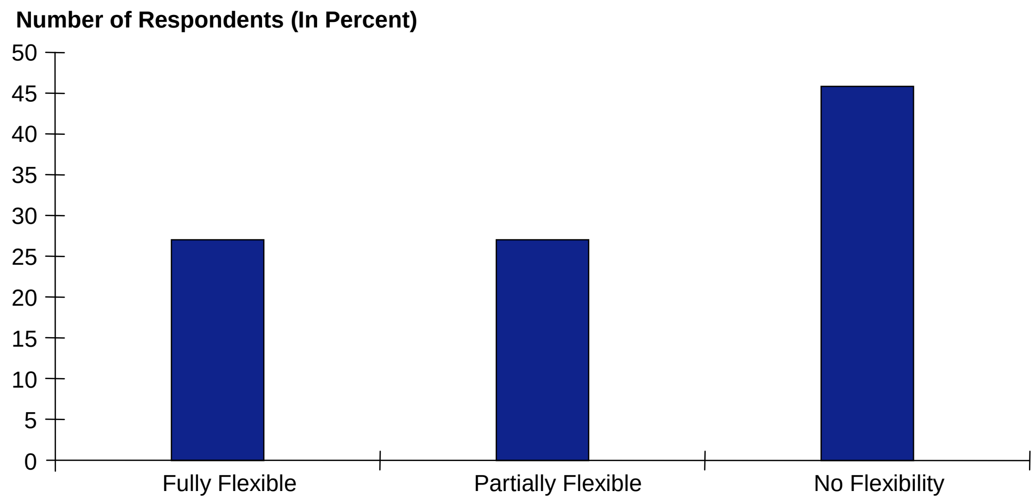


Figure B.7 Distribution of Respondents by Travel Mode to Work

Number of Observations = 84

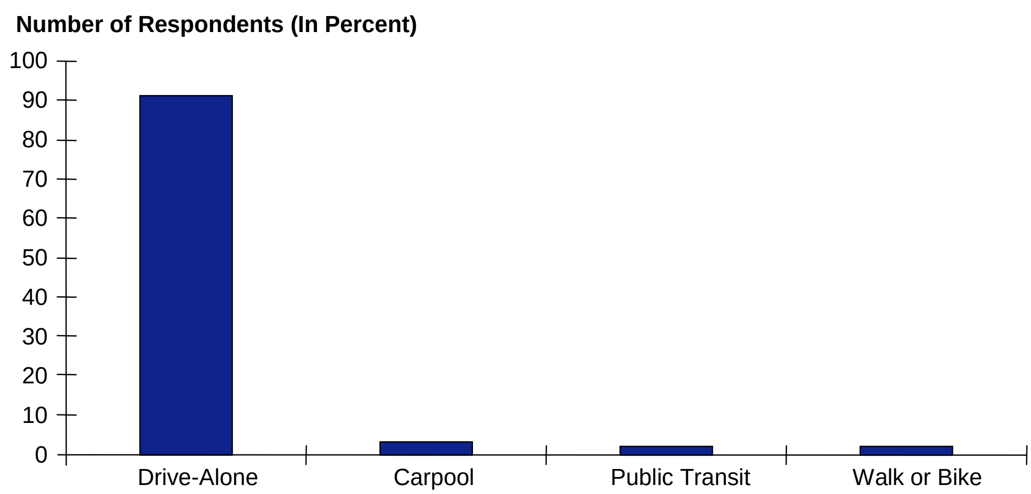


Figure B.8 Distribution of Respondents by Departure Time to Work

Number of Observations = 85

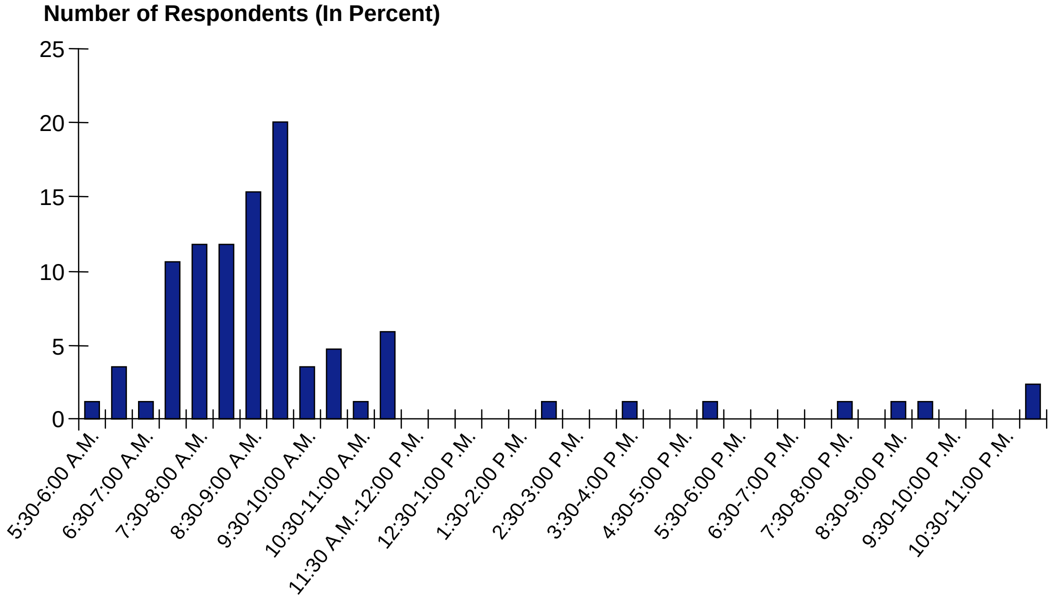
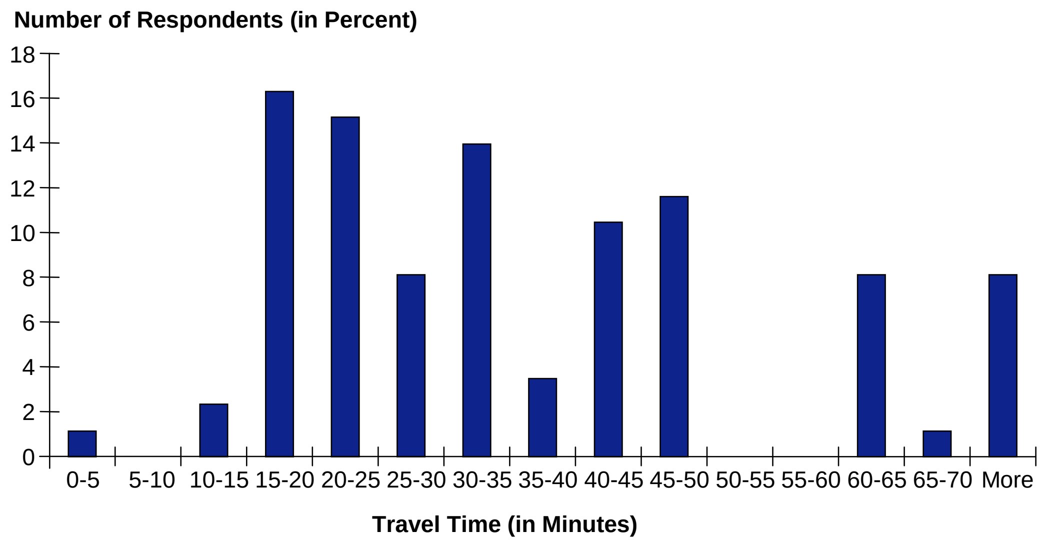


Figure B.9 Distribution of Respondents by Travel Time to Work

Number of Observations = 86



Nonwork Trip Characteristics

Figure B.10 shows the distribution of respondents by travel mode for nonwork trips. Auto trips make up the majority of nonwork trips. Moreover, the percentage of shared-ride trips is larger for nonwork than for work trips, which is consistent with regional and national household travel survey findings. In addition, roughly 8 percent of all nonwork trips are made by transit, in comparison to 2 percent for work trips. This points to transit's role as a transportation service more than as a congestion mitigation strategy. Figure B.11 shows the distribution of respondents by nonwork trip purpose. Most nonwork trips are made for shopping. Figure B.12 shows the distribution of respondents by departure time for nonwork trips, with most trips occurring during the midday. Figure B.13 shows the distribution of respondents by travel time for nonwork trips. The average travel time is 41 minutes, which is larger than the average travel time on work trips. In many household interview surveys, home-based nonwork trips have shorter travel times than do work trips.

