Development of Tools for Assessing Wider Economic Benefits of Transportation

DETAILS

0 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-43406-5 | DOI 10.17226/22502

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The Second
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP 2 REPORT S2-C11-RW-1

Development of Tools for Assessing Wider Economic Benefits of Transportation

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WASHINGTON, D.C.
2014
www.TRB.org

Subject Areas

Economics
Highways
Planning and Forecasting

The Second Strategic Highway Research Program

America's highway system is critical to meeting the mobility and economic needs of local communities, regions, and the nation. Developments in research and technology—such as advanced materials, communications technology, new data collection technologies, and human factors science—offer a new opportunity to improve the safety and reliability of this important national resource. Breakthrough resolution of significant transportation problems, however, requires concentrated resources over a short time frame. Reflecting this need, the second Strategic Highway Research Program (SHRP 2) has an intense, large-scale focus, integrates multiple fields of research and technology, and is fundamentally different from the broad, mission-oriented, discipline-based research programs that have been the mainstay of the highway research industry for half a century.

The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life,* published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: Safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; Renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

SHRP 2 was authorized in August 2005 as part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The program is managed by the Transportation Research Board (TRB) on behalf of the National Research Council (NRC). SHRP 2 is conducted under a memorandum of understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the National Academy of Sciences, parent organization of TRB and NRC. The program provides for competitive, merit-based selection of research contractors; independent research project oversight; and dissemination of research results.

SHRP 2 Report S2-C11-RW-1

ISBN: 978-0-309-27360-2

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ACKNOWLEDGMENTS

This work was sponsored by the Federal Highway Administration in cooperation with the American Association of State Highway and Transportation Officials. It was conducted in the second Strategic Highway Research Program (SHRP 2), which is administered by the Transportation Research Board of the National Academies. The project was managed by David Plazak, Senior Program Officer for SHRP 2 Reliability and Capacity.

The research reported herein was conducted by a team composed of Economic Development Research Group (which designed the collection of spreadsheet tools and authored Chapters 1, 2, and 6) and four subcontractors. They are Cambridge Systematics, Inc. (which co-authored Chapter 3 and the reliability tool), Weris, Inc. (which co-authored Chapter 3 and the reliability tool), ICF International (which authored Chapter 4 and the intermodal connectivity tool), and the Texas A&M Transportation Institute (which authored Chapter 5 and the accessibility tools).

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FOREWORD

David Plazak, *SHRP 2 Senior Program Officer, Reliability and Capacity*

The goal of the SHRP 2 Capacity focus area goal is to develop approaches and tools for systematically integrating environmental, economic, and community requirements into the analysis, planning, and design of new highway capacity. The Capacity Technical Coordinating Committee set out to develop a suite of simple-to-use tools that could assist transportation agencies to assess the economic implications of proposed additions to highway capacity and, in turn, land use. Part of this objective was served by Project C03, which produced 100 detailed before-and-after case studies on the long-term economic and land development impacts of various transportation improvement projects around the nation. An accompanying web portal called T-PICS allows transportation agency staff and others to quickly assess the order-of-magnitude impacts of projects on the regional economy using a transparent reasoning-by-analogy approach. The C03 research report has been published and T-PICS is available as a beta test website at http://www.tpics.us/.

As a part of the C03 research project, the team considered what other potential SHRP 2 research and development activities would be useful in assisting transportation agencies (primarily state departments of transportation and metropolitan transportation organizations) to better understand the implications of proposed capacity investments on their regional economies. The result of this investigation was Project C11.

Project C11 addresses benefit–cost analysis as opposed to economic impact assessment, which was the set of techniques addressed by Project C03. The C11 research team worked to improve the state of the practice in assessing the wider economic benefits of transportation capacity projects. Specifically, they addressed three classes of project benefits that have been generally acknowledged to exist but have been difficult for transportation agencies to address in a systematic and quantitative manner:

- *Travel time reliability benefits.* These benefits derive from reductions in nonrecurrent traffic congestion, improving travel time reliability for both passengers and freight.
- *Intermodal connectivity benefits.* Some transportation projects lead to considerable reductions in access time to key transfer facilities such as airports and marine ports and terminals. These projects often have important benefits for freight shippers and receivers.
- *Market access benefits.* Some transportation projects lead to considerable economic benefits in terms of improved breadth of access to markets for truck deliveries and to labor markets for commuters. Either of these might have major implications in terms of regional economic growth.

Finally, the C11 project team produced an updated benefit–cost accounting framework to tie together these wider categories of benefits with classes of project benefits that have been traditionally considered in benefit–cost analysis in transportation. These include benefits from improved safety, travel time savings (from reductions in recurrent traffic congestion), and vehicle operating cost savings. Besides this final research report, Project C11 produced a set of downloadable spreadsheet tools and the user guides and instructions transportation agency staff and others need to use them. Because it addresses the value of improving travel time reliability, the reliability spreadsheet was tested in 2013 and will be tested during 2014 as part of the SHRP 2 Reliability focus area's L38 analytical tool pilot test project.

CONTENTS

Executive Summary

While the Transportation Project Impact Case Studies (T-PICS) screening tool developed in SHRP 2 Project C03 portrays the general range of economic impacts associated with various transportation projects, most agencies also move on to examine the specific changes in transportation conditions associated with individual project proposals as well as their economic consequences. SHRP 2 Project C11 provides spreadsheet tools to assist local agencies in moving on to this next stage.

The foundation for this project is the fact that transportation projects can lead directly to wider benefits that stem from more than just the traditional measures of traveler impact, which are based on average travel time and travel cost. These wider benefits are effects on business productivity, factors that enable businesses to gain efficiency by reorganizing their operations or changing the mix of inputs used to generate products and services. There are at least three classes of transportation system impacts that can directly lead to wider benefits for business organization and operation: travel time reliability, intermodal connectivity, and market access. These three classes of effects are the focus of this report and are summarized as follows.

Reliability

Some transportation projects are designed to reduce congestion. Those projects may reduce not only average travel times, but also the likelihood of traffic incidents and length of traffic backups that result from each incident. That brings less variability and uncertainty in freight pickup and drop-off times and hence fewer late deliveries. The reduction in late deliveries can enable reduction in inventories and more centralized warehousing and delivery processes to be put in place. These effects are often referred to as supply chain logistics benefits. It is also possible for reliability improvement to reduce employee lateness and hence enable business operations to make more productive use of workers because they show up on time. This effect is often referred to as a labor productivity benefit.

A reliability assessment spreadsheet was developed for this study (Chapter 3). It takes information on the type of highway, projected traffic volume, speed, lanes and capacity, and it then generates measures of a travel time index, average delay, buffer time, and cost of delay. The travel time index and buffer time provide a basis to further calculate the direct economic value of improving reliability, in a separate accounting spreadsheet (the accounting spreadsheets for reliability as well as those for market access and intermodal connectivity are described in Chapter 2).

Intermodal Connectivity

Some transportation projects have the effect of enhancing the frequency of service and reducing total time involved for bus, car, and/or truck movements from business locations to intermodal terminals (including airports, marine ports, rail terminals, and intermodal truck and rail facilities) and vice versa. Other transportation projects may enhance the frequency of air, marine, and/or rail services or enhance the breadth of origins and destinations directly accessible from those terminals. Either way, the result is a faster movement for intermodal travel between some origins and destinations. That can be viewed as reducing travel cost for existing movements, as well as enabling new movements between origins and destinations that were previously not practical or economically feasible.

An intermodal connectivity assessment spreadsheet was developed for this study (Chapter 4). It takes information on the specific intermodal port or terminal affected by a transportation project, projected ground access volume, change in access time, and fraction of vehicles on the affected access routes that have that terminal as their destination. It then looks up information regarding the modes and destinations served by that facility, and from that data it generates a connectivity index. This index provides a basis for calculation of the direct economic value of improving connectivity, in a separate accounting spreadsheet.

Market Access

Some transportation projects have the effect of expanding the breadth of destinations that can be served by same-day truck deliveries from a given business location, or the breadth of area from which a business can reasonably expect to draw customers and workers. These effects are often represented as changes in the effective size or the effective density of the customer market and labor market available to the firm. Expansion of the customer delivery market can enable scale economies in production and delivery processes. Similarly, expansion of the worker labor market can enable scale economies through better matching of specialized business needs and specialized worker skills, and it can also enable more innovation through greater interaction of complementary firms and their employees.

Two market access assessment spreadsheets were developed for this study. One tool uses an effective density metric with a spatial decay factor to assess access from a firm to buyers and suppliers. This tool can also be used to assess labor market access. The second tool uses an impedance threshold metric to assess commuter access. Both work on the same general principal. They take information on zonal population or employment as well as distance or time decay factors and then generate measures of effective market size or effective market density. This information can be used to calculate the direct economic value of improving accessibility, in a separate accounting spreadsheet.

The results from all three categories of project impact spreadsheet can be used directly to generate project impact indicators useful for project evaluation and prioritization processes such as multi-criteria rating systems. They can also be used as drivers for benefit–cost and economic impact models. To aid in this process, a generalized benefit–cost accounting framework is also presented as a fourth class of spreadsheet tool. The accounting framework shows how results of the travel time reliability, intermodal connectivity, and market access tools can be used, together with traditionally measured travel time and travel expense measures, to more fully assess the direct economic benefits that a given roadway improvement may have on both travelers that use it and the operation of businesses that depend on it (for workers, customers, and deliveries). These results can also be used to drive more sophisticated economic impact forecasting and analysis systems to more fully estimate the long-term regional economic growth implications of proposed projects.

CHAPTER 1

Introduction

Project Overview

An underlying theme throughout the second Strategic Highway Research Program (SHRP 2) has been the development of practical, useful, and "accessible" tools that can truly make a difference in transportation investment and planning. This study provides a set of four tools for transportation impact assessment that planners can use to assess the impacts of transportation capacity projects on conditions that directly affect wider economic benefits. These four tools enable measurement of project impacts on (1) travel time reliability, (2) intermodal connectivity, and (3) market access (often abbreviated as "reliability, connectivity, and access" in this report), and they are accompanied by (4) an accounting system or "framework" for incorporating the above three metrics into economic benefit and economic impact analyses.

This report describes the four analytic tools and their technical foundation and provides instructions for users. The Microsoft Excel spreadsheet-based tools are freely available by accessing www.trb.org/main/blurbs/169524.aspx.

A notable aspect of these tools is that they shift the focus of analysis from traditional transportation impact measures (i.e., travel time, cost, and safety) to broader factors that also matter to individual business operators and thus actually "drive" economic development processes (i.e., travel time reliability, intermodal connectivity, and market access). The accounting framework then shows how those factors can be drivers of economic development impact outcomes (reflecting rates of growth and location of economic activities).

These tools are designed as a coordinated suite, though they can also be used individually by staff of state departments of transportation and metropolitan planning organizations. Each of the tools is designed to require only data that are easily collected or assembled by those conducting a sketch planning study, or that can be acquired from data sources that are widely available. They can also be used in conjunction with travel models, land use models, or economic models.

Background: Relationship to SHRP 2 Program

Application of Economic Analysis for Different Planning Stages

To understand the role of these new tools, it is important to first note how an earlier SHRP 2 project (C01) broke down into detail the key decision points in transportation planning and decision-making processes. These various decision points differ in the stakeholder issues being considered and the information available to inform those decisions. At the most in-depth possible level, the key decision points can be grouped as follows:

1. *Early Stage Planning* typically involves a need for a "broad brush" scan of available options and the typical magnitude of economic impacts commonly associated with them and containing basic information about the local context (such as long-range transportation plans and area transportation needs studies).
2. *Middle Stage Planning* more typically requires further analysis to establish the range of likely outcomes through sketch planning procedures that consider not only local context but also expected changes in transportation conditions and access impacts (such as development of project lists in programming processes and initial elements of corridor planning).
3. *Later Stage Planning* typically calls for full, detailed modeling and the analysis is conducted to refine estimates of expected impacts, given details of the project and forecasts of traffic and economic change (such as refinement of planning priorities, alternatives analysis, or environmental studies for large projects).

Early Stage Planning issues are addressed by a previous SHRP 2 project (C03) that developed the T-PICS web tool. That tool is described in text that follows. Later Stage Planning can use existing transportation models, economic impact analysis (EIA) models and benefit–cost analysis (BCA) tools. However, that leaves a gap for Middle Stage Planning, in which full blown models may not be necessary, but initial steps must be taken to identify the motivation for proposed projects and document their magnitude. The products of this new study are designed to help to inform planners at this middle stage, by providing tools they can use to document intended transportation impacts that lead to wider economic benefits. These tools can also help to extend the usefulness of BCA and EIA models, by allowing them to fully incorporate information on wider economic benefits.

Building on Earlier SHRP 2 Products

The tools described in this report build on outcomes and findings from an earlier SHRP 2 project (C03) that developed a national database of case studies documenting the actual, post-construction economic impact of highway and multimodal investment projects. The results of that effort are provided through a web tool, T-PICS, which can be accessed on the web at www.tpics.us. That tool has two distinct uses:

1. It provides a searchable database of case studies covering most types of highway and intermodal facilities. For any type of highway-related project, it is likely that at least a few case studies of experiences elsewhere can be located. Used this way, the case studies provide a rich body of data that can be accessed to immediately inform the public and planners about past experience with similar types of projects, and that information can be used to improve Early Stage Planning. It also provides a database that enables further research on the topic.
2. It provides an expert system that draws from the database to estimate the range of economic impacts most likely to result from any specified type of project in a defined setting. This represents a form of "analysis by analogy," and is a way to define what constitutes a reasonable range for expected impacts of proposed projects, based on prior experiences.

The T-PICS searchable database facilitates further research, and indeed the SHRP 2 C03 Final Report (specifically, Table 4.9 in that report) notes that among the 100 highway capacity enhancement projects that were studied, the dominant motivations were to (1) reduce congestion bottlenecks that add to delay and travel time unreliability, (2) enhance market access for jobs and businesses, and (3) enhance connectivity to intermodal terminals. The T-PICS database contains measures of those elements, and indeed the case study narratives included with T-PICS confirm their importance. In fact, a variety of state DOTs already have project ranking systems that give added priority to proposed projects that enhance intermodal access, system connectivity and business markets. These factors are also recognized as legitimate elements of productivity benefits that can be incorporated into benefit–cost analysis methods applied for federal grant applications.

Despite recognition of the importance of these factors, traditional economic analysis tools (particularly those for benefit–cost analysis) have tended to focus on measurement of the benefits of time savings, expense reduction, and safety enhancement rather than business productivity benefits of improving reliability, intermodal connectivity, and access to new markets.

The use of T-PICS to help assess likely impacts of proposed projects must be conducted carefully. The T-PICS web tool has been a source of interest in the transportation planning community because of the way that it blends ease of use with a complex underlying set of quantitative and qualitative data derived from empirical analysis. Yet, one of the reactions to the case studies and web tools developed for T-PICS has been a concern that case studies can be taken out of context or be otherwise misconstrued. That can occur if a project's proponents or opponents choose to recognize only those cases that fit their needs, or even when they make well-intentioned mistakes. However, naive users mistakenly draw conclusions that every project can be expected to achieve the average results achieved by similar projects elsewhere. The appropriate answer to the concern about misuse of cases is not to require complex simulations or reliance solely on case studies, but rather to develop useful tools that can bridge the gap between these options. Those tools are the subject of this study, focusing specifically on the key factors that are widely recognized by planners, yet often poorly documented by analysts.

The spreadsheet products described in this report are intended to fulfill three needs for the SHRP 2 Capacity Research Program. First, they are intended to complement the SHRP 2 Project C03 product (T-PICS) and enhance the ability of transportation analysts to better incorporate economic issues into middle stage sketch planning applications. Second, they are intended to extend the base of open source, public information and tools that researchers and consultants can use to provide more detailed analyses. Third, they are structured to reinforce the overall integration, usefulness, and accessibility of the multistage decision-making framework that is the core of SHRP 2 Project C01.

CHAPTER 2

Accounting Framework

Overview of Wider Transportation Benefits

Defining the Concept of Wider Benefits

What are wider benefits? Traditionally, benefit–cost analyses for transportation projects in North America have focused on measurement of transportation system efficiency, represented in terms of direct effects on travel time, vehicle operating cost, and collision incident cost—collectively referred to as traveler or "user" benefits. Broader measures of societal benefit commonly add a valuation of pollution emissions reduction. Other environmental and social effects on communities can also be added, but in North America they have generally been treated as externalities that are difficult or impossible to monetize (i.e., express in monetary terms). Sometimes other environmental and social impacts are ignored in benefit–cost analysis because adverse impacts are already covered under environmental review processes in the United States.

It has also been recognized, for some time, that a transportation improvement project can benefit other parties besides the traveler. In particular, the direct effects on travelers can subsequently lead to broader indirect effects on the economy. For instance, savings in business delivery costs may allow businesses to generate greater income, or products to be offered at lower prices—which in turn can lead to greater economic growth. Savings in household transportation costs may also allow households to buy more local goods and services, which can also lead to greater economic growth. The greater economic growth can be viewed in terms of added jobs, wages, or value added (gross domestic product).

However, transportation improvement projects can also lead directly to *wider benefits* that are not captured by the previously-cited set of traveler benefits and their indirect effects. These are impacts on business productivity—factors that enable businesses to gain efficiency by reorganizing their operations or changing the mix of inputs used to generate products and services. These effects are sometimes referred to as *technology change.* There are at least three classes of transportation system impacts that can directly lead to wider benefits for business organization and operation. These three classes of wider effects are the focus of this report. They are reliability effects, intermodal connectivity effects, and market access.

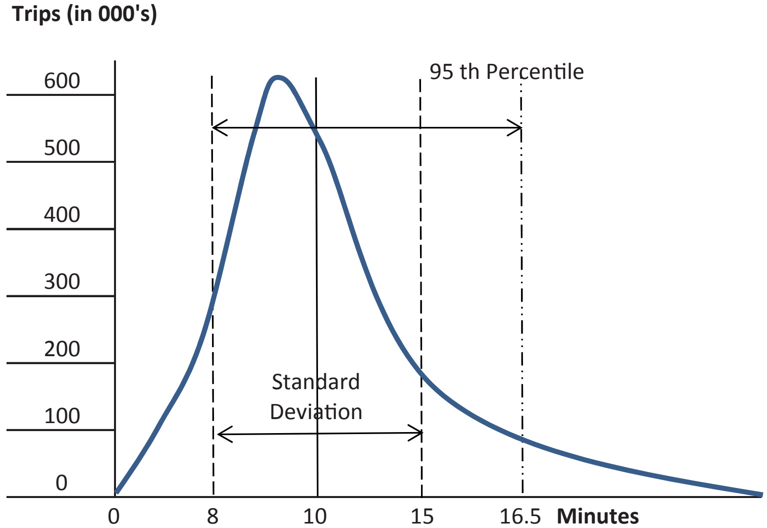
Reliability Effects

Some transportation projects are designed to reduce congestion. Those projects may reduce not only average travel times, but also the likelihood of traffic incidents and length of traffic backups that result from each incident. That brings less variability and uncertainty in freight pickup and drop-off times and hence fewer late deliveries. The reduction in late deliveries can enable reduction in inventories (safety stocks) and more centralized warehousing and delivery processes to be put in place. These effects are often referred to as supply chain logistics benefits. It is also possible for reliability improvement to reduce employee lateness and hence enable business operations to make more productive use of workers who show up on time. This effect is often referred to as a labor productivity benefit.

Figure 2.1 illustrates a typical dispersion of travel times under congested conditions and shows the difference between mean travel time (~10 minutes) and the added schedule padding (buffer time) that a business must add to its schedule to ensure 95% on-time delivery (which in this case adds around 6½ minutes). An alternative measure is the standard deviation around the mean (which in this case is a range of around 7 minutes). Figure 2.1 and other aspects of reliability measurement and impact are discussed in Chapter 3.

Market Access

Some transportation projects have the effect of expanding the breadth of destinations that can be served by same-day truck deliveries from a given business location, or the breadth of



Source: Cambridge Systematics et al. 2013.

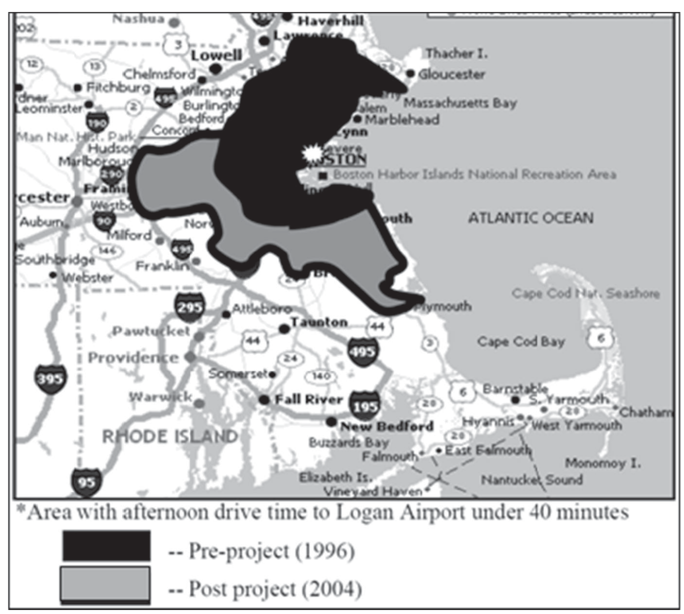
Figure 2.1. Travel time reliability metrics.

area from which a business can reasonably expect to draw customers and workers. These effects are often represented as changes in the effective size or the effective density of the customer market and labor market available to the firm. Expansion of the customer delivery market can enable *scale economies* in production and delivery processes. Similarly, expansion of the worker labor market can enable scale economies through better matching of specialized business needs and specialized worker skills, and can also enable more innovation through greater interaction of complementary firms and their employees. These are sometimes referred to as *agglomeration benefits,* insofar as they enable the benefits of closer worker and business proximity to be realized without requiring the physical relocation of firms or households.

Figure 2.2 shows how a transportation improvement can expand the effective market area for car or truck access to an employment or activity center. In this case, it shows how a highway extension (I-90) and highway expansion (I-93) project broadened the area from which residents could access Boston's airport within a given travel time. Further aspects of market access measurement and impact are discussed in Chapter 5.

Intermodal Connectivity Effects

Some transportation projects have the effect of enhancing the frequency of service and reducing total time involved for bus, car, and/or truck movements from business locations to intermodal terminals (including airports, marine ports, rail terminals or intermodal truck or rail facilities), and vice versa. Other transportation projects may enhance the frequency of air, marine, or rail services, or the breadth of origins and destinations directly accessible from those terminals. Either way, the result is a faster movement for intermodal travel between some origins and destinations. That can be viewed as reducing time and cost for existing movements, as well as enabling new movements between origins and destinations that were previously not practical or economically feasible.



Source: Economic Development Research Group 2006.

Figure 2.2. Market access measurement: Effect of the Central Artery/Tunnel project (I-90/93).

Source: Economic Development Research Group 2013.

Figure 2.3. Illustration of port/terminal as a gateway to new markets showing cities within 2 hours total travel time from downtown Boston based on driving a car or flying to destinations that have hourly or more frequent air service during business hours.

Figure 2.3 shows how intermodal connectivity can expand and can open up new markets. In this case, it shows how frequent air shuttle enables markets outside of the Boston area to be readily accessible for same-day trips to and from Boston. Further aspects of intermodal connectivity and impact are discussed in Chapter 4.

Why Wider Benefits Matter

The three classes of wider effects noted in the preceding text have certain common features:

- First, they all involve change in business firm-level productivity that results from changes in how a firm is organized and operated. The change in the firm's organization and operation leads to either expanding business output achievable from a given set of inputs or to reducing the quantity of inputs required to generate current output.
- Second, they all induce changes in trip making, as reflected in vehicle-miles or person-miles of travel. In the case of expanded market areas, the result may be to enable new trips and longer trips. In the case of enhanced reliability, the result may be to enable fewer delivery vehicles to serve the same market, because a more efficient truck routing pattern can be used that does not require as many returns to the warehouse. (The effect of improving intermodal connectivity is similar to that of improving access, except that the impact occurs by enabling more distant, new markets rather than expanding existing, local markets.)
- Third, they all involve effects that would not be captured by traditional travel models, because they derive benefit from changes in business location and technology use (i.e., mix of labor, fuel, vehicle, and other inputs required to produce goods and services). The technology-induced changes in trip making cited in the preceding paragraph would not be captured by traditional travel modeling processes because they fall outside of the travel time and cost effects that are the basis for predicting induced traffic by even the most sophisticated travel models. In addition, there can be cost savings from scale economies in production processes that do not necessarily lead to any observable change in per capita trip rates or delivery patterns.

The relationship between these wider impact factors and firm reorganization (enabling greater efficiencies of operation) is shown in Table 2.1.

The table shows that the reorganization of business operations tends to fall into two broad classes:

1. Changes that enable less consumption of certain labor or capital inputs because use of those inputs can now be reconfigured (e.g., centralized dispatch and warehousing), and
2. Changes that enable scale economies due to expansion of existing markets (for workers or customers) or expansion into new market areas. This class of impact is sometimes referred to as "agglomeration effects" because they allow firms to effectively achieve scale economies of higher density markets (though this has occurred through time and schedule changes rather than changes in the spatial location of firms or their markets).

An example of wider business benefits not captured by traditional travel models is the real-world case of a new bridge across the Mississippi River. Before the bridge was built, a small ferry carried only cars and operated most but not all of the time (depending on water levels). The closest alternative bridge required 40 miles of extra travel from the ferry location. So it was not surprising that travel demand analysis showed no trucks and few cars crossing the river in that region. And thus, the traditional benefit calculation—multiplying the considerable time and cost savings of a 40-mile detour times a small number of vehicles—showed a relatively small benefit. But regional business and economic development advocates argued that the economically depressed area around the proposed bridge would be an economically efficient and desirable location for industry if only it were accessible by a reliable connection to surrounding urban labor and delivery markets. In other words, the benefit came in the form of business efficiency

Table 2.1. Wider Transportation Benefits and Their Economic Effects: Relationship Between Transportation Changes and Firm Reorganization

Transportation Change	Effect on Firm Reorganization: Business Operation Change
Improved Reliability: Freight Delivery	Tighter delivery schedule – More daily deliveries per vehicle – Fewer vehicles and trips required – Less fuel used – Less staff driver time required Less overtime required at loading dock Less warehouse "safety stocks" required More centralized dispatch & distribution enabled
Improved Reliability: Workers	Fewer late worker arrivals and earlier start of full operation – More hours of full operation per day – Potential for less overtime or extra workers kept on hand
Expanded Access: Freight Delivery	Reconfigure delivery routes for broader scale service area – Larger scale warehouse & more centralized distribution enabled – Longer average trip distance
Expanded Access: Labor Market	Broader scale of labor market available to firms – Better matching of specialized business needs & worker skills – More innovation through interaction with complementary firms (and their employees) – Longer average trip distance
Enhanced Intermodal Connectivity: Freight Delivery	Same-day (or 2-day) delivery to more origins and destinations – Larger scale warehouse & more centralized distribution enabled – Scale economies
Enhanced Intermodal Connectivity: Business Travel	Same-day business interaction with firms in more markets – More innovation through worker interaction with complementary firms

gains that depended on expanding market access, and that helped justify the new bridge.

Application of Wider Transportation Impact Measures

Calculation of Wider Transportation Impacts

While the above-cited processes explain how wider economic benefits occur, it is also necessary to establish that these processes are capturing effects not already incorporated in the traditional measures of travel time and vehicle operating cost.

In benefit–cost analysis, it is imperative that different classes of benefits and their valuations be added without double counting. In economic impact analysis, many of the same elements of user time and cost changes are also recognized as direct effects that are inputs to regional macroeconomic impact forecasting models. And thus, there is a similar need to avoid over-stating direct effects, as that would lead to an over-estimate of total economic impacts.

Concern about double counting can apply for reliability, intermodal connectivity, and market access measures because they are all affected by changes in travel speeds as well as other factors. This is illustrated in Figure 2.4. Figure 2.4 shows that all three measures can reflect changes in characteristics of transportation facilities and their use patterns. These measures are distinct from changes in travel time, though there is still a potential for overlap insofar as all of these benefits can also be affected by changes in speed.

For instance, congestion reduction affects average travel times as well as the variation in travel time (reliability), so care must be taken to avoid adding a reliability effect that is already partially reflected in the valuation of faster travel times. Another issue that arises is that faster travel times also enable broader market access (which may be measured as changes in the effective scale or effective density of markets). So again, care must be taken to avoid adding a market access effect that is already valued in faster travel times.

To address concerns about overlap, the project team made an effort to isolate the added effect of these wider benefits from the potential overlap effect. For instance, the discussion and documentation of the reliability tool shows that an effort has been made to distinguish *recurring delay* (caused by congestion), which affects average travel times, from *nonrecurring delay,* which is due to changes in the frequency and severity of traffic incidents (e.g., crashes or disabled vehicles) in congested conditions.

Similarly, the accessibility tool attempts to measure both the expansion of (1) labor market access to jobs and (2) truck

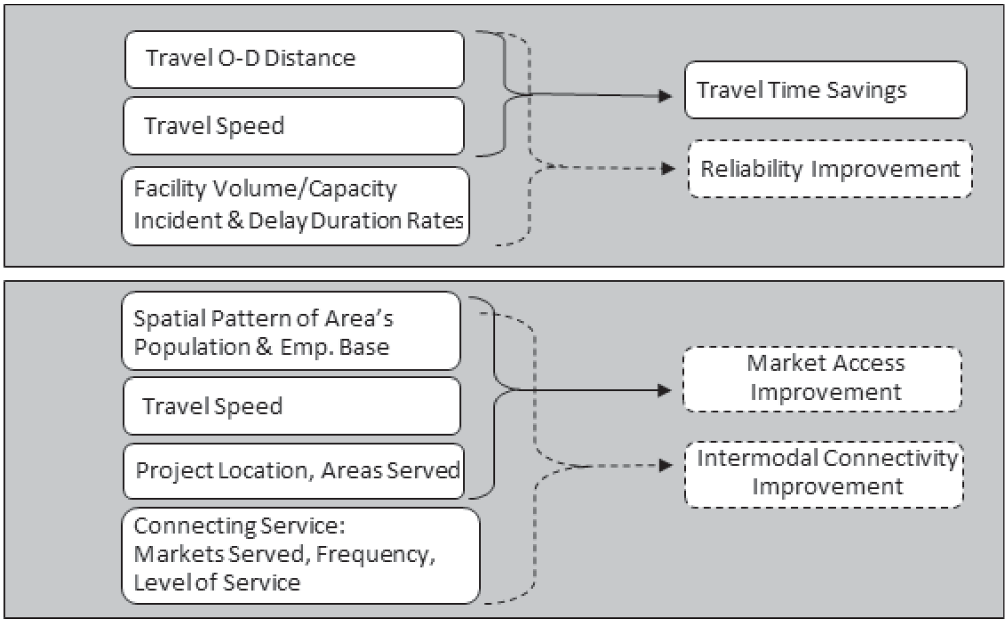


Figure 2.4. Factors affecting reliability and access impacts.

delivery market access to destinations—both focusing on changes that would not be captured by the valuation of time and cost savings for existing trips (based on value of time for car, bus, and truck drivers and their passengers). And, insofar as most benefit–cost analyses are oriented towards benefits for a single mode, the intermodal connectivity effect captures effects related to the interaction of the terminal's level of service for road access to land markets and its access to outside areas via air, marine, and/or rail services.

Another factor that can reduce overlap among these three elements of wider effects is the fact that they are seldom all relevant to any specific transportation project. Projects aimed at reducing congestion most often involve adding lanes or changing the design of interchanges or intersections. Projects aimed at intermodal connectivity tend to be new routes or substantial upgrades to highway routes or rail lines that directly serve an airport, marine port, or rail terminal. And, projects aimed at enhancing market access tend to be new routes or substantial upgrades to highway routes or rail lines that directly connect cities with satellite communities. For that reason, it is rare for all three of these wider effects to be relevant for any single project.

Despite the fact that some effort has been made to reduce overlap of impact measures in the calculation process, and the fact that the three factors driving wider benefit rarely occur at the same time, the research team cannot rule out the possibility of remaining overlap. The existence of remaining overlap ultimately depends on exactly how the various benefit elements are measured and how those measurement definitions interact. Those are issues for future research.

Using Wider Transportation Impacts in Economic Analyses

There are three analytic methods that are commonly used to compare, prioritize, and select transportation projects: Benefit–Cost Analysis (BCA), Economic Impact Analysis (EIA), and Multi-Criteria Analysis (MCA). The classes of wider transportation effects that were previously identified can be used as inputs to all three analytic methods. However, the way that they are used differs depending on the specific method of analysis.

Benefit–Cost Analysis

In BCA, impacts must be measured in terms of quantitative metrics that can be translated into money units and distributed over time to enable calculation of the present value of all benefits and the present value of all costs. Those results are then expressed in terms of either net benefit (benefit minus cost) or benefit–cost ratio.

To allow wider economic benefits to be incorporated into a BCA, each form of benefit must be measured in terms of a quantitative metric (reflecting the change in effective labor or delivery market, change in reliability, or change in multimodal connectivity) that can then be multiplied by a unit value (or elasticity factor) to calculate the total monetary value of that benefit class for each proposed transportation project. The unit valuation (or elasticity factor) may be derived from observed behavior or survey responses, and interpreted as a value of cost savings, net income gain, or willingness to pay. There is a

Table 2.2. Portrayal of Wider Effects in BCA for Projects

Impact Element	Metric for Benefit Calculation in BCA
Improved Reliability: Freight & Service Delivery Trips[a]	$ Valuation (reflecting cost savings, net income gain, or willingness to pay, as appropriate)
Improved Reliability: Worker Commute Trips	
Improved Reliability: Personal/Recreation Trips	
Expanded Access: Freight & Service Delivery Market[a]	
Expanded Access: Labor (Commute) Market[a]	
Expanded Access: Personal/Recreation Destinations	
Enhanced Intermodal Connectivity: Freight Delivery Travel[a]	
Enhanced Intermodal Connectivity: Worker Business Travel	
Enhanced Intermodal Connectivity: Personal/Recreation Travel	

[a] Denotes elements that are most commonly addressed in BCA studies.

literature of empirical research on this subject, which is discussed later in this chapter.