Figure B.10 Distribution of Respondents by Travel Mode on Nonwork Trips

Number of Observations = 201

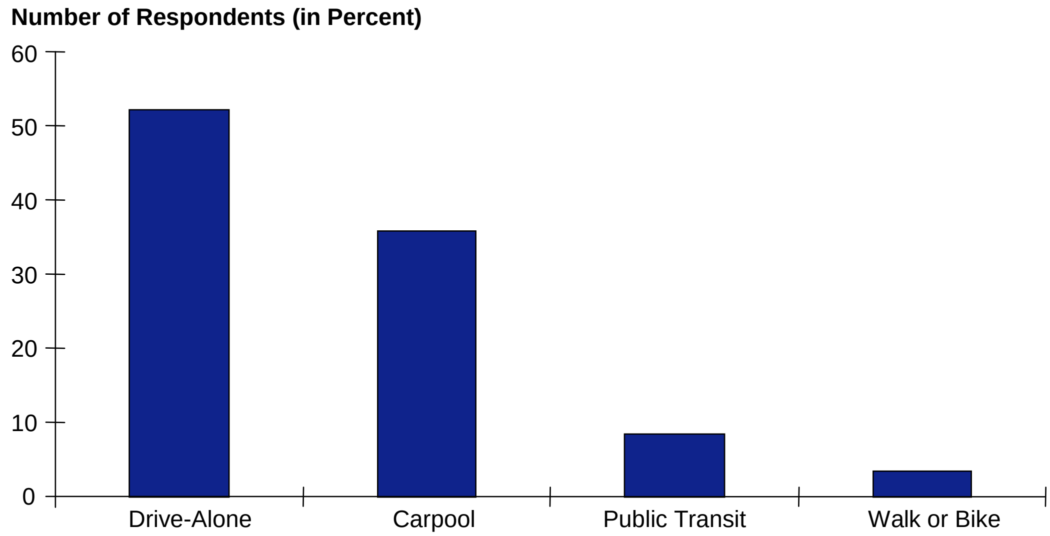


Figure B.11 Distribution of Respondents by Nonwork Trip Purpose

Number of observations = 195

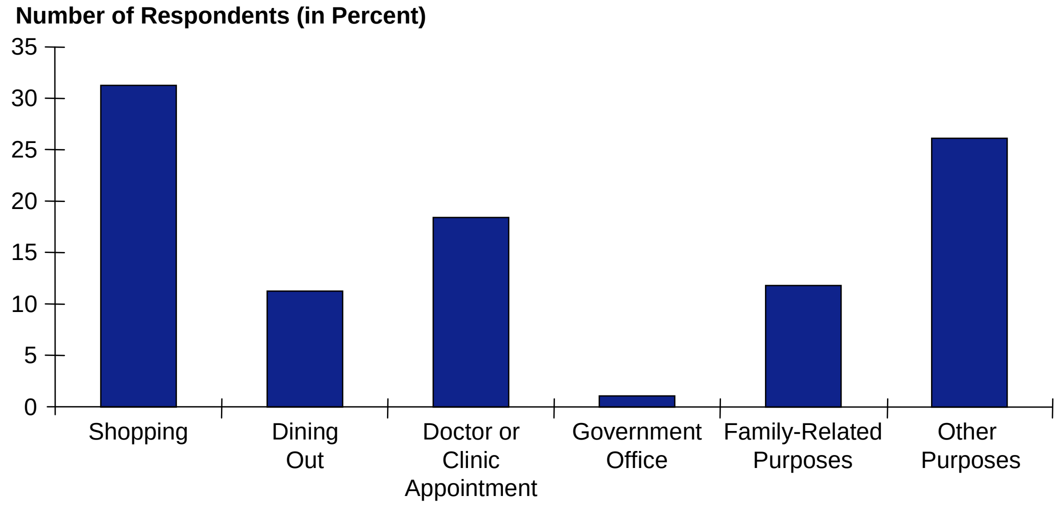


Figure B.12 Distribution of Respondents by Departure Time on Nonwork Trips

Number of Observations = 195

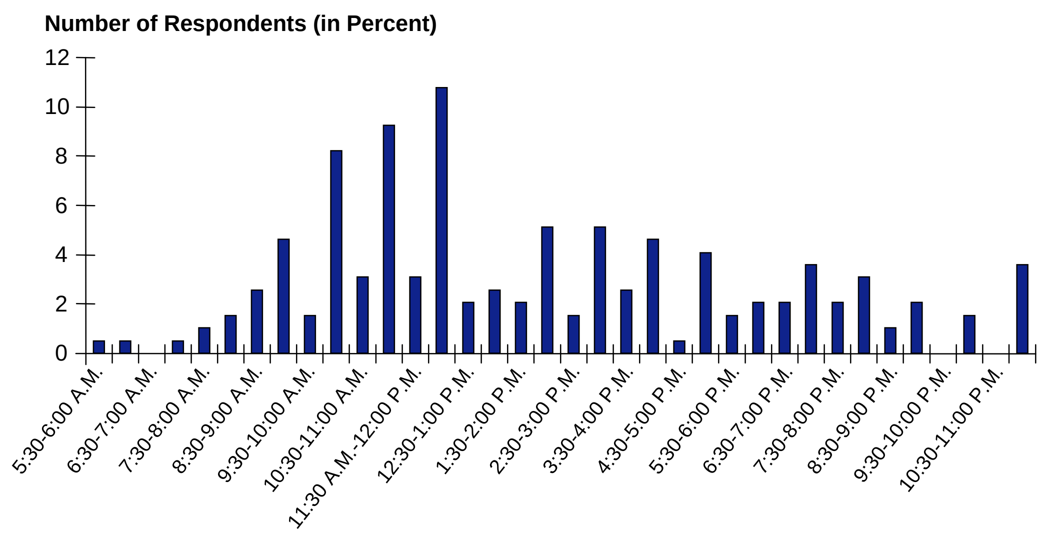
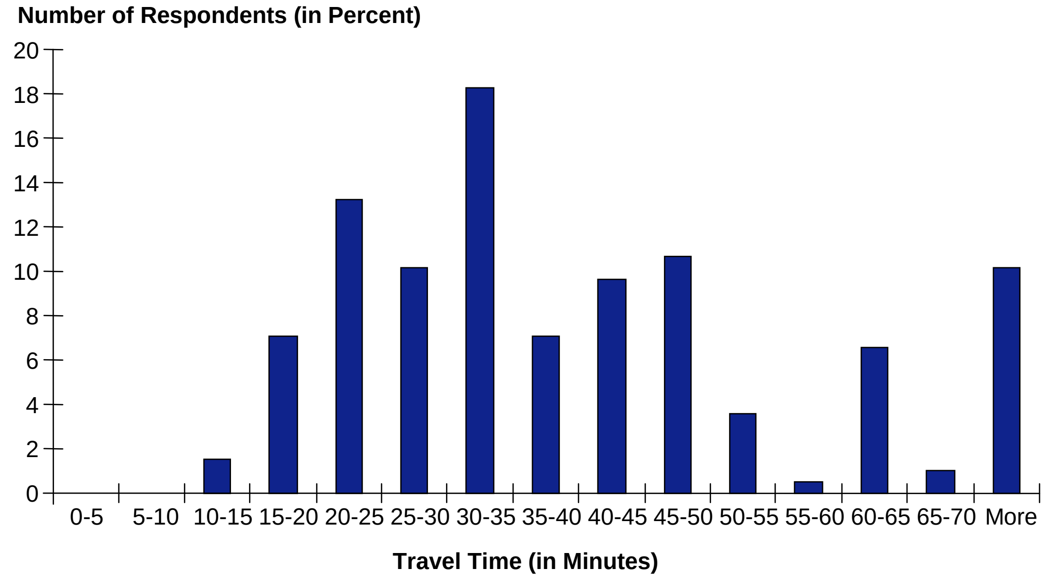


Figure B.13 Distribution of Respondents by Travel Time on Nonwork Trips

Number of Observations = 196



Value of Time Models

The survey results also were analyzed using standard econometric techniques to derive a travel time value and to determine which socioeconomic variables may influence these TTVs. In the discussion below, each analysis is called a "model." All models are estimated using ALOGIT 4.

The Alternatives

Every respondent is given a set of choice experiments involving tradeoffs between travel time and cost. The respondent is asked to choose between the current values of travel time and cost or alternative values of travel time and cost (smaller travel time and larger cost). Therefore, the models developed are discrete binary choice models, where the choice is between two alternatives: 1) do not change travel time and cost from current values (the base alternative), or 2) change travel time and cost from current values.

The Observations

Every observation in the model estimation dataset corresponds to one choice experiment for a given respondent. Every respondent contributes to at least four observations, since there are four choice experiments for nonwork trips, and could contribute up to eight observations if he/she is a worker since there are four additional choice experiments for work trips.

The Utility

The term "utility" is used in economics to denote the degree to which an individual feels that he or she is "better off" by choosing to consume one good versus another. The choice in this case concerns one transportation alternative or another as a consumable good. The utility of each transportation alternative presented in the SEFRUC survey consists of a travel time component and a travel cost component, since, from a user's perspective, these are the two main characteristics of the alternatives. In addition, socioeconomic variables can be included in the models to reflect the effect of household income, work time flexibility, or other characteristics on the choice process. The ratio of the travel time coefficient to the travel cost coefficient is the value of time.

Model Estimation Results

Basic Models

Specification

Three basic models were estimated. Each of these models includes a travel time variable and a travel cost variable. In addition, an alternative-specific constant is included in the base alternative. The first model is estimated using the choice experiments for work trips only. The second model is estimated using the choice experiments for nonwork trips only. The third model is estimated using the choice experiments for all trips (work and nonwork).

- The utility of the base alternative is given by:

$$U_1 = \beta_0 + \beta_1 * \text{travel time}_1 + \beta_2 * \text{travel cost}_1$$

- The utility of the other alternative (change time and cost) is given by:

$$U_2 = \beta_1 * \text{travel time}_2 + \beta_2 * \text{travel cost}_2$$

The value of travel time is given as the marginal utility of a change of one unit in travel time and travel cost, or β_1/β_2, as noted above.

Data Screening

Before estimating the models, the dataset was screened to ensure valid responses. The observation was removed where any of the following conditions was met:

- The choice is invalid: For example, it is neither "a" (the no-change alternative) nor "b" (the change alternative), but some other character (e.g., "10");
- The travel time or travel cost is invalid: Either the travel time value or travel cost value recorded in the choice experiments is "NULL," or the current travel time value recorded in the choice experiment is different from the actual travel time recorded in an earlier question in the survey.

- The respondent pays a public transport fare, but the trip mode is not public transport; and
- The respondent pays a toll or a parking cost, but the trip mode is not auto.
- In addition, for choice experiments corresponding to work trips (Model 1), observations also are removed, where:
- The respondent is neither a full-time worker nor a part-time worker; and
- The trip occurs during the weekend.

Estimation Results

Table B.1 shows the model estimation results for each of the three model runs.

Table B.1 Model Estimation Results for Basic Model Runs

	Model 1 (Work Trips Only)		Model 2 (Nonwork Trips Only)		Model 3 (All Trips)	
Variable	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
Constant	1.7276	4.97	1.1561	5.81	1.3133	7.67
Travel Time (minutes)	-0.1315	-5.34	-0.0723	-6.40	-0.0888	-8.45
Travel Cost (dollars)	-0.6616	-1.16	-0.5212	-1.67	-0.5677	-2.08
Number of Observations	308		762		1,094 [a]	
Initial Likelihood	-213.49		-528.18		-758.30	
Final Likelihood	-161.24		-451.29		-628.56	
"Rho-Squared" w.r.t. zero	0.24		0.15		0.17	
"Rho-Squared" w.r.t. Constants	0.13		0.06		0.08	
Value of Time (dollars per hour)	11.92		8.32		9.39	

[a] There are 24 observations that were recorded as weekend work trips. These were not included in the weekday work trip model estimation, but were included in Model 3 for all trips.

The coefficients of the travel time and travel cost variables are negative, which reflects the expectation that an alternative's utility should decrease as its travel time or travel cost increases. The alternative-specific constant that is included in the utility function of the no-change alternative is positive, which indicates that people have a natural willingness to keep the same travel alternative that they currently have.

For each variable in the models, the coefficient estimate and the t-statistic are reported. A t-statistic with an absolute value larger than 1.645 indicates that the probability that this coefficient is different than zero is more than 90 percent. If the t-statistic is larger than 1.96, the confidence level is 95 percent.

The likelihood statistic is used to assess the improvement in the model's specification as variables are added. The initial likelihood represents the likelihood as if all coefficients were zero, except for the constant term. The final likelihood represents the likelihood that is explained by all the variables included in the model.

The Rho-squared is a measure of goodness-of-fit, which is similar to the R-squared of a regression. The closer the Rho-squared is to 1, the better the model fit. It is defined as:[3]

- Rho-Squared w.r.t. Zero = 1 – (Final likelihood/Likelihood with zero coefficients); and
- Rho-Squared w.r.t. Constants = 1 – (Final likelihood/Likelihood with alternative-specific constants only).

The value of time for work trips, $11.92 per hour, is reasonable and exceeds the value of time for nonwork trips ($8.32 per hour), as expected. The value of time for all trips combined is $9.39, and it falls between the value of time for work trips and nonwork trips.

Alternative Models

The other models that were estimated included travel time, travel cost, and other socioeconomic variables in their utility equations. In particular, household income and work time flexibility were tested to see their effect on value of time. Data records of respondents that did not provide an answer to the income question were removed from the model estimation dataset for models that included income variables, and workers that did not provide an answer to the work time flexibility question were removed from the model estimation dataset for models that included work time flexibility variables.

Models with Income Variables/Stratifications

Table B.2 shows value of time by income class. This is obtained by estimating separate models for different income classes. Two models were estimated: 1) one for respondents whose household income is less than $40,000; and 2) the other for respondents whose household income is more than $40,000. The value of time ($7.78 per hour) for the lower-income classes is smaller than that ($16.67 per hour) for the higher-income classes, as expected. The t-statistic for the higher income model's travel cost coefficient, however, is only -0.713, indicating that, from a statistical standpoint, this coefficient is not significantly different from zero. This formulation would probably not be used as a model to predict the proportion of each income class that would switch to a higher cost, yet faster route. In order to compare the travel cost effect on different income classes, the cost variable was included in both Models 4 and 5 for low- and high-income classes, respectively. The results show that higher-income travelers are likely to be willing to pay more to save time than are lower-income travelers.

---

[3] See for example: Ben-Akiva and Lerman, *Discrete Choice Analysis*, The MIT Press, 1985.

Table B.2 Model Estimation Results for Various Income Classes

	Model 4 Income Under $40,000		Model 5 Income Over $40,000	
Variable	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
Constant	1.0956	4.21	1.5294	5.85
Travel Time (minutes)	-0.0684	-4.01	-0.0807	-5.94
Travel Cost (dollars)	-0.5277	-1.26	-0.2903	-0.71
Number of Observations	441		509	
Initial Likelihood	-305.68		-352.81	
Final Likelihood	-264.42		-285.96	
"Rho-Squared" w.r.t. Zero	0.14		0.19	
"Rho-Squared" w.r.t. Constants	0.04		0.09	
Value of Time (dollars per hour)	7.78		16.67	

Table B.3 presents another specification with income dummy variables. Instead of estimating different models for different income groups, five dummy variables are included in the model to represent five income classes, with the highest-income class chosen as the base income level. An income dummy variable takes a value of one, if the household income of the observation in question belongs to the income group represented by the dummy variable, and is zero otherwise.

Table B.3 Model Estimation Results Using Income Dummy Variables

	Model 6	
Variable	**Coefficient**	**T-statistic**
Constant	0.8825	3.39
Travel Time (minutes)	-0.0775	-7.29
Travel Cost (dollars)	-0.4373	-1.52
Income under $10,000	0.3613	1.23
Income: $10,000-$25,000	0.5433	1.83
Income: $25,000-$40,000	0.2692	1.09
Income: $40,000-$60,000	0.5685	2.22
Income: $60,000-$100,000	0.8220	3.06
Number of Observations	950	
Initial Likelihood	-658.49	
Final Likelihood	-545.49	
"Rho-Squared" w.r.t. Zero	0.17	
"Rho-Squared" w.r.t. Constants	0.07	
Value of Time (dollars per hour)	10.63	

The value of time is $10.63, which is a little higher than the value of time obtained from the basic models. The coefficients of the income dummy variables are positive, which makes sense because it indicates that relative to the highest-income class, lower-income classes are likely to choose the current alternative (which involves more travel time, but less cost than the other alternative). The relative magnitudes of the income dummy variable coefficients are sensible, with one exception. We would expect that, as the income increases, the relative utility of the base alternative decreases. This is indeed the case, with the exception of the $25,000 to $40,000 income category.

Other variations of these models that were estimated involve aggregating or disaggregating income classes and a specification where cost/income is included as a variable in the model, where income is chosen to be the midpoint of the income range (or 1.5 times the lower bound of a range for an open-ended income range).

Work Time Flexibility Models

Table B.4 presents a model estimated using the work trip sample and including two dummy variables: full-work time flexibility and partial-work time flexibility. Thus, the base dummy variable is no work time flexibility. The coefficients of the work time flexibility variables are positive, which indicates that workers with work time flexibility are likely to choose the current alternative that involves longer travel time, because their schedules are flexible relative to workers without work time flexibility. Moreover, the coefficient of the full-work time flexibility variable is larger than that of the partial-work time flexibility variable, which makes sense because workers with full-work time flexibility can tolerate longer travel times (associated with the base alternative) than workers whose schedules are partially flexible. The value of time obtained from this model is $12.27 per hour, which is close to the value of time obtained from the basic work trip model.

Table B.4 Model Estimation Results Using Work Time Flexibility Variables

	Model 7	
Variable	**Coefficient**	**T-statistic**
Constant	1.5828	4.25
Travel Time (minutes)	-0.1289	-5.25
Travel Cost (dollars)	-0.6305	-1.10
Full Work Flexibility	0.3103	0.92
Partial Work Flexibility	0.2005	0.59
Number of Observations	304	
Initial Likelihood	-210.72	
Final Likelihood	-160.06	
“Rho-Squared” w.r.t. Zero	0.24	
“Rho-Squared” w.r.t. Constants	0.13	
Value of Time (dollars per hour)	12.27	

Other variations of this model that were estimated include using one work time flexibility variable (i.e., flexible versus nonflexible), using the entire trip dataset (work and nonwork), and combining flexibility variables with income variables.