Table 2.2 shows the classes of wider transportation effects covered in this report and the most common breakdown of trip purposes. It shows that—in theory—any combination of wider effect and trip purpose may be represented with a value in BCA, though in practice this is usually done only for freight delivery and commuting trips. However, people can also value reliability, connectivity, and access improvements for personal travel.

Once the wider benefits have been assigned dollar values, they can be added to measures of the dollar value of traditionally measured benefits such as travel time, travel cost, safety, and emissions benefits. Additional adjustment for overlap or double counting may also be made, if applicable.

Economic Impact Analysis

In EIA, impacts are measured in terms of how they affect business output, net income generation, and job generation in the economy. For this form of analysis, a distinction is made between (1) direct effects that lead to changes in money flows and (2) direct effects that have a social value (expressed or implied "willingness to pay") but no direct effect on money flows. Effects falling under the first category are usually input to a region-specific economic impact model to calculate the broader macroeconomic impacts on the study region, measured in terms of total regional change in jobs, household income, and GDP.

The first category covers savings in business operating cost or net revenue. This can include savings in vehicle operating expenses as well as savings in working hours for truck drivers and business delivery workers. The cost savings occurs as workers are able to serve more customers in a workday, or fulfill delivery requirements in a shorter time period and have the remaining time available for further productive work. However, savings in schedules or total time for personal travel (i.e., for recreation or to visit friends and relatives) fall into the second category: factors that have a real value to people but do not directly lead to changes in income or spending patterns in the economy.

Once the distinction has been made between transportation changes that do and do not affect money flows, the first category of benefits can be represented as inputs to an economic impact forecasting model. Table 2.3 shows how these effects can be portrayed in monetary terms: as either decreasing business operating cost (for a given level of output) or increasing firm-level productivity (output produced per level of input cost) for directly affected business activities. A regional economic impact model can then be used to show how those direct effects lead to broader macroeconomic effects on regional industry competitiveness, prices, employment, and business growth over time.

Multi-Criteria Analysis

In MCA, impacts are measured in terms of either qualitative ratings or quantitative indices. This perspective allows for the widest possible range of positive and negative impacts to be considered in decision making, and it enables consideration of essentially all ways in which any given project may affect area businesses or households. These include factors such as business cost competitiveness (reflecting change in business operating cost), congestion and supply chain effectiveness (reflecting change in reliability for freight deliveries), job access (reflecting change in labor market size or effective density), and export markets (reflecting change in intermodal connectivity). For any given project, these factors may be assigned values based on either a dollar valuation or a non-dollar rating metric that portrays its relative importance.

Table 2.3. Portrayal of Wider Effects in EIA for Projects

Impact Element	Metric (input to econ model)
Improved Reliability: Freight & Service Delivery Trips[a]	Business $ Cost Savings (logistics cost)
Improved Reliability: Worker Commute Trips	Business $ Cost Savings (labor cost)
Improved Reliability: Personal/Recreation Trips	—
Expanded Access: Freight & Service Delivery Market[a]	Business Output/Cost (delivery scale economies)
Expanded Access: Labor (Commute) Market[a]	Business Output/Cost (specialized skill matching)
Expanded Access: Personal/Recreation Destinations	—
Enhanced Intermodal Connectivity: Freight Delivery Travel[a]	Business $ Cost Savings (logistics cost)
Enhanced Intermodal Connectivity: Business Travel	Business $ Cost Savings (labor cost)
Enhanced Intermodal Connectivity: Personal/Recreation Travel	—

[a] Denotes elements that are most commonly addressed in EIA studies.

Once the various positive and negative factors have been assigned rating scores, they are entered into a project scorecard table along with ratings for other factors that matter for prioritizing projects, such as travel system efficiency and environmental and community impacts. Table 2.4 shows examples of rating factors related to wider transportation impacts that are already being used by four states for project ranking and selection. Some of these metrics are based on quantitative analysis, while others are based on qualitative assessment. Also shown are other generic indicators that can be similarly generated by the tools described in this report.

Altogether, the preceding three tables presented in this section show how wider transportation impacts can be portrayed in a variety of different ways used to rate and rank projects via BCA, EIA, or MCA. The tools developed for this study (described in the chapters which follow) generate indices of reliability effects, intermodal connectivity, and market access effects that can potentially be used for all of these forms of analysis. However, the BCA and EIA applications require transformation of the indices into money metrics, while the MCA application requires only a numeric rating that can be derived from the index.

Accounting Framework

Accounting Structure

Both BCA and EIA require that all impacts of a proposed transportation project be quantified and expressed in monetary terms. However, different elements of impact are covered, depending on the form of analysis. Table 2.5 lays out a general accounting table for defining elements to be included in the different forms of analysis. The columns represent the three most common forms of analysis.

The form of BCA that is most commonly conducted by state DOTs is the assessment of direct impacts on transportation system efficiency. It typically includes expected benefits of a project on travel time and travel cost (i.e., vehicle operating cost) and often also safety, measured as the sum of impacts on all affected trips (and expressed as an annualized present value to reflect impacts on future trips). These effects are referred to as user benefit or transportation system efficiency benefits because they are concerned with the quality and quantity of travel (vehicle flows) by users of the transportation system, and they do not consider effects on other parties.

A broader form of BCA attempts to account for all impacts on society, including non-travelers. This is often referred to as "social" or "societal" benefit–cost analysis. Its accounting of benefits includes all of the transportation system efficiency benefits and also adds external effects on non-travelers. Environmental impacts are most commonly included in this form of BCA, though there is a growing awareness of the need to recognize and also add measures of "wider economic impacts." These are effects on business reorganization that change firm-level productivity and occur as a consequence of changes in reliability, intermodal connectivity, and market access—all factors that are not reflected in average travel time or operating cost metrics. Some freight planners contend that shippers rather than carriers are the actual "users" of the transportation system, arguing that logistics cost savings for shippers should be considered effects on transportation system efficiency rather than external impacts. These wider economic impacts are the subject of this report.

The accounting of impacts in EIA differs from the above in three ways. First, it includes only benefits that affect the flow of money (and not "willingness to pay"), which means that the value of travel time savings is included only for freight travel, paid drivers, business travelers, and situations where commuting time is also expected to affect wage rates. Second,

Table 2.4. Portrayal of Wider Effects in MCA for Projects

Impact Element	Alternative Metrics (Indicator Criteria)
Improved Reliability: Freight Delivery Trips	• Freight Productivity (WI) • Reliability Index–Freight Delivery[a]
Improved Reliability: Any Trips	• Volume/Capacity (OH, NC) • Congestion Relief (MO) • Reliability Index[a]
Expanded Access: Freight and Service Delivery Market	• Promotes Freight Movement (MO) • Promotes Exports from State (WI) • Same-Day Delivery Market (ARC) • Truck Delivery Access Index[a]
Expanded Access: Labor (Commute) Market	• Promotes Job Growth (OH) • 45-min Labor Market Boundary (ARC) • Labor Access Index[a]
Expanded Access: Personal/Recreation Destinations	—
Enhanced Intermodal Connectivity: Freight Exports	• Promotes Exports from State (WI) • Freight Time to Global Markets • Access time to Intl. Gateway (ARC) • Index of Access to Intl. Gateway[a]
Enhanced Intermodal Connectivity: Any Trips	• Multimodal Impact (OH) • Intermodal Connectivity (MO) • Connections to Network (WI) • Access time to Intermodal Terminals (ARC) • Index of Access to Intermodal Terminal[a]
Enhanced Intermodal Connectivity: Personal/Recreational Travel	—

Note: Alternative metrics are shown for multi-criteria rating factors used to rank projects in four states: WI = Wisconsin DOT, OH = Ohio DOT, NC = North Carolina DOT, MO = Missouri DOT. ARC = Appalachian Regional Commission: performance indicator used in reports on project impacts, though not for ranking projects.

[a] Denotes indicator developed in this report that can be used directly for multi-criteria rating or used to generate other indicators listed in the table.

the regional economic impact models count changes in business travel cost as reductions in the cost of production, while changes in household costs are considered shifts in household budget or spending patterns. Third, it counts business attraction and inward investment effects on economic growth, including effects of cost competitiveness changes that lead to spatial and business sector shifts in trade flows, investment flows, and prices. This latter category of effect also requires use of a regional or national economic impact model.

Valuation of Wider Benefits

All benefit and cost elements used in BCA, as well as the direct inputs to EIA models, must be expressed in monetary terms. To accomplish this, it is necessary to quantify measures of direct benefit and cost—which may be expressed in terms of time, distance, crashes, or an index value impact—into money units. Table 2.6 classifies the factors that are most commonly considered as benefits from transportation investments.

The first group in that table represents those benefits that are commonly measured in BCA: travel time, cost, safety, and emissions. There is standard guidance available from U.S. DOT and other nationally-recognized sources on the per unit valuation of changes in those measures. The second group represents wider transportation effects that have direct economic consequences for businesses, yet have been hard to quantify in the past and hence are not yet not commonly measured. The third group represents other social and environmental impacts. This report focuses specifically on the second group, comprised of three key classes that produce wider benefit: reliability, intermodal connectivity, and market access. The measurement of each is discussed in the following text, and valuation factors are then summarized in Table 2.7.

The first class of wider benefit is reliability. This is most commonly measured through a statistical indicator of travel time variation, either the "standard deviation" or "buffer time," as explained earlier in text discussing Figure 2.1. Both indicators are measured in units of minutes or hours, and the two tend to generate numbers of roughly the same magnitude. They are typically assigned a reliability ratio of 0.7 to 1.5, which means that they have a value/hour in the range of 0.7

Table 2.5. Accounting Table: Difference in Benefit Factors Covered by BCA and EIA

Benefit or Impact Element	BCA		EIA
	Transportation System Efficiency Benefit	Full Societal Benefit	Econ Development Benefit[a]
$ Value of Travel Time Savings (driver + passengers)	Yes	Yes	Yes (F, C)
$ Value of Vehicle Operating Cost Savings	Yes	Yes	Yes (F, C, P)
$ Value of Safety Improvement (Crash reduction)	Yes	Yes	Yes (F, C, P)
$ Value of Reliability (Logistics) Cost Savings	[b]	Yes[c]	Yes (F, C)
$ Value of Market Access (Agglomeration) Benefit	[b]	Yes[c]	Yes (F, C)
$ Value of Intermodal Connectivity Benefit	[b]	Yes[c]	Yes (F, C)
$ Value of Environmental & Social Benefits	[b]	Yes	[d]
$ Value of Indirect Impacts on Economic Growth (through changes in competitiveness, prices)	[b]	[b]	Yes[e]

Note: F = freight delivery and other business travel, C = commuting, P = personal travel.

[a] For economic impacts, only certain classes of trips are covered, and only to the extent that there is change in business cost, business output, wage rates, or household spending patterns.

[b] Denotes effects that are not typically included in this form of analysis.

[c] Denotes effects that fall within the category of full societal benefits, but which are commonly not measured. They are the subject of this study.

[d] Denotes effects that are typically ignored because they affect quality of life rather than money expenditures, though they may be included if a money cost to business or households can be established.

[e] Denotes effects that are generated by macroeconomic impact models; all other effects listed in this column are inputs to a macroeconomic impact model.

to 1.5 times the value assigned to changes in average travel time (see Chapter 3 for further discussion on this topic).

The reliability spreadsheet tool presented in Chapter 3 derives measures of recurring and nonrecurring congestion delay. Recurring delay is defined as the added time that occurs due to slower average traffic movement on congested routes. Nonrecurring delay is the additional travel time which occurs due to traffic incidents and associated traffic queues (backups), which increase exponentially in severity as congestion worsens. The nonrecurring delay is computed based on a conservative measure that reflects the 50th to 80th percentiles of travel times. In other words, it represents the added travel time buffer or schedule padding (beyond the median or average travel time) that is needed to ensure on-time performance 80% of the time. The nonrecurring delay metric and associated travel time index can be directly used as a factor in multi-criteria rating schemes, and it can also provide the basis for monetary valuation of reliability in BCA (or as input to EIA models).

Table 2.6. Classification of Transportation Project Benefits

Benefit or Impact Element	Units for Measuring Change in $
Traditionally Measured Benefits	
Travel Time Savings	Value of driver + passenger travel time savings
Vehicle Operating Cost Savings	Cost savings from reduced vehicle-miles or vehicle-hours of travel
Safety Improvement	Value of reduction in crash incidents
$ Value of Environmental Benefit	Value of reduction in tons of emissions
Wider Economic Benefits	
Reliability Benefit	Cost savings or income gain from less nonrecurring delay
Market Access Benefit	Income or GDP gain from effective size or density gain
Intermodal Connectivity Benefit	Income or GDP gain from intermodal connectivity benefit
Other External (Environmental and Social) Benefits	
Other Environmental Impact	Value of reduction in water, noise, visual, other pollution
Social Impacts	Value or enhancement in social factors

The reliability spreadsheet tool calculates the value of reliability improvement based on the following assumptions: (1) for passenger travel, it assumes a $19.86/hour average value of time multiplied by a 0.8 reliability ratio, and (2) for business travel, it assumes a $36.05/hour average value of time multiplied by a 1.1 reliability ratio. However, all these values can be changed within the reliability tool. Table 2.7 shows that significantly higher or lower values of time delay and reliability ratios may be appropriate for some types of travel. In particular, there is evidence that both the value of time delay and the reliability ratio should be significantly higher than the business default level when the route serves delivery of time-sensitive, high-value products used in just-in-time production processes.

Another class of wider benefit is market access. This is most commonly measured through a statistical indicator of the *effective market size* or *effective market density.* The market scale metric reflects the magnitude of workers' opportunities (for a labor market) or customer delivery opportunities (for a delivery market) that a business can access from a given location. The density metric merely standardizes the market scale, based on a per resident, per worker, or per square-mile factor. The value of increasing accessibility is defined by an elasticity: the percent increase in economic activity (income or GDP) that is generated per 1% increase in effective market scale or effective density.

The market access tools presented in Chapter 5 calculate market scale and effective density for two forms of market access benefit: (1) access to broader buyer-supplier markets for truck deliveries and (2) access to broader labor markets which enable greater matching of worker skills to specialized labor needs. The former is addressed through change in the effective density of business markets, measured in terms of employment base. The latter is addressed through change in the effective labor market size, measured in terms of jobs accessible from a given population location (or vice versa).

The market access tools also illustrate how the benefit value of market access enhancements can be calculated (though care must be taken in its use for BCA). The tool for assessing delivery market access multiplies the expansion of the effective employment base by a measure of average GDP per worker. This yields a measure of *gross impact,* reflecting the added GDP that can be reached for deliveries from a given location as a result of improved transportation. This can be used as a metric for multi-criteria rating of delivery market growth, and as a benchmark for analysis of localized economic impacts. However, for BCA (and input to EIA models), it is necessary to consider that the added delivery market was already being served in other ways prior to the transportation improvement, so only the smaller net gain (attributable to more efficient business operations) should be considered as an added benefit. Table 2.7 shows the range of elasticity measures that can be used to capture the net percentage increase in aggregate business income or GDP that can be attributed to a given percentage increase in effective delivery market size or density.

For assessment of labor markets, the market access tool also calculates the value of commuter cost savings for induced trips enabled by the greater job opportunities. This can be useful for sketch planning applications in which induced trip changes are not otherwise estimated, and it can also be useful as a metric for multi-criteria rating of labor market expansion. However, for BCA (and input to EIA models), it is necessary to distinguish economies of scale in business operations that are beyond trip cost savings. These are the incremental benefits related to specialized skill matching that come from access to larger scale markets and enable firms to achieve greater labor productivity and hence offer higher wage rates. Table 2.7 shows the range of elasticity measures that can alternatively be used to estimate the firm-level productivity effect of changes in labor market access. These values can vary depending on the mix of industries affected by enhanced labor market access. In particular, there is evidence that the percent increase in labor productivity from a given percent increase in labor market scale (or effective density) tends to be greatest for industries that provide specialized services or manufacture technology products requiring specialized workforce skills. The scale (or effective density) of the local labor market appears to be less of a factor for businesses that provide natural resources or resource-based products.

Intermodal connectivity is also another class of wider benefit. This is most commonly measured through a statistical index that reflects both (1) the average travel time to the nearest intermodal air, marine, and rail terminals, and (2) the magnitude of connecting services and number of connections to outside origins and destinations that can be accessed from each of these terminals. The value of this index is reflected by an elasticity that shows the percent productivity increase resulting from a 1% change in accessibility to each type of intermodal terminal.

The intermodal connectivity tool presented in Chapter 4 calculates intermodal market access for airports, marine ports, and rail terminals in the United States. The calculation is based on three scale factors: (1) the scale of activity (person-trips or vehicle-trips) using the intermodal terminal, (2) the scale of connecting services provided there, including the frequency of air, marine, or rail services and the number of different origins and destinations that can be accessed by using them, and (3) the scale of surrounding population or business activity that can easily access that terminal. The tool provides three outputs. One is a measure of truck pickup and delivery time saved by enhanced access to a specific intermodal port. The second is an index of connectivity importance, based on the above-cited three scale factors. The third is the product of the first two; it reflects the magnitude of aggregate truck pickup and delivery time savings, scaled by the importance of the intermodal terminal.

The intermodal connectivity tool's output metrics can be directly used as factors in multi-criteria rating schemes. They can also provide a basis for estimating effects on firm-level labor productivity (output per worker). Table 2.7 shows the range of elasticity measures that can be used to estimate the net percentage increase in overall business income or GDP attributable to a given percentage increase in an index of intermodal connectivity. Research studies to date have shown that elasticities at the high end of this range are associated with access to airports, and those at the low end of the range are associated with access to rail terminals. It is also important to note that only certain industry sectors depend on, and are affected by, access to intermodal terminals. In general, business and professional service industries tend to grow with airport access while resource-based industries tend to grow with access to intermodal rail terminals (Alstadt et al. 2012).

In Table 2.7, "Reliability Ratio" = [(value of a change in reliability)/(value of a change in travel time)], where an improvement in reliability is measured in terms of minutes, representing either the standard deviation or the buffer time beyond the mean. An improvement in reliability is thus measured in terms of aggregate trip-hours saved and is valued by multiplying it times both the unit value of time savings and the Reliability Ratio. "Productivity Elasticity" = [(% change in productivity)/(% change in market access)], where an improvement in productivity is reflected by the increase in income, value added, or output generated in an area, and expanded market access is reflected by growth in the effective size or density of the market that surrounds that area.

Accounting Framework User's Guide and Instructions

Introduction and Purpose

The accounting framework spreadsheet lays out the categories of direct economic benefits that a given roadway improvement may have on travelers using it, and on the operation of businesses that depend on it (for workers, customers, or deliveries). It does not include environmental, social, and

Table 2.7. Typical Range of Conversion Factors for Deriving Dollar Values of Benefits

Benefit or Impact Element	Units for Measuring Change	Type of Conversion	Typical Range	Source
Traditionally Measured Benefits				
$ Value of Travel Time Savings (driver & passengers)	Vehicle-hours of travel (VHT)	Unit value of time ($ per vehicle hour)	$12.00 to $73.30	A
$ Value of Vehicle Operating Cost Savings	Vehicle-miles of travel (VMT)	Unit value ($ per vehicle-mile)	$0.44 to $1.73	B
$ Value of Safety Improvement (Crash reduction)	Incidents per 100,000 VMT	Unit value ($ per incident)	$3,285 to $9.1 million	C
$ Value of Environmental Benefit	Tons of emissions	Unit value ($ per ton)	$1,300 to $290,000	D
Wider Benefits				
$ Value of Reliability (Logistics) Cost Savings	Nonrecurring delay per vehicle trip	Unit value of time × Reliability Ratio	($12 ∗ 0.8 = $9.60) to ($24 ∗ 1.2 = $29)	E
$ Value of Market Access (Agglomeration) Benefit	% change in effective market scale or density	Productivity elasticity	0.02 to 0.08	F
$ Value of Connectivity Benefit	% change in intermodal connectivity index	Productivity elasticity	0.04 to 0.010	G

Sources:
A. On value of time savings (value depends on mode and trip purpose): U.S. DOT 2012 and 2011.
B. On cost per mile of vehicle operation (value depends on type of vehicle): American Automobile Association 2012 (for cars) and Trego and Murray 2009 (for trucks).
C. On cost of vehicle crashes on roads: U.S. DOT 2012 and 2013.
D. On cost per ton of emissions (for various pollutants and carbon): U.S. DOT 2012.
E. On valuation of reliability: Stogios et al., forthcoming; Brownstone and Small 2005; Ghosh 2001; Li et al. 2010; Börjesson and Eliasson 2008; Small et al. 2005; Tilahun and Levinson 2010; Carrion and Levinson 2010; De Jong et al. 2009; Fosgerau et al. 2008; Yan 2002; Asensio and Matas 2008; and Tilahun and Levinson 2009.
F. On elasticity of economic impact of agglomeration: Alstadt et al. 2012; Ciccone 2002; Eddington 2006; Graham 2007; Graham et al. 2009; Melo et al. 2009; Rosenthal and Strange 2003; Venables 2007; and Weisbrod et al. 2001b.
G. On elasticity of impact of connectivity: Alstadt et al. 2012.

other broader impacts that are also important considerations in decision-making. Also, it does not include indirect and secondary effects on the economy. That is not because those factors are any less important, but rather because this study was commissioned to enable more complete analysis of the ways in which wider economic benefits can occur as a direct consequence of individual highway projects.

The spreadsheet shows how these wider effects can be incorporated into benefit–cost analysis. Many of the wider benefit metrics that are generated here can also be applicable for multi-criteria ratings and as input to macroeconomic impact models. However, this spreadsheet is intended to show how wider benefits can be portrayed in BCA.

The steps described below illustrate how the various classes of benefit can be estimated in the context of "sketch planning" (i.e., where no traffic simulation or economic simulation models are used, and a proposed project will enhance a single highway corridor). The spreadsheet tool is designed for highway projects, though the same basic concepts can apply for other modes. For instance, the market access and connectivity benefits can also apply for transit projects and the road reliability benefits can apply for transit projects that relieve highway congestion.

The overall design entails three steps:

1. On the Inputs tab, the user first selects the type of project and its objective or expected impacts, to help determine which classes of benefit need to be calculated.
2. The user then enters information on the nature of changes in use and performance of the affected facility, including relevant results from the reliability, connectivity, and access tools, as applicable.
3. On the Results tab, the user can then view how these additional benefits affect the relative benefit of the proposed project.

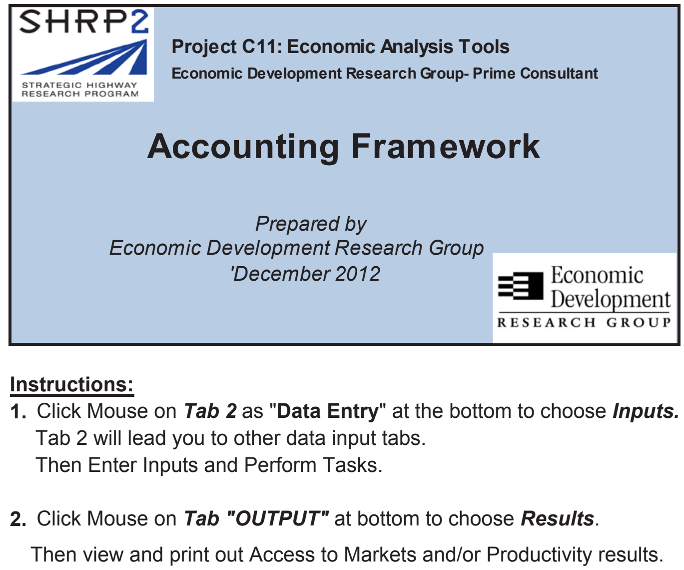


Figure 2.5. Screenshot of opening tab for the accounting framework spreadsheet.

These input and result tabs are described below in more detail.

1. Click the tab labeled 1–START to see the opening screen (Figure 2.5). The bottom of the workbook on your screen displays brief instructions on using the tool.
2. To choose inputs and enter the requested data, at the bottom of the workbook, click the second tab, 2–INPUT. The system prompts you to identify the applicable project objective or expected impact(s), given five major classes of impact (shown in Table 2.8). It is possible that multiple impacts are expected, though most often only a single impact will apply. Depending on the answer you enter, the system may prompt you to enter information from one or more input forms.

Table 2.8. Inputs for Tab 2 of the Accounting Framework Spreadsheet

	Traffic Impact	Reliability	Access to Labor Markets	Access to Buyer–Seller Markets	Intermodal Connectivity
Capacity Expansion to reduce congestion on existing route	YES	YES			
New or Upgraded Route to enhance access from residential area to employment centers	YES		YES		
New or Upgraded Route to enhance truck delivery market area	YES			YES	
New or Upgraded Route to enhance truck movement to/from air, marine, or rail terminals	YES				YES
Highway Projects to enhance safety	YES				

3. To enter data, at the bottom of the worksheet, click the tab labeled 3–FORMS.
4. Enter data into the input forms (input examples are shown in Table 2.9). The traffic analysis assumptions may be drawn from Table 2.7 (sources are listed below it). For Form 1 (Traffic Impact), you can obtain data to enter into the top three rows from engineering estimates or a transportation network model. For Forms 2 through 5, the data are drawn from the output or results tables of the relevant wider benefit wide spreadsheets (covered in Chapters 3, 4, and 5).

The specific locations from which to draw this input data are shown in Figures 2.6 through 2.10.

Note that when running the Reliability Spreadsheet to arrive at results such as those depicted in Figure 2.6, scenarios for Build and No Build must be run separately.

Table 2.9. Inputs for Tab 3 Accounting Framework Spreadsheet

Benefit Category	Passenger (Commuting) Trips		Commercial (Truck) Trips		Personal Travel	
	No Project	With Project	No Project	With Project	No Project	With Project
Traffic Analysis Assumptions						
Persons per trip	1.3		1.1		X	
Tons of freight per trip	0		8		X	
Value of time per person	$12		$24		X	
Average cost per crash	$3,285		$4,400		X	
Econ Elasticity: Labor Market	0.03		X		X	
Econ Elasticity: Delivery Market	X		0.06		X	
Econ Elasticity: Air Connectivity	0.03		0.04		X	
Econ Elasticity: Port Connectivity	X		0.02		X	
Econ Elasticity: Rail Connectivity	X		0.03		X	
(1) Traffic Impact						
Vehicle-miles of travel						
Vehicle-hours of travel						
Crashes per 100,000 Vehicle-miles of travel						
(2) From the RELIABILITY Form						
Total Equivalent Delay (annual h)					X	X
Cost of Unreliability					X	X
(3) From the ACCESS TO LABOR MARKETS Form						
Total Employment Accessible					X	X
Concentration Index (CI)					X	X
Commuter Cost (induced)					X	X
(4) From the ACCESS TO BUYER–SUPPLIER MARKETS Form						
Effective Density of Market					X	X
Total GDP Increase					X	X
(5) From the INTERMODAL CONNECTIVITY Form						
Terminal Type: Air, Marine, Rail					X	X
Connectivity Raw Value					X	X
Value of Time Savings					X	X
Weighted Connectivity					X	X

Note: X denotes fields that are not used. This is either because the data item is not applicable or because it pertains to personal travel, which does not have any wider economic benefits that are recognized at this time.

Total Annual Weekday Delay (veh-hrs)	
Recurring delay	27151
Incident delay	70197
Total equivalent delay	139160
Total equivalent delay (passenger)	123339
Total equivalent delay (commercial)	15821
Total Annual Weekday Congestion Costs ($)	
Passenger	
Cost of recurring delay	$1,937,132
Cost of unreliability	$512,390
Total congestion cost	$2,449,522
Commercial	
Cost of recurring delay	$418,622
Cost of unreliability	$151,724
Total congestion cost	$570,346

Figure 2.6. Screenshot of reliability spreadsheet Results Report tab.

Note that to use the intermodal connectivity spreadsheet tool and arrive at results such as those depicted in Figure 2.10, passenger and commercial effects must be run separately.

Obtaining Results

The input data are used to calculate either an absolute change or a percentage change in relevant transportation impact metrics, and those values are then multiplied by the applicable unit value or elasticity value to derive the total dollar value of impacts.

EMPLOYMENT CENTERS	COMMUTER COSTS ($)
1093	$16,285
1133	-$4,317
1057	$94
1075	$151
TOTAL	***$12,213.00***

Figure 2.8. Screenshot from the access to labor spreadsheet—Results-2 (Commuter Costs).

To view the results of these intermediate calculations, click the tab labeled 4–INTERMEDIATE (Figure 2.11).

To view the final results, click the tab labeled 5–RESULTS (Figure 2.12). The table of results shows the dollar value of relevant benefits for a given year. This includes traditionally measured benefits, as well as the wider economic benefits that are the focus of this study. These results can be used in several ways.

For benefit–cost analysis, further work is necessary. Since the benefits are shown for a single year, it is necessary to re-run the analysis for additional years in order to construct a time series of benefits. From that time series, the net present value of long-term project benefits can be calculated and compared to the net present value of project costs.

These results can also be used to provide inputs to regional economic impact models in order to calculate broader and indirect effects on the economy, though of course only those impacts that directly affect the flow of money (costs incurred and income generated) would be included.

	EA = Employment Accessible (sectoral) within Threshold			*CI = Concentration Index*		
EMPLOYMENT CENTERS	EA (No-Build)	EA (Build)	Difference in EA	Base Year CI (No-Build)	Reference Year CI (Build)	Difference in CI
1093	28,418	35,109	6,691	1.26	1.39	0.14
1133	7,448	17,292	9,844	1.11	0.76	(0.35)
1057	11,565	20,447	8,882	0.67	0.50	(0.18)
1075	8,627	6,725	(1,902)	1.20	3.32	2.12
TOTAL	***56,058***	***79,573***	23,515	***4.24***	***5.98***	***1.74***

Figure 2.7. Screenshot from the access to labor spreadsheet—Results-1 (Labor Market Size).

	EFFECTIVE DENSITY/ POTENTIAL ACCESS 'SCORES'		
	NO BUILD	BUILD	
	2002	2035	
ZONES	EFFECTIVE DENSITY	EFFECTIVE DENSITY	TOTAL PRODUCTIVITY($)
1009	8970	14133	$29,483,575
1033	5980	9417	$82,572,197
1043	8153	12021	$82,440,420
1057	6137	10818	$20,758,304
1059	5835	9947	$40,412,607
1073	14666	19520	$1,182,070,836
1075	5079	8748	$18,278,858
TOTAL	***54820***	***84604***	***$1,456,016,797***

Figure 2.9. Screenshot from the access to markets (buyer–seller) spreadsheet—Results.

Facility 2

Facility Details	**index**	
Facility Type	Airport Passenger	
Facility Name	Sky Harbor Intl Airport	
	Value	**Units**
Activity	39,338,123	passengers
Value		
Unique Origins/destinations	218	
Facility Connectivity Raw Value	85.8	
Relative Activity	45.4%	
Relative Value		
Relative Origins and Destinations	60.1%	
Relative Facility Connectivity Index	27.2%	
Project Summary		
Number of annual passenger vehicles	10,000	
Total passenger vehicle hours saved (All passenger vehicles)	5,000	
Total Value	$89,387	
Number of passenger vehicles associated with th	2,512	
Time savings for facility	1,256	
Value of time savings for facility	$22,453	
Weighted connectivity	**1,925,503.5**	

Figure 2.10. Screenshot from the intermodal connectivity spreadsheet—Results.

Benefit Element	No Build Scenario	Build Scenario	Diff	Multiplier Value	% Diff	Elasticity Value
Passenger Trips						
Vehicle-Hours	152,885	140,546	-12,339	$12.00	--	--
Vehicle-Miles	2,658,120	2,658,120	0	$0.64	--	--
Safety: Crash reduction (crashes)	7.1	6.2	-0.9	$3,285	--	--
Benefit for Induced Trips (trips)	0	0	0	$6.00	--	--
Cost of Unreliability	270,476	256,195	-14,281	$9.60	--	--
Accessible Employment Base	56,058	79,573	--	--	42%	0.03
Effective Density for Delivery Base	--	--	--	--	--	--
Weighted Connectivity Score	2,432	3,275	--	--	35%	0.04
Commercial (Freight Delivery) Trips						
Vehicle-Hours Saved (hrs)	10,320	8,738	-1,582	$24.00	--	--
VMT Savings (miles)	186,068	186,068	0	$1.46	--	--
Safety: Crash reduction (crashes)	0.1	0.5	0.4	$3,285	--	--
Benefit for Induced Trips (trips)	0	0	0	$12.00	--	--
Cost of Unreliability	81,724	75,862	-5,862	$28.80	--	--
Accessible Employment Base	--	--	--	--	--	--
Effective Density for Delivery Base	54,820	84,604	--	--	54%	0.03
Weighted Connectivity Score	5,925	8,342	--	--	41%	0.04

Figure 2.11. Screenshot of Intermediate Calculations—Tab 4. Cells with dashes have no applicability.