Age-Based Models

Table B.5 presents a model estimated with age as the market stratification. The model estimates the utility of travel under current circumstances for travelers less than 50 years of age, as well as for those over 50 years of age. The time and cost coefficients for both age groups are negative, indicating that the utility of remaining with the current alternative decreases as time and cost increase. The value of time is $8.33 and $10.17 for the 50 and under and the over 50 groups, respectively. One possible reason for this result is that the over 50 group includes many working individuals with higher incomes than the under 50 group.

Table B.5 Model Estimation Results Using Work Time Flexibility Variables

	Model 8			
	Age Under 50		Age Greater than 50	
Variable	Coefficient	T-statistic	Coefficient	T-statistic
Constant	1.2136	4.67	1.3991	6.12
Travel Time (minutes)	-0.0796	-5.55	-0.0983	-6.54
Travel Cost (dollars)	-0.5732	-1.38	-0.5802	-1.60
Number of Observations	470		624	
Initial Likelihood	-325.78		-432.52	
Final Likelihood	-272.79		-355.27	
"Rho-Squared" w.r.t. Zero	0.16		0.18	
"Rho-Squared" w.r.t. Constants	0.08		0.08	
Value of Time (dollars per hour)	8.33		10.17	

Other variations of this model that were estimated include using one work time flexibility variable (i.e., flexible versus nonflexible), using the entire trip dataset (work and nonwork), and combining flexibility variables with income variables.

Conclusion

The models that involve socioeconomic variables provide additional information on the effect of household income or work time flexibility on the choice process, and consequently on the value of time.

Since most of the different models estimated gave similar values of time (mostly falling in the range of $9.00 to $12.00), the basic models are the least complex and, therefore, preferred source from which to derive values of time.

C. Methodology for Travel Time Value Calculation

C.1 Automobiles and Commercial Vehicles

This section documents the derivation of travel time values for user benefits analysis in Southeast Florida. A proposed approach for developing travel markets and hourly values for these markets is described.

Methodology

The methodology for developing travel time values for application in Southeast Florida user benefit analysis was:

- Determine application;
- Determine travel markets;
- Determine hourly values; and
- Incorporate results of survey.
- Additional components for Managed Lane users
- Travel time value by commodity type

Each is described below.

Determine Application

User benefits analysis is used to estimate the impacts of alternative transportation investments. Travel time impacts are one of several categories of user benefits, which also include vehicle operating costs, out-of-pocket costs, and some component of vehicle crash costs. User benefits are generally measured in a relative sense in comparison to a no-build or status quo condition. Benefits are generally calculated as the net of benefits minus project capital costs, or as the ratio of benefits to costs. Generally, the benefits estimates correspond to some future condition, and both the benefits and costs are converted into current dollars by applying a discount factor.

User benefit estimates may be applied to almost any type of transportation study that ultimately results in a change in highway travel times. Both micro- and macro-level applications have been developed that match the breadth and scope of such projects. Generally speaking, the more small scaled the transportation project is, the more detailed the analysis can be, in terms of the determinants of travel time and capacity. Examples of such determinants are the presence and width of shoulders, roadway grade, and lane width. More fine-grained analyses also can collect more accurate data on the constituents of travel, such as vehicle mix, vehicle occupancy, etc. However, micro-scale analyses generally capture impacts over a limited geographical range. Depending on the scale of the project, this may be entirely appropriate. Macro-scale analyses generally use outputs from travel demand models. They are sensitive to the relationship between changes in travel times on individual roadway segments and the change in travel paths between origins and destinations, and potentially the changes in the destination choices of travelers.

Based on numerous discussions with FDOT staff, a set of travel time markets that could be applied either at a micro- or a macro-scale analysis was proposed.

Determine Travel Markets

Earlier literature review found that state-of-the-practice analyses use a relatively consistent set of travel markets. The AASHTO and the FHWA apply separate values of time for business and nonbusiness travel. A summary of review of travel markets based on previous user benefits studies evaluated in the literature review is presented below.

Table C.1 lists three broad markets: 1) residential, 2) visitor, and 3) business. The table further shows how each can be broken down into constituent markets, and how those constituent markets can be used in a modeling/TTV application framework. To develop a TTV for a market, the current share of that market in the total traffic stream of the study area was determined and forecasted. In addition, a plausible, transparent value for that market was developed. The desire to develop an approach with good policy sensitivity must be balanced against the practical concerns of data and modeling limitations. The travel markets were developed with these objectives in mind.

The table notes the difficulties of developing markets based on demographic or socioeconomic characteristics, due to insufficiency of data or the likely absence of meaningful variations within that market. Markets based on trip purpose and vehicle classification dovetail nicely with existing data and forecasting tools. As noted in the table, travel by occupation/industry could be added as levels of detail, depending on several factors, including whether the stratification could be applied within the existing regional model's framework and whether sufficient detail on employment is available.

Once the core market values were determined, adding markets for the micro- and macro-analyses mentioned above were considered.

Table C.1 Potential TTV Markets Stratified by Trip Purposes

General Market	Stratification	Assessment
Residential	Age	Useful for distinguishing work versus nonwork populations more accurately. However, very difficult to forecast at subregional/traffic analysis zone (TAZ) level.
	Income	Useful for distinguishing distributional impacts, but can lead to biased conclusions in our opinion if used for user benefit analysis. Also difficult to forecast.
	Sex	Potentially useful for distributional analysis and potentially useful in theory due to different travel patterns/needs (i.e., women make more linked trips), but little research supporting this stratification in a reliable formulation.
	Trip purpose	Ties directly to past research, standard regional demand modeling frameworks, and travel surveys. Potentially, work trips could be disaggregated by occupation/industry.
	Mode	Correlated with income and trip purpose. Difficult to use in application in the evaluation of new transit services that may appeal to a socioeconomic group not previously attracted to transit.
Visitor	Trip Purpose	Visitor time constraints make and spending make this market attractive for inclusion. Worth exploring whether there is a reliable way to estimate these trips.
	Age	Age/visitor segmentation is difficult to model reliably. Also, it is not clear that there is a significant difference in visitor TTV by age.
Business	Industry	Difficult to obtain reliable information on travel patterns by industry. While statewide estimates could be developed, origin/destination (O/D) or subregional estimates would be much more difficult to generate reliably.
	Vehicle Classification	Reasonable vehicle class data available from FDOT's traffic count program. Could develop profiles of each vehicle class by type of commodity and by functional classification based on District's economic profile.

Determine Hourly Values

Core Markets. Core market hourly values were developed by following the procedures outlined in the AASHTO and the FHWA literature. For each core travel market:

- An hourly wage specific to Southeast Florida workers was determined based on the NIPA data from the Bureau of Economic Analysis and the U.S. Census.
- Using guidance from secondary sources in the literature review, a percentage of the hourly wage rate was applied for each core market. The wage component to be included for each travel market was determined.

Macro-Scale Markets. FDOT District has collected home interview survey data, which tell us the shares of travel by a number of home-based and non-home-based trip purposes. A crosswalk table that distributes TTVs by core market into TTVs by model trip purpose was developed, based in part on an analysis of the home interview survey. A sample of such a crosswalk for a micro analysis is shown in Table C.2**Error! Reference source not found.**. The crosswalk produced a weight for an average TTV estimate.

Table C.2 Trip Purpose and Core TTV Crosswalk

	Core Market 1	Core Market 2	Core Market 3	Core Market 4	Average Value
	TTV 1	TTV 2	TTV 3	TTV 4	$XX.XX
Home-based work	HBW share	HBW share	HBW share	HBW share	**$XX.XX**
Home-based shopping	HBShop share	HBShop share	HBShop share	HBShop share	**$XX.XX**
Home-based school	HBSch share	HBSch share	HBSch share	HBSch share	**$XX.XX**
Home-based social/ recreational	HBSR Share	HBSR Share	HBSR Share	HBSR Share	**$XX.XX**
Home-based other	HBO share	HBO share	HBO share	HBO share	**$XX.XX**
Home-based unknown	HBU share	HBU share	HBU share	HBU share	**$XX.XX**
Non-home-based	NHB share	NHB share	NHB share	NHB share	**$XX.XX**

Micro-Scale Markets. Likewise, a crosswalk table was developed between the markets most likely of interest in a micro-scale (individual roadway segments) analysis and the core markets. Since traffic counts are readily available for individual roadway segments, developing travel markets that correspond to vehicle classification and by time of day was feasible. Developing the crosswalk was in part the product of an iterative process of engineering judgment and review by experts. The analysis of traffic count data provided by FDOT has produced a distribution of vehicle classifications by roadway functional classifications that will be used in this effort.

Incorporate Results of Survey

The TTV estimates were augmented and expanded by a new market research survey that was conducted in January 2005. The survey instrument collected a limited amount of demographic information, and also asked respondents to choose between pairs of hypothetical trips, generally between a longer, cheaper trip and a shorter, more expensive trip. By evaluating the correlation between demographic variables and the tradeoff respondents make between time and cost, additional travel markets beyond those discussed here were identified. Secondly, the effective values of time that are produced from this analysis were compared to the values that were obtained from the "engineering" analysis previously described. However, such approaches to estimating travel time values consistently produce values far lower than what the "engineering" approach is likely to produce. A more productive use of the values perhaps was to use the relative differences between the travel markets analyzed as a way of validating the engineering approach.

Additional Components for Managed Lane users

As mentioned in A.1, travel time value of managed lane users can be expressed as a sum of Value of Time (VOT), Value of Travel Time Savings (VTTS), and Value of Reliability (VOR)

$TTV_{(ML)}$ = VOT + VTTS + VOR, where

- VOT: same method as general purpose lane users
- VTTS: Travel time savings valued as 49% of hourly household income
- VOR: Travel time reliability valued as 100% of hourly household income

The Florida Department of Transportation has conducted a couple of studies to evaluate VTTS and VOR. The study indicates that per hour VTTS is valued at 49% of hourly household income while VOR is rated at around 80%-100% value of time. Accordingly, managed Lane User travel time value is reflected by the equation below:

Managed lane user travel time saving[4] for I-95 Managed Lane is found to be 25 minutes per hour traveled comparing with general purpose lane users combining AM and PM peak hours. Reliability, on the other hand, does not have Travel time reliability is defined as the 95th – 50th range measurement of traveler's travel time. Currently, there is not specific report of reliability measurement from I-95 Managed Lane. A nominal value of 2 minutes is used in the calculator.

Truck Driver Travel Time Value by Commodity Type

For single- and combination-unit trucks, the user cost methodology has been modified to add a segmentation reflecting commodity types with different sensitivities to value of time. As shown in Table C.3 below, the groupings are reflected below by Standard Classification of Transported Goods (SCTG) code:

- High sensitivity: commodities with extreme time-sensitivity as a result of perishability,
- Medium sensitivity: goods not necessarily damaged by time delays, but with high on-time delivery expectation, and

[4] 2012 I-95 Managed Lanes Monitoring Report, March 2013

- Low sensitivity: non-perishable household and other goods whose deliveries are acceptable close to scheduled date.

Table C.3 Commodity Time Sensitivity Factor by Group

Time Value Sensitivity	SCTG Codes	Examples	Time Value Factor
High	01-07, 43	Live animals, flowers, fruit	1.66
Medium	08-26, 31-33	Alcohol, chemicals, minerals	1.00
Low	27-30, 34-42	Paper, electronics, furniture	0.75

Note: Developed from Value of Time for Road and Commercial Vehicles, University of Leeds, 2001.

These factors are applied as multiplier to truck driver TTVs to reflect regional truck driver TTVs. Table C.4 shows top ten commodity compositions for Southeast Florida and Florida.

Table C.4 Commodity Composition (Truck Equivalent)

Southeast Florida		Florida	
Commodity Type	**Proportion**	**Commodity Type**	**Proportion**
Non-metallic mineral products	16%	Gravel	14%
Waste/scrap	14%	Non-metallic mineral products	13%
Gravel	11%	Waste/scrap	12%
Gasoline	5%	Other food stuffs	5%
Cereal grains	5%	Other agricultural products	4%
Other food stuffs	5%	Natural sands	4%
Natural sands	5%	Fertilizers	4%
Fuel oils	3%	Gasoline	4%
Other agricultural products	3%	Coal-n.e.c.	3%
Coal-n.e.c.	2%	Articles-base metal	3%

Source: Freight Analysis Framework 3.4.

C.2 Transit Vehicles

This section presents the methodology and underlying assumptions applied in developing a methodology for calculating transit user TTVs for Southeast Florida. The methodology is documented in a spreadsheet-based calculator tool to be provided as part of this product.

Introduction

Existing literature was reviewed to determine TTVs for transit users within the United States and throughout the world. Factors influencing TTVs were identified, and proposed values were established for such factors based on the research conducted. Three geographic levels were used for the purpose of comparison: Southeast Florida, Florida, and United States.

Methodology

The methodology applied by the accompanying travel time value calculator for application in Southeast Florida transit user benefit analysis is as follows:

- Determine application;
- Determine travel markets; and
- Determine transit user TTVs.

Each element is further described below.

Determine Application

When evaluating transportation investment alternatives, Benefit-Cost (B-C) analysis is widely used. Travel time savings is one of the most popular user benefit indicators. To better interpret travel time savings and to better incorporate such a benefit indicator into the B-C analysis, travel time savings are converted into monetary value. Cambridge Systematics has performed an analysis about the TTVs of auto drivers for FDOT District 4. User benefits are generally measured in a relative sense in comparison to a no-build condition. Benefits are generally measured as the net benefits minus project capital costs, or as the ratio of benefits to costs. Generally, the benefits estimates correspond to some future condition and both the benefits and costs are converted into current dollars by applying an inflation factor. Using this approach, TTVs of transit users can be applied to almost all kinds of studies involving transit investment or re-evaluation.

Determine Travel Markets

The study for transit user TTVs divided trips of transit users into different markets in order to address different needs of various study purposes.

According to an extensive literature review, travel markets for transit user TTVs varies dramatically (see A.2). In order to provide the most relevant and consistent methodology, studies within the United States were given more consideration. Such studies are relatively consistent in methodology of choosing travel time markets and estimating transit user TTVs.

Table C.5 lists two travel market categories applied in this study: time of day and trip type. These two major categories are crossed and can produce up to seven travel markets (TTVs of business trips do not change by time of day) with corresponding TTVs.

Table C.5 Travel Time Value Markets

		Time of Day	
		Peak Hour	**Off-Peak Hours**
Trip Type	Commuter	*	*
	Local personal	*	*
	Local Visitor	*	*
	On-the-clock	*	

Other travel markets, such as age, income level, sex, and business industry, may be desirable. However, there are only very limited studies related to such markets. Therefore, transit users TTVs related to these markets were not provided for the calculator.

Determine Transit User TTVs

Methodologies estimating transit user TTVs applied by studies within the United States were generally consistent. Most studies agree that such TTVs should be a proportion of total household income. The proportion of household income varies by travel market. It is widely agreed that TTVs of business (on the clock) trips are the same as the traveler's hourly wage, no matter what time the trip occurs. Transit users' trips other than for business purpose have different TTVs depending on trip type and time of day, as specified in Table C.5. Transit user TTVs of a specific travel market for year n is estimated by:

$TTV_n = W_i * p_i * f_n$

where:

W_i = Average wage of people within travel market i in year 2010;

p_i = Proportion (percentage) of TTVs to hourly household income in travel market i; and

f_n = Inflation factor of year n to year 2010 (base year).

Household income was extracted from National Household Travel Survey, U.S. Census, and local survey data. Inflation factors provided by the U.S. Bureau of Labor Statistics and U.S. Census can be applied to estimate household income for year 2014 and after. Proportions of TTVs to household income of interested travel markets were estimated by Cambridge Systematics.

The seven travel markets can be aggregated so that TTVs of transit users in broader markets can be estimated. Results of estimated TTVs were provided in levels of 1-market, 2-market, 3-market, 4-market, and 7-market.

By following these steps, the accompanying TTV Calculator (Excel spreadsheet tool) was assembled to estimate current year (2014) and target year (any year later than 1980) transit travel time values for various market segments and geographical areas, including Southeast Florida. The tool has been built to facilitate easy updates to future-year conditions from the U.S. Government data sources.

D. Vehicle Operating Cost Literature Review Findings

D.1 AUTOMOBILES

Objective

This section provides background information on the valuation of VOC as reported in relevant literature (A.1). The objective of this review was to provide an overview of existing studies on vehicle operating costs in the United States and elsewhere.

Format

This evaluation included a review of the following:

- Existing VOC studies conducted in several states in the United States;
- User benefit applications developed and/or used by the FHWA;
- Implied values of VOC from a review of application;
- VOC for electric vehicles (EVs), hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs); and
- Review of existing sources of data, both nationally and internationally.

Literature Review Findings

The literature review provided relevant information on source of data and data availability, vehicle mix in the United States, methods for converting national data to state or local levels, definitions of VOC and the factors affecting those costs, and models and applications used to compute VOC.

The review findings are summarized below and included the following:

- Relevant sources of information, such as:
  - The American Automobile Association (AAA), which provides several operating and ownership costs for several types of vehicles in their first four years of operation.
  - Runzheimer International, which publishes annual estimates of typical annualized ownership and operating costs for several types of vehicles.

  - The Black Book, the Kelly Blue Book, Intellichoice, and Edmunds, which provide information on new and used vehicle costs. Information includes model age, condition, mileage, age, and geography.
  - The U.S. Environmental Protection Agency (EPA) and the Transportation Energy Data Book, which provide relevant information on fuel and pollutant consumption.
  - U.S. Department of Energy, Alternative Fuels Data Center.
  - The U.S. Census Bureau and the AASHTO's "Redbook."
- A list of all vehicle operating cost parameters, namely:
  - Vehicle energy consumption (traditional fuel, alternative fuel, and electricity);
  - Oil;
  - Batteries;
  - Fuel taxes;
  - Tires; and
  - Depreciation partially as a result of mileage.
- A list of all life-cycle costs, including fixed and variable/operating costs. These fixed vehicle costs are:
  - Depreciation as a result of age and new brand availability;
  - Maintenance;
  - Finance charges; and
  - Licensing and registration.
- A list of all major factors that influence vehicle operating costs, namely:
  - Urban versus rural setting;
  - Pavement roughness;
  - Stop-and-go conditions;
  - Speed; and
  - Price changes (consumer price index).
- A list of all vehicle classes found in the United States market. Most studies and data sources classify vehicles as small/subcompact cars, medium/intermediate cars, vans, light trucks, and heavy trucks.
- Sources for vehicle fleet mix shares at the national and state level. No information relevant to local vehicle fleet mix shares was available. Local vehicle mix shares were determined by vehicle shares by engine fuel type for the United States as a whole and vehicle registration data by vehicle size for

Florida. The proxy model assumed the shares to be the same at the local level as at Florida State level.

- An investigation of several user-benefit applications has shown that two models, MicroBENCOST and the HERS, provide detailed lists of information to compute the impacts of project improvements on users' vehicle costs. MicroBENCOST and HERS both include the effects of speed cycling, pavement condition, and road curvature in determining vehicle operating costs. However, both models rely upon consumption rates and cost values that were originally derived in a 1982 study by Zaniewski et al. Cal-B/C and the STEAM both use a simpler analysis model that relies upon more recent and available data. Cost varies with speed only for STEAM and Cal-B/C. Finally, the Intelligent Transportation Systems (ITS) Deployment Analysis System (IDAS) is only used to evaluate ITS-related projects.

Numerous studies and sources were investigated in this effort. Twenty-four references were finally selected and considered relevant to the VOC study. Articles were summarized and major findings reported. These articles are organized into three categories:

1. Data source literature, which included a list of available sources for computing VOCs internationally, nationally, at the state level, and in Florida.
4. Analysis literature, which included methods and assumptions used by agencies and states to compute VOCs. This section also includes review of factors affecting VOCs.
5. Software models literature, which are software used to evaluate the benefits and cost incurred as a result of project improvements and construction delays.

Below is a list of all articles.

Data Source Literature

- 2013 Vehicle Running Costs (Australia)
- About Vehicle Operating Costs (Australia);
- The Cost of Driving and the Savings from Reduced Vehicle Use (Canada);
- Driving Costs (Canada);
- Your Driving Costs, 2013 (United States);
- Characteristics of Urban Transportation Systems (United States);
- Cost of Owning and Operating Automobiles, Vans, and Trucks, 1991;
- Annual Energy Outlook, 2013 and 2014 Early Release (United States); and
- The Vehicle Fleet – Our Nation's Highway – 2000 (United States).

Analysis Literature

- Transportation Cost and Benefit Analysis Techniques, Estimates and Implications
- The Cost of Construction Delays and Traffic Control for Life-Cycle Cost Analysis of Pavements;
- Estimating Vehicle Operating Costs;
- Transportation Cost Analysis Investigating Individual's Perception of Auto Travel Cost;
- Extra Vehicle Operating Costs: What Motorists Pay to Drive on Roads in Need of Repair;
- Estimating International Roughness Index from Pavement Distresses to Calculate Vehicle Operating Costs for the San Francisco Bay Area;
- Methodology to Improve Pavement-Investment Decisions;
- The Per-mile Costs of Operating Automobiles and Trucks; and
- Motor Vehicle Emission Simulator (MOVES) model run.

Software Models Literature

- IDAS, a tool for integrating ITS into the planning process;
- HERS;
- MicroBENCOST;
- Cal-B/C; and
- MOVES.

D.2 COMMERCIAL VEHICLES

Objective

This section provides background information on the valuation of vehicle operating costs (VOC) for commercial use vehicles, as reported in relevant literature. The objective of this review is to provide an overview of existing studies on vehicle operating costs for single-unit and combination-unit trucks in the United States.

This evaluation included a review of the following:

- Existing relevant VOC studies conducted in several states in the United States; and
- User benefits applications developed and/or used by the FHWA.

Literature Review Findings

The literature review provided relevant information on source of data and data availability, definitions of VOC and the factors affecting those costs, and models and applications used to compute VOC for commercial use vehicles.

A summary of the principal findings from the sources reviewed is presented below.

- **Attributes to consider –** Fuel, maintenance, repair, and depreciation-related costs are common to most VOC methodologies. Depreciation costs are often included as well. According to current FHWA guidance, operating costs that can be affected by a transportation improvement are appropriate for inclusion in user benefit analyses. A large portion of insurance costs, as well as ownership costs, are unaffected by highway improvements and are less appropriate for user benefit analysis. Inventory costs are appropriate for the freight-carrying portion of commercial vehicle travel. However, these costs depend on the type of freight carried, which varies widely by location.
- **Several of the analytical approaches link fuel consumptions to speed –** Approaches that are applied at the level of roadway segments, such as the HERS, use speed models to estimate speed. More aggregate approaches use mileage-based factors.

Table D.1 below summarizes the literature review results by source.

Table D.1 Summary of Literature Review On Vehicle Operating Costs of Commercial Vehicles

Source	VOC Factors	Range of Values ($/mile, in 2004 Dollars)	Compatibility With SEFRUC Data Needs
Minnesota DOT	Fuel, maintenance repairs, tires, depreciation	$0.51-$0.62	High – values are recent and fuel costs can be adjusted. However, lack of distinction between single-unit and combination-unit vehicle operating costs is a drawback.
HERS	Fuel, oil, maintenance repairs, tires, depreciation	$0.69-$0.75 (based on HERS runs for FDOT)	Medium – Separate costs for single unit and combination unit vehicles are calculated. VOCs that vary by speed are important consideration for SEFUC study – HERS uses elaborate speed model. VOCs vary by speed, speed cycling, grade, pavement condition, and curvature.
American Association of State Highway and Transportation Officials (AASHTO) – User Benefits for Highways	Fuel, oil, maintenance repairs, tires, depreciation, inventory, ownership, insurance	$0.57-$0.91	Medium-low: Costs are shown to vary by speed. Maintenance costs appear significantly lower than other sources. Ownership costs appear to include factors beyond depreciation. Fuel consumption varies by speed. Based on secondary sources.
StratBENCOST	Fuel, oil, tires, maintenance and repair, depreciation	$0.44	Medium-low: Cost breakdown not provided and lower than other efforts.
Cal-B/C	Fuel and non-fuel operating costs (presumably consistent with other definitions)	Assuming 10 mph, $0.65	Costs are stratified by speed.

1.0 The Per-Mile Costs of Operating Automobiles and Trucks

Source

Barnes, G., and P. Langworthy, *The Per-Mile Costs of Operating Automobiles and Trucks,* Minnesota Department of Transportation, 2003.

Synopsis

This report describes a methodology and a spreadsheet model for calculating the variable costs of operating trucks for use in benefit/cost analysis of highway projects. The concern in this report is the marginal cost of driving a truck one additional mile. That is, the focus on costs that increase when a truck is driven more, such as fuel use and tire wear; and ignore costs, such as insurance and finance costs, that are incurred regardless of how much the truck is driven. The specific costs that were addressed are:

- Fuel consumption,
- Routine Maintenance,
- Tires,
- Repairs, and
- Depreciation.

Methodology

Minnesota DOT developed estimates of truck costs from research sources due to lack of third-party cost estimates. A generalized composite value for truck-operating costs was developed also due to lack of cost information for specific truck types and sizes.

The baseline per-mile values for the five cost categories were estimated in the following ways (adjustment factors are discussed later):

1. **Fuel –** Trucks operate at an average 7 mpg.

6. **Maintenance –** Truck maintenance costs are about three times that of a mid-sized car and were anticipated to inflate at three percent annually.

7. **Tires –** Tire replacement costs are about three times the cost per mile for tires for passenger vehicles.

8. **Repair –** Truck repair costs are generally about three times that of a mid-sized car and are anticipated to inflate at three percent annually. Repair costs are included in the cost of maintenance estimation.

9. **Depreciation –** The National Automobile Dealers Association (NADA) provides adjustment factors for used vehicle prices based on mileage above and below the assumed average for a vehicle of a given age. Trucks were assumed to be a Class IV vehicle depreciating at 6.5 cents per miles for trucks five years old or less, and 11.5 cents per mile for trucks over five years old.

Adjustment factors are applied to some of the identified cost categories, in order to account for stop-start conditions, unusual pavement roughness, and the possibility of price changes over time. Table D.2 summarizes the adjustments that apply to each cost. Table D.3 underscores the effect of various pavement roughness indices on select truck operating costs, including truck maintenance and repairs, tires, and depreciation. Finally, the impact of stop-start conditions on truck operating costs is described in Table D.4.

Table D.2 Use of Adjustment Factors

Cost Category	Stop-Start Conditions or City Conditions	Pavement Roughness	Price Change
Fuel	Full Increase	No	Yes
Maintenance	Partial increase	Yes	Yes
Tires	No	Yes	No
Repairs	Partial Increase	Yes	Yes
Depreciation	Partial Increase	Yes	No

Source: The Per Mile Costs of Operating of Operating Automobiles and Trucks.