Benefit Element	Value of Benefit in Target Year
Passenger Trips	
Value of Vehicle-Hours Saved	$148,068
Value of VMT Savings	$0
Value of Safety: Crash reduction	$2,957
Value of Benefit for Induced Trips	$0
Value of Reliability Improvement	$14,281
Value of Enhanced Labor Market Access	$352
Value of Enhanced Delivery Market Access	$0
Value of Enhanced Intermodal Connectivity	$388
Adjustment for Overlap in Above	$0
Total ----->	$166,046
Commercial (Freight Delivery) Trips	
Value of Vehicle-Hours Saved	$37,968
Value of VMT Savings	$0
Value of Safety: Crash reduction	-$1,311
Value of Benefit for Induced Trips	$0
Value of Reliability Improvement	$5,862
Value of Enhanced Labor Market Access	$0
Value of Enhanced Delivery Market Access	$456
Value of Enhanced Intermodal Connectivity	$457
Adjustment for Overlap in Above	$0
Total ----->	$42,976

Figure 2.12. Screenshot of Results—Tab 5.

CHAPTER 3

Reliability

Technical Guide

Introduction and Purpose

The purpose of the Reliability Module is to allow users to assess quickly the effects of highway investments in terms of both typical travel time and travel time reliability. In the past, economic assessments have been made strictly on the basis of typical travel time, but current research shows that travelers also value reliability of travel time. Accounting for this additional benefit means that transportation improvements have even more positive effects on users and the economy than heretofore thought.

The Reliability Module is structured as a sketch planning tool that involves minimal data development and model calibration. It uses the results of other SHRP 2 projects in its methodology as well as methods from earlier studies. The procedure is based on making estimates of recurring and nonrecurring congestion, combining them, and using predictive equations to develop reliability metrics.

Background on Travel Time Reliability

A review of several SHRP 2 projects identified how they defined "reliability."

Project C04 (Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand) defined reliability as ". . . the level of (un)certainty with respect to the travel time and congestion levels." It then used statistical measures, primarily the standard deviation of travel time, as the metrics used in subsequent analyses.

Project C05 (Understanding the Contributions of Operations, Technology, and Design to Meeting Highway Capacity Needs) defined it by saying ". . . the reliability of the performance is represented by the variability that occurs across multiple days."

Project L02 (Establishing Monitoring Programs for Travel Time Reliability) said the following: "It is important to start by observing that travel time reliability is not the same as (average) travel time. . . . Travel time reliability is about travel time probability density functions (TT-PDFs) that allow agencies to portray the variation in travel time that exists between two locations (point-to-point—P2P) or areas (area-to-area—A2A) at a given point in time or across some time interval. It is about estimating and reporting measures like the 10th, 50th, and 95th percentile travel times." Functionally, Project L02 used the notion developed in Project L03 that reliability can be measured using the distribution of travel times for a facility or a trip.

Project L04 (Incorporating Reliability Performance Measures in Operations and Planning Modeling Tools) used this definition: ". . . models formulated in this research is based on the basic notion that transportation reliability is essentially a state of variation in expected (or repeated) travel times for a given facility or travel experience. The proposed approach is further grounded in a fundamental distinction between (1) systematic variation in travel times resulting from predictable seasonal, day-specific, or hour-specific factors that affect either travel demand or network capacity, and (2) random variation that stems from various sources of largely unpredictable (to the user) unreliability."

Project L03 (Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies) used an expanded definition of reliability to include not only the idea of variability but failure (or its opposite, being on time) as well.

In terms of highway travel, the SHRP 2 Reliability Research Program defined reliability this way: ". . . from a practical standpoint, travel time reliability can be defined in terms of how travel times vary over time (e.g., hour to hour, day to day). This concept of variability can be extended to any other travel-time-based metrics such as average speeds and delay. For the purpose of this study, travel time variability and reliability are used interchangeably."

A slightly different view of reliability is based on the notion of a probability or the occurrence of failure often used to characterize industrial processes. With this view, it is necessary to define what "failure" is, in terms of travel times. In other words, a threshold must be established. Then, one can count the number of times the threshold is not achieved or not exceeded. These types of measures are synonymous with "on-time performance" since performance is measured relative to a pre-established threshold. The only difference is that failure is defined in terms of how many times the travel time threshold is exceeded while on-time performance measures how many times the threshold is not exceeded.

In recent years, some non-U.S. reliability research has focused on this other aspect of reliability, the probability of "failure," where failure currently is defined in terms of traffic flow breakdown. A corollary is the concept of "vulnerability," which could be applied at the link or network level: This is a measure of how vulnerable the network is to breakdown conditions.

Project L07 (Identification and Evaluation of the Cost-Effectiveness of Highway Design Features to Reduce Non-recurrent Congestion) used L03's definition.

Project L11 (Evaluating Alternative Operations Strategies to Improve Travel Time Reliability) defined reliability: "Travel-time reliability is related to the uncertainty in travel times. It is defined as the variation in travel time for the same trip from day to day (same trip implies the same purpose, from the same origin, to the same destination, at the same time of the day, using the same mode, and by the same route). If there is large variability, then the travel time is considered unreliable. If there is little or no variability, then the travel time is considered reliable."

A wide range of viewpoints on the definition of travel time reliability clearly exists, but there is also a great degree of commonality. Travel time reliability relates to how travel times for a given trip and time period perform over time. For the purpose of measuring reliability, a "trip" can occur on a specific segment, facility (combination of multiple segments), any subset of the transportation network, or can be broadened to include a traveler's initial origin and final destination. Measuring travel time reliability requires that a sufficient history be present in order to track travel time performance.

There are two widely held ways that reliability can be defined. Each is valid and leads to a set of reliability performance measures that capture the nature of travel time reliability:

1. The variability in travel times that occur on a facility or a trip over the course of time; and
2. The number of times (trips) that either "fail" or "succeed" in accordance with a pre-determined performance standard.

In both cases, reliability (more appropriately, unreliability) is caused by the interaction of the factors that influence travel times: fluctuations in demand (which may be due to daily or seasonal variation or to special events), traffic control devices, traffic incidents, inclement weather, work zones, and physical capacity (based on prevailing geometrics and traffic patterns). These factors will produce travel times that differ from day to day for the same trip.

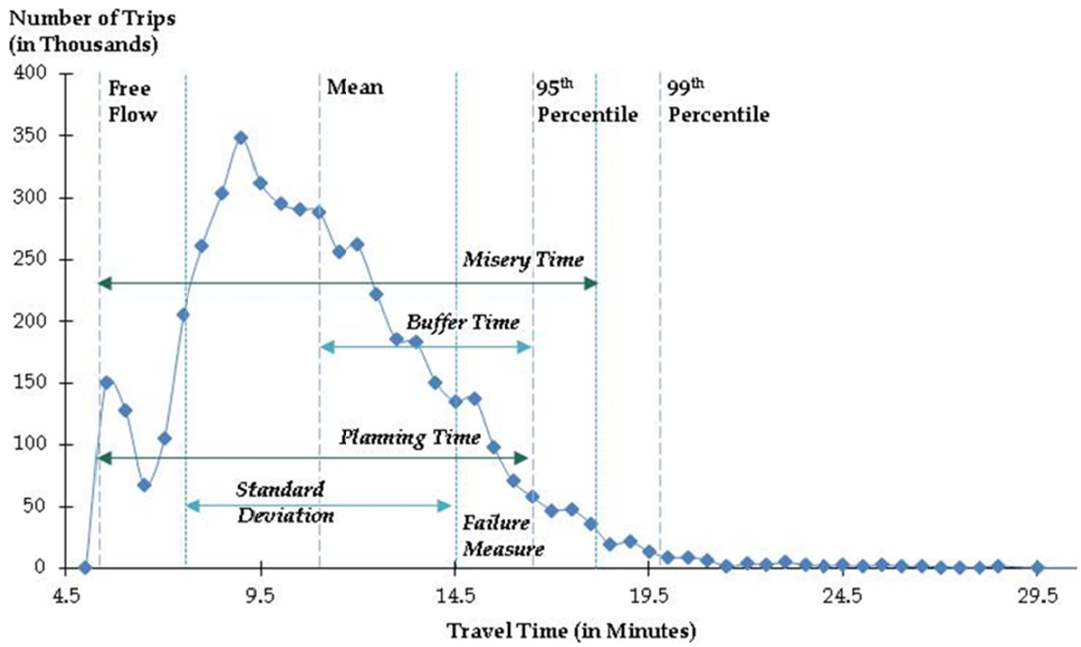
From a measurement perspective, reliability is quantified from the distribution of travel times, for a given facility or trip and time period (e.g., weekday peak period), that occurs over a significant span of time (one year is generally long enough to capture nearly all of the variability caused by disruptions). A variety of different metrics can be computed once the travel time distribution has been established, including standard statistical measures (e.g., kurtosis, standard deviation), percentile-based measures (e.g., 95th percentile travel time or Buffer Index), on-time measures (e.g., percent of trips completed within a travel time threshold), and failure measures (e.g., percent of trips that exceed a travel time threshold). The reliability of a facility or trip can be reported for different time slices (e.g., weekday peak hour, weekday peak period, and weekend). Figure 3.1 shows an actual travel time distribution derived from roadway detector data and the metrics that can be derived from it. Note that a number of metrics are expressed relative to the free flow travel time, which becomes the benchmark for any reliability analysis. The degree of (un)reliability then becomes a relative comparison to the free flow travel time.

The Value of Travel Time Reliability

Valuing travel time has a long history in transportation modeling and analysis. The value of travel time (VOT) refers to the monetary values travelers place on reducing their travel time. VOT has been long established from a basis in consumer theory where value is related to a wage rate or some portion of it. It is considered one of the largest cost components in benefit–cost analysis of transportation projects because one of the benefits for travelers in a transportation improvement is the reduction of travel time (Vovsha et al. 2011).

In contrast, the value of reliability (VOR) is a relatively new concept. VOR refers to the monetary values travelers place on reducing the variability of their travel time. Reliability has most often been considered qualitatively and is associated with the statistical concept of variability (Carrion and Levinson 2010). However, it is clearly recognized by travelers of all types. Travelers account for the variability in their trips by building in "buffers" as insurance against late arrival. This action implies that the consequence of arriving late is "costly" and should be avoided (OECD 2010). Efficiency and productivity lost in these buffers or safety margins represent an additional cost that travelers absorb.

Reliability is of such sufficient value to transportation system users that they are willing to pay for reduced travel time, as



Source: Cambridge Systematics et al. 2013.

Figure 3.1. The travel time distribution is the basis for defining reliability metrics.

has been demonstrated by empirical studies. Variability in the costs which are acceptable to different travelers for different trips suggests that this value is not uniform for all types of trips (Waters 1992). The difference in value between users and the type of use must be quantified to be understood and applied appropriately.

For the business traveler and freight shippers, time is money. The just-in-time delivery aspect of the present economy implies a high cost associated with an unreliable transportation system and a corresponding value for travel time reliability. Freight providers are a unique category of transportation users in many aspects; however, the value placed on reliability is consistent with or greater than with other travelers.

Past research studies have used the Reliability Ratio (VOR/VOT) as the most convenient way to measure reliability in an empirical study. Table 3.1 summarizes the values of reliability for passenger travel that were included in the reviewed research.

Of these studies, the Carrion and Levinson 2010 work is the most comprehensive. They were selective in their choice of studies because they were using them for a meta-analysis. It is interesting that there is less variation among more recent studies, and if the means of each individual study is used, the reliability ratios are grouped in the 0.5 to 1.5 range. Figure 3.2 is taken directly from Carrion and Levinson. Previously, SHRP 2 Project C04 also noted the same range. The SHRP 2 L05 effort more narrowly focused the Reliability Ratio range to 0.9 to 1.25 based on including only the research with the most rigorous methods. A Florida DOT study recommended a Reliability Ratio range of 0.8 to 1.0, based on their assessment of the most rigorous studies (Elefteriadou and Cui 2007). The authors also mentioned that the value could be "as much as three times higher" if strict schedule adherence is required for the trip.

For the reliability spreadsheet tool, the 80th–50th percentile is used as the measure of the reliability space. This produces a conservative estimate of reliability.

Specification of Inputs

Inputs are provided for base condition as well as for one or more improvement scenarios.

Basic Analysis Unit

Highway segments are the basic unit of analysis, and input data pertains to them. Segments can be of any length but it is recommended that they not be so long that the characteristics change dramatically along the segment, or too short that input is burdensome. Reasonable segment lengths would be as follows:

- Freeways: between interchanges;
- Signalized highways: between signals; and
- Rural highways (nonfreeways): 2 to 5 miles.

For the purpose of output, segments are aggregated into highway sections in order to be compatible with the reliability prediction equations.

Table 3.1. Past Research on the Value of Reliability: Passenger Travel

Authors	Study Type	Reliability Ratio (personal auto use)	Reliability Metric/Definition
Brownstone and Small (2005)	RP/SP	1.18	90th–50th Percentile
Ghosh (2001)	RP	1.17	90th–50th Percentile
Li et al. (2010)	SP	0.70	Scheduling approach; standard deviation
Börjesson and Eliasson (2008)	SP	1.27	Ratio of sensitivity to standard deviation to sensitivity of the mean
Small et al. (1995)	SP	2.30	Standard deviation
Small and Yan (2001)	SP	2.51	Standard deviation
Small et al. (2005)	RP	0.91	80th–50th Percentiles
Tilahun and Levinson (2010)	SP	0.89	90th–50th Percentile
Carrion and Levinson (2010)	RP	0.91	90th–50th Percentile
De Jong et al. (2009)	SP	1.35	Standard deviation
Fosgerau et al. (2008)	RP	1.00	Standard deviation
Yan (2002)	RP/SP	0.97	90th–50th Percentile
Asensio and Matas (2008)	SP	0.98	Scheduling approach; standard deviation
Bhat and Sardesai (2006)	RP/SP	0.26	Scheduling approach; standard deviation
Senna (1994)	SP	0.76	Standard deviation
Black and Towriss (1993)	SP	0.55–0.70	Standard deviation
Tilahun and Levinson (2009)	SP	1.0	Scheduling approach; difference between actual late arrival and usual travel time
Ubbels et al. (2005)	SP	0.5	Scheduling approach; difference between early/late arrival time and preferred arrival time
Koskenoja (1996)	SP	0.75	Average schedule delay (late and early)
Parsons Brinckerhoff et al. (2013)	RP	0.7–1.5	Standard deviation per unit distance
Stogios et al. (forthcoming)	RP	0.57–2.69	Standard deviation per unit distance

Note: RP = Revealed Preference (based on observed behavior); SP = Stated Preference (based on survey responses).

Inventory Data

- Route.
- Beginning mile point.
- Beginning landmark.
- Ending mile point.
- Ending landmark.
- Highway type.
  - Freeway (access controlled);
  - Multilane (nonsignalized, nonaccess controlled);
  - Signalized; and
  - Rural two-lane.
- Number of lanes.
- Free flow speed.
  - Alternately, the posted speed limit.

Traffic Data

- Average Annual Daily Traffic (AADT), current.
- Annual traffic growth rate (%).

Truck Data

- Percentage of trucks in the traffic stream (combinations plus single units).

Capacity Data

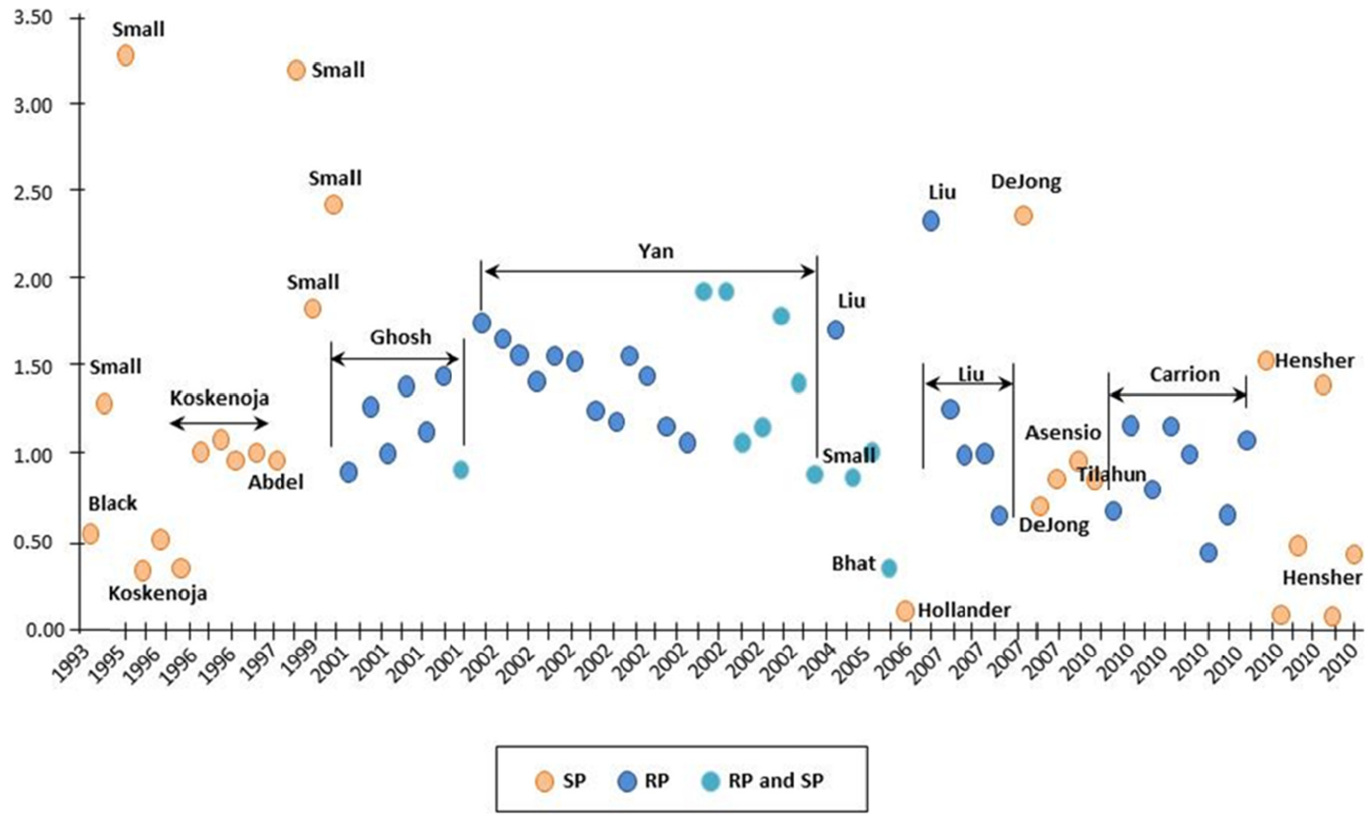
- Peak capacity as determined with *Highway Capacity Manual* procedures.
  - Alternately, the G/C ratio (effective green time divided by cycle length) for signalized highways; and
  - Terrain (flat, rolling, or mountainous) for freeways and rural two-lane highways.

Time Horizon

- Number of years into the future for which the analysis applies.

Analysis Period

- Specify the hours of the day for which the analysis will be run.



Source: Carrion and Levinson 2010.

Figure 3.2. Reliability ratios from previous studies.

Economic Analysis Data

- Unit cost of travel time, personal ($/hour): default = $19.86 (*HERS-ST Highway Economic Requirements System—State Version: Technical Report,* 2005).
- Unit cost of travel time, commercial ($/hour): default = $36.055.
- Reliability Ratio, personal: default = 0.8 (based on Stogios et al., forthcoming).
- Reliability Ratio, commercial: default = 1.16.

Output and Calculations

Output

Outputs are produced for the entire project length in table form. Outputs are displayed for the base condition and all improvement scenarios. A variety of reliability metrics are produced to allow users wide flexibility in interpreting the results. They also permit users to make independent estimates of the value of reliability if they want to use alternative measures of the reliability space, such as the following:

- Year of analysis (the future year);
- Recurring delay (hours);
- Incident delay (hours);
- Total delay (hours);
- Overall travel time index;
- 95th percentile travel time index;
- 80th percentile travel time index;
- Percent of trips < 45 mph;
- Percent of trips < 30 mph;
- Cost of recurring delay;
- Cost of unreliability; and
- Total congestion cost.

Calculations

Calculations are done for each hour and direction on the study segments. The results are summed over all segments and reported for the current year and forecast year. Equations 3.1 through 3.17 follow.

Calculate Future Year AADT:

$$\text{FutureAADT} = \text{AADT} * (1 + \text{TrafficGrowthRate})^{\text{NumberOfYears}} \quad (3.1)$$

Calculate HCM * Capacity (if not directly input) for Freeways and Multilane Highways Without Signals:

$$\text{Capacity} = \text{IdealCap} * N * F_{HV} \quad (3.2)$$

where

Capacity = One-way capacity;
IdealCap = 2,400 passenger cars per hour per lane (pcphpl) if free flow speed ≥70 mph, or 2,300 pcphpl otherwise;
N = number of through lanes in one direction;
F_{HV} = heavy vehicle adjustment factor: 1.0/(1.0 + 0.5 HV) for level terrain, 1.0/(1.0 + 2.0 HV) for rolling terrain, 1.0/(1.0 + 5.0 HV) for mountainous terrain (rare in urban areas); and
HV = daily proportion of trucks in traffic stream.

Signalized Highways:

$$\text{Capacity} = \text{IdealSat} * N * F_{HV} * g/C \quad (3.3)$$

where

Capacity = One-way capacity;
IdealSat = Ideal saturation flow rate (1,900 pcphpl);
N = number of through lanes in one direction;
F_{HV} = heavy vehicle adjustment factor: 1.0/(1.0 + 0.5 HV) for level terrain, 1.0/(1.0 + 2.0 HV) for rolling terrain, 1.0/(1.0 + 5.0 HV) for mountainous terrain (rare in urban areas); and
g/C = effective green time divided by cycle length (0.45 for arterials, 0.35 for other highway classes).

Rural Two-Lane Highways:

$$\text{Capacity} = \text{IdealCap} * F_{HV} * F_G \quad (3.4)$$

where

Capacity = Two-way capacity;
IdealCap = 3,200 passenger cars per hour (pcph);
F_{HV} = heavy vehicle adjustment factor (1 or 1 + $P_T[E_T - 1]$);
P_T = percent of trucks;
E_T = Passenger car equivalents from Table 3.2; and
F_G = grade adjustment factor from Table 3.3.

Calculate AADT/Capacity (C):

$$\text{AADT/C} = \text{FutureAADT/TwoWayCapacity} \quad (3.5)$$

Note: For all multilane and signalized highways, TwoWay Capacity is the one-way capacity times two.

Calculate Hourly Volumes for Hours to Be Used in the Analysis:

Multiply AADT and FutureAADT by the appropriate hourly factor from Table 3.4. For multilane highways, the analysis is done by each direction individually. For rural two-lane highways, the analysis is done for both lanes combined, that is, the hourly volume is the sum of the a.m. and p.m. directions.

Table 3.2. Passenger Car Equivalents for Trucks (E_T)

Two-Way Flow Rates (pcph)	Type of Terrain		
	Level	Rolling	Mountainous
0–600	1.7	2.5	7.2
>600–1,200	1.2	1.9	7.2
>1,200	1.1	1.5	7.2

Note: Flow rates are determined by using the "AADT/C<7" condition from Table 3.3 and combining the a.m. and p.m. percentage for the peak hour, which is assumed to be the hour ending at 18:00 (Hour 18 in Table 3.4).

Calculate Free Flow Speed (if speed limit is input in lieu of the actual free flow speed): This calculation is from Dowling et al. 1997.

$$\text{FreeFlowSpeed} = (0.88 * \text{SpeedLimit}) + 14, \text{ for freeways and rural two-lane highways} \quad (3.6)$$

$$\text{FreeFlowSpeed} = (0.79 * \text{SpeedLimit}) + 12, \text{ for signalized highways} \quad (3.7)$$

Calculate Travel Time per Unit Distance (Travel Rate) for the Current and Forecast Years:

$$t = \{(1 + (0.1225 * (v/c)^8))\}/\text{FreeFlowSpeed}, \text{ for } v/c \le 1.40 \quad (3.8)$$

where

t = travel rate (hours per mile);
v = hourly volume; and
c = capacity (for an hour, previously defined).

Note: v/c should be capped at 1.40 (Cambridge Systematics et al. 1998).

Table 3.3. Grade Adjustment Factors (f_G) for Highway Performance Measuring System

Two-Way Flow Rates (pcph)	Level	Rolling	Mountainous
0–600	1.00	0.71	0.57
>600–1,200	1.00	0.93	0.85
>1,200	1.00	0.99	0.99

Table 3.4. Hourly Traffic Distributions

	Freeway, Weekday						Other, Weekday					
	AADT/C						AADT/C					
	LE 7.0		7.1–11.0		GT 11.0		LE 7.0		7.1–11.0		GT 11.0	
	Peak Direction		Peak Direction		Peak Direction		Peak Direction		Peak Direction		Peak Direction	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
Hour Ending	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume	Percent of Daily Volume
1	0.42	0.58	0.44	0.57	0.47	0.54	0.34	0.47	0.37	0.47	0.41	0.49
2	0.27	0.33	0.27	0.34	0.27	0.32	0.21	0.28	0.23	0.27	0.24	0.28
3	0.23	0.25	0.22	0.26	0.20	0.24	0.15	0.18	0.17	0.18	0.18	0.20
4	0.23	0.22	0.21	0.21	0.18	0.18	0.14	0.14	0.16	0.15	0.17	0.18
5	0.38	0.29	0.35	0.28	0.31	0.25	0.24	0.18	0.28	0.20	0.33	0.27
6	1.17	0.68	1.12	0.69	1.06	0.72	0.74	0.42	0.81	0.48	1.03	0.67
7	3.26	1.75	3.16	1.90	2.86	2.18	2.23	1.19	2.35	1.27	2.55	1.72
8	4.83	2.90	4.59	3.05	3.90	3.27	4.11	2.28	3.85	2.39	3.57	2.79
9	3.56	2.57	3.80	2.76	3.66	3.04	3.45	2.33	3.42	2.39	3.09	2.78
10	2.58	2.24	2.75	2.30	2.94	2.53	2.64	2.29	2.69	2.31	2.68	2.47
11	2.46	2.33	2.50	2.34	2.68	2.49	2.64	2.56	2.65	2.54	2.62	2.57
12	2.56	2.56	2.61	2.61	2.73	2.69	2.90	3.02	2.90	2.98	2.83	2.89
13	2.65	2.71	2.68	2.75	2.75	2.78	3.20	3.35	3.17	3.30	3.04	3.13
14	2.70	2.77	2.75	2.81	2.82	2.86	3.14	3.24	3.14	3.22	3.06	3.13
15	2.93	3.12	2.93	3.15	2.97	3.15	3.18	3.44	3.12	3.37	3.21	3.34
16	3.26	4.01	3.21	3.87	3.21	3.60	3.40	4.13	3.35	3.93	3.41	3.78
17	3.47	4.81	3.38	4.43	3.28	3.82	3.46	4.78	3.49	4.49	3.47	3.92
18	3.42	4.85	3.32	4.39	3.29	3.77	3.31	4.83	3.45	4.55	3.39	3.86
19	2.66	3.23	2.66	3.20	2.82	3.22	2.68	3.23	2.75	3.31	2.82	3.12
20	1.95	2.23	1.97	2.25	2.12	2.36	2.14	2.41	2.18	2.53	2.28	2.53
21	1.54	1.78	1.54	1.79	1.62	1.86	1.73	1.97	1.75	2.07	1.83	2.09
22	1.40	1.63	1.44	1.69	1.54	1.74	1.49	1.71	1.50	1.77	1.55	1.80
23	1.14	1.30	1.19	1.39	1.27	1.46	1.10	1.26	1.11	1.25	1.22	1.29
24	0.79	0.98	0.83	1.05	0.89	1.07	0.74	0.94	0.75	0.90	0.83	0.97
Total	49.87	50.13	49.92	50.08	49.84	50.16	49.36	50.64	49.67	50.33	49.71	50.29

Note: AADT/C = Annual average daily traffic/capacity.
Source: Science Applications International Corporation and Cambridge Systematics 1994.

Compute the Recurring Delay in Hours per Mile:

$$\text{RecurringDelayRate} = t - (1/\text{FreeFlowSpeed}) \quad (3.9)$$

Compute the Delay Due to Incidents (IncidentDelayRate) in Hours per Mile:

The lookup tables from the *IDAS User's Manual* are used to calculate incident delay. This requires the *v*/*c* ratio, number of lanes, and length and type of the period being studied, which is set at one hour (Cambridge Systematics 2003). (For rural two-lane highways, use number of lanes = 2.) This is the base incident delay.

If incident management programs have been added as a strategy or if a strategy lowers the incident rate (frequency of occurrence), then the "after" delay is calculated as follows:

$$D_a - D_u * (1 - R_f) * (1 - R_d)^2 \quad (3.10)$$

where

D_a = Adjusted delay (hours of delay per mile);
D_u = Unadjusted (base) delay (hours of delay per mile, from the incident rate tables);
R_f = Reduction in incident frequency expressed as a fraction (with $R_f = 0$ meaning no reduction, and $R_f = .30$ meaning a 30% reduction in incident frequency); and
R_d = Reduction in incident duration expressed as a fraction (with $R_d = 0$ meaning no reduction, and $R_d = .30$ meaning a 30% reduction in incident duration).

Changes in incident frequency are most commonly affected by strategies that decrease crash rates. However, crashes are only about 20% of total incidents. So, a 30% reduction in crash rates alone would reduce overall incident rates by 6% (.30 * .20 = .06).

Compute the Overall Mean Travel Time Index (TTI_m):

This includes the effects of recurring and incident delay.

$$\text{TTI}_m = 1 + \text{FFS} * (\text{RecurringDelayRate} + \text{IncidentDelayRate}) \quad (3.11)$$

where FFS is the free flow speed.

Because the data on which the reliability metric predictive functions do not include extremely high values of TTI_m, it is recommended that TTI_m be capped at a value of 6.0, which roughly corresponds to an average speed of 10 mph. Even though the data included highway sections that were considered to be severely congested, an overall annual average speed of 10 mph for a peak period was never observed. At $\text{TTI}_m = 6.0$, the reliability prediction equations are still internally consistent.

Compute Reliability Metrics Using the SHRP 2 L03 "Data Poor" Equations:

The equations for the 80th and 50th percentile TTIs were developed specifically for this module using the original SHRP 2 Project L03 data.

$$\text{TTI}_{95} = 1 + 3.6700 * \ln(\text{TTI}_m)$$

$$\text{TTI}_{80} = 5.3746 / \{(1 + e^{(-1.5782 - 0.85867 * \text{TTI}_m)})^{(1/0.04953)}\}; \ \text{TTI}_{80} \geq 1.0$$

$$\text{TTI}_{50} = 4.01224 / \{(1 + e^{(1.7417 - 0.93677 * \text{TTI}_m)})^{(1/0.82741)}\}; \ \text{TTI}_{50} \geq 1.0$$

$$\text{PercentTripsOccurringLT45mph} = 1 - e^{(-1.5115 * (\text{TTI}_m - 1))}$$

$$\text{PercentTripsOccurringLT30mph} = 1 - \{0.333 + [0.672 / (1 + e^{(5.0366 * (\text{TTI}_m - 1.8256))})]\} \quad (3.12)$$

where

TTI_{95} is the 95th percentile TTI;
TTI_{80} is the 80th percentile TTI;
TTI_{50} is the 50th percentile TTI;
PercentTripsOccurringLT45mph is the percent of trips that occur at speeds less than 45 mph; and
PercentTripsOccurringLT30mph is the percent of trips that occur at speeds less than 30 mph.

Calculate Travel Time Equivalents Separately for Passenger Cars and Trucks:

$$\text{TTI}_{e(\text{VT})} = \text{TTI}_{50} + a * (\text{TTI}_{80} - \text{TTI}_{50}) \quad (3.13)$$

where

$\text{TTI}_{e(\text{VT})}$ = the TTI equivalent on the segment, computed separately for passenger cars (personal travel) and trucks (commercial travel); and
a = the Reliability Ratio (VOR/VOT), which is 0.8 for passenger cars and 1.1 for trucks.

The use of the median to capture the "typical" or "average" condition is to avoid double counting: The mean value from the full distribution has some of the variability built in, the median less so.

Compute Total Equivalent Delay Based on the TTI_e, Separately for Passenger Vehicles and Trucks:

$$\text{TotalEquivalentAnnualWeekdayDelay}_{\text{VT}} = ((\text{TTI}_{e(\text{VT})}/\text{FreeFlowSpeed} - 1/\text{FreeFlowSpeed}) * \text{AVMT}_{\text{VT}}) \quad (3.14)$$

where

$\text{TotalEquivalentAnnualWeekdayDelay}_{\text{VT}}$ is in vehicle-hours, separately for vehicle types (passenger and truck for now);

$AVMT_{VT}$ = HourlyVolume * SectionLength * Pct * 260; and
Pct = percent of trucks in traffic stream (for commercial traffic) or 1 − percent of trucks in traffic stream (for passenger travel).

Compute Congestion and Reliability Costs:

$$TotalDelayCost_{VT} = TotalEquivalentAnnualWeekdayDelay_{VT} * UnitCost_{VT} \quad (3.15)$$

$$RecurringDelayCost_{VT} = TotalDelayCost_{VT} * (TTI_{50}/TTI_{e(VT)}) \quad (3.16)$$

$$ReliabilityCost_{VT} = TotalDelayCost_{VT} - RecurringDelayCost_{VT} \quad (3.17)$$

Costs should be computed separately for each vehicle type (passenger versus commercial) and summed.

Assessing the Impacts of Highway Improvements

Highway improvements of various types need to be translated into changes in the input parameters. Specifically, improvements can affect capacity, volume, and incident characteristics.

If a capacity analysis is not done offline, then the Module will compute a new capacity for the improvement if there are changes in

- Number of lanes or truck percentage (freeways);
- Number of lanes, truck percentage, or green-to-cycle ratio (signalized highways);
- Truck percentage of grade (two-lane highways); or
- Free flow speed (all highways).

Additional geometric improvements may be considered if the user performs an offline capacity analysis. Examples include lane and shoulder widening, median separation, and turn lane additions at signalized intersections. Offline capacity analysis will also identify the increase in capacity due to signal progression and converting stop sign-controlled intersections to signal control.

If an improvement changes the volume (AADT or traffic growth rate), the user needs to indicate the change. This can only be done offline; the module does not deal with estimating demand changes.

For Incident Characteristics, the tool uses both incident frequency and incident duration to estimate nonrecurring delay. Incident frequency is primarily affected by reductions in crashes (a subset of total incidents) due to safety improvements. Crash reduction factors for a wide variety of geometric and operating improvements can be found in the *Highway Safety Manual.* Chapter 2 of the manual discusses how these are incorporated into the procedure. Note that a safety improvement can also increase capacity; the user should check whether this is the case and perform an offline capacity analysis if warranted.

Incident duration is affected by incident management strategies. The information in Table 3.5 can be used to determine the reduction in incident duration.

Reliability Module User's Guide and Instructions

Introduction and Purpose

The Reliability Module presented here is a sketch planning corridor spreadsheet tool based on SHRP 2 Reliability Project L03 research that estimates the benefits of improving travel time reliability for use in benefit–cost analysis. Local travel time reliability data are not required because reliability measures are embedded in the L03 work. Agencies will typically have the required inputs (e.g., traffic volume, roadway capacity, AADT, percent of trucks, number of lanes, and growth rate).

Before You Start

1. At the website http://www.tpics.us/tools, under **Tools**, click the link for **Reliability Tool.** Download "SHRP 2 C11 Reliability Module.xlsm" and open it using Microsoft Excel. (A version number is usually added to the end of this file name such as "SHRP 2 C11 Reliability Module v9.2.xlsm".)
2. If prompted to **Enable or Disable Macros** when the file opens, be sure to choose **Enable.** Optionally, to permanently enable macros in Microsoft Excel 2007 and 2010, follow these steps:
   a. For Excel 2007 and 2010, first click the **Office** button (upper-left corner).
   b. Click **Excel Options.**
   c. Select the **Trust Center** options and click **Trust Center Settings** (Figure 3.3).
   d. In **Macro Settings,** click the radio button **Enable All Macros** (Figure 3.4).
   e. For earlier versions of Excel, navigate to **Tools**>**Options.** Select the **Security Tab** and click **Macro Security.** Select **Low.**

The Reliability Module requires you to understand two key concepts:

1. *Scenario:* A scenario represents a set of highway and traffic conditions. It is input and named by the user, which is saved and reported on by the tool. These scenarios are kept even after the program is closed.
2. *Session:* A session consists of a set of scenarios. If there are scenarios saved when the Reliability Module is opened, this is considered to be a previous session. When a new session

Table 3.5. Incident Management Impacts

Improvement	Impact
Incident Management (IM): Improving from no formal IM program to a program that includes detection, verification, and service patrols	*Atlanta*—Average time between first report and incident verification was reduced by 74%. Average time between verification and response initiation reduced by 50%. Average time between incident verification and clearance of traffic lanes reduced by 38%. The maximum time between incident verification and clearance of traffic lanes was reduced by 60% (Booz Allen Hamilton 1997). *Houston*—Average 30-minute incident duration reduction (RITA 1997). IDAS Model recommends a default reduction in incident duration of 9% for incident detection, 39% for incident response systems, and 51% for combination incident detection and response systems (Cambridge Systematics 2003). *Georgia (Navigator)*—Reduced incident clearance time by an average of 23 minutes and reduced incident response time by 30% (Institute of Transportation Engineers 1997). *Maryland (CHART)*—Reduced the blockage duration from incidents by 36%. This translates to a reduction in highway user delay time of about 42,000 hours per incident (Chang and Rochon 2007). 15% to 38% reduction in all secondary crashes; 4% to 30% reduction in rear-end crashes; and 21% to 43% reduction in severe secondary crashes (Institute of Transportation Engineers 1997).
RECOMMENDATION Improved equipment for incident detection and verification (CCTV)	Based on CHART, reduce incident lane-hours lost by 36%. *Brooklyn*—Average time required to clear incident from roadway reduced by 66% (Stough 2001). *San Antonio (TransGuide)*—20% improvement in response time (21% reduction for major incidents and 19% for minor incidents) (Turner et al. 1998).
RECOMMENDATION Improved interagency communications for incident detection and verification	Based on *TransGuide* and assuming that incident response time is 20% of incident duration time, reduce incident duration by 4%. *Minneapolis/St. Paul (Highway Helper)*—Automatic tow truck dispatch program is credited with a 20-minute reduction in incident response and removal times (85% improvement) (ATA Foundation and Cambridge Systematics 1997).
RECOMMENDATION Improved equipment and service for incident response	Assuming that response time is 20% of incident duration time, reduce incident duration by 17%. *Hayward, California*—38% reduction in incident duration and 57% reduction in breakdown duration (Skabardonis et al. 1995). *Northern Virginia*—Reduction in duration for all incidents is 2 to 5 minutes for cell phone in response vehicles, 2 to 5 minutes for CAD screens in response vehicles, and 4 to 7 minutes for GPS location for response vehicles (Maas et al. 2001). *Oregon*—The duration of delay-causing incidents decreased by approximately 30% on Highway 18 and 15% on Interstate 5 (service patrol addition) (Bertini et al. 2001). *Pittsburgh*—Service patrol reduced response time to incidents from 17 to 8.7 minutes (FHWA 2000). *Washington State*—Average freeway incident clearance time for large trucks reduced to 1.5 hours from 5 to 7 hours without the incident response team (Hall 2000).
RECOMMENDATION Service Patrols	For the implementation of service patrols, reduce incident duration by 38%.

Note: CHART = Coordinated Highways Action Response Team; CCTV = closed-circuit television; CAD = computer-assisted drafting.
Source: Cambridge Systematics et al. 2013.

is created, all scenarios created in the previous session are deleted. Users can save the Reliability Module under a different file name to retain the previous session.

Quick Start Guide

To create a new scenario, erasing any scenarios currently in file, follow these steps:

1. At the website http://www.tpics.us/tools, under **Tools**, click the link for **Reliability Tool** and open it using Microsoft Excel file (choose to enable macros if prompted).
2. Select the tab named 2–INPUTS.
3. Click **Begin a New Session**.
4. Click **Yes**.
5. Click **Yes** (Reminder: *all* Scenario data will be deleted).
6. In the **Scenario Inputs** window, click **New Scenario**.
7. In the **New Scenario** window, enter a Scenario name.
8. If using default input values, select the **Using Default Values** checkbox.
9. In the **Scenario Inputs** window, enter all required input data.
10. To save this Scenario, click **Save Scenario**.

To create a new Scenario, in addition to Scenarios currently in file, follow these steps:

1. Open the file (choose to enable macros if prompted).
2. Choose the tab named 2–INPUTS.
3. Click **Resume a Previous Session**.

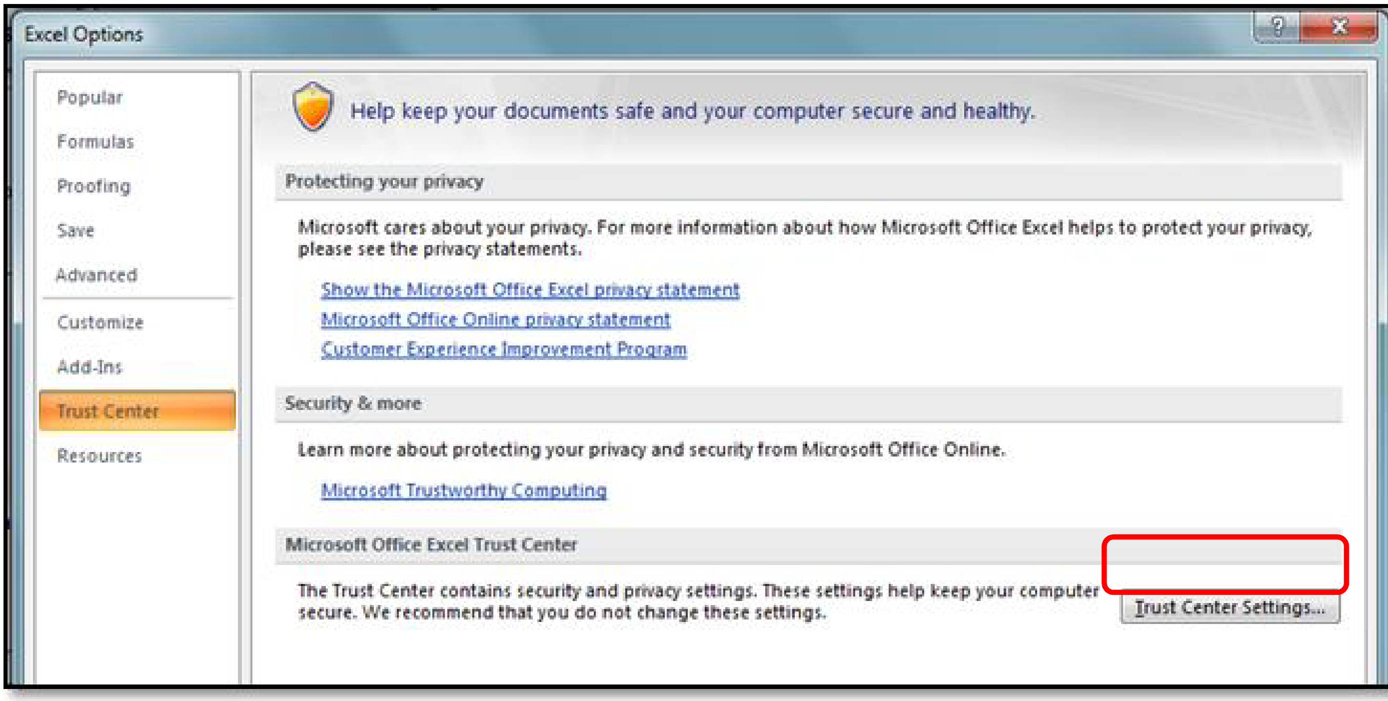


Figure 3.3. Screenshot of Trust Center settings.

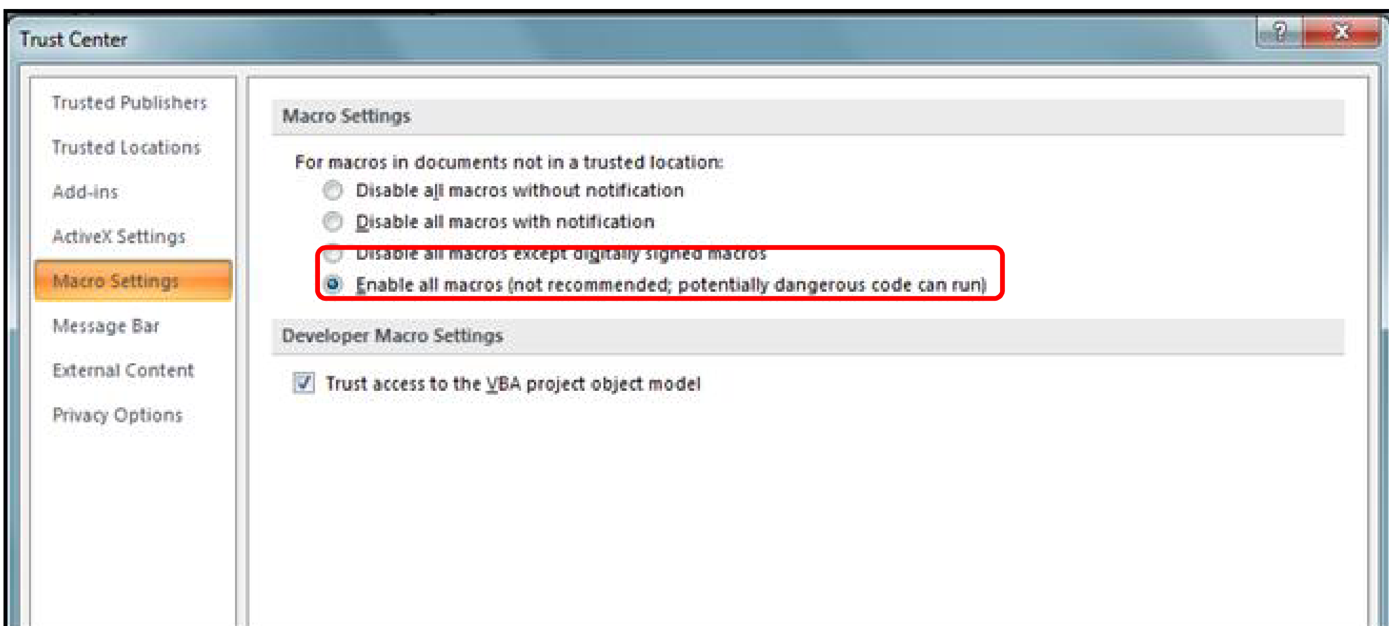


Figure 3.4. Screenshot of how to enable all macros.

4. In the **Scenario Inputs** window, click **New Scenario**.
5. In the **New Scenario** window, enter a scenario name.
6. If using default input values, select the **Using Default Values** checkbox.
7. In the **Scenario Inputs** window, enter all required input data.
8. Click **Save Scenario** to save this Scenario.

To view results, click **Results** while in the **Scenario Inputs** window. Before attempting to view Results, be sure to have entered (and saved) at least one Scenario.

Entering Inputs

Figure 3.5 shows the screen that displays when you open the Reliability Module for the first time. Here you can see when your version of the Reliability Module was last updated as well as a brief set of instructions for the tool.

To begin entering data:

1. Click the tab labeled 2–INPUTS. The 2–INPUTS tab displays (Figure 3.6).
2. Read the instructions listed by each button.
3. Do one of the following:
   a. If you want to **Resume a Previous Session**, click that button, and continue reading instructions at the heading **Using the Scenario Inputs Window**.
   b. If you want to **Begin a New Session**, click that button. Note that doing so will first delete all currently entered data. Optionally, you can hide or unhide (password-protected) sheets used in the background of the tool. Continue reading instructions at the heading Entering a New Scenario.

Using the Scenario Inputs Window

1. On the 2–INPUTS tab, after you click **Resume a Previous Session,** the **Scenario Inputs** window displays (Figure 3.7).

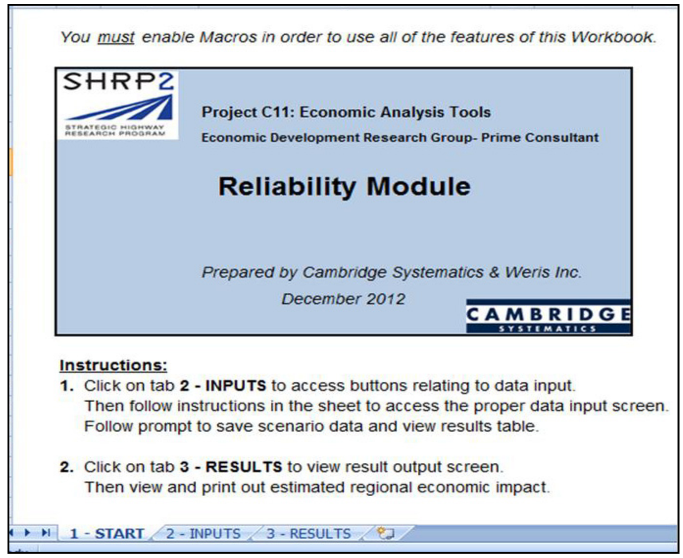


Figure 3.5. Screenshot of opening tab of Reliability Module (1—START).

Descriptions of the navigation buttons are in Table 3.6, and inputs and their descriptions are shown in Table 3.7.

2. Enter all pertinent information about a specific scenario.
3. When you are finished, click the button for either **Save Scenario**, **Delete Current Scenario**, **Results**, or **New Scenario**.

Entering a New Scenario

To enter a new scenario:

1. In the **Scenario Inputs** window, click the **New Scenario** button. The dialog box shown in Figure 3.8 displays.
2. Enter a Scenario name.
3. If you want the system to automatically fill in the default values for several input parameters, select the **Use Default Values** checkbox. The system will fill in the default values for the data fields, as listed in Table 3.8.

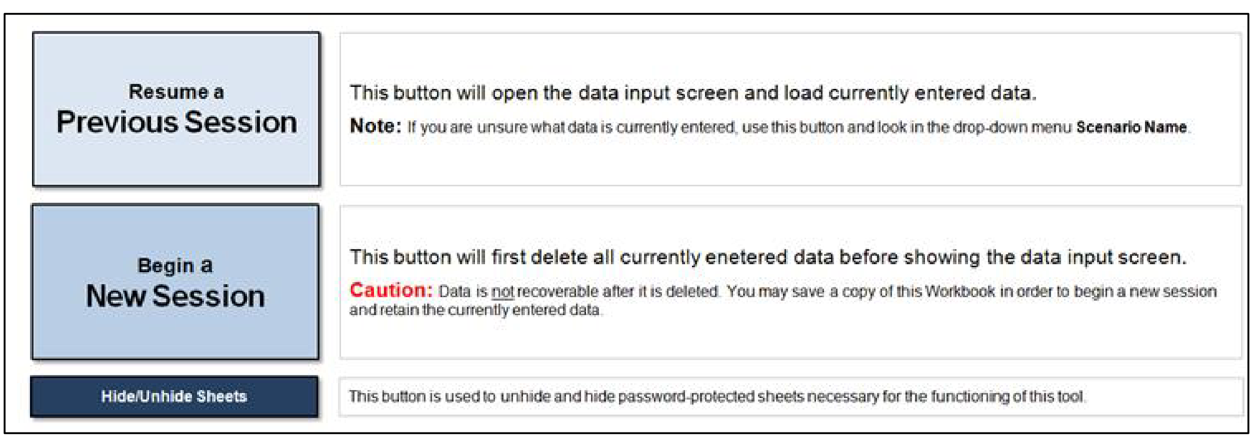


Figure 3.6. Screenshot of first screen on the 2—Inputs Tab.

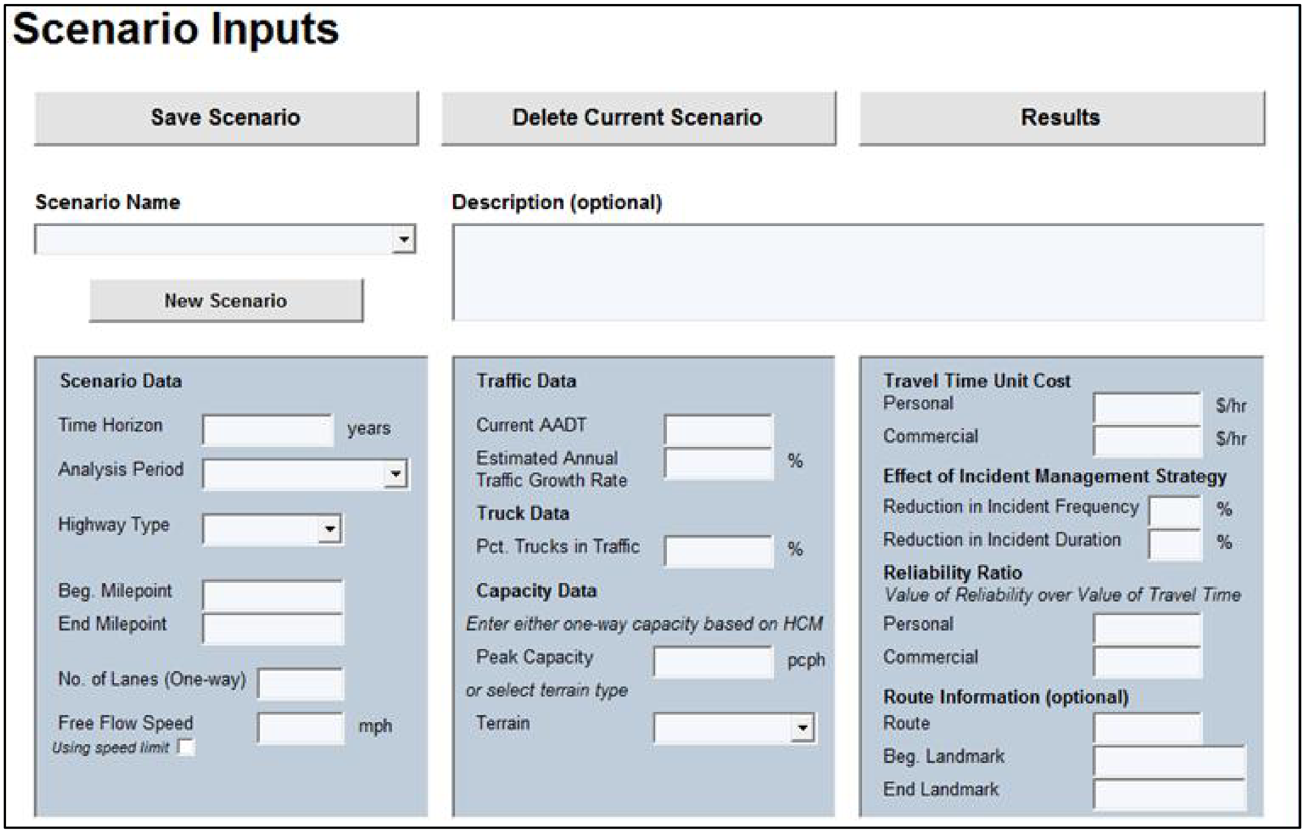


Figure 3.7. Screenshot of the Scenario Inputs page—Tab 2.

4. Click **OK.** The **Scenario Inputs** window displays (Figure 3.7).
5. Enter all pertinent information about a specific scenario.
6. When you are finished, click a button either for **Save Scenario**, **Delete Current Scenario**, **Results**, or **New Scenario**.

In the **Scenario Inputs** window (Figure 3.7), if you want to save the scenario under a different name, enter the name in the **Scenario Name** field.

If there are no Scenarios currently saved, enter and save a Scenario before attempting to explore the functionality of the Reliability Module. Not doing so may impact the proper running of the program.

Table 3.6. Buttons in the Inputs Window—Tab 2

Buttons in the Inputs Window	
New Scenario	Displays a dialogue box for creating a new Scenario.
Save Scenario	Saves the currently entered data to the Scenario selected from **Scenario Name**.
Delete Current Scenario	Permanently deletes the Current Scenario from the **Scenario Name** drop-down list.
Results	Navigates to the Results tab.

If there are no Scenarios entered and the program stops working, close the program without saving it, reopen the file, and enter a Scenario using the steps outlined above.

Obtaining Results

In the tab labeled 3–RESULTS, results are displayed for each scenario entered through the 2–INPUTS tab. By default, the results are given in a summary form, with scenarios organized in columns. A detailed, hourly view is available for individual scenarios as well. For more detailed information about the results, including their calculation, refer to the Reliability Technical Guide in Chapter 2.

Organizing Results

On the 3–RESULTS tab, the heading **Current Year** contains the following:

- *Congestion Metrics*—Key measures of congestion, such as overall travel time mean index, 95th and 80th percentile travel time index, and percent of trips that occur at speeds less than 45 mph and 30 mph.
- *Total Annual Weekday Delay*—Total annual weekday delay in vehicle-hours, categorized by congestion types (recurring and incident delay) and vehicle types (passenger and truck).

Table 3.7. Input Fields and Their Meanings—Tab 2

Field Name	Req?	Description
Scenario Name	Yes	A unique name used to describe a Scenario
Description	No	An optional description of the Scenario
Time Horizon	Yes	Number of years into the future for which the analysis applies
Analysis Period	Yes	Specify the hours of the day for which the analysis will be run
Highway Type	Yes	Freeway, Signalized, or Two-lane Rural
Beg. Milepoint	Yes	Beginning milepoint is used with end milepoint to determine length of highway to analyze
End Milepoint	Yes	Ending milepoint is used with begin milepoint to determine length of highway to analyze
No. of Lanes (One-way)	Yes	The number of lanes in one traffic direction (does not apply to Two-lane Rural)
Free Flow Speed	Yes	Free Flow Speed (FFS) is the average speed that a motorist would travel if there is no congestion or other adverse condition
Using Speed Limit	Yes	This is a checkbox. When checked, the FFS field can be used to enter the posted speed limit, which is then used to calculate the FFS
Current AADT	Yes	Current AADT volume
Est Annual Traffic Growth Rate	Yes	Estimated future annual average daily traffic volume
Pct. Trucks in Traffic	Yes	Percent trucks in the traffic stream (combinations + single units)
Peak Capacity	Yes	Peak capacity as determined using *Highway Capacity Manual* procedures
Terrain	Yes	Flat, Rolling, or Mountainous. Can be used to calculate Peak Capacity
Personal Travel Time Unit Cost	Yes	Unit cost of travel time, personal ($/hour): Default = $19.86
Commercial Travel Time Unit Cost	Yes	Unit cost of travel time, commercial ($/hour): Default = $36.05
Reduction in Incident Frequency	Yes	Reduction in incident frequency, expressed as a percentage, due to the addition of an incident management program/strategy. Default = 0%
Reduction in Incident Duration	Yes	Reduction in incident duration, expressed as a percentage, due to the addition of an incident management program/strategy. Default = 0%
Personal Reliability Ratio	Yes	The ratio of value of travel time reliability over value of travel time for the general motorists. Default = 0.8
Commercial Reliability Ratio	Yes	The ratio of value of travel time reliability over value of travel time for commercial vehicles. Default = 1.1
Route	No	Route name
Beg. Landmark	No	Name of beginning landmark
End Landmark	No	Name of ending landmark

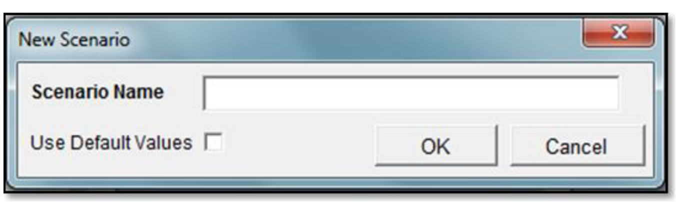


Figure 3.8. Screenshot of New Scenario input screen—Tab 2.

Table 3.8. Default Values for the Reliability Module

Data Field	Default Value
Personal Travel Time Unit Cost	$19.86
Commercial Travel Time Unit Cost	$36.05
Reduction in Incident Frequency	0%
Reduction in Incident Duration	0%
Personal Reliability Ratio	0.8
Commercial Reliability Ratio	1.1

- *Total Annual Weekday Congestion Costs*—Total annual weekday delay cost incurred by congestion, categorized by congestion types (recurring and unreliability costs) and vehicle types (passenger and truck).

On the 3–RESULTS tab, the heading **Future Year,** which is determined by Time Horizon, contains the following:

- *Congestion Metrics*—Key measures of congestion, such as overall travel time mean index, 95th and 80th percentile travel time index, and percent of trips that occur at speeds less than 45 mph and 30 mph.
- *Total Annual Weekday Delay*—Total annual weekday delay in vehicle-hours, categorized by congestion types (recurring and incident delay) and vehicle types (passenger and truck).
- *Total Annual Weekday Congestion Costs*—Total annual weekday delay cost incurred by congestion, categorized by congestion types (recurring and unreliability costs) and vehicle types (passenger and truck).

Summary View

In the Summary view (Figure 3.9), aggregated results are shown for all scenarios. To view the hourly results for a particular

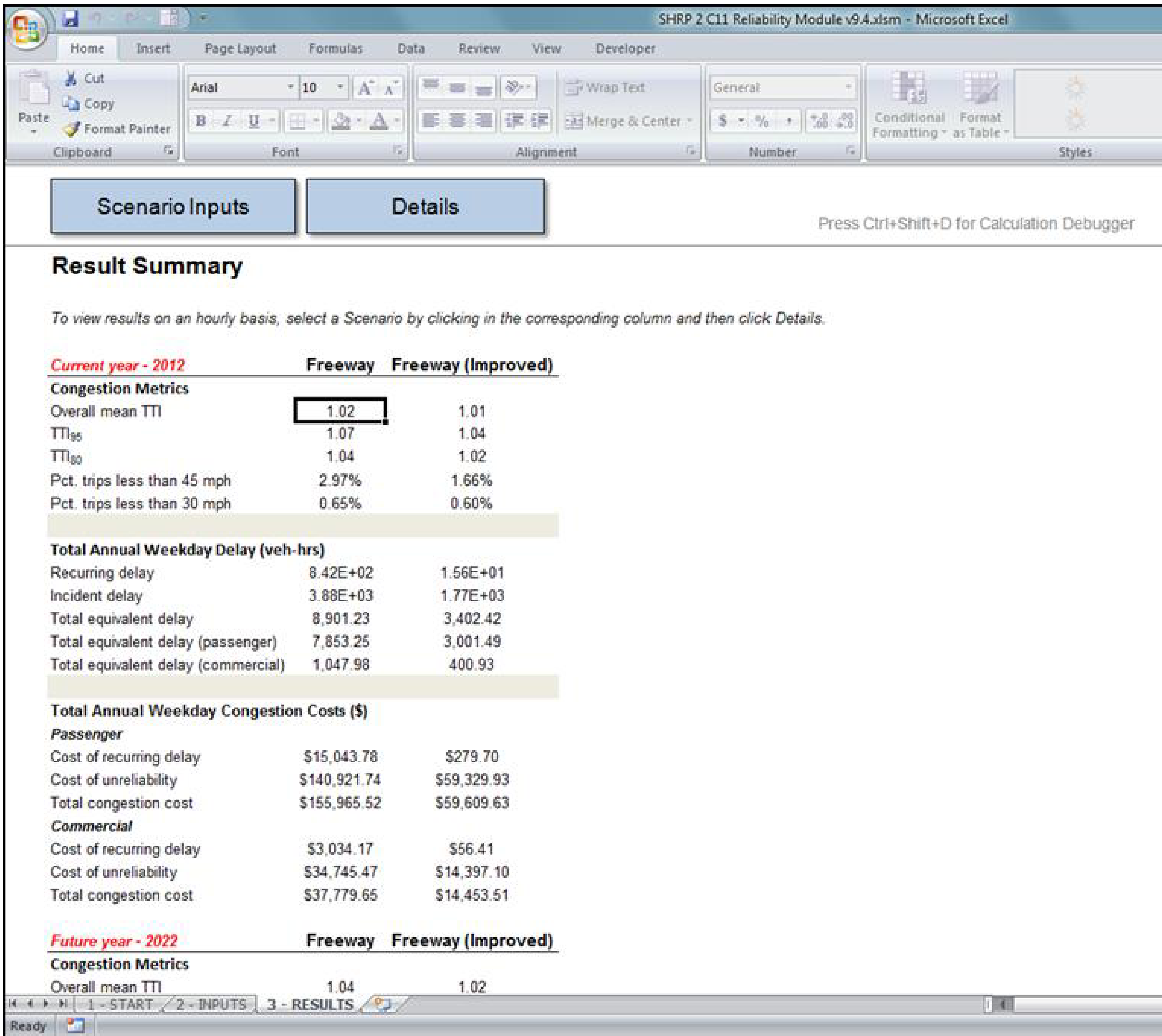


Figure 3.9. Screenshot of the RESULTS summary page—Tab 3.

scenario, click in the column containing the desired scenario and then click **Details**. In the case shown in Figure 3.9, clicking **Details** would show hourly results for scenario "Freeway," because a cell in the column with the results for "Freeway" has been selected.

Details View

In the Details view (Figure 3.10), hourly results are shown for one specific scenario. Several input parameters are displayed in italics underneath the scenario name and pertain only to the scenario being currently viewed.

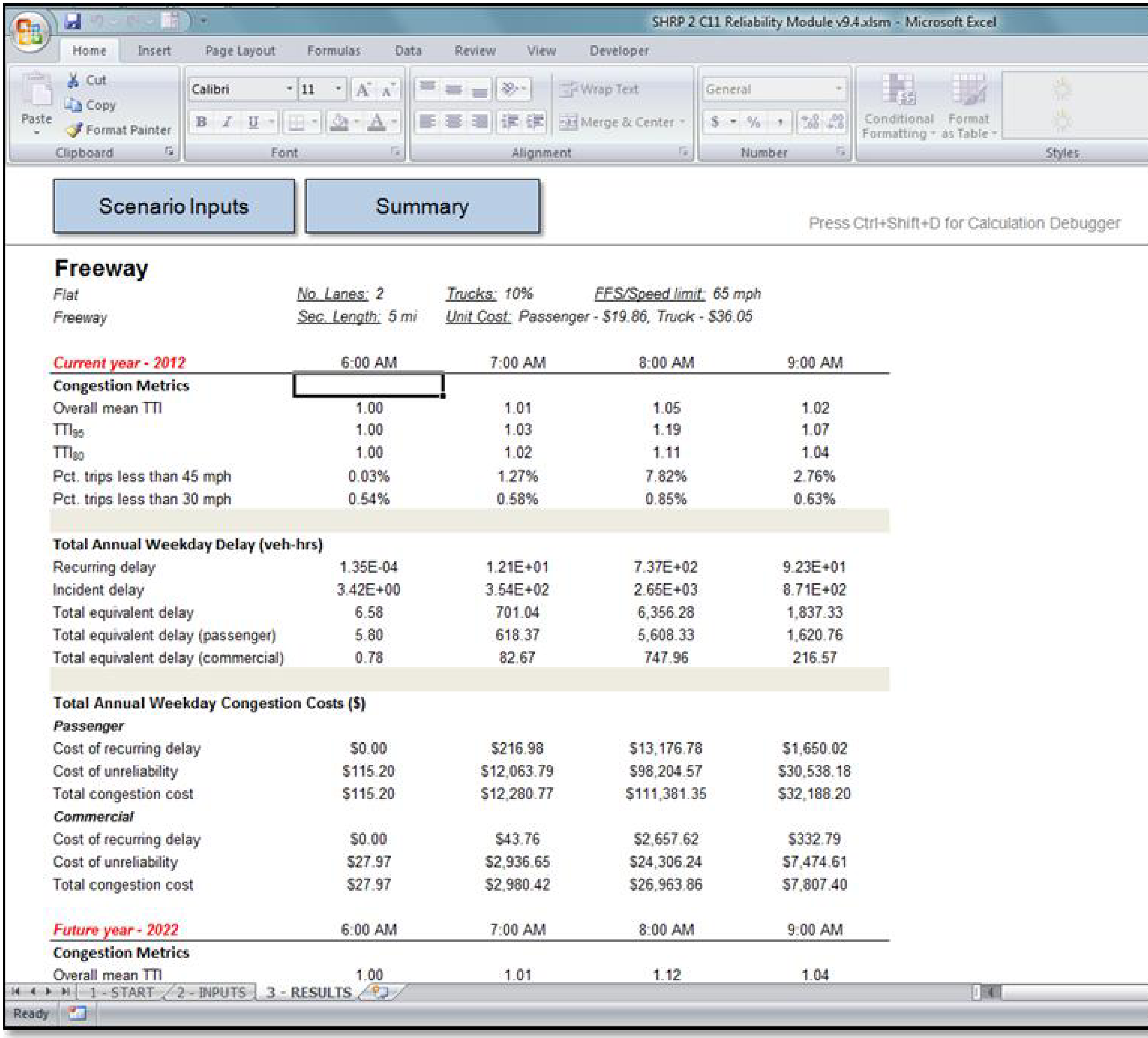
Calculation Debugger

Pressing Ctrl+Shift+D while in the 3–RESULTS tab displays the **Calculation Debugger** window (Table 3.9). Here, many variables that are used in calculating the results are displayed and organized by scenario, year, and hour. In Figure 3.11, one can see that by scrolling down through the **Calculation Debugger** window, one can view the data from all scenarios currently saved in the Module.