Table D.3 Effect of Pavement Roughness on Select Truck Operating Costs

Present Serviceability Rating (PSR)	International Roughness Index (IRI) (Inches/Miles)	IRI (m/km or mm/m)	Adjustment Multiplier
2.0 or worse	170	2.7	1.25
2.5	140	2.2	1.15
3.0	105	1.7	1.05
3.5 and better	80	1.2	1.00

Source: The Per Mile Costs of Operating of Operating Automobiles and Trucks.

Table D.4 Effect of Stop-Start Conditions on Truck Operating Costs

Cost Category	Stop-Start Conditions or City Conditions	Adjustment Multiplier
Fuel	Full Increase	1.31
Maintenance	Partial increase	1.15
Tires	No	1.00
Repairs	Partial Increase	1.15
Depreciation	Partial Increase	1.15

Source: The Per Mile Costs of Operating of Operating Automobiles and Trucks.

Commercial Vehicles Operating Cost Data

Table D.5 shows baseline per-mile costs in 2004 cents for trucks for a baseline scenario of highway conditions, smooth pavement, and fuel prices of $1.50 per gallon.

Table D.5 Per-Mile Costs, Highway Driving
Cents Per Mile *(In 2010 Dollars)*

Cost Category	Commercial Vehicles
Total	51.5
Fuel	25.4
Maintenance/Repairs	12.4
Tires	4.1
Depreciation	9.5

Source: The Per Mile Costs of Operating of Operating Automobiles and Trucks.

Table D.6 shows per-mile costs given city rather than highway conditions, with other assumptions the same. This fairly sizeable impact is even greater when "congested" conditions are assumed.

Table D.6 Per-Mile Costs, City Driving
Cents Per Mile *(In 2010 Dollars)*

Cost Category	Commercial Vehicle
Total	62.7
Fuel	33.2
Maintenance/repairs	14.4
Tires	4.1
Depreciation	10.9

Source: The Per Mile Costs of Operating of Operating Automobiles and Trucks

Table D.7 shows highway driving conditions per-mile costs given extremely rough pavement (PSI = 2); again with other assumptions the same as the baseline.

Table D.7 Per-Mile Costs, Highway **Driving, Extremely Poor Pavement Quality**
Cents Per Mile *(In 2010 Dollars)*

Cost Category	Commercial Vehicle
Total	58.0
Fuel	25.4
Maintenance/repairs	15.3
Tires	5.2
Depreciation	11.9

Source: The Per Mile Costs of Operating of Operating Automobiles and Trucks

2.0 HERS

Source

Federal Highway Administration, Highway Economic Requirements System, 2000.

Synopsis

The HERS computer model estimates investment requirements for United States highways by adding together the costs of highway improvements that the model's benefit/cost analyses indicate are warranted. In making its estimates, HERS relies on extensive, nationwide data on highway segments, such as pavement conditions and expected growth in traffic. The model uses information such as vehicle operating costs obtained from other sources.

A major strength of HERS is its ability to assess the relative benefits and costs associated with alternative options for improving the nation's highway infrastructure. As such, its estimates can be useful as a general guide for the investment requirements of the highways included in the model, such as rural and urban interstates; and for assessing relative investment requirements over time. However, HERS is limited in four ways: It does not completely account for the effect of highway improvements on all other highways and modes of transportation, it does not fully account for the uncertainties associated with its methods, data and assumptions, it relies on computational shortcuts to approximate the future lifetime benefits of an improvement, and it uses data that vary in quality.

Methodology

Vehicle operating costs (per mile) are affected by the following:

1. Vehicle type;
2. Vehicle condition;
3. Average speed;
4. The effects of traffic signals and stop signs;

5. Variations in speed on sections without signals or stop signs;
6. Curves;
7. Grades;
8. Pavement condition; and
9. Unit prices for fuel, oil, tires, etc.

The HERS VOC procedure reflects all these influences, except for vehicle condition and variations in speed on sections without signals or stop signs. HERS distinguishes among small automobiles, medium/large automobiles, four-tire trucks, and four classes of heavy trucks. The procedure is based on data that was developed by Zaniewski in 1980. The reviewed version of the procedure used 2002 fuel prices; other unit prices were indexed to 2002 dollars (for oil, tires, repair and maintenance, and vehicles); and efficiency-factor adjustments that approximate the effects of technology changed through 2002.

Operating costs per mile increase with average speed, but they are affected to an even greater extent by the existence of traffic-control devices, particularly stop signs. For sections without traffic-control devices, the lack of sensitivity of the HERS procedure to the fifth influence produces a slight downward bias in HERS estimates of VOC and a slight upward bias in the estimated effects of speed on VOC, because increasing congestion results in both lower speeds and increasing variations in speed. If the HERS VOC procedure were applied to work zones, this last effect would result in estimates that suggest work zones *reduce* VOCs.

In addition to the above costs, vehicle operators pay fuel taxes and other taxes and fees to various government agencies. These expenditures usually are classified as transfer payments rather than resource costs; that is, they represent financial transfers from one entity to another, rather than cost to the economy. HERS produces separate estimates of fuel taxes, but not registration fees or other transfer payments.

Vehicle Fleet Segmentation

Five truck types: four tires, six tires, and more than three-axle single unit; and three to four axles and more than five-axle combination.

Commercial Vehicles Operating Cost Data

Table D.8 shows VOC costs by cost components for a variety of single-units and combination trucks.

Table D.8 Commercial Vehicles VOC Component Prices
In 2010 Dollars

Vehicle Type	Fuel ($/Gallon)	Oil ($/Quart)	Tires ($/Tire)	Maintenance and Repair ($/1,000 miles)	Depreciable Value ($/Vehicle)
Trucks					

Single Units					
4 Tires	1.183	4.854	107.0	176.4	31,287
6 Tires	1.183	1.942	258.2	330.0	46,752
3+ Axles	1.035	1.942	639.5	466.7	102,853
Combination					
3-4 Axles	1.035	1.942	639.5	483.4	119,141
5+ Axles	1.035	1.942	639.5	483.4	129,548

Source: HERS.

3.0 User Benefit Analysis for Highways

Source

AASHTO, August 2003.

Synopsis

The Use Benefit Analysis for Highways manual presents a comprehensive methodology for evaluating the user benefits, including vehicle operating costs of commercial vehicles, from highway improvements.

Methodology

Vehicle operating and ownership costs are one of the three user cost components that are common across all improvement types and serve as inputs to the User Benefit Formula. Operating costs include fuel and oil, maintenance, and tires. Ownership costs include insurance, license and registration fees, taxes, economic depreciation, and finance charges. In special cases, they also include inventory cost of the cargo on the vehicle.

Vehicle Fleet Segmentation

- Trucks.

Commercial Vehicles Operating Cost Data

Table D.9 presents the fuel consumption rates by traveling speed used for computing fuel costs per vehicle miles traveled for trucks. Table D.10 is an illustrative example of the cost of owning and operating commercial use vehicles for two district traveling speeds (35 mph and 50 mph).

Table D.9 Fuel Consumption Rates
Gallons Per Mile

Speed (mph)	Truck	Speed (mph)	Truck
5	0.503	40	0.176
10	0.316	45	0.170
15	0.254	50	0.166
20	0.222	55	0.163
25	0.204	60	0.160
30	0.191	65	0.158
35	0.182	70	0.511

Source: Inputs to SPASM based on Cohn, Roger Wayson, and Roswell, 1992, *Environmental and Energy Considerations*, in Transportation Planning Handbook, Institute of Transportation Engineers.

Table D.10 Example of Commercial Vehicles VOC Component Prices
In 2010 Dollars

Speed Cost Component	35 mph ($/VMT)	50 mph ($/VMT)
Fuel Cost	0.3021	0.2755
Maintenance, Repairs and Tires	0.0593	0.0593
Operating Costs	0.3613	0.3348
Vehicle Cost	0.2563	0.2563
Insurance Cost	0.0356	0.0356
Inventory Cost	0.0773	0.0541
Ownership Cost	0.6532	0.6267
Total Cost	1.0146	0.9615

Source: User Benefit Analysis for Highways Manual, August 2003.

*Assumptions include the following: 1) Vehicle Cost = $60,000; 2) Salvage Value at End of Life = $5,000; 3) Vehicle Life = 8 years; 4) Miles per Year = 50,000; 5) Cargo Value = $200,000; and 6) Insurance per year = $1,500.

4.0 California Life-Cycle Benefit/Cost Analysis Model

Source

California DOT (Caltrans), California Life-Cycle Benefit/Cost Analysis Model, 1999.

Synopsis

The Cal-B/C presents an overview and a comparison of several existing models for the computation of vehicle operating costs for commercial vehicles.

Review of Several VOC Models

Surface Transportation Efficiency Analysis Model (STEAM) – This model employs a methodology that separates VOC estimates into fuel and nonfuel components. Default values are included for both of these components in the model, but can be changed by the user. The fuel component considers the effect of speed on fuel consumption for autos and trucks. The nonfuel component employs a fixed cost-per-mile regardless of speed. Nonfuel costs include tires and maintenance. Use-based depreciation is not included, nor is oil.

The most innovative aspect of the STEAM model is the way in which it handles the fuel component. By calculating the fuel consumption per gallon at the average speed and multiplying this figure by the cost per gallon, STEAM allows users to vary fuel costs without having to adjust each of the speed/consumption estimates. STEAM's default fuel cost values exclude taxes (which, as transfer payments, should not be considered in a benefit/cost model).

Default values for the fuel consumption rates used in STEAM come from the Institute of Transportation Engineers' 1992 *Transportation Planning Handbook*. However, these rates were derived from a study published by Caltrans in 1983. Nonfuel VOC is taken from a 1992 U.S. DOT publication, *Characteristics of Urban Transportation Supply*, and is converted to 1997 dollars. These costs originated in the American Automobile Association publication, *Your Driving Costs.*

Highway Economic Requirements System (HERS) – This was developed for the FHWA to analyze highway widening and pavement, and alignment improvement projects at the national level. HERS uses a fairly complex methodology, in which VOC are calculated for seven vehicle types (two types of automobiles and seven types of trucks) as a function of fuel, oil, tires, maintenance and repair, and mileage-based depreciation. The process requires three steps and uses three equations for each step:

1. Constant speed VOC, calculated as a function of average speed, average grade, and pavement condition;
2. Excess VOC (those that occur above the constant speed VOC), calculated as a function of speed cycling; and
3. Additional excess VOC, calculated as a function of road curvature.

The cost estimate procedures used in HERS were revised in 1997. However, the model relies upon consumption rates and cost values that were originally derived in a 1982 study by Zaniewski et al. of the Texas Research Foundation for the FHWA.

StratBENCOST – In the StratBENCOST model, VOCs are calculated by obtaining a consumption rate and grade according to vehicle type (auto, truck, or bus) for each component (fuel, oil, tire wear, maintenance and repair, and depreciation). Total VOC for each component is found by applying an equation that includes facility length, traffic volume, a value for excess VOC (obtained through a separate equation), and the relevant component cost. These values are each multiplied by a pavement adjustment factor, and finally summed across components for the base and alternate cases. The difference between the two cases yields VOC savings.

The values for VOC component costs are derived from the *HERS Technical Memorandum (Updated Values for Costs and Efficiencies, 1997)*. As noted above, the values for HERS originated with the 1982 Zaniewski et al. study. VOC consumption rates and excess costs are from the NCHRP 7-12, which developed MicroBENCOST.

Cal-B/C – The methodology for Cal-B/C was developed to be simple and to make use of the most recent available data. The accuracy of a more complex model would likely be offset by the resources needed for gathering and estimating data.

The methodology used in Cal-B/C is similar to that found in STEAM, which separates fuel operating costs from nonfuel VOC. VOC include fuel, tires, and maintenance and repairs costs. Among the components of VOC, the relationship between fuel consumption and speed is the most widely understood and modeled. Since fuel rates are separated from other costs, fuel prices (minus taxes) can be updated without altering consumption rates. Moreover, consumption rates can be updated as revised estimates become available.

Fuel consumption data are based on estimates of average consumption for the year 2000, obtained from California Air Resources Board Motor Vehicle Emission Inventory (MVEI) models, and on consumption by speed relationships. The fuel consumption rates for trucks used in Cal-B/C are shown in Table D.11. The model determines the appropriate fuel consumption rate based on speed for each project year.

Table D.11 Fuel Consumption Rates
Gallons Per Mile

Speed (mph)	Truck	Speed (mph)	Truck
5	0.310	40	0.185
10	0.181	45	0.223
15	0.135	50	0.264
20	0.118	55	0.316
25	0.120	60	0.374
30	0.133	65	0.439
35	0.156	70	0.511

Source: Motor Vehicle Inventory Emission.

Consumption rates are converted into the fuel consumed using "affected vehicle-miles traveled," calculated as the length of the corridor (or distance where traffic is affected in the case of passing lanes) multiplied by average daily traffic (ADT). These daily estimates are converted into annual estimates by multiplying by 365.

The result is multiplied by the fuel cost. This calculation is performed separately for each year of the project.

The model, at the time of review, used $1.14 per mile ($1.44 in 2004 dollar), which was the WEFA[5] estimate for fuel costs in 2000, converted to year 2000 dollars using the GDP deflator. WEFA fuel cost estimates were reported in the California Motor Vehicle Stock, Travel, and Fuel Forecast. Cal-B/C uses a fixed cost-per-mile estimate, with a separate estimate for cars and trucks. Nonfuel cost estimates are based upon those found in the STEAM model plus an estimate for depreciation. The STEAM estimates were updated to year 2000 dollars using the GDP deflator. Truck depreciation costs are based on values provided by Paccar Inc., the largest truck manufacturer worldwide. Assuming a truck price of $145,000, annual depreciation of 15 percent, and average annual mileage of 120,000, average annual truck depreciation is 0.18 cents per mile. Total nonfuel costs are the sum of the STEAM estimate and depreciation estimates updated to the year 2000.