Note on Saving and Closing the File

Inside the **Scenario Inputs** window, any changes to scenario data must be saved manually using the **Save Scenario** button (see Figure 3.12). If there are any unsaved changes to a scenario when you attempt to either create a new scenario or view Results, a dialog box prompts you to save these changes. The fields where changes have been made are marked in red, and you can choose to continue and save the changes by clicking **Yes** in the dialog box, continue and discard the change(s) by clicking **No**, or click **Cancel** and remain in the **Scenario Inputs** window.

However, on closing the file, there will never be a prompt to save changes, even if the 3–RESULTS tab has been changed from **Summary** to **Details** view (or vice versa). This is because the Reliability Module has been set up to automatically save at points such as this, for the user's convenience.



Current year - 2012	6:00 AM	7:00 AM	8:00 AM	9:00 AM
Congestion Metrics				
Overall mean TTI	1.00	1.01	1.05	1.02
TTI_{95}	1.00	1.03	1.19	1.07
TTI_{80}	1.00	1.02	1.11	1.04
Pct. trips less than 45 mph	0.03%	1.27%	7.82%	2.76%
Pct. trips less than 30 mph	0.54%	0.58%	0.85%	0.63%
Total Annual Weekday Delay (veh-hrs)				
Recurring delay	1.35E-04	1.21E+01	7.37E+02	9.23E+01
Incident delay	3.42E+00	3.54E+02	2.65E+03	8.71E+02
Total equivalent delay	6.58	701.04	6,356.28	1,837.33
Total equivalent delay (passenger)	5.80	618.37	5,608.33	1,620.76
Total equivalent delay (commercial)	0.78	82.67	747.96	216.57
Total Annual Weekday Congestion Costs ($)				
Passenger				
Cost of recurring delay	$0.00	$216.98	$13,176.78	$1,650.02
Cost of unreliability	$115.20	$12,063.79	$98,204.57	$30,538.18
Total congestion cost	$115.20	$12,280.77	$111,381.35	$32,188.20
Commercial				
Cost of recurring delay	$0.00	$43.76	$2,657.62	$332.79
Cost of unreliability	$27.97	$2,936.65	$24,306.24	$7,474.61
Total congestion cost	$27.97	$2,980.42	$26,963.86	$7,807.40
Future year - 2022	**6:00 AM**	**7:00 AM**	**8:00 AM**	**9:00 AM**
Congestion Metrics				
Overall mean TTI	1.00	1.01	1.12	1.04

Figure 3.10. Screenshot of the Details view of RESULTS—Tab 3.

Table 3.9. Buttons in the Results Tab—Tab 3

Buttons in the Results Tab	
Scenario Inputs	Displays up the **Scenario Inputs** window.
Details (if in Summary view)	Displays the hourly results for a particular scenario.
Summary (if in Details view)	The default view, showing aggregated results for all scenarios.
Ctrl+Shift+D	Pressing Ctrl+Shift+D displays the **Calculation Debugger**. The **Calculation Debugger** is a dialog box that shows many more variables, calculated in the background, which are not needed for normal use.

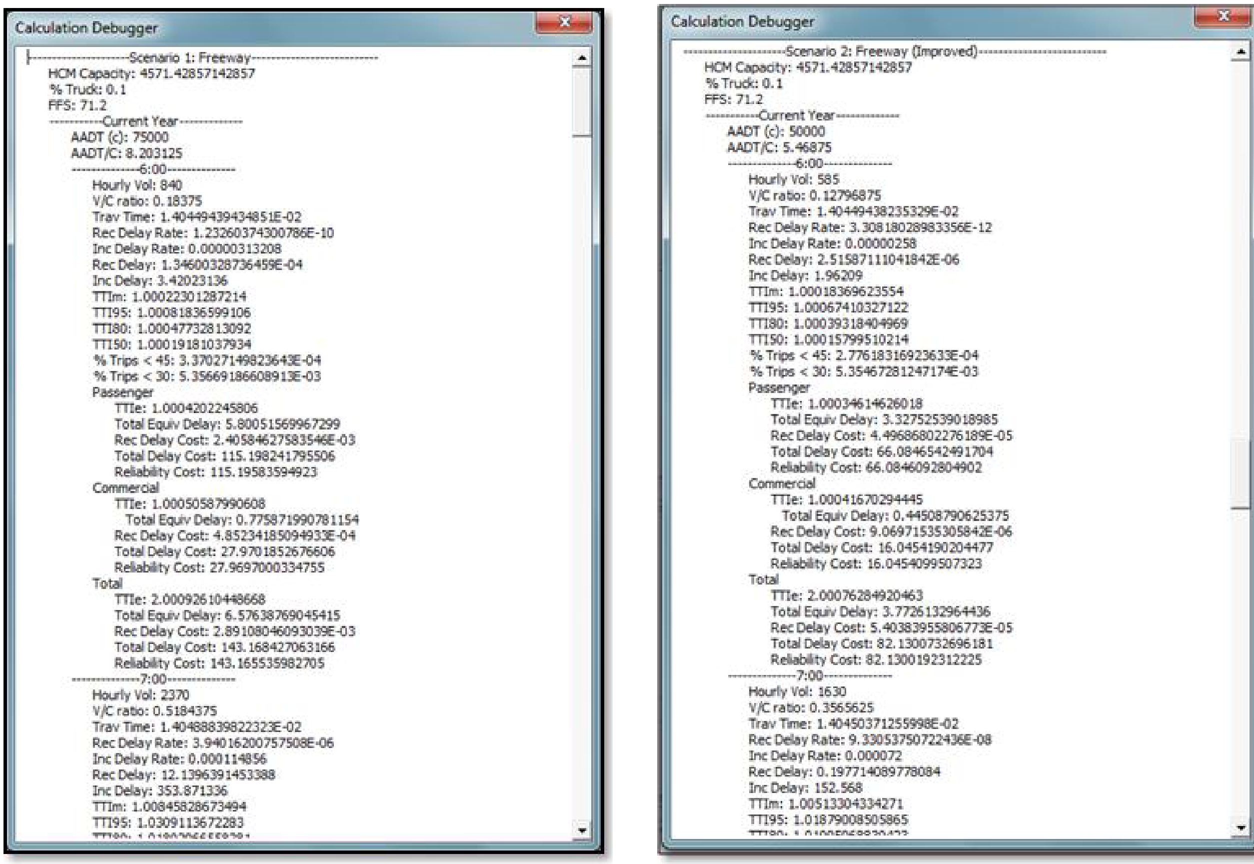


Figure 3.11. Screenshots of Calculation Debugger.

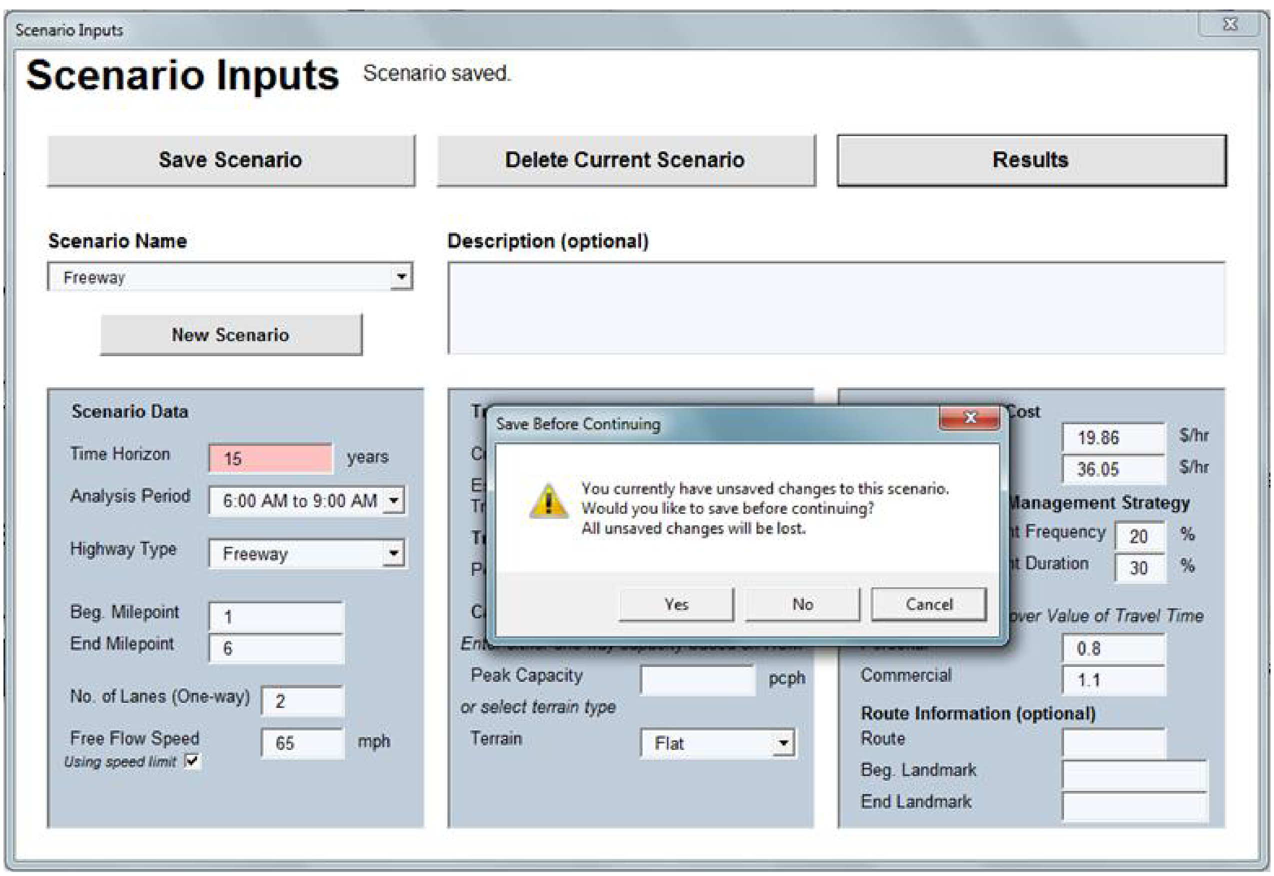


Figure 3.12. Screenshot of Scenario Inputs, including dialog box to **Save Before Continuing.**

CHAPTER 4

Connectivity

Technical Guide

Introduction and Purpose

This chapter provides an overview of the methodology used by the tool for assessing the value of intermodal connectivity and also providing instructions for its use. The tool can be used in conjunction with other tools developed through the C11 project to estimate the economic development benefits of a highway improvement. The value of an intermodal terminal is that it connects different modes of transportation, enabling passengers and freight to reach a greater number of destinations by accessing transportation modes with more preferable service and cost characteristics.

The connectivity value provided by a terminal is related to the type of service that it connects to, the location of the terminal, the overall level of activity at the terminal, and the number of other locations that can be reached through the terminal. The tool methodology proposed here provides data and requests user inputs to evaluate each of these aspects of connectivity. The tool also requests data on the proposed highway improvement, and these data are used to estimate how this investment will affect the facility and connectivity.

Specification of Inputs

There are three different types of terminal data required by the tool. Some of these data are included within the tool, while the user is required to enter other data. The data included in the tool are drawn primarily from public data sources. Data pre-loaded in the tool cover three categories: the *level of activity* of a terminal, the *value of goods* moved (for freight), and the *number of locations* served by the facility. The level of activity includes tonnage or containers for freight or trips for passenger modes. The value of goods is measured in value per ton or value per container. The number of locations served measures how many other unique geographic areas (domestic and international) this terminal connects to.

User Inputs

In the intermodal connectivity tool, on the **Intermodal Facility Inputs** page, the user selects the state where they want to evaluate a facility and the type of facility (airport freight, airport passenger, rail freight, rail passenger, marine freight). From a drop-down menu the user then selects the specific intermodal terminal that will be affected by the proposed improvement.

In the Improvement Inputs section, the user specifies the distance of the improvement from the facility, the number of trucks or passenger vehicles on the segment improved, the hours saved per truck or passenger vehicle, the value per vehicle hour saved, and the fraction of vehicles on the segment associated with the intermodal terminal being evaluated. Default values for a truck hour or passenger vehicle hour are included: The system uses a value of $18 per passenger vehicle hour saved, which is based on average vehicle occupancy of 1.59 and average value of personal time of $11.24 per hour. For freight, the system uses a value of $86 per hour for a truck hour (including crew cost and freight logistics cost) (Schrank et al. 2012).

An exponential distance decay function provides a default value for the percentage of passenger or freight vehicles operating on a segment associated with an intermodal facility. This value assumes that the benefit of a roadway improvement to an intermodal facility decreases as the distance from the facility affected increases. The further from the intermodal facility the roadway improvement is, the fewer vehicles there are that are traveling to or from the intermodal facility. It is recommended that the user provide an actual estimate of the percentage of vehicles accessing the intermodal facility from the improved roadway segment, but the default values can be used to make some rough comparisons of the relative value of different roadway improvements and affected facilities in a region.

Output and Calculations

Connectivity Index

The tool combines the data inputs into an index that will measure the connectivity value provided by the terminal and can be used to compare connectivity at different terminals. This can help prioritize and select highway improvements with access to terminals offering higher levels of connectivity. The research team's approach involves developing an index for each mode separately. The general form of the calculations for the freight connectivity index and the passenger connectivity index is shown in Equations 4.1 through 4.3.

$$\text{Freight connectivity index} = \text{Tons of freight} * \text{Average value per ton} * \text{Number of distinct locations served} \quad (4.1)$$

$$\text{Freight connectivity index} = \text{Containers of freight} * \text{Average value per container} * \text{Number of distinct locations served} \quad (4.2)$$

$$\text{Passenger connectivity index} = \text{Number of passengers} * \text{Number of distinct locations served} \quad (4.3)$$

Because of data limitations, the approach above varies somewhat by mode.

- *Marine Port—Freight.* For marine freight, total containers and tons arriving and leaving from the port are multiplied by an average value per ton and average value per container estimated from Freight Analysis Framework (FAF) data. This number is then multiplied by the number of origin and destination ports served. The number of distinct port locations served is estimated based on the vessel entrances and clearances data. This data shows the previous and next port for all the vessels entering specific ports. One limitation of this approach is that these data do not show information on multi-stop container ship routes that may occur before the previous port clearance or after the next planned port arrival.
- *Air Passenger.* For airport passenger facilities, the information to determine the number of passengers arriving at or leaving from the airport is drawn from U.S. Department of Transportation's T-100 Domestic and International Air Carrier Data, available from the Bureau of Transportation Statistics. The research team measured connectivity by the number of distinct locations that are served by direct flights.
- *Air Cargo.* For air cargo, to estimate the index, total freight tons is multiplied by the number of origins and destinations and an average value per ton. The average value per ton is derived from FAF data estimated at the state level. These are multiplied together to calculate a connectivity index.
- *Freight Rail.* For freight rail intermodal terminals, the research team estimated activity using the annual container lift capacity of the terminal. An average value per container, based on FAF data, is used to estimate value. Connectivity is estimated using the number of origin–destination multimodal markets served, from the Federal Highway Administration's FAF (Freight Analysis Framework, 2007). These include city pairs, but also larger geographical areas for smaller markets. The tool currently focuses the rail calculation on rail intermodal container facilities.
- *Passenger Rail.* For passenger rail, the research team focused on Amtrak intercity rail terminals. Total tickets and number of locations served are used to estimate an index for these facilities.

Table 4.1 shows the data that are be used to perform the calculations for each mode.

Weighted Connectivity

The output of the calculations described is a relative facility connectivity index for each intermodal terminal. This score is then multiplied by the savings associated with the highway improvement estimated from the IMPROVEMENT INPUTS entered by the user (described previously). The number of vehicles associated with the facility multiplied by the hours saved per vehicle and the value of time are used to estimate the value of the highway segment improvement to the vehicles accessing the intermodal facility. This value is then multiplied by the relative connectivity index for a facility to estimate a weighted connectivity value.

Value for Benefit Assessment

The freight and passenger weighted connectivity scores can be used to rank different investments on their relative value for improving intermodal connectivity.

Updating the Tool

Most of the data sources used in the tool are updated on an annual basis, and therefore the tool could be updated on a periodic basis with publicly available data. Some processing would be required for most of the databases used. In addition,

Table 4.1. Types of Data by Intermodal Terminal Type and Source

Intermodal Facility Type	Input	Data	Source
Marine Port—Freight	Facility	Top marine ports by state	U.S. Army Corps of Engineers Ports and Waterways Facilities
	Activity Level	Total containers Total tons	U.S. Army Corps of Engineers, 2009 Waterborne Commerce of the United States
	Connectivity	Number of unique port destinations and origins	U.S. Army Corps of Engineers, Vessel Entrances and Clearances Data
	Value	Value per ton Value per container	FAF
Airport—Passenger Facility	Facility	Passenger airports by state	U.S. DOT T-100 Domestic and International Air Carrier Data
	Activity Level	Total passengers	U.S. DOT T-100 Domestic and International Air Carrier Data
	Connectivity	Number of distinct locations served by direct flights	U.S. DOT T-100 Domestic and International Air Carrier Data
Airport—Cargo Facility	Facility	Cargo airports by state	U.S. DOT T-100 Domestic and International Air Carrier Data
	Activity Level	Freight tons	U.S. DOT T-100 Domestic and International Air Carrier Data
	Connectivity	Number of unique airport destinations and origins served	U.S. DOT T-100 Domestic and International Air Carrier Data
	Value	Average value per ton	FAF
Freight Rail Intermodal Terminal	Facility	Major intermodal container terminals	FHWA Intermodal Connector Facility List
	Activity Level	Annual lift capacity (user input) Average value per container	Value per container estimated from FAF
	Connectivity	Number of unique rail origins and destinations served by rail for region.	FAF database
Passenger Rail Terminal	Facility	Amtrak intercity rail terminals	Amtrak website
	Activity Level	Total tickets (departing and arriving)	Amtrak National Fact Sheet
	Connectivity	Number of origin and destination stations	Amtrak website

Note: FHWA = Federal Highway Administration; FAF = freight analysis framework.

the tool contains formulas that search for specific ranges within each database. These formulas and ranges would need to be updated if the data are updated. The databases used by the tool can be accessed in the hidden data sheets contained in the tool.

Connectivity Module User's Guide and Instructions

Introduction and Purpose

The intermodal connectivity tool evaluates the impact of roadway improvement on intermodal connectivity. The tool estimates a connectivity value that can be used to compare the relative value of different roadway investments for connectivity at specific intermodal terminals.

The intermodal connectivity tool requires two types of inputs and generates outputs in a separate tab. On the Inputs tab, the user first selects which intermodal facilities they want to evaluate for the impact of a proposed roadway improvement. The user then enters the characteristics of the roadway improvement they are considering. Then on the Results tab the user reviews the outputs provided by the tool, which show data on the relative connectivity value that a roadway improvement provides for the different intermodal facilities specified. The three tabs are described in more detail.

Entering Inputs

To enter inputs, click the tab labeled 1–START and review brief instructions on using the tool.

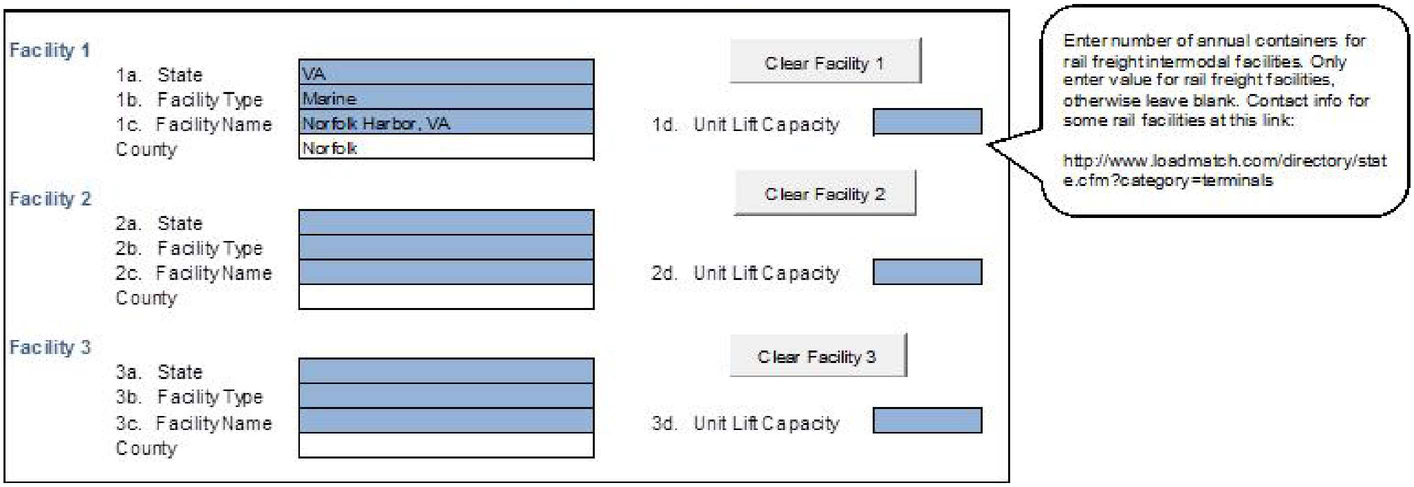


Figure 4.1. Intermodal facility inputs—Tab 2.

Intermodal Facility

To enter the facility inputs:

1. At the bottom of the workbook, click the tab labeled 2–INTERMODAL FACILITY INPUTS (see Figure 4.1).
2. In field **1a,** select the state where you want to evaluate intermodal facilities.
3. In field **1b,** select the type of intermodal facility you want to evaluate (airport freight, airport passenger, rail freight, passenger rail, or marine freight). In field **1c** the tool provides a drop-down list of facilities of that type covered by the tool. If available, the tool shows the county where the facility selected is located.
4. If you selected rail freight, in field **1d,** provide the annual container lift capacity of the facility. If you do not have this information, use the web address listed in the text box next to the **Unit Lift Capacity** field to find the contact information for rail intermodal facilities. You can contact the facility to obtain the container lift capacity information to enter into field **1d.** You can select up to three different facilities to evaluate at once. In the case depicted in Figure 4.1, the user has selected the same facility, but will evaluate the impact of different improvements on the facility.

Improvement Inputs

To choose improvement inputs:

1. At the bottom of the workbook, click the tab labeled 3–IMPROVEMENT INPUTS (see Figure 4.2). The state, facility type, and facility names shown in blue shaded boxes are populated from the information previously entered (for a description of these inputs, see Table 4.2).
2. In field **1a,** enter a name for the roadway improvement being considered (e.g., "Highway 94 Access Improvements").
3. In field **1b**, enter the distance of the transportation improvement from the intermodal facility being evaluated, in miles. Distance could be calculated using any appropriate mapping software (including free software such as Google Maps).
4. In field **1c**, enter the number of trucks within the study area. This is the number of trucks (for freight facilities) or passenger vehicles (for passenger facilities) per year using the highway improvement segment in one year. You should enter the total number of trucks or passenger vehicles using the highway improvement segment, even though only a fraction of these may be associated with the facility.
5. In field **1d**, for freight facilities enter the hours saved per truck; for passenger facilities enter the hours saved per passenger car. This value should be entered as the fraction of an hour (for example, 10 minutes should be entered as 0.1667 or =10/60).
6. In field **1e**, for freight facilities enter the value per truck hour; for passenger facilities enter the value per passenger vehicle hour saved. For freight facilities, this value is a combination of crew cost and freight logistics costs, and these two cost components should be summed together before entering the value. Alternatively, you can use the default value for per truck hour value of time or per passenger vehicle hour of time that the system provides. If you do enter a value in field **1e,** that value will be used rather than the default value.
7. In **1f**, enter the fraction of trucks at the infrastructure investment location associated with the intermodal location, if the information is available. For instance, a user may have local survey information on the percent of vehicles accessing an intermodal facility from a specific roadway. Entries must be between 0 and 1 (for example, 30% of vehicles using the highway improvement segment and accessing the intermodal facility should be entered as 0.3). Alternatively, you can use the default value for the fraction

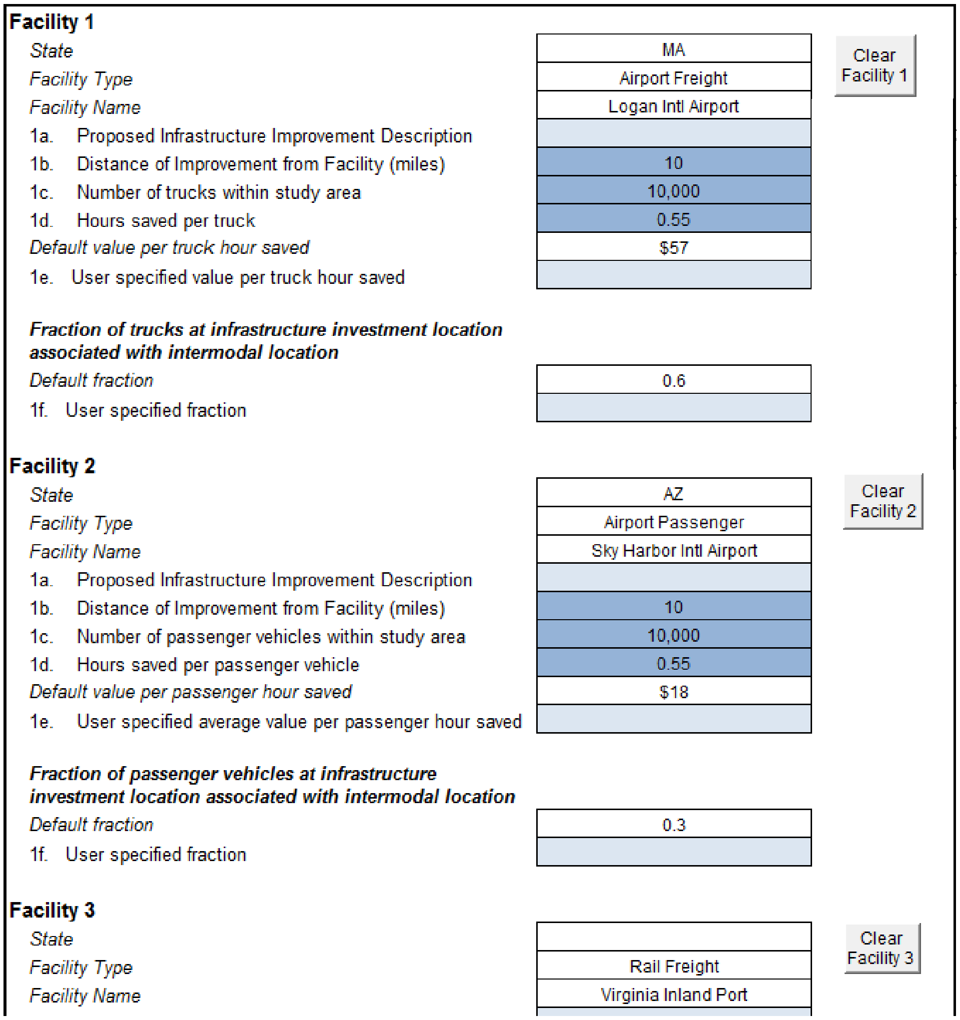


Figure 4.2. Roadway improvement inputs page—Tab 3.

Table 4.2. Roadway Improvement Inputs for Tab 3

Input	Description
1b Distance of improvement from facility (miles)	Calculate the distance in miles of the transportation improvement to the proposed facility using Google Maps or other appropriate mapping software.
1c Number of trucks within study area	The number of trucks or passenger vehicles per year using the highway improvement segment. The total number of trucks or passenger vehicles should be entered, though only a fraction may be traveling to the facility.
1d Number of trucks within study area	The hours saved per truck for freight facilities, or hours saved per passenger car for passenger facilities. This value should be entered as a fraction of an hour (e.g., enter 10 minutes as 0.1667).
1e Value per truck hour saved	The assumed value per truck hour saved for freight facilities, or the value per passenger car hour saved for passenger facilities. Users can either use the calculated default value, or enter their own value based on available information. If a value is entered in 1e, that value will be used in the calculation, rather than the default. For freight facilities, this value is a combination of crew cost and freight logistics costs, and the two cost components should be summed together before entering the value, if the default is not used.
1f Fraction of trucks associated with intermodal facility	This factor assumes that the farther away from the intermodal facility the improvement is the less impact it will have on the intermodal facility. A default exponential distance decay factor is calculated based on the distance. Users can either use the calculated default value, or enter their own value based on differences in local information. If a value is entered in 1f, that value will be used in the calculation, rather than the default value.

Facility 1

Facility Details	Container Connectivity Index	
Facility Type	Marine	
Facility Name	Norfolk Harbor, VA	
	Value	**Units**
Activity	1,472,851	containers
Value	$68,631	per container
Unique Origins/Destinations	64	
Facility Connectivity Raw Value	64.7	
Relative Activity	26.9%	
Relative Value	15.0%	
Relative Origins and Destinations	51.6%	
Relative Facility Connectivity Index	10.5%	
Project Summary		
Number of annual trucks	10,000	
Total truck hours saved (all trucks)	5,000	
Total Value	$284,638	
Number of trucks associated with the facility	6,310	
Time savings for facility	3,155	
Value of time savings for facility	$179,595	
Weighted connectivity	11,618,616.5	

Facility 1

Facility Details	Bulk Connectivity Index	
Facility Type	Marine	
Facility Name	Norfolk Harbor, VA	
	Value	**Units**
Activity	41,569,373	tons
Value	$309	per ton
Unique Origins/destinations	220	
Facility Connectivity Raw Value	28.2	
Relative Activity	17.6%	
Relative Value	27.0%	
Relative Origins and Destinations	25.0%	
Relative Facility Connectivity Index	2.8%	
Project Summary		
Number of annual trucks	10,000	
Total truck hours saved (all trucks)	5,000	
Total Value	$284,638	
Number of trucks associated with the facility	6,310	
Time savings for facility	3,155	
Value of time savings for facility	$179,595	
Weighted connectivity	5,073,289.2	

Facility 2

Facility Details		
Facility Type		
Facility Name		
	Value	**Units**
Activity		
Value		
Unique Origins/destinations		
Facility Connectivity Raw Value		
Relative Activity		
Relative Value		
Relative Origins and Destinations		
Relative Facility Connectivity Index		
Project Summary		
Number of annual trucks		
Total truck hours saved (all trucks)		
Total Value		
Time savings for facility		
Value of time savings for facility		
Weighted connectivity		

Facility 2

Facility Details		
Facility Type		
Facility Name		
	Value	**Units**
Activity		
Value		
Unique Origins/destinations		
Facility Connectivity Raw Value		
Relative Activity		
Relative Value		
Relative Origins and Destinations		
Relative Facility Connectivity Index		
Project Summary		
Number of annual trucks		
Total truck hours saved (all trucks)		
Total Value		
Number of trucks associated with the facility		
Time savings for facility		
Value of time savings for facility		
Weighted connectivity		

Facility 3

Facility Details		
Facility Type		
Facility Name		
	Value	**Units**
Activity		
Value		
Unique Origins/destinations		
Facility Connectivity Raw Value		
Relative Activity		
Relative Value		
Relative Origins and Destinations		
Relative Facility Connectivity Index		
Project Summary		
Number of annual trucks		
Total truck hours saved (all trucks)		
Total Value		
Time savings for facility		
Value of time savings for facility		
Weighted connectivity		

Facility 3

Facility Details		
Facility Type		
Facility Name		
	Value	**Units**
Activity		
Value		
Unique Origins/destinations		
Facility Connectivity Raw Value		
Relative Activity		
Relative Value		
Relative Origins and Destinations		
Relative Facility Connectivity Index		
Project Summary		
Number of annual trucks		
Total truck hours saved (all trucks)		
Total Value		
Number of trucks associated with the facility		
Time savings for facility		
Value of time savings for facility		
Weighted connectivity		

Figure 4.3. Screenshots of results pages—Tab 4.

of trucks at the infrastructure investment location accessing the intermodal location, which is calculated using an exponential distance decay factor based on the distance. This factor assumes that the further away from the intermodal facility that the roadway improvement occurs, the less impact it will have on the intermodal facility. If you do enter a value in field **1f**, that value will be used in the calculation, rather than the default value.

Obtaining Results

To view your results:

1. At the bottom of the workbook, click the tab labeled 4–RESULTS.
2. View and print out estimated relative connectivity value.

Depending on the type of facility selected, the tool will calculate different indices. By comparing the relative connectivity value produced by different roadway investments, you can determine which provides the greatest benefits to intermodal connectivity.

This sheet shows the raw data for level of activity, value of shipment, and number of unique origins and destinations for the selected facility. It also provides the raw score of the connectivity index, before it is adjusted for the roadway improvement inputs. This sheet also provides

- The relative level of activity of the selected facility as a percentage of the highest level of activity from a facility of the same type;
- The relative value of the facility's shipments compared to the highest value of shipped goods from a facility of the same type;
- The relative number of unique origins/destinations of the facility compared to the highest number of unique origins and destinations of a facility of the same type; and
- The relative connectivity score of the facility compared to the highest connectivity score of a facility of the same type. For instance, a relative activity value of 33.8% for a freight airport indicates that the airport has an activity level (in tons) that is 33.8% of the largest air cargo facility in the country. There is no value associated with passenger modes, and thus there is no relative value associated for passenger modes either.

Additionally, this sheet also provides a summary of the project improvements. The summary includes the number of trucks or passenger vehicles annually traveling through the highway improvement segment, the total hours saved due to the improvement for all trucks or passenger vehicles, and the total value of time saved for all trucks or passenger vehicles. Using information from the Improvement Inputs sheet, the Results sheet shows the number of trucks or passenger cars associated with the intermodal facility in a year, the time savings for the facility over a year, and the annual value of time savings for the facility (see Figure 4.3). This value of time savings for the facility is multiplied by the raw connectivity value to find a weighted connectivity. The weighted connectivity score can be used to rank how different types of roadway improvements compare to each other in terms of improving intermodal connectivity.

CHAPTER 5

Accessibility

Technical Guide

Introduction and Purpose

The specific objective for this part of the C11 project research was to develop sketch plan approximations to the economic value for market access. To aid that objective, this chapter provides a technical guide for documenting the methodology and framework for (1) determining market access and (2) determining an order-of-magnitude approximation of the value of that access. It also provides instructions for using the spreadsheet tools developed for that objective.

Market access is an important intermediate determinant of regional macroeconomic change. Infrastructure investments can affect the pattern of interregional linkages, location, or expansion of economic activity, and they can also affect the kinds of activity that develop, in part, because of the implications for cost savings and productivity. The argument relies on the logic that one first needs to have access to a market before one can benefit from it. Transportation networks play a crucial role in providing systems and agents linkages in economic space via access to markets and sectors that comprise those markets. The economic value of market access can be drawn from theories of agglomeration, new economic geography, and site selection decisions of businesses. Of these, theories of agglomeration and new economic geography offer the most potential for the development of linkages between access to markets and value attributable to that access.

Access to Buyer-Supplier Markets: Objectives

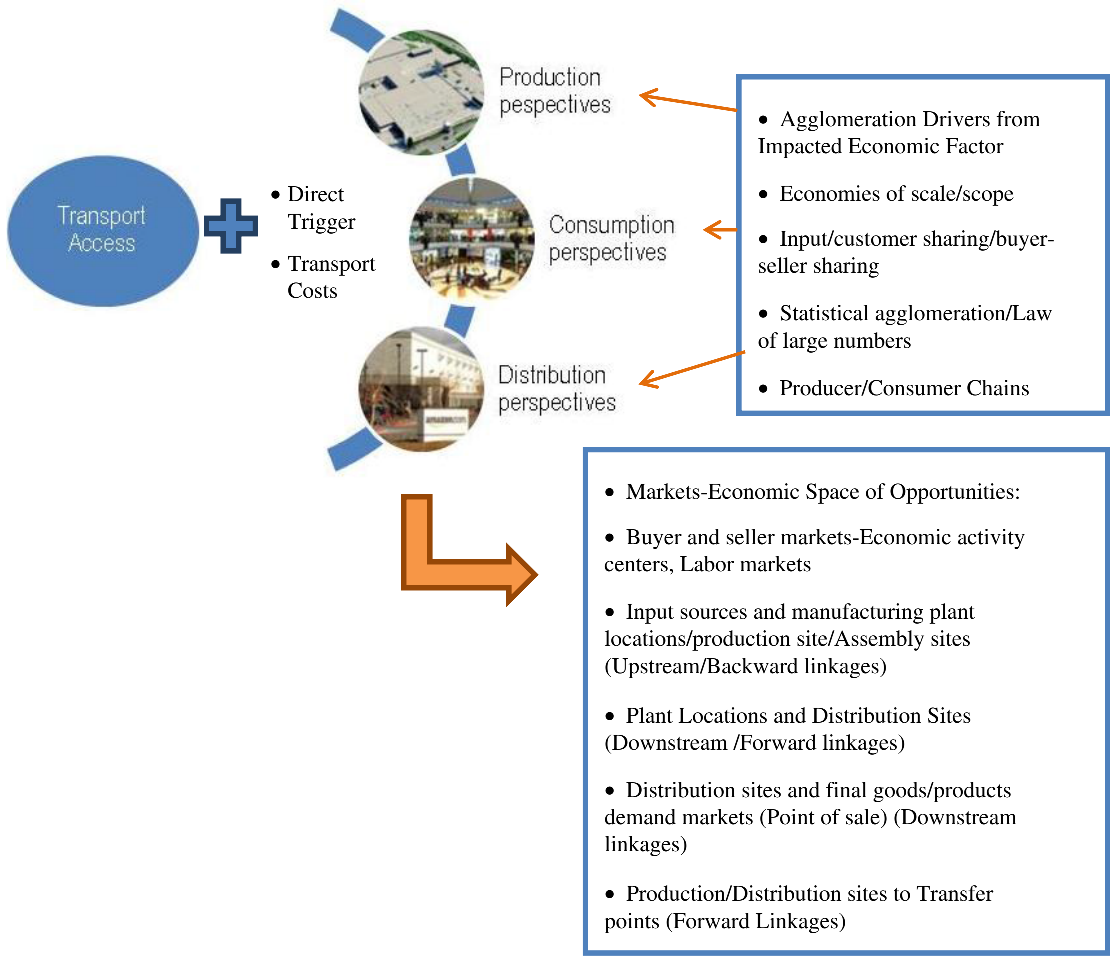
The objectives of buyer–supplier type market access measures are to provide simple tools to serve as an aid in transportation planning by allowing transportation planners and other users to do the following:

- Estimate region-based access to markets at any point in time or from a transportation improvement for a set of regions (zones). These are proxies for production, consumption, and distribution-related economic triggers (e.g., scale, scope, input matching, sharing) that may be induced by transportation improvements.
- Measure transport-induced access changes to specialized inputs (labor, in this case), which is useful when there is a specialized industry sector located in the impact region or study area.
- Facilitate market access comparisons for the same zone and impact area at separate temporal scenarios or Build scenarios.
- Facilitate market access (as performance metrics) comparisons at a given point in time across zones.
- Facilitate market access (as performance metrics) aggregate comparisons for impact area versus another benchmark or control area, data permitting.
- Provide an order-of-magnitude assessment of the potential economic implications of changes in transportation-induced access, in terms of productivity gains or losses in dollar terms for a study area.
- Provide value in corridor planning, project planning, and visioning exercises when promoting economic opportunity by emphasizing the "where" of the investment.

Framework for Measuring Market Access and Value

A broad framework for approximating the effect of market access to determine potential economic value must necessarily draw on theories of agglomeration. The framework is based on the following components:

- Identification of the relevant markets and the associated economic triggers for market access to have economic value and the user groups they are applicable to. This is encapsulated in Figure 5.1. and Tables 5.1 and 5.2.



Source: Quigley 1998 and 2008; Polenske 2003.

Figure 5.1. Highways, market access, and agglomeration drivers.

Table 5.1. Transportation, Agglomerative Implications from Production, Consumption, and Distribution Perspectives

Economic Trigger	Urbanization/ Localization	Production Perspective—A	Consumption Perspective—B	Distribution Perspective—C
Scale economies and scope	No/Indivisibilities leading to higher outputs and benefits.	Occurs within firms with larger plant sizes (industries associated with production–manufacturing). Lower unit costs.	Public goods. Diversity in consumer goods. Lower unit costs with access to larger centers (e.g., retail).	Reduction in transportation costs for large centers (distribution, terminals) (e.g., Walmart distribution center) and for cargo load bundling.
Shared inputs	Yes/Yes	Shared inputs in production.	Shared inputs in consumption of differentiated goods (e.g., amenity markets).	Lower unit distribution costs.
Transaction costs (transportation costs) and pooling labor	Yes/Yes	Lower unit costs by enhancing access to suppliers and buyers.	Lower unit prices via access customer markets and shopping districts.	Lower unit distribution costs.
Law of large numbers—statistical economies	Yes/Yes	Access to large number of suppliers/supply pooling.	Access to more markets for services goods/diversification risk associated with single buyer.	Lower unit distribution costs.
Economies of dispersion (horizontal or vertical networks)	No/Yes and dispersion	Producer chains access to specialized markets within chains.	Access to demand/distribution markets.	Reduction in distribution costs.

Source: Quigley 1998 and 2008; Polenske 2003.

Table 5.2. Transportation/Highways, Specific Markets, and Two Types of Measures to Capture Economic Value of Market Access

	Origin Market (Supplier)	Destination Market (Demand)	User Group	Measurable Direct Economic Value in Terms of Costs	Measure Type: Isochronal/Local or Relative Access/Gravity–Regional
Production	Intermediate goods: Input markets—Labor–home locations	Places of work/ Employment locations	Commuters	Economic costs associated with commuting	Access to key employment centers/work sites within reasonable commute times
Production	Intermediate goods: Input markets—Raw materials and other	Production locations	Trucks, freight	Economic costs associated with shipments	Access to key supplier sites within reasonable travel times
Production–Consumption	Final goods: Production sites	Locations of final demand: Product markets	Trucks, freight	Economic costs associated with shipments delivery and potential price effects	Access to key customer markets within reasonable travel times
Production–Distribution	Final goods: Production sites	Distribution sites/ Centers or transfer points	Trucks, freight	Economic costs associated with shipments delivery and potential price effects	Access to key customer markets within reasonable travel times
Distribution–Consumption	Final goods: Distribution sites/Warehouse sites	Locations of final demand: Product markets	Trucks, freight	Economic costs associated with shipments delivery	Access to key customer markets within reasonable travel times
Distribution–Consumption	Final goods: Distribution sites/Warehouse sites	Transfer sites such as ports, airports for reach to other domestic or international markets	Trucks, freight	Economic costs associated with shipments delivery/ Demand and price effects	Access to key transfer points within reasonable travel times
Production–Consumption–Distribution	Suppliers of the broadest variety	Buyers of the broadest variety	All	Productivity gains from input matching, sharing, learning	Zone-to-zone access between production–consumption–distribution markets (captures both multitude and attractiveness, and transportation costs). This can be put into a generalized form where it can aggregate interaction between one or more buyer/supplier centers to all other buyer/supplier centers in the study area. Gravity measure with regional access.

Note: Cost savings turn into actual economic value pending other factors like ability to substitute, pass on savings, and demand elasticity. There are also other dimensions of economic value that may be difficult to measure in predictive settings such as actual employment effects and business attraction effects. In most cases, direct value may end up partly as cost savings that are either entirely disposable income or passed on for additional value. Of course, measurement of costs also requires good data on users themselves.

- Sensitivity to transportation costs and transportation scenarios.
- Spatial scale for consideration, aggregation, and comparability.
- Spatial unit within the context of spreadsheet-driven tools.
- Types of measures and economic implications of access changes.
- Simplicity in communicating.

Relevant Types of Markets and Economic Triggers

Figure 5.1 and Table 5.1 provide useful starting points for the identification of economically relevant markets from supply-and-demand perspectives originally laid out by Quigley (1998). Table 5.1 has been adapted from Quigley's work and includes features (or economic triggers) identified by Quigley that allow us to identify the pertinent markets. It also includes dispersion economies identified by Polenske (2003) as an additional trigger. Because firms use factors in the production process (backward linkages) to provide goods and services sold in the final consumption side markets (forward linkage), transportation networks become the mechanisms for enabling linkages between those markets. Table 5.1 attempts to provide a framework for capturing the economic value associated with market access by considering (1) the economic triggers and (2) the relevant markets from three perspectives of production, consumption, and distribution. These are further refined in Table 5.2.

User Groups

The three perspectives mentioned above are known to impact all highway users (passengers and freight) since market access associated with transportation cannot occur in a vacuum. The transportation network is characterized by users: passengers (including commuters who provide labor supply) and freight (truckers in the case of highway networks). Hence, the three market types shown in Figure 5.1 and two user groups (passengers and freight) must be effectively connected in meaningful ways so that economic value may be inferred from those measures. Table 5.2 formalizes these concepts into specific markets and how they may be measured as well as the specific user groups to which they apply.

Comparison with Markets Defined in Earlier Works

Some earlier efforts have identified that, in general, there are four types of markets that can be served or expanded due to a new highway link: labor markets, sales markets, business-to-business markets, and pass-by traffic. They also note that new projects may take many forms—creating an entirely new connection between areas, improving an existing connection, bypassing certain areas, and/or improving access to certain areas. These changes, they note, can lead to any of six major economic market effects by enhancing

1. The reach of residential customer markets (approximated by change in population within 45 minutes of a local business district),
2. The reach of supplier markets (approximated by change in supply purchases occurring within a 3-hour one-way drive time),
3. The reach of labor markets (approximated by change in employment living within a 45-minute one-way commute time),
4. The reach of recreation and tourism markets (approximated by change in population living within a two-hour one-way drive time),
5. Service to pass-by traffic (traffic dependent) markets (approximated by a change in AADT), and
6. Connections to other modes (Weisbrod et al. 2001a).

The study by Weisbrod et al. also develops a spreadsheet that includes worksheets to approximate market areas by change in employment in fixed impact zones relative to a key destination site. These are then used to approximate employment growth or business attraction using a variety of sensitivities (e.g., labor or pass-by). Similar measures are also seen in other studies (Weisbrod et al. 2001b and Weisbrod et al. 2003). The markets discussed in this report include most of those shown in Figure 5.1 and also bring in distribution-related markets from an agglomeration perspective (Table 5.2 and Figure 5.1).

Sensitivity to Transportation Costs and Scenarios

For economic evaluation of transportation projects and policies, market access measures must be sensitive to transportation costs. Transportation projects serve to impact access directly through their influence on costs. It is typical to represent the ease of travel between an origin market and destination market in at least three distinct ways for evaluation: (1) travel time in minutes or hours (this is also the measure always used in traditional benefit–cost analysis); (2) distance between markets as a proxy to transportation costs (in miles or kilometers); and (3) generalized travel costs (in dollars) that could include any or all of the following: time costs, operating costs, and other incidental costs such as tolls (if applicable for travel within the target markets). These data are typically obtained from travel demand models and in other cases based on the specific measures that may also be developed with commonly available Geographic Information System (GIS) tools. In the absence of travel demand model data, sketch plan mechanisms or default skims can be used. One such default skim is the distance skims provided by Oak Ridge National

Table 5.3. Project Types, Planning Contexts, Relevant Transportation Costs, and GIS-Based Data Sources for Transportation Costs to be Used for Market Access Measures

Capacity Project Type (Line/Point)	Appropriate Transportation Costs	Data Sources	Comments	Default Public Data Sources, if any
Add New lanes/links including gateway projects providing landside access to hubs/ports	Distance, time, and/or generalized costs (GC)	Statewide, Metropolitan Planning Organization (MPO) travel demand model skims or custom skims Network layers	GC require manual estimation, if not available directly	ORNL highway skims for distances. Custom developed network distances from public domain network data such as National Highway Planning Network (NHPN) or FAF instead of straight line-distances or Statewide and MPO networks (as the scope may be)
Add New lanes/links (Tolls)	Distance, time and/or generalized costs with tolls	Same as above	GC require manual estimation, if not available directly	Same as above
Widening only	Travel time and/or generalized costs	Same as above	GC require manual estimation, if not available directly	—
Widening and Tolls (e.g., General purpose lanes and HOT lanes)	Travel time and/or generalized costs	Same as above	GC require manual estimation, if not available directly	—
Bypass	Travel time and/or generalized costs	Same as above	GC require manual estimation, if not available directly	—
Interchange/Point	Travel time	Same as above	—	—
Policy and Planning Context				
Corridor Studies for collaborative decision making	Distance, time and/or generalized costs with tolls	Same as above	GC require manual estimation, if not available directly	Same as earlier
Policies that affect transportation costs (e.g., pricing)	Distance, time, and/ or generalized costs with tolls	Same as above	GC require manual estimation, if not available directly	Same as earlier

Note: MPO = metropolitan planning organization.

Laboratory (ORNL) (Table 5.3). Similarly, network layers and zonal layers can be used to approximate distances and speed changes, both of which may be combined to provide an alternate sketch plan travel time approximation.

There are other factors besides types of costs that must be considered if transportation costs are to be of value in an evaluative context. These are shown in Table 5.3 and include the following:

- *Types of transportation projects or policies:* Some types add or influence capacity provision and can vary significantly in terms of transportation costs. Table 5.3 shows the transportation cost elements of highway project types and their linkage to market access measures. Similar concepts may also be developed for transit projects and other projects, but they are not the focus in this discussion. Enhanced connectivity to key regions, removal of access bottlenecks, and congestion alleviation have been associated with economic development or productivity implications in the past. As highways run both ways, enhanced connectivity not only provides market access to firms in lagging areas but also allows firms in leading areas to reach markets. A decline in transportation costs could help competitive firms in leading areas easily scale up production to reach these new markets at lower cost relative to local producers in other areas.
- *Transportation Scenarios—Project or Policy Baseline (No Build) and Alternative (Build) scenarios:* The impacts on market access may be examined by exploring transportation cost outcomes under Build/No Build scenarios. These may be temporally separated at different time periods (base year and a future reference year) or for the same time period.

Additionally, the scope of the project or policy (e.g., within a metropolitan region, connecting multiple regions within a state, or within a single county) would impact how the data are assimilated for assessing transportation costs.

- *Urban–rural configuration:* For instance, connectivity projects that link rural–urban areas (or periphery–center areas) are best assessed using a variety of costs to reflect the shrinking of distance and its relation to change in access to economic markets.
- *Congestion:* Congestion relief projects influence travel times for commuters and freight. In such cases, time-of-day factors (peak, off-peak) also influences transportation costs and market access (Weisbrod et al. 2001b, for instance, discuss how congestion affects access for the National Cooperative Highway Research Program).

Spatial Scope/Scale of Analysis, Aggregation, and Comparability of Measures

In order to measure market access, it is necessary to consider the following factors: (1) impact areas and (2) spatial scales for influence.

1. *Impact areas or study areas.* These are typically defined and developed by the nature and scope of the project itself for measuring travel costs and/or activity and to measure market opportunities. Impact areas developed based on travel sheds of system users will allow a direct linking between important supply-and-demand markets and locations within that region. Line and point investments may be evaluated using fixed impact areas defined by travel sheds or typical boundaries considered in corridor studies. Bypasses could require a large impact area compared to other line investments to account for spatial redistributional effects. Large-scale projects with network effects and regional policies are best evaluated for all zones that are included in travel demand skims.
2. *Comparisons over space and time.* Market access measures must be comparable within and across regions at any given time, if they have to be used in an evaluative context. For instance, gravity-based measures may be obtained for individual regions but may be aggregated for all spatial units in a study area and compared to the control area. Region scores may be also benchmarked to a maximum score in the study area and discussed in relative terms. Finally, they should also be temporally comparable if they have to be used in an evaluation context—a technicality being that temporal comparisons of measures must be able to tease out net contributions of transportation-induced access from gross contributions of access and activity changes (such as labor population) to see the value-added access.

Spatial Unit for Determination of Measures—Context within Spreadsheet Delivery Format

The *spatial unit for determination* is set at the zonal level for which skims are developed (county, tract, or Transportation Analysis Zones [TAZ]). This is the most suited unit within the context of tools developed in a spreadsheet. All of the isochronal measures indicated in Table 5.3 present a difficulty in terms of delivery in spreadsheet format since the “impact zones” themselves are not independent of the use of GIS. In other words, GIS-network analysis functions aid in identifying these impact zones, also known as market areas. There are several commercial GIS tools that have this part of the functionality.

The reliance on the “zone,” as a unit, arises within the context of spreadsheets and avoids the practical difficulties of having to identify the universe of potential markets and locations (which in reality could be millions of locations). A second advantage of keeping the unit of analysis as the zone for both gravity and isochronal measures is that it ensures that the spreadsheets do not become overly complicated.

Types of Measures and Economic Implications of Access Changes

Table 5.2, Column 6, proposes two types of measures of market access to address all three market types and also discusses how the value of those markets may be approximated. The two measures are as follows:

- *Access to Buyer–Supplier Markets (Customer Base).* This measure is a broad-based regional measure that aims to approximate productivity gains from all economic triggers and sources listed in Table 5.1, column 1. Transportation projects affect transaction costs and alter the potential for businesses, regions, and individuals to reap the gains or losses from other economic triggers that may be activated. For instance, transportation costs shrink the economic space, reduce the difficulties associated with transacting in that space, and may lead to productivity gains. This measure assumes that connectivity to market centers is important and suggests that improving linkages between firms and those centers within the region may lead to productivity gains. While the actual magnitude of effect is still debatable, there is ample evidence to suggest access to economic mass is associated with positive productivity gains.
- *Access to Markets at Demand Sites as a Local Measure.* This measure suggests that there should be as many separate measures as there would be user group “suppliers” and “demanders” or “destinations.” Table 5.2 identifies six categories of this type, all of which may coexist at the same time in any given situation based on the specific regional context

of an improvement. The report focuses on the tool development of one specific input market in the production process—labor at demand sites—employers or work sites. In this case, a transportation improvement is considered as leading to transportation cost reductions, which in turn implies cost savings in travel time to commuters (labor inputs). These commuter cost savings may lead to higher labor productivity associated with the work sites as long as commuters are able to pass on some cost savings to employers. If not, cost savings end up as changes in personal disposable income.

In the works of Weisbrod et al. (2001b), all the markets are measured as isochronal or contour measures, with reference points such as business districts, to anchor the measurement of highway-induced access change from every zone in the drive time area to the anchor district or zone. These market accessibility changes are combined with business sensitivity factors (e.g., worker dependency, freight sensitivity, pass-by dependency) to approximate the extent of potential business cost reduction or revenue expansion for each type of business.

Simplicity and Value in Communication

The framework is driven by a bottom-up approach consistent with the access for actors (users and freight) on one hand, and what is easy to understand and communicate on the other hand. Gravity measures are useful because they are consistent with economic theory. Such measures are increasingly finding their way into evaluation contexts internationally and are part of many regional models. Cumulative opportunity measures of daily access appeal directly to both the user group and end users. Visual maps of both types of market access measures can serve as valuable communication tools for scenario analysis, policy assessments, and corridor studies to share with economic development agencies and other interested stakeholders. These visual maps can only be developed with GIS tools either in the private domain (such as ESRI and others) and/or open-source tools. However, the economic value can, at present, only be approximated using the tools developed in this report.

Both of the toolkits discussed in this section were developed as Excel spreadsheets. As noted earlier, this formulation required that the research team first develop the tools using zones as the appropriate reference point for assessing markets from a practical standpoint. The second guiding criterion for the tools is built-in flexibility to accommodate zones of any type, including user-defined zones, so that the sheets could be used for any setting in any location. The third criterion is the development of tools around a framework that could lend itself to being expanded to accommodate more markets or users as the case may be. The fourth and final criterion is simplicity in use and built-in charting capabilities.

Specification of Inputs

Access to Buyer–Supplier Markets Inputs

Gravity and isochronal measures require zonal activity data as land use inputs to reflect appropriate markets at the zone level. These may include total population, total employment, or sectoral employment. (The activity unit could also be a ratio of the desired employment group to total employment in any zone.) Activity data are needed for the base year and year(s) for which the analysis is intended to be carried out for all of the zones in the impact area. Table 5.4 provides a list of population, employment, and labor force-related public data sources and also distinguishes how the activity units are classified, by place of work and/or place of residence. This analysis recommends that if the links to economic value are to be made, then it is more appropriate to use place of work to the extent possible.

Several private forecast data sources may also be used that provide pertinent data, including but not limited to Woods and Poole and Global Insight. Many census-related databases are now moving to provide high-quality base year data online, accompanied by customized mapping (such as the On-the-Map application) to make better quality free data available to make this process easier.

The choice of activity inputs, the corresponding decay parameters, and the elasticities require an understanding of the industry mix in the study area. The more diverse a region, the better positioned it is to use total population and/or total employment in your study. If, however, there is evidence of industry specialization in one or more sectors, it is better to use sectoral employment to approximate market access for those sectors.

Impedance Inputs: Skim matrices (impedance matrices) are required for a baseline scenario and an alternate scenario. The skims can be typical travel time skims, distance-based, or based on generalized costs of transportation. The last option is used when monetary costs come into play. When travel times are used for the analysis, they should be obtained from assignment models as they consider the demand between all locations into equilibrium travel times. While it may be very difficult to obtain separate times and/or costs for passengers or truckers, it may be possible to recognize that freight costs are different than passenger costs and could include additional components (i.e., user type and/or trips differentiation is possible). The default mechanism is still to start off with the premise that costs are identical for all user classes—this is what all travel demand models provide, and in such cases, the analysis is really applicable to all trips.

Table 5.4. Public Data Sources for Gravity and Daily Measures of Market Access

Market Access Measure	Data	Public Data Activity Sources Base Year	Base/Future-Forecast Years	Place of Residence/ Place of Work
Potential Access	Employment/Population	1. Census Tape Files, Metropolitan planning organizations (MPOs) demographic layers and other 2. County Business Patterns and Bureau of Economic Analysis through FedStats 3. American FactFinder—Population, Employment	Base year of analysis and forecasts Forecasts from MPO or private sources for years for which scenarios are developed	Place of Residence (Proxies Potential Work Force) Place of Work (actual workforce)
Effective Density	Employment typically (but population may be used also)	Employment by place of work—Longitudinal Household Employment Dynamics (LHED) On-The-Map Data (LHED) (allows online GIS visualization of data) ESRI's core data	Base year of analysis and forecasts Forecasts from MPO or private sources for years for which scenarios are developed	Place of Work (actual workforce) Varies
Daily Access—Labor Market	Employment	LHED—By place of residence and place of work by sector and worker quality	Base year data and forecast year data	Place of Work
Daily Access—Labor Market	Commute Thresholds	Census Transportation Planning Package/American Community Survey	—	Not applicable. In-house surveys or private sources

Access to Specialized Labor/Worker Inputs/Employers Inputs

Specialized labor markets refer to labor pools of skilled labor that provide labor related inputs in the business or production process. These employee/worker markets could envelope several individual categories, including but not limited to the following:

1. Industry-specific employment (or labor force in a specific industry sector).
2. Labor force of a specific occupational category.
3. Labor force of a specific skill level, age group, or other category.

When labor is a critical input in the firm's production process, access changes to work sites (employment locations) may lead to changes in the commuting costs and labor productivity under certain assumptions. Commuters who travel to work provide the supply markets to those who demand it, the firms or work sites. Henceforth, these work sites will be denoted as *employment centers* in this report. Transportation projects that improve travel times or shrink distances for commuters can enhance the reach of employment centers to additional specialized labor pools, or even the other way around, enhance the reach of markets to workforce. At least two studies have used cumulative opportunity measures with critical threshold travel commute times in connection with labor productivity implications (Prud'homme and Lee 1999, Matsuo 2008).

An isochronal daily accessibility measure of labor markets, as an input in the production process, is proposed in Table 5.2. This set of measures reflects the behavior of users (employees and commuters) in terms of how far commuters and users are willing to travel to work sites. It is simple enough to serve as a basis for both communication as well as visualization. However, improvements to employment locations and work sites could enhance productivity by linking markets to the suppliers (commuters) and be associated with other spin-off effects. This does require assumptions on how much is internalized by commuters and how much is passed on to firms and is supported by some empirical evidence on commuting wage differentials.

This measure, being a cumulative opportunity measure, simply indexes the accessibility of labor force according to the number that can be reached from the work site within meaningful travel distances or times. The measure is not without caveats, especially the treatment of all zones identically within the contour. However, it is presented on the basis of its conceptual simplicity. It is defined by a very sharp decay (as a special case of a gravity measure and using a general decay function $f()$ it can be measured as shown in Equation 5.1.

$$f(d_{ij}) = 1 \text{ if } d_{ij} \leq \text{threshold (e.g., 30 minutes), or}$$

$$f(d_{ij}) = 0 \text{ if } d_{ij} > \text{threshold (e.g., 30 minutes)} \quad (5.1)$$

Output and Calculations

Access to Regional Markets (Output and Calculations)

The outcomes for both gravity-based market access measures presented in this report can be represented using scores as metrics for individual zones (market proxies). These scores can be aggregated across zones in a study area and can be developed for any transportation scenario. They can be compared to each other and also time periods.

Gravity Measures for Assessing Regional Access to Markets

This section discusses the various elements of the "Access to Customer and Labor Markets" measure. The tool approximates region-based access from transportation improvements as guidance for transportation planning. Regions may be defined by using census geographies (Counties, Census Tracts, and Block Groups, Blocks, or other geographies such as TAZ) and even user-defined geographies. A powerful way of measuring the regional market access of geographies is a gravity-based measure that combines both the network and the producer, consumer, and distributor markets as encapsulated by the surrounding land use. This form of linking is very much in the tradition of new economic geography models, where market potential functions made their appearance as a way to describe changes in economic geography. Gravity measures assume that the potential for economic activity at any location is a function both of its proximity to other economic centers and of their economic size or "mass." The analogy with the law of gravity is explicit in that the influence of each center on the "economic potential" of a location is assumed to be directly proportional to the volume of economic activity at the former, and inversely proportional to the travel cost separating them. The economic potential of the location is found by summing the influences on it from all other centers in the system. Trip making effects of most new infrastructure are often inversely related to distance, and more trips at shorter distances are observed than longer distances, hence gravity measures may seem a good approximation of access to markets (even though they are not so intuitive).

Market Access Performance Measures to Assess Planned Projects

This tool uses a Hanson-like gravity-based representation for highway-induced access based on a fixed functional form—inverse distance for measurement of market access for the time being. The measure, based on employment and population, can be used to approximate external economies of scale and scope that may be brought about due to large transportation investments. Such measures of market access account for both the transportation network as well as surrounding land use (Handy and Niemeier 1997). Planners can also use these metrics to facilitate comparisons across zones in a variety of spatial and temporal settings. To that extent, these measures can be used as performance measures.

Effective Density

Effective density (ED) (see Equation 5.2) is one such measure and is synonymously used as a measure of accessibility to employment (place of work employment) as the activity unit. This measure, originally proposed by Graham (2007), has become incorporated in the United Kingdom's (UK's) Department of Transport (DFT), and it was the UK's sole measure of accessibility used to approximate agglomerative implications from transportation projects. The effective density (Graham 2007) of employment or population accessible to any firm in industry o located in Zone i as given by an inverse power function gravity measure is shown in Equation 5.2.

$$\text{Effective Density} = \text{Scale Factor} + \sum_{j}^{i \neq j} \frac{E_j}{d_{ij}^{\alpha}} \qquad (5.2)$$

where
E_i = the employment in Zone i;
E_j = the total employment in ward j;
d_{ij} = the impedance (distance, time, or generalized cost) between i and j; and
α = the impedance decay parameter.

The scale factor is defined by scale factor as calculated in Equation 5.3.

$$\text{Scale factor} = \frac{E_i}{\left(\sqrt{\frac{A_i}{\pi}}\right)^{\alpha}} \qquad (5.3)$$

where
E_i = the respective activity of the zone for which effective density is calculated;
A_i = the area of the zone for which effective density is calculated; and
α = the impedance decay parameter.

ED may also be estimated at the sector level using sectoral employment (at present, only one functional form is considered). Since transportation networks alter local access, the scale factor may be important in evaluating highway projects.

Potential Access

Potential Access (PA) is identical to ED when the scale factor is suppressed and the activity unit is set to population or employment. Similar to PA, Drucker and Feser (2012) propose a region access to labor pools, using the shares of sectoral or specific type of employment to total employment instead of employment or population as in Equation 5.2.

ED and PA Approximate Buyer–Seller Markets

Both measures are identical (with the exception of the scale factor) and both approximate markets through land-use-based activity proxies. Higher density of activity (e.g., population, employment) are assumed to imply more, bigger markets or activity centers that bring buyers and sellers together and also allow for greater input matching, sharing, and learning. Further, Keeble et al. note that the mass or activity component in these measures could be conceived as “a broad surrogate indicator of possible markets for traded goods and services, of input sources and opportunities for component linkages, of the availability of commercial information and business service. . . .” and that “. . . the index should seek to measure regional accessibility to economic activity in terms of transport costs of all kinds . . . rather than narrowly or simply as transport costs of the type implied by traditional Weberian industrial location theory” (Keeble et al. 1988). If the focus is only on the change, then either of the two measures may be used.