Commercial Vehicles Operating Cost Data

The Caltrans' Benefit/Cost model results are shown in Table D.12. A brief summary of other models, including STEAM, HERS, and StratBENCOST is presented in Table D.13.

Table D.12 Caltrans Model VOC Estimates Results

Vehicle Class	Cost ($2010)
Fuel	$030 (@ 10 mpg)
Nonfuel	$0.35
Total	$0.65

Source: STEAM estimates and California Benefit/Cost Model.

---

[5] WEFA, Inc. is a leading worldwide economic forecasting company that focuses environmental issues.

Table D.13 Truck Operating Cost Ranges and Model Attributes
In 2010 Dollars

Attribute	STEAM	HERS	StratBENCOST
Costs include:	Fuel, tires, maintenance and repairs	Fuel, oil, tires, maintenance and repairs, depreciation	Fuel, oil, tires, M&R, depreciation
Cost varies according to:	Speed (for fuel only)	Speed, speed cycling, grade, pavement condition, and curvature	Speed, speed cycling, grade, pavement condition, and curvature
Range, dollars per mile (year)*	$0.15	~$0.25**	$0.44
Sources(s)	ITE Transportation Planning Handbook (1992) → from HEEM model (1983) and U.S. DOT****	Zaniewski et al. (1982)	HERS and MicroBENCOST (each based on Zaniewski et al.)

*The range provided in for automobiles. For most models, the range represents VOC at different speeds, such that the high number represents VOC at the lowest speed (usually 5 mph) and the low number represents VOC at the most efficient speed (between 35 and 60 mph usually).

**HERS calculates a range of estimates that vary according to many factors.

***These vehicle types are considered in the user benefits section of the model. Rail VOC may be considered other parts of the model.

****Sources used for the STEAM model.

E. Methodology for Vehicle Operating Costs

E.1 AUTOMOBILES

This section presents the methodology and underlying assumptions for localizing vehicle operating costs in Southeast Florida.

Introduction

Existing literature and procedures to determine cost components, road and vehicle-related variables, and vehicle mix to be considered when determining VOCs in Southeast Florida were researched.

The study area included Indian River, St. Lucie, Martin, Palm Beach, and Broward Counties in District 4, and Miami-Dade County in District 6. Vehicle Costs were collected for small-, medium-, and large-sized vehicles wherever data were available.

Methodology

The following eight major cost components were researched and localized:

1. Vehicle energy consumption (traditional fuel, alternative fuel, and electricity);
2. Fuel taxes;
3. Routine maintenance and repairs;
4. Batteries;
5. Tires;
6. Depreciation;
7. Finance charges;
8. Safety; and
9. License and registration.

The study set vehicle life span to 11.4 years for small-, medium-, and large-sized vehicles. In addition, vehicle operating costs were computed for 12,500 miles of yearly traveling conditions.

Finance charges, licensing and registration fees are not dependent on the distance traveled and are regularly expressed in dollars per year; however, for the purpose of this study and based on recommendations from the FDOT District 4 Office of Systems Planning, these vehicle costs were converted to annual dollars per mile driven for the purpose of computing a total vehicle cost, including both operating and non-operating costs.

The methodology Cambridge Systematics used to collect and compute local vehicle cost components is described below.

Vehicle Energy Consumption

There are two issues in calculating vehicle energy costs: 1) the expected consumption of vehicle energy by a given vehicle model, and 2) the price of fuel/electricity. The two issues were addressed separately, so that analysts can modify assumptions about fuel mileage and prices as values vary over time.

The energy price for transportation sector in the 2013 Annual Energy Outlook data provided on the Energy Information Administration (EIA) website was used as the main data source. Along with existing energy price, the data also provides energy price forecast out into 2040. Electricity price was obtained from the EIA's real price viewer. Residential real price was converted to gas gallon equivalent (GGE) using a conversion factor of 33.7 kWh per GGE[6], then adjusted for efficiency because electric vehicles are 3.4 times as efficient as internal combustion engines[7].

Average automobile energy efficiency were obtained from Edmunds website for selected small-, medium-, and large-models.

For all selected vehicle classes, city/highway vehicle energy efficiency factor were estimated using information provided by AFDC[8]. It was also assumed that averagely a Southeast Florida driver drives 7,500 city miles and 5,000 highway miles a year.

Fuel cost estimates were developed based on the following equation:

$$Vehicle\ Energy\ Cost_{\$/mile} = VEP * FC$$

$$VEP = \text{Vehicle Energy Price (2010 dollars per gallon)}$$

$$FE = \text{Fuel Efficiency (miles per gallon)}$$

$$FC = \text{Fuel Consumption}_{\text{Gallon/mile}} = \frac{7{,}500 / FE(city) + 5{,}000 / FE(highway)}{12{,}500}$$

Estimates for average automobile fuel efficiencies by vehicle class are presented in Table E.1.

---

6 Alternative Fuel Data Center (AFDC) (www.afdc.energy.gov/fuels/fuel_properties.php).

7 GREET (The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model) 1 2012 rev2 Model (http://greet.es.anl.gov/)

8 Alternative Fuel Data Center (www.afdc.energy.gov/fuels/fuel_properties.php)

Table E.1 Average Automobile Fuel Efficiency

Vehicle Class	Small-Sized Vehicle (mpg)	Medium-Sized Vehicles (mpg)	Large-Sized Vehicles (mpg)
City Conditions			
Gasoline	22	22	17
Diesel	29	29	20
Hybrid	37	48	28
Electricity	128	126	78
Compressed Natural Gas (CGN)	27	27	27
Flex Fuel (E85)	14	14	15
Highway Conditions			
Gasoline	30	28	26
Diesel	40	40	29
Hybrid	45	45	26
Electricity	109	101	74
Compressed Natural Gas (CGN)	38	38	38
Flex Fuel (E85)	20	20	22

Fuel Taxes

Federal and state gas tax rates currently are fixed at 18.4 and 24 cents per gallon, respectively. County-level gas tax option rates were provided by the Florida's Transportation Tax Sources Primer. The Primer provides detailed information as of January 2014 on local gas tax options in all 67 counties.

Fuel tax cost estimates were developed using the following equation:

$$Fuel\ Tax\ Cost_{\$/mile} = FT * FC$$

$$FT = \text{Federal, State, and Local Fuel Tax Rates (2010 dollars per gallon)}$$

$$FC = \text{Fuel Consumption}_{\text{Gallon/mile}} = \frac{7{,}500 / FE(city) + 5{,}000 / FE(highway)}{12{,}500}$$

Routine Maintenance and Repairs

The maintenance and repair costs by vehicle size provided by AAA's *Your Driving Costs 201*3 were used in this study. According this AAA report, maintenance costs include retail parts and labor for normal, routine maintenance as specified by the vehicle manufacturer. They also include the price of a comprehensive extended warranty with one warranty claim deductible of $100 and other wear-and-tear items that can be expected to require service during five years of operating the vehicle. Sales tax is included on a national average basis.

Table E.2 Average Maintenance and Repair Cost per Mile by Vehicle Size
In 2010 Dollars

	Small Sedan	Medium Sedan	Large Sedan	Average
Average Maintenance Cost/Mile	$0.046	$0.049	0.054	$0.050

Source: Your Driving Costs 2013, AAA.

Tires

A set of four new Michelin Primacy MXV4 tires' prices for different vehicle sizes were researched and used as the cost of tires (Table E.3). The Southeast Florida and average Florida sales taxes were then applied to calculate tire costs per mile.

Table E.3 Average Cost of a Tire by Vehicle Size
In 2010 Dollars

Vehicle Class	Small-Sized Vehicle	Medium-Sized Vehicle	Large-Sized Vehicle
Florida and Southeast Florida	$57	$196	$203

As a rule of thumb, tires are changed every 60,000 miles for small-, medium-, and large-sized cars. Accordingly and based on 12000 miles yearly travel distance, a new set of tires would be required approximately once every five years.

The cost of a new set of tires including installment was developed using the following equation:

$$New\ Tires\ Cost_{\$/mile} = (NT / MPOC) * VMT$$

$$NT = \text{Cost of a Set of New Tires (4) (2010 dollars)}$$

$$MPOC = \text{Number of Miles Driven Prior to Installing New Tires (miles)}$$

$$VMT = \text{Vehicle Miles Traveled (miles per annum)}$$

The Southeast Florida and average Florida sales taxes were then applied to calculate tire costs per mile.

Safety

Safety cost associated with driving involves three components: 1) identifying average number of property damage only accidents (PDO), number of injuries and number of fatalities per vehicle mile traveled; 2) estimating the costs associated with each PDO, injury, and fatality; 3) determining the number of vehicle miles traveled for the study area.

Safety cost estimates were developed using the following equation:

$$
\begin{aligned}
&Safety\ Cost\\
&= (Number\ of\ PDO\ per\ VMT * \frac{Cost}{PDO}\\
&+ Number\ of\ Personal\ Injuries\ per\ VMT * \frac{Cost}{Injury}\\
&+ Number\ of\ Fatalities\ per\ VMT * \frac{Cost}{Fatality}) * VMT\text{Safety Cost}\\
&= (\text{Number of PDO per VMT} * \frac{\text{Cost}}{\text{PDO}}\\
&+ \text{Number of Personal Injuries per VMT} * \frac{\text{Cost}}{\text{Injury}}\\
&+ \text{Number of Fatalities per VMT} * \frac{\text{Cost}}{\text{Fatality}}) * \text{VMT}Safety\ Cost\\
&= (Number\ of\ PDO\ per\ VMT * \frac{Cost}{PDO}\\
&+ Number\ of\ Personal\ Injuries\ per\ VMT * \frac{Cost}{Injury}\\
&+ Number\ of\ Fatalities\ per\ VMT * \frac{Cost}{Fatality}) * VMTSafety\ Cost\\
&= (Number\ of\ PDO\ per\ VMT * \frac{Cost}{PDO}\\
&+ Number\ of\ Personal\ Injuries\ per\ VMT * \frac{Cost}{Injury}\\
&+ Number\ of\ Fatalities\ per\ VMT * \frac{Cost}{Fatality}) * VMTSafety\ Cost\\
&= (Number\ of\ PDO\ per\ VMT * \frac{Cost}{PDO}\\
&+ Number\ of\ Personal\ Injuries\ per\ VMT * \frac{Cost}{Injury}\\
&+ Number\ of\ Fatalities\ per\ VMT * \frac{Cost}{Fatality} * VMT
\end{aligned}
$$

The data obtained associated with number of accidents and VMT in South Florida as compared to Florida are summarized in Table E.4. Table E.5 presented the cost associated with PDO, injury, and fatality.

Table E.4 Average Number of PDO, Injury, and Fatalities per VMT and VMT in South Florida and Florida

Crash Type/Rate	2010 Indian River	2010 St Lucie	2010 Martin	2010 Palm Beach	2010 Broward	2010 Miami-Dade	2010 SEFL	2010 Florida
Fatalities	26	29	27	123	179	246	630	2,444
Injuries	950	1887	1210	12,397	20,540	29,065	66,049	195,104
PDO	404	900	654	5,459	12,505	24,598	44,520	108,353
VMT (in millions)	1,473	3,074	2,083	12,105	15,790	19,551	54,077	195,755

Table E.5 Average Number of PDO, Injury, and Fatalities per VMT and VMT in South Florida and Florida

Crash Type	Human Capital Costs Per Crash (2010$)
Fatal	$1,532,918
Disabling Injury	$137,162
Evident Injury	$51,590
Possible Injury	$34,968
PDO	$7,880

Depreciation

Most vehicle depreciation is due to the simple passage of time, but some portion is dependent on the number of miles that the vehicle has been driven. Marginal depreciation by age and miles was determined using standard tables from the Kelly Blue Book Official Car Guide.

It is expected that cars, sports-utility vehicles, and trucks lose around 20 percent of their purchase value within the first year of purchase. In addition, the automotive lease guide and the Kelly Blue Book estimate that nonluxury cars retain roughly 40 percent of their original cost by the end of the third year of purchase or lease. Residual values are highest among German cars, and lowest among U.S. vehicle brands. On the other hand, luxury cars are expected to retain roughly 50 percent of their initial value over the same period.