Economic Implications of Change in Market Access—Productivity

Equation 5.4 expresses productivity implications from changed proximity to denser markets (Graham and Van Dender 2011), population, and/or centers of economic activity (external economies) through a shrinking of space for all zones in the impact area (*P*).

$$P = \sum_i \left[\left(\frac{E_b}{E_{nb}} \right)^{\mu} - 1 \right] \times \text{per worker}(\text{GRP}_i) \times E_i \qquad (5.4)$$

where

P = impact area;
E_b, E_{nb} = the effective densities or potential access measures for a project Build (*b*) scenario and a project No Build (*nb*) scenario;
GRP_i = per employee gross regional product in Zone *i;*
μ = an elasticity or response parameter reflecting response of productivity to changes in market access; and
E_i = total employment activity in Zone *i.*

This equation can be used to compare economic outcomes from large or small changes in access or for small or large time intervals. Analogous to benefit–cost analysis (BCA), the Build and No Build scenarios may refer to a base year (*t*) and a reference year (*s*) with $s \geq t$.

μ—Elasticity of Productivity

In the implementation of ED and PA-related productivity outcomes, the DFT guidance does not differentiate between investment types and suggests using the same value for all types of investments, new or improved. Under such a rule, adding investments will continue to add value as long as access benefits are positive. Two factors impact the choice of elasticity: (1) the activity unit used in access measurement—population, total employment, or sectoral employment—and (2) whether it is a completely new link versus an improved link. Other things being equal, it is well documented that the potential economic outcomes from subsequent investments are typically lower. However, further work is needed to ensure the robustness of measures and specification for intra-urban settings. In such cases, the value of μ is to be treated identically to a sensitivity parameter and the base value must be lowered. The value of μ also depends on the activity unit. If the activity unit for the market access and productivity assessment is sectoral employment, then μ must reflect productivity responses for that sector—current estimates are guided by studies that are either dated or pertain largely to the manufacturing sector (Graham 2007 and Melo et al. 2009). If the interest is only in changes in access, μ may be set to 0 and the residual outputs of productivity may be ignored.

α—Estimates of Decay

Estimates of α (distance or cost decay) are required. α (alpha) is a behavioral parameter. Those with access to MPO travel demand models may use the data from those models to calibrate decay. However, this is impractical in most cases, because most planners and users often may not be able to invest time and resources into this effort. Simple rules of thumb must guide the effort, followed up with sensitivity analysis since the results of these measures are sensitive to this parameter. These rules of thumb should include average trip lengths for the study area if (1) most of the trip lengths for the study area are short, then alpha is typically higher than 2 and could even go as high as 5 or 6 (should most of the trips be longer trips, then, alpha is lower); or (2) the study area is categorized by specialized industries (industry related alphas vary and it is more appropriate to treat the activity in these industries separate from other sectors, which may be combined). Most studies sidestep the issue altogether and set this value at 1 (Gutiérrez 2001). The data in this report suggest that this parameter and the results must be subjected to sensitivity tests. Higher values of alpha place more emphasis on markets in close proximity, while low values of alpha place more emphasis on markets farther away. As an example, if alpha = 1 and using distance as an impedance variable, activity at a market that is 5 miles away has 1/5th of an impact relative to activity at a market that is just 1 mile away. With a value of alpha = 2, the 5-mile market only has 1/25th of the impact. Clearly, the value of alpha has much to do with economic connectivity between markets and associated trip making behavior and will vary region-to-region. Given this uncertainty, the best approach to the alpha is to develop a sketch plan assessment of the alpha based on commuting profiles for the region.

Determine Economic Implications of Planned Investments

Not all investments can generate equal returns since regions are fundamentally different in their economic landscape. Even within regions there are significant differences. The market access measures combine density, speed, and other network attributes into simple constructs that can be used by transportation planners and engineers to understand the potential broader economic implications of planning transportation investments. The broader economic measure is a baseline assessment of potential productivity gains and/or losses attributable to transport-induced access changes only. Simply, higher levels of access (regardless of type) to key markets are more conducive to economic opportunity than lower levels, all other things being equal (*ceteris paribus*). The productivity estimates obtained from this toolkit developed in this report are an order-of-magnitude estimate.

This toolkit is helpful for project evaluation that induces significant change to the structure of the regional economy, such as connectivity projects or new improvements (with or without tolls); planned network improvements; and improvements—widening (with or without tolls).

When the Gravity Measure Is Appropriate

The use of these measures is justified where it is relatively easy to develop or extract required travel demand data inputs from MPO or statewide planning models, from pre-calculated skims like those provided by ORNL, or user-created impedances from networks. They are not recommended for small, local projects. Furthermore, it is important to have background understanding of the regions and the industries that serve those regions to the extent that they influence trip making behavior of passengers and commuters and freight. The U.S. Department of Agriculture Economic Research Service (USDA-ERS) provides a typology that helps understand and analyze industry concentrations. Additionally, the Bureau of Economic Analysis also provides several resources that allow one to understand industry specializations for county-based regions using location quotients. The more diverse a regional employment base, the more important it becomes to analyze gains in those industries separate from specialized sectors.

Value in Corridor Studies, Visioning, and Alternatives Analysis

The measures developed are also useful for corridor planning studies to identify projects for inclusion in metropolitan transportation improvement programs and statewide improvement programs or for corridor studies, in general. Corridors typically have study areas that are anchored by transportation routes and can serve multiple jurisdictions and modes. They connect population, customer, seller, labor and work markets, and they have a core focus of facilitating movement between markets.

Access to Specialized Labor/Worker Inputs/Employers (Output and Calculations)

First, as a departure from previous work in this area, firm access to labor markets is measured by three metrics using an isochronic formulation with three elements:

1. Change in the effective labor market area in terms of the number of accessible zones for the threshold, measured by change in the number of zones in the Build and No Build scenario.
2. Change in the available workforce at that threshold travel time, measured as the change in employment in the Build and No Build scenario.
3. Change in the threshold of specific concentration indices (Equation 5.5), approximated as threshold of specific location quotient for the sector selected.

Both metrics 1 and 2 are highly visual concepts in that they may be visually communicated to stakeholders. Metric 3, concentration measures, on the other hand, is very industry-specific and of greater value for specialized industry sectors. In order for the indices to be useful for competitive advantage of regions or to be meaningful, it is important to consider all pertinent centers. All metrics may relate to the ability of enhanced matching between employers and employees/commuters and reduction in search costs.

$$\mathrm{CI}_{k,\mathrm{threshold}} = \frac{E_{j,\mathrm{threshold}} \Big/ \sum_j E_{j,\mathrm{threshold}}}{\sum_k E_{j,\mathrm{threshold}} \Big/ \sum_k \sum_j E_{k,\mathrm{threshold}}} \qquad (5.5)$$

This metric is a proxy for the strength of agglomeration with feasible work commute times and distances that may be influenced by transportation projects and has been used to assess and confirm the potential for transportation-induced firm relocation (Bok and Oort 2011). Hence, the Concentration Index (CI) could be a useful predictor for positive economic implications in terms of business attraction when the time periods in comparison are not too far removed and as long as the economic climate in the region can support the higher availability of workforce.

Much like gravity measures, these measures may also be partitioned and customized to study daily access changes with respect to the following:

- Special categories of workforce (quality differentiators such as age group, sector, and occupational categories), as long as public domain or private data sources may be leveraged for this purpose.
- Effects of congestion and time-of-day effects through the consideration of daily time-dependent travel times.

These metrics are part of Toolkit 2. Toolkit 2 serves as a complement to Toolkit 1, Access to Markets. Toolkit 2 is important when (1) the transportation link serves an important role in work commute—linking place of work to place of residence—to work sites and (2) the study area is specialized in specific industry sectors.

Finally, a fourth metric is change in commuter costs. The economic value associated with changes in labor markets to work sites can be approximated by changes in commuter costs. These commuter cost changes may only be partially internalized by commuters and firms, leading to changes in labor productivity. The standard rule-of-half has been adapted to provide estimates of commuter cost savings for both passenger commute trips and business trips coming into the employment centers. For any trip type (personal, work, commute, or business) the weighted costs are assessed using Equation 5.6 (Commuter Costs Change). This outcome is provided as an optional outcome measure and is most reliable when good quality information is provided on commuter trips for work to the employment centers. The analysis, however, allows one to enter as a default the origin–destination daily trip table matrix using the home-based work trip purpose or a more appropriate user class.

$$1.2 * \left(\frac{w_1 + w_2}{w_1}\right) * \text{value of time adjustment} * \left(C^0_{ij,T} - C^1_{ij,T}\right)\left(T^0_{ij,T} + T^1_{ij,T}\right) + 1.2 * \left(\frac{w_1 + w_2}{w_2}\right) * (\text{value of time adjustment}) * \left(C^0_{ij,\text{OT}} - C^1_{ij,\text{OT}}\right)\left(T^0_{ij,\text{OT}} + T^1_{ij,\text{OT}}\right) \quad (5.6)$$

where

C^0_{ij} = cost between origin (i) and employment center (j) before investment;
C^1_{ij} = cost between origin (i) and employment center (j) after investment;
T^0_{ij} = demand (flow) between origin (i) and employment center (j) before investment;
T^1_{ij} = demand (flow) between origin (i) and employment center (j) after investment;
T = the commute threshold;
OT = outside threshold average commute threshold;
w_1 and w_2 = weights (average trip length or time);
value of time adjustment (personal commute trip) = assumed at 50% of the wage rate per U.S. Office of Management and Budget (OMB); and
value of time adjustment (business trip) = assumed at 100% of the wage rate per OMB.

The suggested percent allocations for valuation of travel time savings can be user-specified. However, these are the percentages the research team recommends. Finally, factor 1.2 is an assumed constant for automobile vehicle occupancy. These costs are annualized for the entire year using 260 work days in the year. At present, only time related costs are considered, and subsequently, vehicle operating costs could be considered.

GIS Usage for Visualization of Study Area, Data, and Measures

Study Areas and Data

GIS provides the natural mechanism to showcase the study area around the project and its economic characteristics, including locations of buyer and supplier markets. Locations of major consumer markets such as city and population centers and metro regions can now be mapped with relative ease. Similarly, there is an ongoing revolution in GIS-led data visualization effort for most Census Bureau data that allows viewing study area general characteristics and allows for enhanced graphics and mapping. An excellent example is the Census Bureau's On-the-Map application (http://onthemap.ces.census.gov/). Similarly, the USDA-ERS also provides excellent data.

Measures

Using GIS for developing market access measures, like those discussed above, has a number of advantages:

1. Assessment of transportation options is easy, as represented by a digital road network;
2. Data can be handled in a generally more flexible way, including a wider range of options for integration of data and other types of measures from different sources; and
3. It enables cartographic presentation of results, which again opens for visual interpretation and error assessment.

None of these are currently possible within a spreadsheet environment. Beyond charts, all the outputs from these tools will need to be exported to GIS tools to aid visualization.

Figure 5.2. Study area.

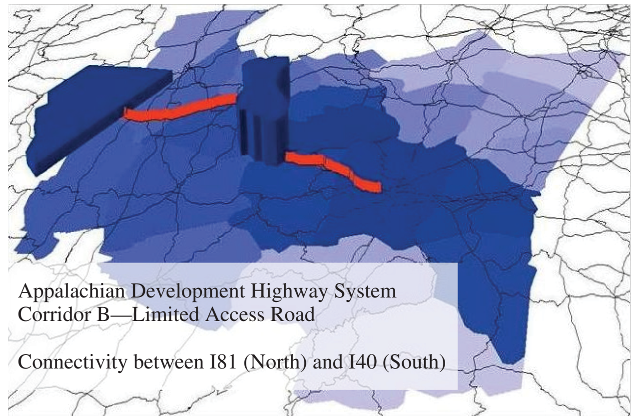


Figure 5.3. Illustration of gravity market access to customer/labor markets showing two county markets with higher gains in access relative to other region markets in the study area. This illustration is an example of Appalachian Development Highway System—Corridor B Rural–Urban Connectivity. Counties with higher gains are shown in 3-D and in the darkest shading.

Illustrations of a study area and market access visualization are shown in Figures 5.2 through 5.4. Figure 5.3 demonstrates the gravity representation for a rural–urban connectivity project in the Appalachian region. Figure 5.4 refers to access of work sites to commuters in an urban area such as Houston (Harris County). The depictions presented in Figures 5.3 and 5.4 illustrate the market reach of employment centers at various commute time thresholds.

Future Research

Subsequent improvements are certainly warranted to these measures and tools. Future versions should be able to

- Automatically visualize an inherently spatial distribution of an improvement.
- Consider other types of functional forms.

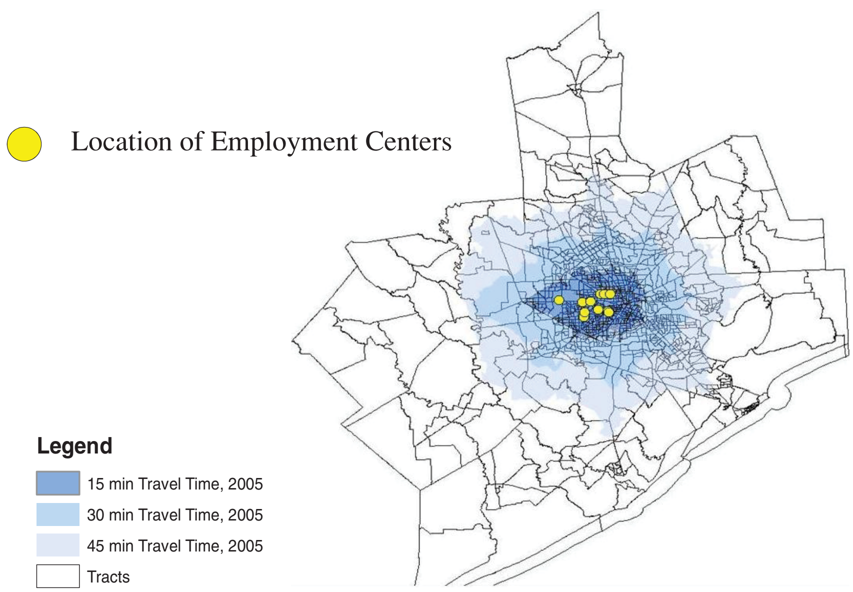


Figure 5.4. Illustration of access to labor markets in an urban area showing accessible market areas for 15, 30, and 45 minute commute times. This illustration is an example of* Houston *Galveston Area Transportation Improvements No Build Scenario, 2005.

- Consider other types of costs that could be linked to economic outcomes.
- Extend to consider freight markets.
- Consider actual case implementation of these tools in a variety of settings.
- Consider planning applications and exercises of these measures in specific applications such as corridor studies.
- Consider development of toolkits within a GIS environment, in order to integrate the calculation, mapping, and viewing all within the same framework.
- Explore further within the context of traditional benefit–cost analysis.

Access to Buyer–Seller Markets Module User's Guide and Instructions

Introduction and Purpose

Disclaimer

This tool is designed to provide preliminary guidance for computing market access to customer and labor markets at the regional level for a base year and a reference year resulting from a new or improved transportation improvement affecting those regions. Three measures of access are provided, which can all be developed for any impact region as performance measures and may be used in planning exercises. The tool can also be used to generate an "order of magnitude" economic implication in terms of potential productivity gains from transportation strategies. The results provided by this tool should not be used as the sole basis for making a decision on a project, since other factors can lead to economic impacts. If the results of this tool are positive, the implementing agency may take it as only one indication of the likely effects from an anticipated project from access changes and must temper the result with local knowledge on market conditions for inputs and products. For instance, higher levels of input access are meaningful if firms can actually utilize those additional inputs. This same tool may be used for any number of zones for measuring market access of a given zone with its neighbors; however, this tool is not appropriate when the number of regions (zones) exceeds 30. Users with more than 30 zones are urged to conduct sensitivity analysis and assess the robustness of outputs.

Objectives

The objectives of this tool are to serve as an aid in transportation planning by allowing planners to

1. Estimate region-based market access at any point in time or from a transportation improvement for a set of regions (zones). These are proxies for scale economies that may be induced by transportation improvements. To that extent, the tool allows the calculation of two proxy measures of general market access: ED and PA.
2. Measure transportation-induced access changes to a specialized labor pool, which is useful when there is a specialized industry sector located in the impact region or study area. The measures can be used as stand-alone performance measures.
3. Facilitate market access (as performance metrics) comparisons for the same zone and impact area at separate temporal scenarios and/or Build scenarios.
4. Facilitate market access (as performance metrics) cross-sectional comparisons across zones.
5. Facilitate market access (as performance metrics) aggregate comparisons for impact area versus another benchmark or control area, data permitting.
6. Provide an order-of-magnitude assessment of the potential economic implications of changes in transportation-induced access in terms of productivity gains or losses in dollar terms for a number of user-specified zones and years.
7. Provide value in corridor planning, project planning, and visioning exercises to promote economic opportunity under the condition that this performance measure is only one of the requisites for ensuring positive outcomes from transportation investments by emphasizing the "where" of the investment.

For an in-depth discussion of what this tool is, what it can provide, and when it should and should not be used, refer to the technical guide at the beginning of this chapter.

Entering Inputs

Introduction and Purpose

This toolkit is currently highway-mode-oriented but could be extended to include transit as long as travel times reflect transit.

When the Access to Buyer–Seller Markets tool opens, a brief set of instructions displays, describing which tabs to enter data into and how to use the Results tab. To begin entering data, click the tab labeled 2–Data Entry and follow the instructions listed by each button.

In this worksheet, activity is a representation of economic markets (customer, buyer, and product-based markets as well as inputs and seller markets), which are linked together in space through transportation networks. Activity data may include total population, total employment, or sectoral employment. If you want to know how access to a specific regional labor pool will change, the activity unit could be a ratio of the desired employment group to total employment in any zone. Activity data should be for the base year and years for which the analysis is intended to be carried out for all of the zones in the impact area. These data are available from a number of public and private domain sources. The current capability of this tool allows you to analyze two time periods for which there are corresponding skims. You may also obtain some of these activity inputs if you have access to trip generation data or you can easily assemble it from other sources.

In this worksheet, the time inputs are set for facilitating comparisons between two time periods. These time periods are referred to as *base year* (a time period that reflects a situation that can be considered a baseline do-nothing or No Build scenario) and *reference year.* The reference year corresponds to a do-something or Build scenario and is typically a year that could be the same as the base year or a year in the future. The base and reference years correspond to the time frames and scenarios for the No Build and Build scenarios from the accompanying travel demand models. A multitude of scenarios may be developed for comparison and evaluation.

Set Impact Area

In this exercise, the impact area is set to be the 6 abutting counties and the first order of adjacent neighboring 16 counties (Figures 5.5 and 5.6). Other methods may be used to set impact area such as those based on commute thresholds, buffer set regions, or yet other measures.

Parameter Inputs and Other Specifications

To input parameters and other specifications:

1. On the tab labeled 2–DATA ENTRY, click **Parameters and Selections.** The **Parameters and Inputs Section** page displays (Figure 5.7).
2. Enter information into the fields for **Impedance Decay Factor**, **Base Year of Analysis** (which is usually a No Build scenario year), **Reference Year of Analysis** (which is usually a Build scenario year), and **Productivity Elasticity**.
3. To calculate results, select either **EFFECTIVE DENSITY** or **POTENTIAL ACCESS**.
4. To save the parameters and selections, click **Save the Parameters in the Spreadsheet**.

When you are finished, click **Close.** All inputs and selections are saved automatically in the worksheet tab labeled 3–PARAMETERS. See Figure 5.7 for example.

As mentioned before, this tool uses a Hanson-like gravity-based representation for highway-induced access based on a fixed functional form. For a discussion of this topic and inputs such as ED, PA, Distance Decay, Productivity, and Elasticity of Productivity, refer to the technical guide at the beginning of this chapter. Table 5.5 presents suggested elasticity ranges to use in evaluations.

Entering Activity Data (Employment or Population)

If the number of zones is less than or equal to 10, enter activity data. If using the user-friendly window (shaded in blue on the

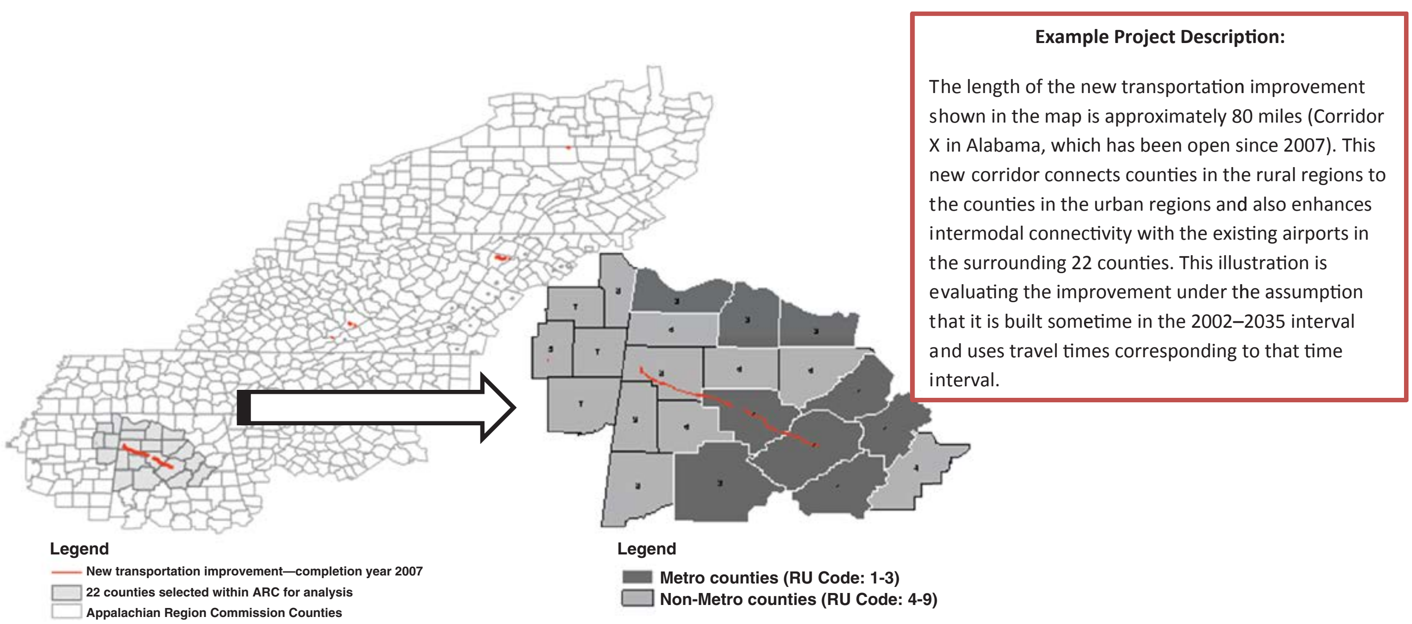


Figure 5.5. Effective density calculation tool: Spatial location of the study area (22 counties with Economic Research Service [ERS] defined rural—urban [RU] continuum codes around Corridor X). Corridor X is the ARC region. (Project type: New Link; project location: varies, urban–rural.)

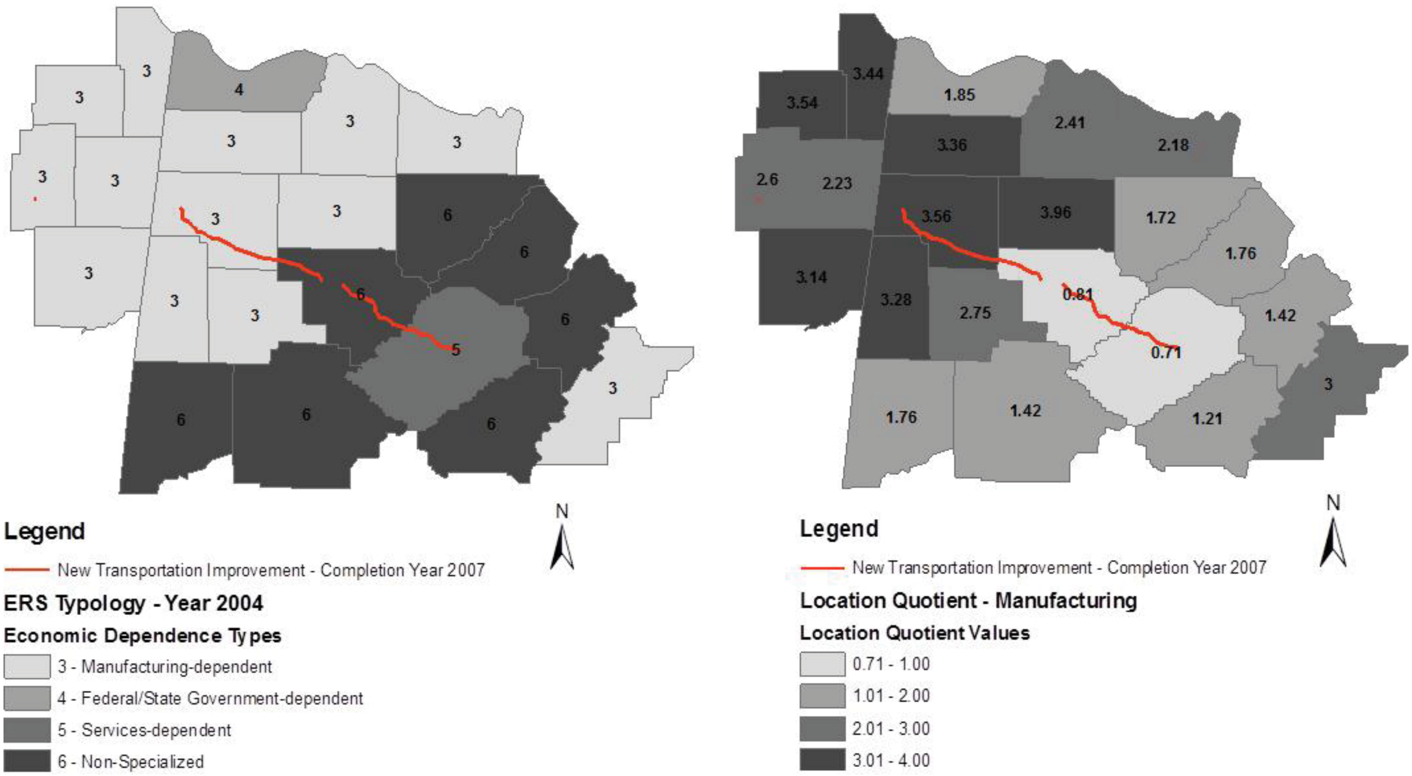


Figure 5.6. Study area economic evaluation: ERS typology and location quotient for manufacturing for the study area.

user's screen), type zones and their activity value, 10 or less. The zones and the corresponding data get printed automatically.

For the other option, when the number of zones is more than 10, the spreadsheet displays the tabs titled 4–INPUT ACTIVITY NO BUILD and 5–INPUT ACTIVITY BUILD. In this worksheet you must enter information about zones and their activity levels, either by directly entering values or by copying and pasting values from elsewhere in the spreadsheet, as shown in Figure 5.8. A similar procedure is required for both the Build and No Build scenario.

Impedance Inputs

Skim matrices (impedance matrices) for a baseline scenario and an alternate scenario both need to be entered into the tool. The skims can be typical travel time skims, distance-based, or based on generalized costs of transport. The last is used when monetary costs are the method of measurement for transportation impedance. These skims can be obtained from the MPO (projects within MPOs) or state DOT (statewide focus). For generalized costs, all skims need to be monetized to facilitate comparisons, especially when tolls are involved. When using skims, it is important to ensure that intra-zonal (diagonal) elements are not zero when entered into the worksheets and an accurate representation of intra-zonal distances, times, or generalized costs is estimated.

When travel times are used for the analysis, they should be obtained from assignment models, because the models consider the demand between all locations into equilibrium travel times. Those conducting the analysis should be mindful of the following when obtaining skims:

- Spatial resolution or zones will be the level at which the accessibility evaluation will be conducted.
- Intra-zonal travel times represent the diagonal elements of the skim matrix and refer to the time taken for intra-zonal trips. A typical approach is to use the nearest-neighbor approach and approximate intra-zonal travel time as half of the average of inter-zonal travel times of *n* nearest neighbors to any given zone (where *n* can be any 2, 3, or 4 of the nearest neighbors). For example, if you are interested in approximating intra-zonal travel time for Zone 1, the nearest spatial neighbors (based on centroid-to-centroid distances of zones) are Zones 3 and 4, and inter-zonal travel time from Zone 1 to Zone 3 (t_{13}) is 4 minutes and the inter-zonal travel time from Zone 1 to Zone 4 (t_{14}) is 3 minutes, then the intra-zonal travel time for Zone 1 is 1.75 minutes. The calculation is given in Equation 5.7.

$$\frac{1}{2}\left(\frac{t_{13}+t_{14}}{2}\right)=t_{11} \tag{5.7}$$

(continued on page 64)

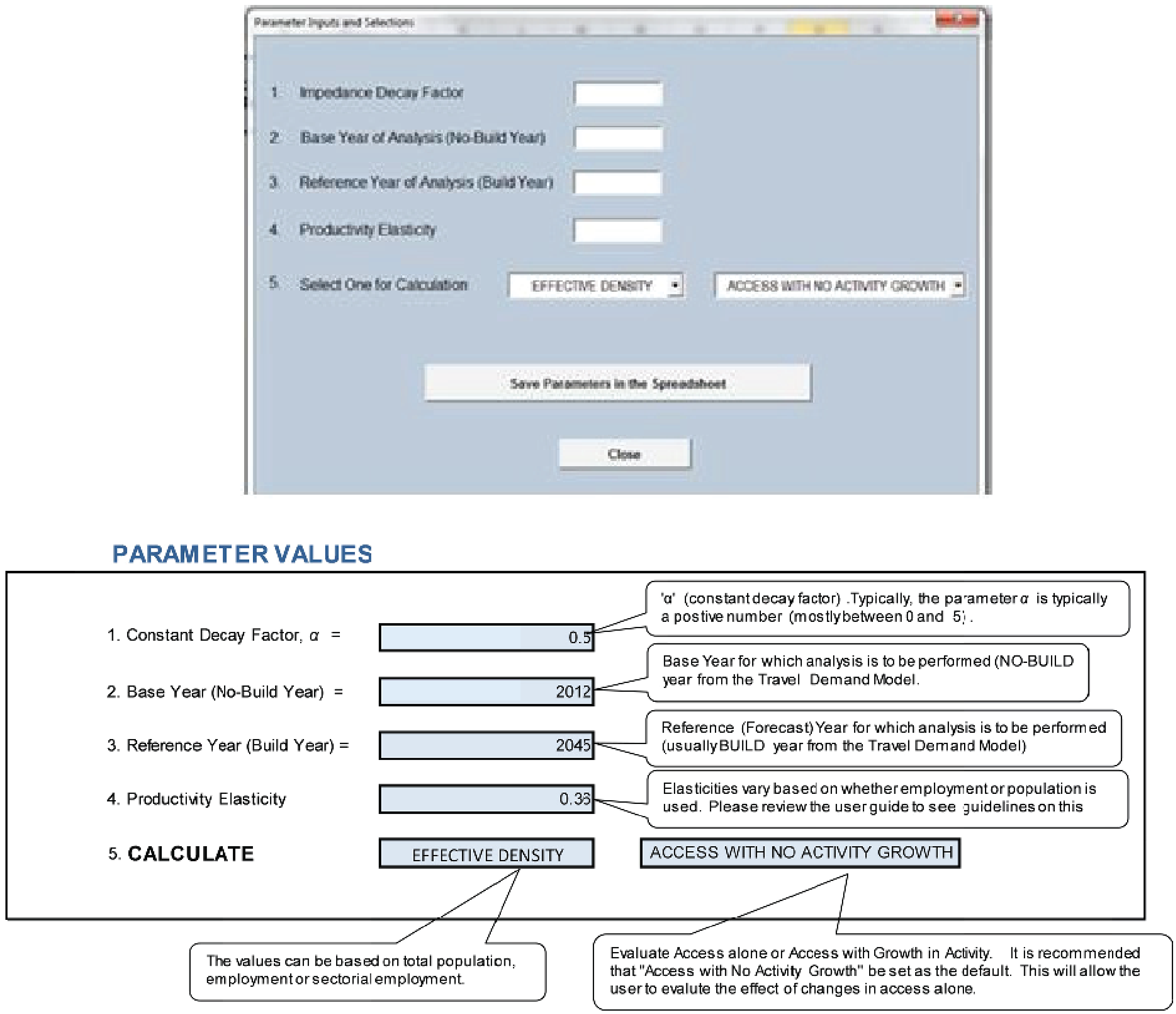


Figure 5.7. Tab 3: Parameter inputs and selections.

Table 5.5. Suggested Elasticity Ranges for Evaluation

Activity	**μ Range**	**New Capacity or Improved**
Population	0.20–0.01	0.06 for new capacity; 0.03 or less for improved.
Employment	Similar to above.	Similar to above.
Manufacturing Employment	Mean estimate 0.03 (Min –0.36; Max 0.319) Value selected must be based on how specialized the industry is within the region. Suggested value is 0.03 and subjected to sensitivity analysis.	0.03 for new capacity and lower than 0.03 for improved.
Other Sectors	Limited guidance is available at this time.	Limited guidance is available at this time.