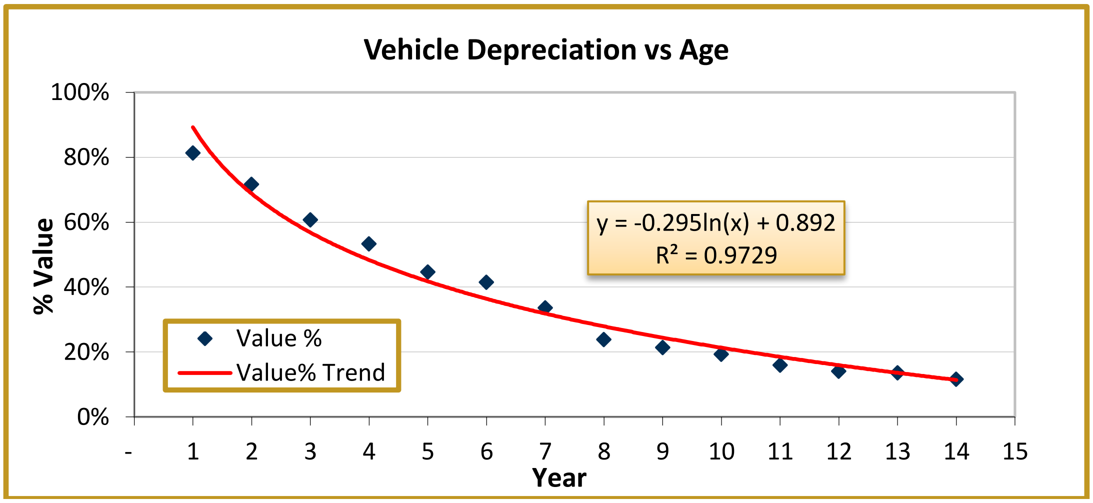
Age depreciation was determined by fixing the driving distance to zero and collecting data on cost of purchase for selected brand names by vehicle size (Toyota Corolla/Small-Sized Vehicle, Ford Taurus/Medium-Sized Vehicle, and Ford Crown Victoria/Large-Sized Vehicle) on a yearly basis between ages 0 and 10. These brand names were shown to be the most popular in Southeast Florida, according to findings on vehicle shares by brand name from the Florida DMV vehicle registration tag database.

Depreciation by miles driven also was collected. For each represented vehicle make, purchasing costs were collected for 0; 60,000 (fifth year); and 90,000 miles (end of vehicle life span as recommended by the FHWA's Office of Highway Policy Information) driven.

Miles and age-driven depreciation costs were converted to yearly figures based on 12,500 miles yearly traveling conditions.

Figure E.1 below shows vehicle depreciation by vehicle age. A regression equation is provided for application in the calculator tool. Annual depreciation cost is developed by percent depreciated multiplied by vehicle price. Per mile depreciation cost can then be further calculated based on annual mileage.

Figure E.1 Vehicle Depreciation by Age



Soure: Kelly Blue Book

Finance Charges

Finance charges are not region specific. Auto loan annual percentage rate (APR) of 4.18% was collected from www.bankrate.com. In addition, state sales taxes and county surtaxes (where appropriate) were applied and weighted based on population size.

Finance charges are regularly expressed in dollars per year, since these are fixed and do not vary with the actual distance driven; however, for the purpose of consistency, finance charges were expressed in dollars per mile driven.

Finance charge estimates were developed using the following equation:

$$Finance\ Charges_{\$/mile} = FC/VMT \ ^{*}Inflation\ Factor$$

FC = Total Finance Charges per year (2010 dollars)

VMT = Vehicle Miles Traveled (miles per annum)

License and Registration

Tax collector offices in the District 4 counties, Miami-Dade, and in representative counties in the remaining five districts were contacted. The office provided information on license, registration, tag, and title service fees for small-, medium-, and large-sized vehicles.

Weighted average license and registration fees for both Florida and the combined Florida District 4 and Miami-Dade County region were computed using 2010 total population counts as obtained from Florida's Office of Economic and Demographic Research (Table E.6).

License and Registration fees are regularly expressed in dollars per year, since these are collected on a one-time-only or yearly basis and are therefore not dependent on the distance traveled; however, for the purpose of consistency, license, and registration fees were expressed in dollars per mile driven.

License and registration costs were developed using the following equation:

$$License\ and\ Registration\ Cost_{\$/mile} = \begin{array}{l}(R/VMT) + (IR/(VMT*LS)) + (LP/(VMT*LS)) \\ + (LF/(VMT*LS))\end{array}$$

R = Registration Cost by Vehicle Weight (2010 dollars)

IR = Initial Registration (2010 dollars)

LP = New License Plate Issuance (2004 dollars)

LF = License Fees (2010 dollars)

LS = Vehicle Life Span

LF = Average Years Between License Registration

VMT = Vehicle Miles Traveled (miles per annum)

Table E.6 License and Registration Fee Estimates
Florida and Southeast Florida (In 2010 Dollars)

Vehicle Class	Small-Sized Vehicle	Medium-Size Vehicle	Large-Sized Vehicle
Initial Registration	$225.0	$225.0	$225.0
Registration by Vehicle Weight	$47.0	$58.0	$72.0
Issuance of a New License Plate	$28.0	$28.0	$28.0
Initial License Fee for First Florida License	$48.0	$48.0	$48.0

Source: Tax collector offices in FDOT District 4 offices, Miami-Dade County, and select counties from the remaining five FDOT District Offices.

Vehicle Operating Costs for Generalized Traveling Conditions

Generalized travel conditions, in terms of vehicle mix, vehicle age, vehicle-miles traveled, stop-and-go conditions, and speed were developed to generate VOCs. A spreadsheet calculator is to be developed separately to estimate generalized VOCs for various scenarios based on the following factors:

- Annual average mileage;
- Average vehicle life span;
- Stop-and-go scenarios: city or highway conditions;
- Average speed scenarios; and
- Tires change frequency scenarios.

For the purpose of this effort, average vehicle operating cost estimates were developed based on the following generalized traveling conditions:

- **Vehicle Mix –** According to findings from the Annual Energy Outlook 2013, the vehicle mix in the United States consists of small (6.0 percent), medium (41.2 percent), and large-sized vehicles (42.63 percent).
- **Vehicle Age and Life Span–** The average vehicle life span is 16 years for small-, medium-, and large-sized vehicles, while average vehicle age roads is 11.4 as of 2014.
- **Vehicle Miles Traveled –** The average yearly travel distance for small, medium, and large size are assumed to be 12,500 miles. This yearly travel distance was used to compute vehicle operating costs per mile driven.
- **Speed –** The average speed was set to 38 mph based on travel speed estimates for Southeast Florida input from HERS for Florida.

E.2 COMMERCIAL VEHICLES

This section presents the methodology and underlying assumptions for localizing single- and combination-unit truck operating costs in Southeast Florida.

Introduction

Existing literature and procedures to determine cost components, road and truck-related variables, and vehicle mix for estimating the operating costs of commercial vehicles in Florida and the southeast region of the State were researched.

The study area included Indian River, St. Lucie, Martin, Palm Beach, and Broward Counties in District 4, and Miami-Dade County in District 6. Vehicle costs were collected for single- and combination-unit trucks.

Truck cost data from the remaining districts in Florida were collected to compare Southeast Florida's results to the State's figure in addition to already-available national data.

Methodology

The following eight major cost components were researched and localized:

1. Fuel;
2. Fuel taxes;
3. Routine maintenance and repairs;
4. Tires;
5. Depreciation;
6. Finance charges;
7. Insurance; and
8. License and registration.

The study set the average vehicle life span to five years for both single- and combination-unit trucks. In addition, single-unit truck (SUT) operating costs were computed for 1111,000 miles of yearly traveling conditions (including 33,300 city miles and 77,700 highway miles); while combination-unit truck (CUT) operating costs were computed for 176,000 miles per year (including 35,200 city miles and 140,800 highway miles).

The HERS[9] recognizes five components of operating costs, including fuel and oil consumption, tire wear, maintenance and repair, and mileage-based depreciation. It also is Federal policy[10] not to include finance charges, insurance costs, license and registration fees, and age-based depreciation when computing the cost of operating vehicles, as these are believed to be dependent on the number of years of service and are regularly expressed in dollars per year. However, for the purpose of this study and based on recommendations from the FDOT District 4 Office of Systems Planning, these truck costs were converted to annual dollars per mile driven for the purpose of computing a total vehicle cost, including both variable and fixed costs.

The methodology used to collect and compute local truck cost components is described below.

---

[9] HERS-ST Version 2.0: Highway Economic Requirements System – State Version (Draft Version).

[10] Economic Analysis for Highway Decision-Makers, U.S. Department of Transportation, December 2004.

Fuel

There are two issues in calculating fuel costs: 1) the expected consumption of fuel by a given vehicle model, and 2) the price of fuel. The two issues were addressed separately, so that analysts can modify assumptions about fuel mileage and prices as values vary over time.

Average pump prices for year 2010 (excluding Federal, state, and local taxes) were collected from the Energy Information Administration.

For the selected truck classes, fuel efficiency estimates for city and highway condition were provided.

Fuel cost estimates were developed based on the following equation (using SUT as an example:

$$Vehicle\ \ Energy\ Cost_{\$/mile} = VEP * FC$$

$$VEP = \text{Vehicle Energy Price (2010 dollars per gallon)}$$

$$FE = \text{Fuel Efficiency (miles per gallon)}$$

$$FC = \text{Fuel Consumption}_{\text{Gallon/mile}} = \frac{33{,}300 / FE(city) + 77{,}700 / FE(highway)}{111{,}000}$$

Estimates for average truck fuel efficiencies by vehicle class for Florida and Southeast Florida are presented in Table E.7. These results were obtained from the Annual Energy Outlook 2013. The more conservative rates were used for the purpose of this study, as shown in Table E.7.

Table E.7 Average Truck Fuel Efficiency in Florida and Southeast Florida

Vehicle Class	Single-Unit Truck (mpg)	Combination-Unit Truck (mpg)
City	13.9	6.1
Highway	18.8	8.2

Source: MOVES.

Fuel Taxes

Federal and state gas tax rates currently are fixed at 24.4 and 24.0 cents per gallon, respectively. County-level gas tax option rates were collected from the Florida's 2014 Transportation Tax Sources Primer. The Primer provides detailed information as of January 2014 on local gas tax options in all 67 counties.

Weighted average fuel tax rates for both Florida and the combined FDOT District 4 and Miami-Dade County region were computed using 2010 total population counts, as obtained from Florida's Office of Economic and Demographic Research.

Fuel tax cost estimates were developed using the following equation (using SUT as an example):

$$Fuel\ Tax\ Cost_{\$/mile} = FT * FC$$

$$FT = \text{Federal, State, and Local Fuel Tax Rates (2010 dollars per gallon)}$$

$$FC = \text{Fuel Consumption}_{\text{Gallon/mile}} = \frac{33{,}300 / FE(city) + 77{,}700 / FE(highway)}{111{,}000}$$

Fuel taxes are not considered in a typical user benefit application. For example, three FHWA-supported software tools (HERS, STEAM, and IDAS) that estimate user benefits for various purposes exclude fuel taxes.

Routine Maintenance and Repairs

According to findings from the Minnesota DOT, the Upper Great Plains Transportation Institute and work completed by Zaniewski[11], routine maintenance and repair costs per mile for single- and combination-unit trucks range between approximately three times to four times that of a medium-sized car. These costs were derived using existing computed/collected data on the cost of changing filter and oil and major vehicle tune-ups and check-ups for medium-sized vehicles.

Maintenance and repairs costs included the following components:

- Oil/filter job for every 11,000 miles,12 including:
  - The number man-hours required to do a routine oil/filter change; and
  - The cost of the material (oil and filter).
- Overall 50,000 miles vehicle tune-up, including:
  - The number of man-hours required to do a routine tune up; and
  - The cost of material (brakes, coolant check up, rotating tires, etc.).
- Overall 100,000 miles vehicle check-up:
  - The number man-hours required to do a routine tune up; and
  - The cost of material (brakes, transmission, coolant change, rotating tires etc.).

---

[11] Zaniewski, J. P., et al., *Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors*, Texas Research and Development Foundation, Federal Highway Administration, Austin, Texas, June 1982.

[12] Oil change intervals are dependent on the quality of the oil used. For ordinary oil quality Volvo commercial vehicles dealerships recommend an oil change every 11,000 miles to ensure that vehicle engine operates appropriately throughout the life span of a truck.

Data on intervals between consecutive oil changes and major commercial vehicles preventive maintenance and repairs work were obtained from Volvo Trucks North America (www.volvo/trucks.com).

Accordingly and based on 100,000 miles[13] yearly travel distance:

- Nine oil/filter repair jobs are anticipated on a yearly basis;
- Two major truck tune-ups are expected annually; and
- One major truck check-up is anticipated on an annual basis.

For future updates, routine maintenance and repairs cost estimates were developed using the following equation:

$$Oil\ Cost_{\$/mile} = (OC / MPOC) * VMT \ \ \text{*Inflation Factor}$$

OC = Cost of One Oil Change Job (2010 dollars)

$MPOC$ = Number of Miles Driven Between Consecutive Oil Change Jobs (miles)

VMT = Vehicle Miles Traveled (miles per annum)

$$Service / Repairs\ Cost_{\$/mile} = (SR / MPOC) * VMT \ \ \text{*Inflation Factor}$$

SR = Cost of One Full Service and Repair Job (2010 dollars)

$MPOC$ = Number of Miles Driven Between Consecutive Service Jobs (miles)

VMT = Vehicle Miles Traveled (miles per annum)

Tires

A set of four new Michelin Primacy XZA2 Energy tires' prices for commercial trucks were researched and used as the cost of tires. The American Trucking Association and findings from Mark Berwick's truck costs for owner/operators study recommend tires be changed every 205,000 miles for most commercial vehicle types.

Accordingly and based on annual travel distance of SUT and CUT, a new set of tires would be required approximately once every two years.

For future updates, the cost of a new set of tires including installment was developed using the following equation:

$$New\ Tires\ Cost_{\$/mile} = (NT / MPOC) * VMT \ \ \text{*Inflation Factor}$$

NT = Cost of a Set of New Tires (2010 dollars)

$MPOC$ = Number of Miles Driven Prior to Installing New Tires (miles)

VMT = Vehicle Miles Traveled (miles per annum)

---

[13] M. Berwick, *Truck Costs for Owner/Operators*, Upper Great Plains Transportation Institute, October 1997.

Safety(Insurance)

For commercial trucks, safety costs associated with driving were estimated using insurance costs. Agents with Allstate Insurance were contacted in each of the six-county study region for quotes for single-unit trucks. Quotes also were collected from one representative location in each of the remaining five districts. Comprehensive yearly quotes were provided for mid-30s male drivers with clean records.

Insurance estimates were based on the rate for one 35-year-old, married male driver with no violations or accidents in the past five years, the primary use of the vehicle being for local and regional business. Insurance levels are as follows:

- Bodily injury liability – $50,000 coverage limit per person and $100,000 coverage limit by accident;
- Property damage – $10,000 per accident;
- Medical payments coverage – $2,000 per person;
- Personal injury protection – Full deductible;
- Collision – $250 deductible; and
- Comprehensive Insurance – $250 deductible.

Insurance costs are regularly expressed in dollars per year; however, for the purposes of consistency, insurance costs are expressed here in dollars per mile driven.

Insurance cost estimates were developed using the following equation:

$$Insurance\ Cost_{\$/mile} = \frac{Insurance\ Cost_{35\ Year\ Old\ Male\ Good\ Driving\ Record}}{VMT} * Inflation\ Factor$$

$$VMT = \text{Vehicle Miles Traveled (miles per annum)}$$

Insurance costs for combination-unit trucks were obtained from local Volvo dealerships in Florida. Insurance costs can be as low as $2,000 per year for basic coverage and as high as $6,000 per year if equipment and goods moved are included in the coverage. Dealership agents noted that a higher coverage is required in most cases; hence, a conservative $6,000 quote was used for this estimate.

Depreciation

Most vehicle depreciation is due to the simple passage of time, but some portion is dependent on the number of miles that the vehicle has been driven. The Minnesota DOT study on commercial vehicles depreciation estimated marginal depreciation by age and mileage at 0.6 cents and 0.9 cents per mile, respectively.

.

Finance Charges

Finance charges are not region specific. Commercial vehicle loan APR (5.5%) were obtained from www.safecu.org[14]. In addition, state sales taxes and county surtaxes (where appropriate) were applied and weighted based on population size.

Finance charges are regularly expressed in dollars per year, since these are fixed and do not vary with the actual distance driven; however, for the purpose of consistency, finance charges were expressed in dollars per mile driven.

Finance charge estimates were developed using the following equation:

$$Finance\,Charges_{\$/mile} = FC/VMT \ \ {}^{*}Inflation\ Factor$$

FC = Total Finance Charges per year (2010 dollars)

VMT = Vehicle Miles Traveled (miles per annum)

License and Registration

Tax collector offices in the District 4 counties, Miami-Dade, and in representative counties in the remaining five districts were contacted to obtain information on license and registration fees. The office provided information on license, registration, tag, and title service fees for single- and combination-unit trucks.

Weighted average license and registration fees for both Florida and the combined Florida District 4 and Miami-Dade County region were computed using 2010 total population counts, as obtained from Florida's Office of Economic and Demographic Research (Table E.8).

License and registration fees are regularly expressed in dollars per year, since these are collected on a one-time-only or yearly basis, and are therefore not dependent on the distance traveled; however, for the purpose of consistency, license, and registration fees were expressed in dollars per mile driven.

---

[14] https://www.safecu.org/loan_rates.asp

Table E.8 License and Registration Fee Estimates
Florida and Southeast Florida (In 2010Dollars)

Vehicle Class	Single-Unit Truck	Combination-Unit Truck
Initial Registration	$225.0	$225.0
Registration by Vehicle Weight	$251.0	$1,322.0
Issuance of a New License Plate	$10.0	$10.0
Initial License Fee for First Florida License	$75.0	$75.0
Total	**$293.00**	**$1,364.00**

Source: Tax collector offices in FDOT District 4 offices, Miami-Dade County, and select counties from the remaining five FDOT District Offices.

License and registration costs were developed using the following equation:

$$\text{License and Registration Cost}_{\$/mile} = \begin{array}{l}(R/VMT) + (IR/(VMT*LS)) + (LP/(VMT*LS)) \\ +(LF/(VMT*LS))*\text{Inflation Factor}\end{array}$$

R = Registration Cost by Vehicle Weight (2004 dollars)

IR = Initial Registration (2010 dollars)

LP = New License Plate Issuance (2010 dollars)

LF = License Fees (2010 dollars)

LS = Vehicle Life Span

LF = Average Years Between License Registration

VMT = Vehicle Miles Traveled (miles per annum)

E.3 TRANSIT VEHICLES

This section identifies the average cost to operate transit vehicles in the United States; and stratifies costs at the national, statewide, and local level for Southeast Florida.

Methodology

Transit vehicle operating costs are provided for distinct transit technologies, including the following:

- Fixed-route bus (motorbus),
- Commuter rail,
- Heavy rail,
- Light-rail transit (LRT), and
- Demand response transit.

Data were obtained from the National Transit Database (NTD), maintained by the Bureau of Transportation Statistics, and includes the cost subcategories as reported to NTD. The analysis was also based on a review of existing literature and cost reporting procedures to determine cost components, as well as methodologies of determining operational costs from previous studies.

Transit operating expenses are presented for the United States; the State of Florida; and for six local counties, including Miami Dade, Broward, Palm Beach, Martin, St. Lucie, and Indian River. Both total costs and averages (total divided by number of agencies) are provided for four transit operating technologies.

Cost subcategories are listed for each technology, together with the values obtained from the NTD. These 12 subcategories, as shown below, included itemized expenditures associated with operations of each of the four technologies at the three geographic levels.

1. Operators wage;
2. Other salaries and wages;
3. Fringe benefits;
4. Services;
5. Fuel and lube;
6. Tires;
7. Other materials and supplies;
8. Utilities;
9. Casualty and liability;
10. Tax;
11. Purchased transportation; and
12. Miscellaneous.

Operating Costs

Operating costs, as they relate to transit, are the expenditures in current U.S. dollars associated with operation of an individual technology by a given operator. They include distributions of “joint expenses” to individual technologies and exclude “reconciling items,” such as interest, expenses, and depreciation.

Operating costs were obtained for transit technologies operated at the national state, and local level. Costs for different existing and proposed technologies were broken down to calculate averages for the following metrics:

- Cost per vehicle mile;
- Cost per vehicle revenue hour; and

- Cost per unlinked passenger trip.

Ridership

Ridership is based on the number of unlinked passenger trips reported to NTD, which refers to the number of passengers that board public transportation vehicles, regardless of transfers made. A passenger is counted each time he/she boards a vehicle, even if on the same journey from origin to destination. Ridership statistics for Southeast Florida were analyzed by agency. There are nine reporting agencies in the region serving six counties, with a total ridership of 155.1 million[15] trips for the year 2012.

In Table E.9, operating costs of local transit technologies are compared against averages for the State of Florida, as well as national averages.

Table E.9 Operating Cost and Ridership for Transit Technologies
In 2010 Dollars

		Southeast Florida	Florida	U.S.
Motorized Bus	Operating Costs ($000)	$433,499	$764,118	&15,596,486
	Ridership (Unlinked Trips, in thousand)	128,893	226,161	4,561,250
Commuter Rail	Operating Costs ($000)	$52,795	$52,795	$3,719,503
	Ridership (Unlinked Trips, in thousand)	4,006	4,006	91,240
Heavy Rail	Operating Costs ($000)	$72,451	$72,451	$6,578,006
	Ridership (Unlinked Trips, in thousand)	18,706	18,706	3,732,000
Light Rail	Operating Costs ($000)	-	$1,686	$1,413,558
	Ridership (Unlinked Trips, in thousand)	-	306	463,070
Demand Response	Operating Costs ($000)	$90,710	$153,840	$2,311,793
	Ridership (Unlinked Trips, in thousand)	3,312	5,900	70,310

Source: National Transit Database 2012 data deflated into 2010 dollars.

[15] National Transit Database, 2012.

Southeast Florida Existing Transit Technologies

This section reviews technologies currently in use in the Southeast Florida region, and includes the individual transit agencies from the Counties of Miami-Dade, Broward, Palm Beach, Martin, St. Lucie, and Indian River. Technologies described include Motorized Bus, Commuter Rail, Heavy Rail, and Demand Response.

A Motorized Bus (MB) is the conventional technology of fixed-route bus transportation, in which a bus, typically 40 feet long, travels at set time intervals (schedule) along a fixed route, making stops at pre-determined locations. While motorbuses provide more unlinked trips in the USA than all other technologies combined, rising fuel costs, as well as carrying capacity constraints and community preferences, have led agencies to prioritize new transit technologies, such as light rail.

Operating costs for bus systems on a passenger basis are typically higher than for rail systems due to constraints of passenger capacity per vehicle. While one bus driver can operate a vehicle that can hold 40 passengers, two Tri-Rail employees can operate a train that can accommodate up to 188 passengers[16].

Community buses are a subset of this technology. These are typically smaller 20 to 30-foot vehicles operated by local municipalities using Federal subsidies. Operating costs for this technology are not reported separately in the NTD or in local reports, and so are assumed to be the same as for motorbuses in terms of costs per mile or hour of service. Although they cost less to buy and use slightly less fuel than 40-foot vehicles, costs per passenger-trip typically turn out higher due to the lower capacity of these smaller vehicles.

A commuter rail system is a technology that is distinguishable from other rail systems, in that, it is an urban passenger train service that runs to a central city from one or several adjacent suburbs. Tri-Rail in South Florida is unique, in that, it passes along an urban fringe of several different cities.

Compared to other existing technologies in the study area, operating costs per vehicle revenue mile are typically high for commuter rail, as are costs per unlinked passenger trip. However, costs per actual passenger mile are less than the other technologies, reflecting the longer trips made by this technology and the higher passenger capacity of commuter rail vehicles.

Demand Response transit (DR), also known as Paratransit, is a bus system that offers on-demand service, typically to disabled individuals and the elderly. A demand-response vehicle is typically 20 to 25 feet long and accommodates anywhere from 10 to 15 passengers, and frequently carries passengers in wheelchairs.

---

[16] Parsons Brinckerhoff, 2007, Hillsboro Metropolitan Planning Organization (MPO) Transit Study.

DR services are offered in all major incorporated cities in Southeast Florida; and in many smaller metropolitan areas, their operating budget exceeds that of standard fixed-route bus service.

Operating costs are reported by expenditure category as reported to NTD to show the approximated amount of expenditures in 2010 dollar values utilized in certain functional areas of transit system operations. The subcategories, as discussed in the methodology portion of this section, are operators' wages, other salaries and wages, fringe benefits, services, fuel and lube, tires, other, utilities, casualty and liability, taxes, purchased transportation, and miscellaneous expenses. Amounts shown in Table E.10 illustrate the distribution of expenditures among these different subcategories. Original data shown in Table E.10 are in 2010 dollars.

Table E.10 Itemized Transit Operational Expenditures for Southeast Florida
In 2010 Dollars

		Bus	Commuter Rail	Heavy Rail	Demand Response
Operators' Wage		$ 127,733,481	$ -	$ 3,778,265	$ -
Other Salaries & Wages		$ 101,752,920	$ 6,412,059	$ 26,168,574	$ 5,213,159
Fringe Benefits		$ 73,056,535	$ 1,916,851	$ 7,651,126	$ 2,390,688
Services		$ 38,637,716	$ 23,052,315	$ 17,570,281	$ 1,859,270
Materials and Supplies	Fuel and Lube	$ 60,119,536	$ 7,908,997	$ 2,299,144	$ -
	Tires and Other	$ 23,324,280	$ 914,110	$ 118,866	$ 27,964
	Others	$ -	$ -	$ 11,006,648	$ -
Utilities		$ 1,594,678	$ 868,711	$ 2,939,370	$ 227,691
Casualty and Liability		$ 6,797,028	$ 1,661,576	$ 919,078	$ 136,943
Tax		$ -	$ -	$ -	$ -
Purchased Transportatio	In Report	$ -	$ 9,458,649	$ -	$ 76,563,390
	Separate Report	$ -	$ -	$ -	$ -
Misc Expense		$ 482,815	$ 601,348	$ -	$ 4,290,809
Expense transfer		$ -	$ -	$ -	$ -
ADA Related		$ -	$ -	$ -	$ -
		$ 433,498,988	$ 52,794,615	$ 72,451,352	$ 90,709,916

Source: National Transit Database 2012

Operators' wages cover the labor of employees of the transit agency who are classified as revenue vehicle operators or crew. Other salaries and wages covers auxiliary labor not directly associated with operating transit vehicles. Fringe benefits include the payments or accruals to others on behalf of an employee and payments and accruals direct to an employee arising from something other than direct labor.

Materials and supplies refer to all the tangible products necessary for maintenance and upkeep, excluding any capital costs for expansion or renovation. Sales taxes and excise taxes (except on fuel and lubricants) are included in the cost of the material or supply.

Utilities refer to the payments made to various utility companies for utilization of their resources. Casualty and liability are the cost elements covering protection of the transit agency from loss through insurance programs and compensation of others for their losses due to acts for which the transit agency is liable. Taxes include petroleum taxes on fuel and lubricants, as well as all taxes levied against the transit agency by the government.

Purchased transportation refers to services that are operated by private companies that, while not associated with local, state, or national government, are still subject to government reporting requirements. For the local study area, purchased transportation includes DR services for Miami-Dade, Broward, and Palm Beach Counties. Palm Beach County uses purchased transportation to administer a small portion of its MB fleet. The South Florida Regional Transportation Administration (SFRTA) is a purchased transportation agency that administers Tri-Rail, as well as the MB fleet that shuttle passengers from rail stations to surrounding areas.