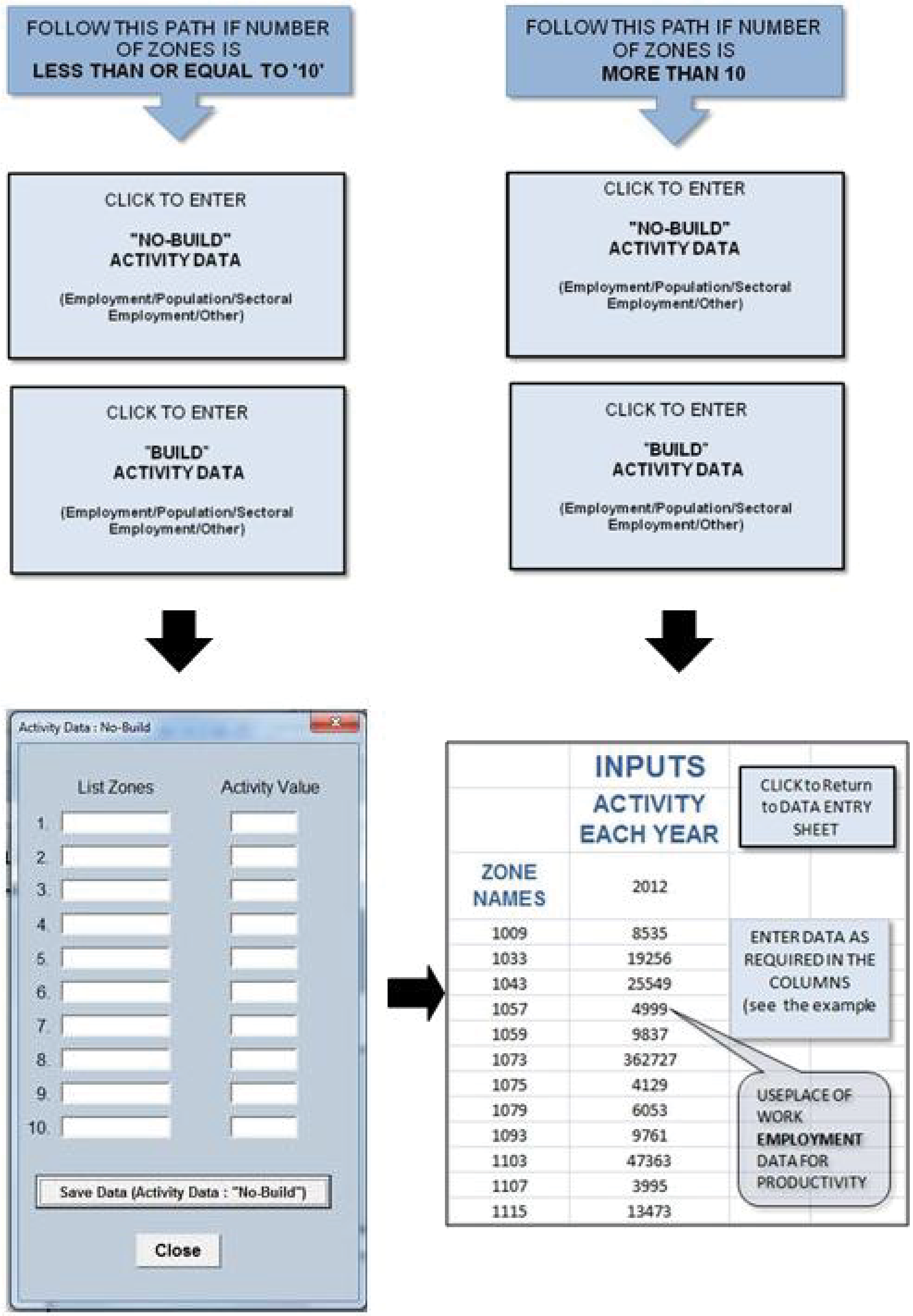


Figure 5.8. Impact zones and activity data input base year (for No Build and Build scenarios)—Tabs 4 and 5.

(continued from page 61)

This option is provided in TransCAD, and other travel demand models have similar algorithms. When distance impedances are used, the area of the zone in consideration and π (3.14) are both often used to approximate intra-zonal distance (see scale factor in (5.3)).

- The study area, which is the area for which the analysis is to be conducted, is distinctly different from MPO or statewide travel demand model study areas. The only time when both are identical is when system-wide or network-wide improvements are being evaluated at the same time. If you are evaluating a single capacity project, the main factor that determines what the zone's study area should include is primarily based on the project type (new link with or without tolls, bypass, widening). A second associated factor is the travel shed associated with the project.
- Origin–destination matrix (or demand representation) represents the Build and No Build demand scenarios and the time frames for which the Build (reference) and No Build (base) scenario impedances can be developed.
- Time periods.

For new links in the roadway, the research team suggests that first a simpler, distance-based skim be used, followed by a travel time skim or generalized cost skim. In any case, link travel time inputs are vital for the rigor of benefit–cost analysis, and, similarly, for any study of access, the transportation-induced zone-to-zone impedances (whether time or distance or generalized costs) are valuable and of critical importance.

Entering Impedance Data

Similar to when you use activity data, use the clickable box to enter impedance data as it is shown in Figure 5.9 (No Build and Build case).

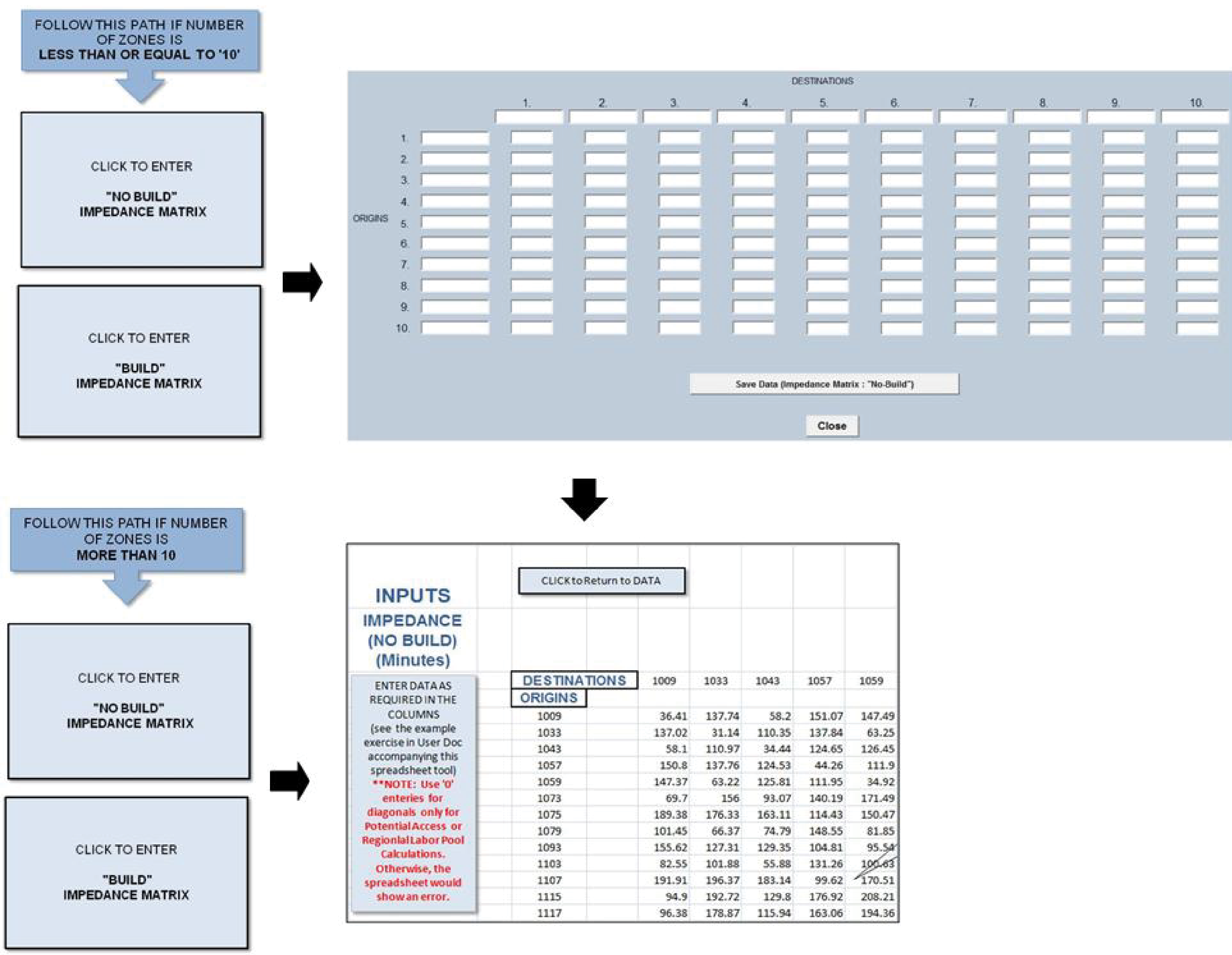


Figure 5.9. Entering impedance data for impact zones (for No Build and Build scenario)—Tabs 6 and 7.

Entering Per Capita Gross Regional Product (GRP) and GRP Proxy Data

Enter the GRP data or its equivalent proxy data in the same way that you entered activity data, as described earlier. See Figure 5.10 for reference. The GRP data are used for productivity calculations, as mentioned previously. If regions are smaller than metropolitan statistical areas (MSAs), then per capita gross regional product proxies have to be used. Due to a lack of better metrics, the research team recommends the use of average annual wages as the per capita GRP proxy. Much of the theoretical economic literature suggests that inter-urban wage differences reflect productivity differences. Hence, the common wage assumption in inter-urban settings must be approached with caution.

Getting the Output (Market Access/Productivity)

To see the outputs, click the dialog box, shown in Figure 5.11. Please note that loading a large number of zones might slow the computations. Twenty-two (22) zones are shown in the example exercise (system processor Intel Core2 Duo); the

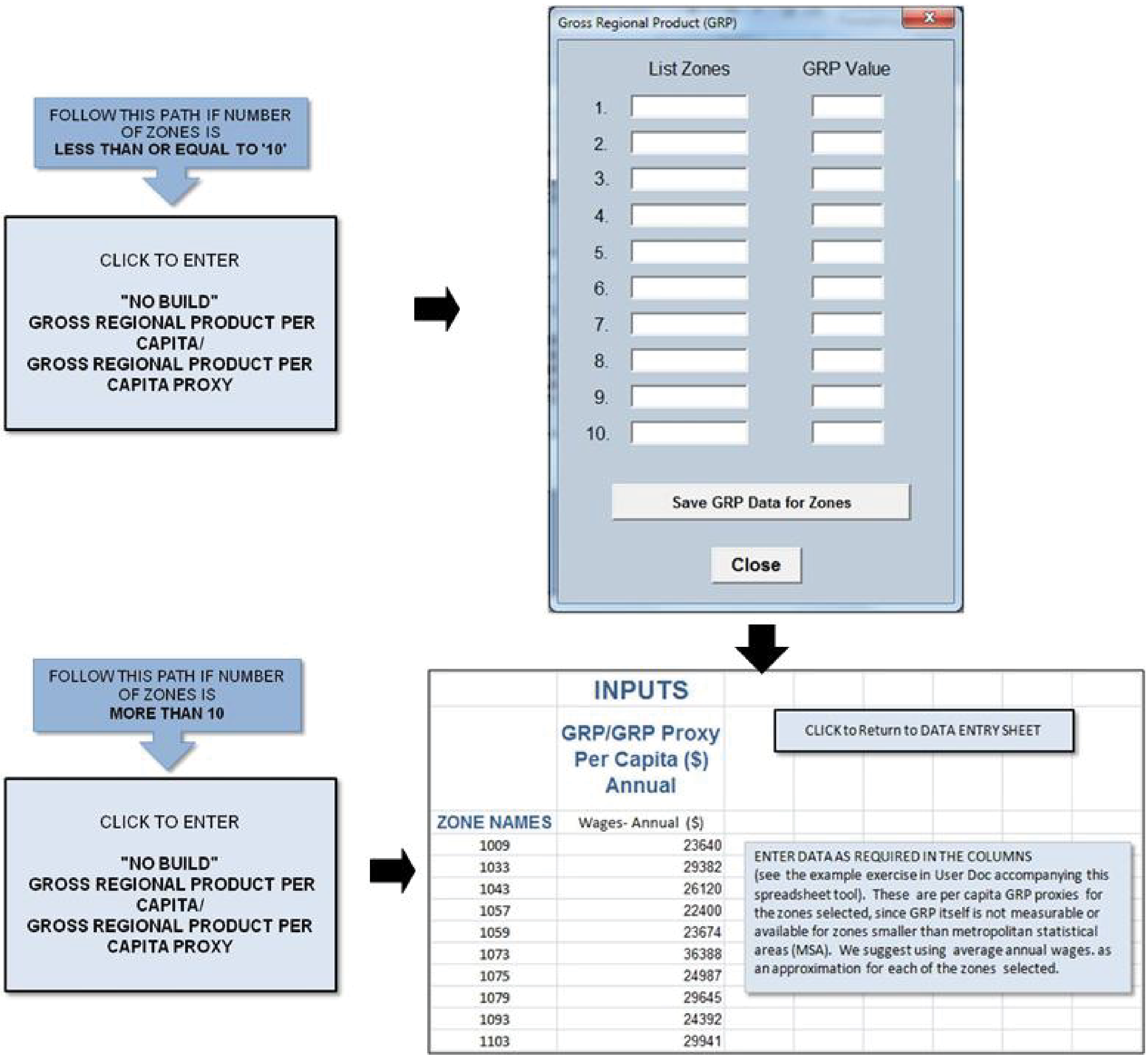


Figure 5.10. Entering per capita GRP/GRP proxy data—Tab 8.

Figure 5.11. Click the first box to calculate results for effective density/potential access and productivity.

time taken for a single run is approximately 20 seconds. To clear all the saved data and output, click the dialog box shown in Figure 5.12. Remember that using the **CLEAR DATA & OUTPUT** button will clear all entries in the spreadsheet. You should save files loaded with data so that you can use them later.

Obtaining Results

The output consists of ED and/or PA values for each of the zones and the total. The outputs are for both No Build and Build case scenarios (see Figure 5.13). A separate column also shows the Productivity output in terms of monetary values (dollars) against each zone. The toolkit also has built-in dynamic charting capabilities. The chart provided alongside access measures and productivity outputs allows easy comparisons between the calculated ED values across the two scenarios (Figure 5.14).

GIS Mapping

A GIS mapping output is also shown in Figure 5.15. This capability is currently conducted externally by exporting all outputs to ESRI's ARCGIS. Other open source tools can be used when ARCGIS or similar tools are not available.

Figure 5.12. Click the box to clear all input and output data stored in the spreadsheet.

OUTPUTS

EFFECTIVE DENSITY/ POTENTIAL ACCESS 'SCORES'

CLICK to Return to DATA ENTRY SHEET

	NO BUILD	BUILD	
	2012	2045	
ZONES	EFFECTIVE DENSITY	EFFECTIVE DENSITY	TOTAL PRODUCTIVITY($)
1009	8970	14133	$29,483,575
1033	5980	9417	$82,572,197
1043	8153	12021	$82,440,420
1057	6137	10818	$20,758,304
1059	5835	9947	$40,412,607
1073	14666	19520	$1,182,070,836
1075	5079	8748	$18,278,858
1079	6616	10219	$24,998,875
1093	5803	10824	$48,962,819
1103	8092	11769	$168,662,104
1107	5722	8556	$11,557,414
1115	8611	9719	$12,242,559
1117	11519	14416	$155,615,611
1121	6539	9128	$79,721,936
1125	7378	10207	$228,228,806
1127	7634	12587	$66,615,581
1133	6125	10539	$37,073,151
28057	6797	12568	$26,717,619
28081	6582	11872	$307,440,840
28095	5195	8869	$57,198,950
28117	4867	8467	$37,790,906
28141	5132	8054	$19,666,888
TOTAL	***157432***	***242398***	***$2,738,510,856***

Figure 5.13. Toolkit output (market access to labor or customer markets), total estimated productivity gains or losses ($)—Tab 8.

Access to Labor Markets Module User's Guide and Instructions

Introduction and Purpose

Disclaimer

This tool is designed to provide a spreadsheet-driven approach to computing transportation-induced changes in access of work sites and employment centers to specialized labor markets for a base year (No Build scenario) and a reference year (or Build scenario) resulting from new or improved transportation projects. The tool may also be used to obtain an order-of-magnitude measure of economic consequences (costs and savings) that may accrue to passenger users who commute to those sites. The tool is most useful when all key employment centers within a given, specific category in the study area are evaluated at the same time. However, computation times are

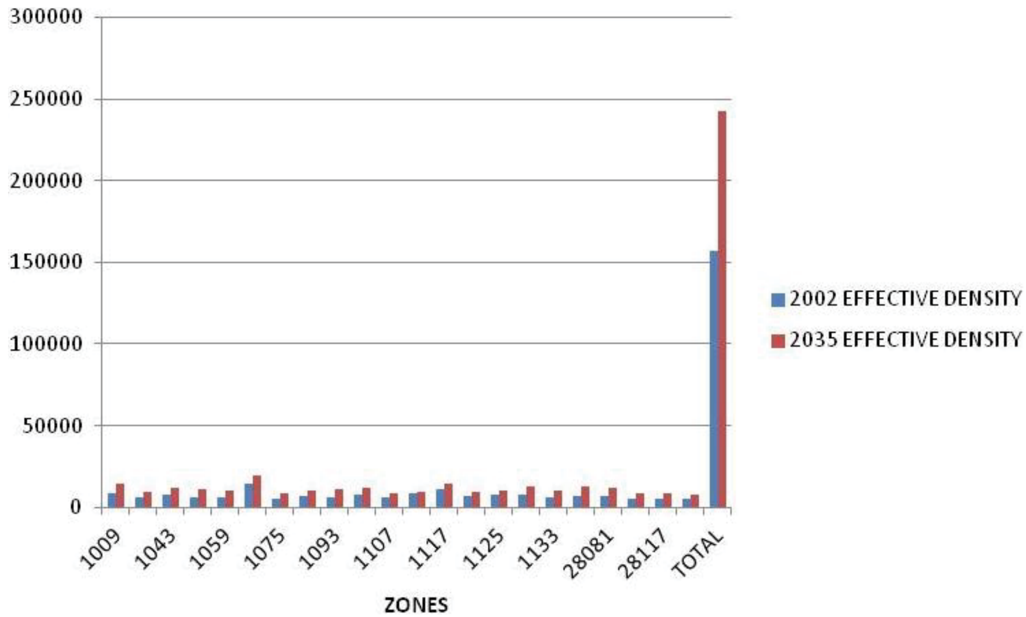


Figure 5.14. Dynamic charts of outputs—Tab 8.

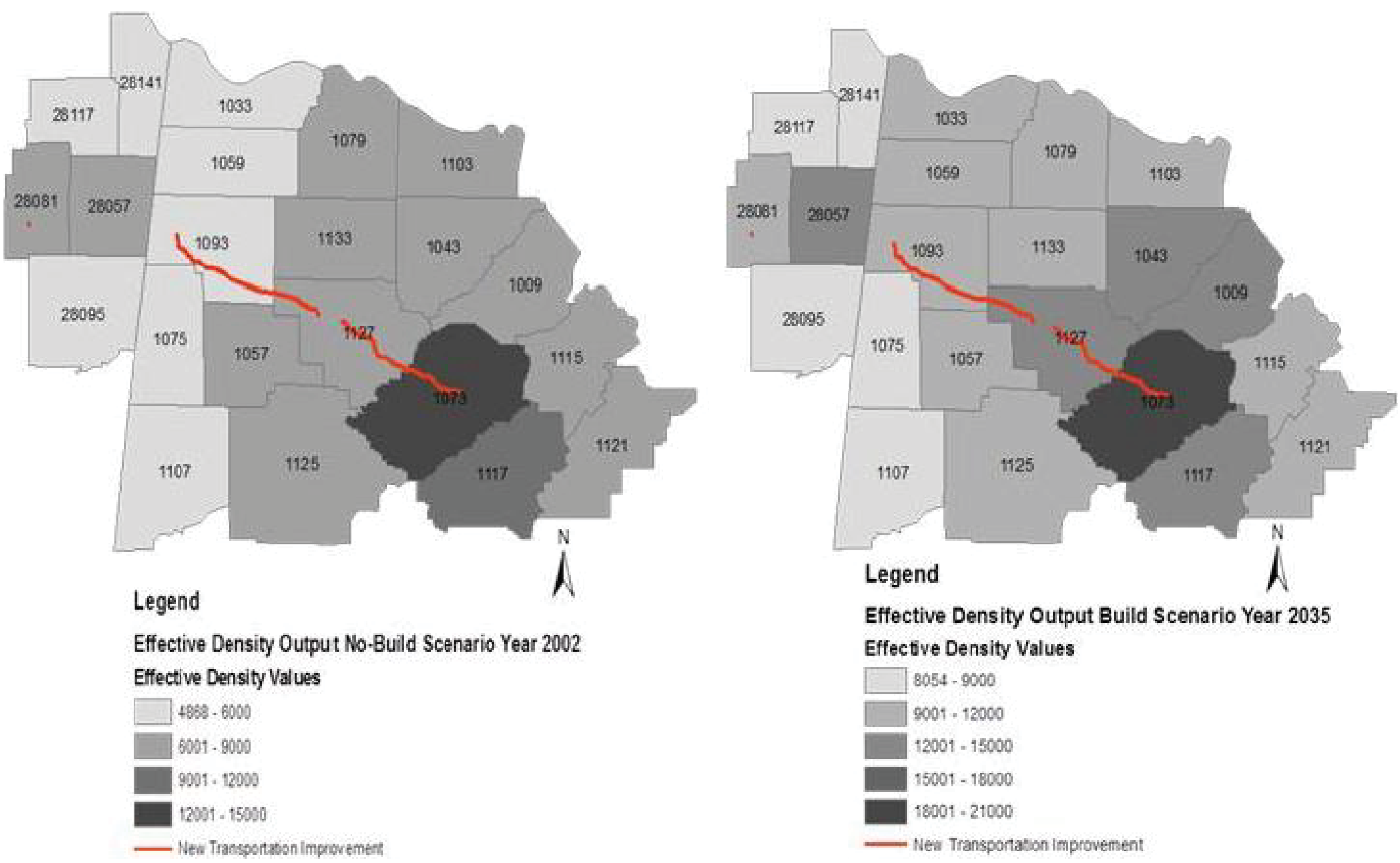


Figure 5.15. GIS mapping of effective densities as measure of market access—Tab 8.

long when there are more than 30 employment centers. Transportation projects in regions with specialized industry sectors (with a need for specialized labor inputs) could use this tool as a preliminary assessment of how the productivity at work sites may be affected.

Objectives

The objective of this tool is to measure the influence of transportation on access to specialized labor markets. The value of the tool lies in its ability to approximate the value for commuters and employers when new or improved transportation projects impact the commute to work sites.

Additionally, planners could use this toolkit to analyze transportation projects in regions with specialized industry sectors. They could also use this as a preliminary assessment of how much more or less connected they are to their input markets (workers, in this case) and how transportation projects could alter that connection. Industry clusters interact with business within their own sectors and at the same time interact with other, related sectors. This tool does not compute the productivity implications. Follow up work is certainly required to consider productivity implications and other input, such as user markets. However, one important feature of this toolkit is the time-of-analysis aspect into peak, off-peak, and entire day for determining variations during peak periods.

This tool, which measures access to labor markets, complements the previously presented tool, which measures access to buyer–seller markets. This tool is important when (1) the transportation link serves an important role in linking place of work to place of residence for commuting trips and (2) the focus within the study area is concentrated on specialized industry sectors.

The following section discusses three main measures that this toolkit is designed to provide, assuming that work site locations are identifiable for the study area. In other words, this toolkit cannot be used to identify the employment centers themselves or any degree of specialization of industries in the study. The user must know this information and enter it into the toolkit. The industry mix analysis is considered to be an important requirement before using any of the tools produced. Alternatively, local knowledge of the strength of industry clusters would be both useful and valuable.

Entering Inputs

When you open the Access to Specialized Labor Markets tool, the screenshot in Figure 5.16 displays. A brief set of instructions displays, describing which tabs to enter data into and how to

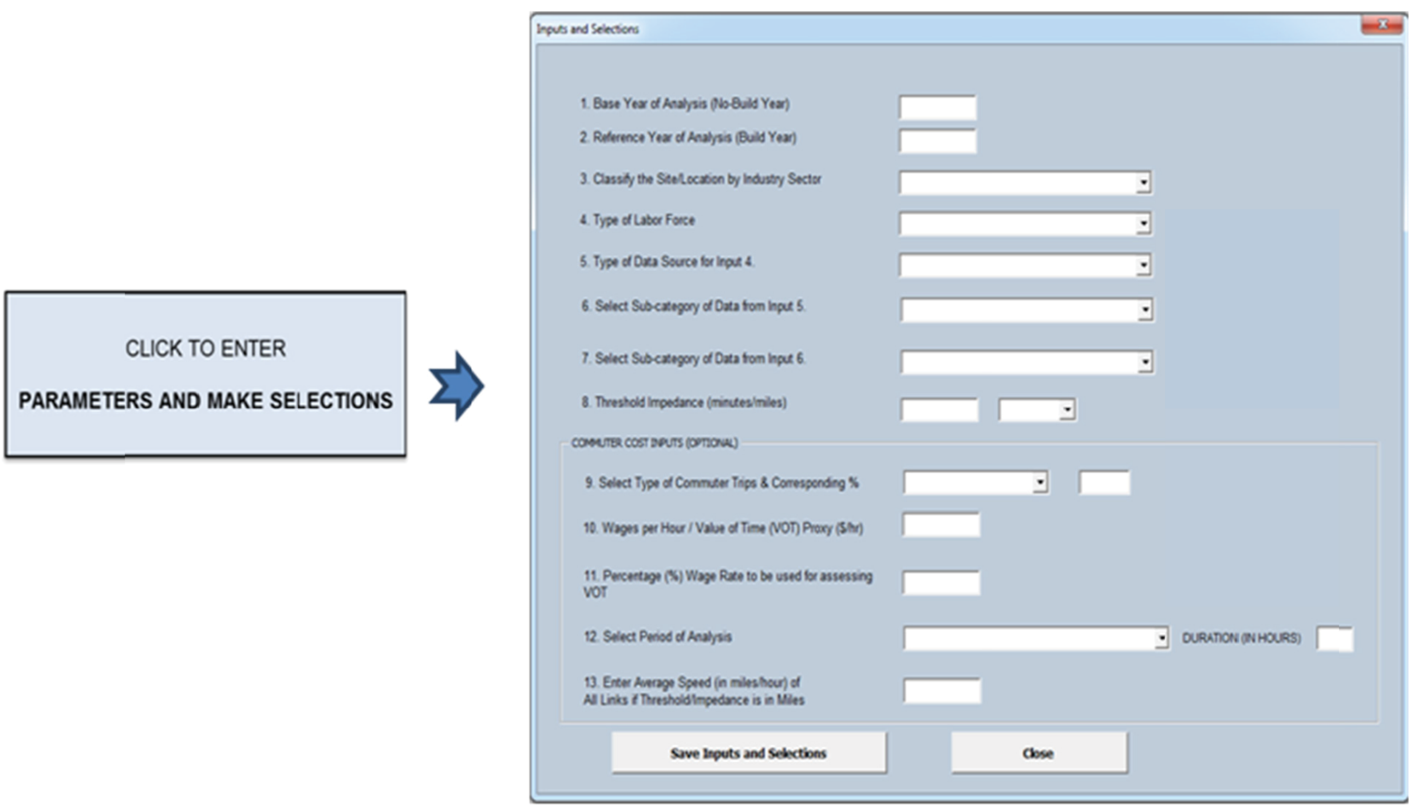


Figure 5.16. Input parameters and selections—Tab 2.

use the Results tab. To begin entering data, click the tab labeled 2–DATA ENTRY and follow the instructions listed by each button.

Entering Input Parameters and Selections (Tab 2)

On the 2–DATA ENTRY worksheet, click the button **CLICK TO ENTER PARAMETERS AND MAKE SELECTIONS**, shown in Figure 5.16.

1. Enter the Base Year, as shown in Figure 5.17. The Base Year is the same as the No Build year. The default Base Year is 2002.
2. Enter the Reference Year as shown in Figure 5.18. It is determined by the travel demand model's Build year analysis. Both Base and Reference years refer to the years for which No Build and Build scenarios are developed from travel demand models.
3. Select **Industry Sector** for the employment center(s) in the study area. The drop-down list and the details of 20 different two-digit North American Industrial Classification System (NAICS) sectors appear, as shown in Figure 5.19. The default selection is industry sector NAICS 31-33: Manufacturing. This example (shown in Figure 5.19) uses manufacturing because the study area is specialized in manufacturing. As noted earlier, the tool analyzes all employment centers in a given group or category in the study area at one time. It is only under these conditions that the CI is representative of agglomerative or concentration aspects associated with employment locations. Other industry categories can be analyzed separately and saved separately. If you will be analyzing more than one industry sector, the research team recommends saving the file with a new file name and restarting from Step 1 for each sector.
4. Select the type of labor force data as shown in Figure 5.20, which either need to be examined or for which access effects must be determined. The first option is **Potential/Population Labor Force.** The second option and the default selection is **Employed Labor Force**.
5. If you selected **Employed Labor Force** in Step 4, you will be required to specify that further by selecting the specific type of employment **By Place of Residence,** shown in Figure 5.21. The default selection is **By Place of Work.**
6. Select the specialized labor category data type. The image in Figure 5.22 shows various categories that you may specify that are available for the user to choose from the drop-down list. The default selection is **By Industry Sector**. These subcategories are designed in such a way that your only input labor force data are for the specific subcategory selected and for the time periods selected.

Figure 5.17. Base year selection.

Figure 5.18. Reference year selection.

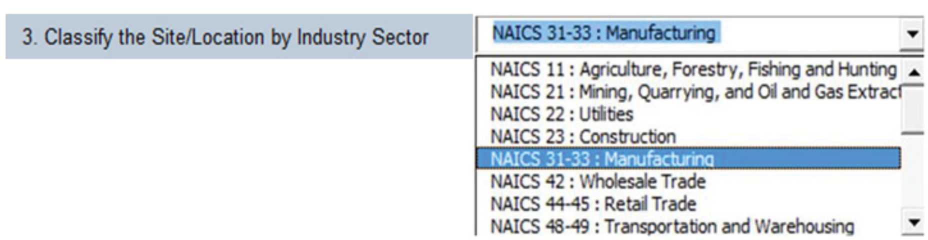


Figure 5.19. Selection industry sector for employment centers.

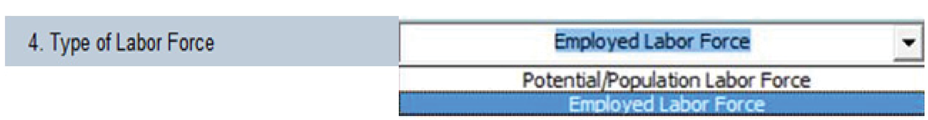


Figure 5.20. Selection of labor force market.

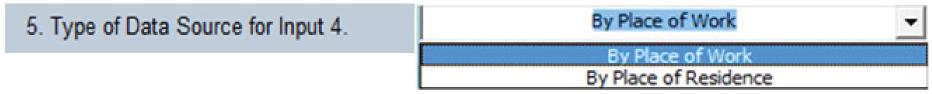


Figure 5.21. Selection of type of labor force data.

Figure 5.22. Selection of specialized labor category (e.g., industry sector, occupation, age, skill level).

In this case, the quality of employment data inputs is important. While public domain datasets like Census Labor Employment and Household Dynamics (LEHD) and other Census data can provide base year data, high-quality inputs are required for projected year data. Additionally, occupational categories are hard to obtain at any resolution lower than the county level, hence private domain data may be used as inputs, when available.

7. If you selected **By Industry Sector** in Step 6, you will be required to identify whether you wish to study "own" industry employment or employment in any closely related sector or category. Various options available under each of the subcategory from Step 6 are shown in Figure 5.23. The default selection is made for **NAICS 31-33: Manufacturing.**

   Figure 5.24 shows the contents of all the drop-down selections in their expanded form.

8. Enter the **Threshold Impedance** around each employment center, in terms of minutes or miles, as shown in Figure 5.25. This selection is required to identify the labor market area associated with this commute threshold. This is the typical commute time or distance to all the employment centers. The Census Transportation Planning Package and now the American Community Survey provide typical commute times or distances to work by mode and may be input here. Alternatively, in-house surveys or origin–destination surveys may be used in lieu of public domain data, when available.

   Steps 9 through 14 are required only if you want commuter cost implications. See Figure 5.26 for details about the commuter cost inputs needed.

9. Select the type of trip and the corresponding overall share of these trips (Figure 5.27) for the study area.
10. Enter the wages per hour or value of time proxy in dollars per hour (Figure 5.28) that is most appropriate for the sector in consideration, as set for employment centers. This is used for valuing commuter costs (see equations in this chapter's technical guide).
11. Enter the percentage of the wage rate that will be used in the valuation of time costs (Figure 5.29). The default value is 50 (i.e., 50%). Personal trips are valued at 50% of the wage rate while business trips are valued are 100% of the wage rate, per OMB guidance.
12. In this step, you may select the specific time-of-day (period) for which the analysis is to be carried out (see Figure 5.30). Three options are provided: **Peak, Off-peak**, and **Entire**

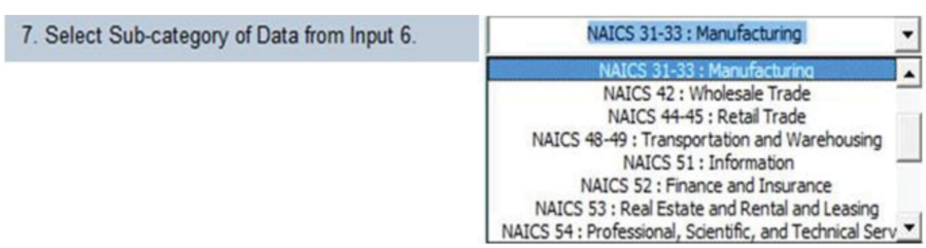


Figure 5.23. Specification of labor force sought in specific industry sectors in relation to employment center industry.

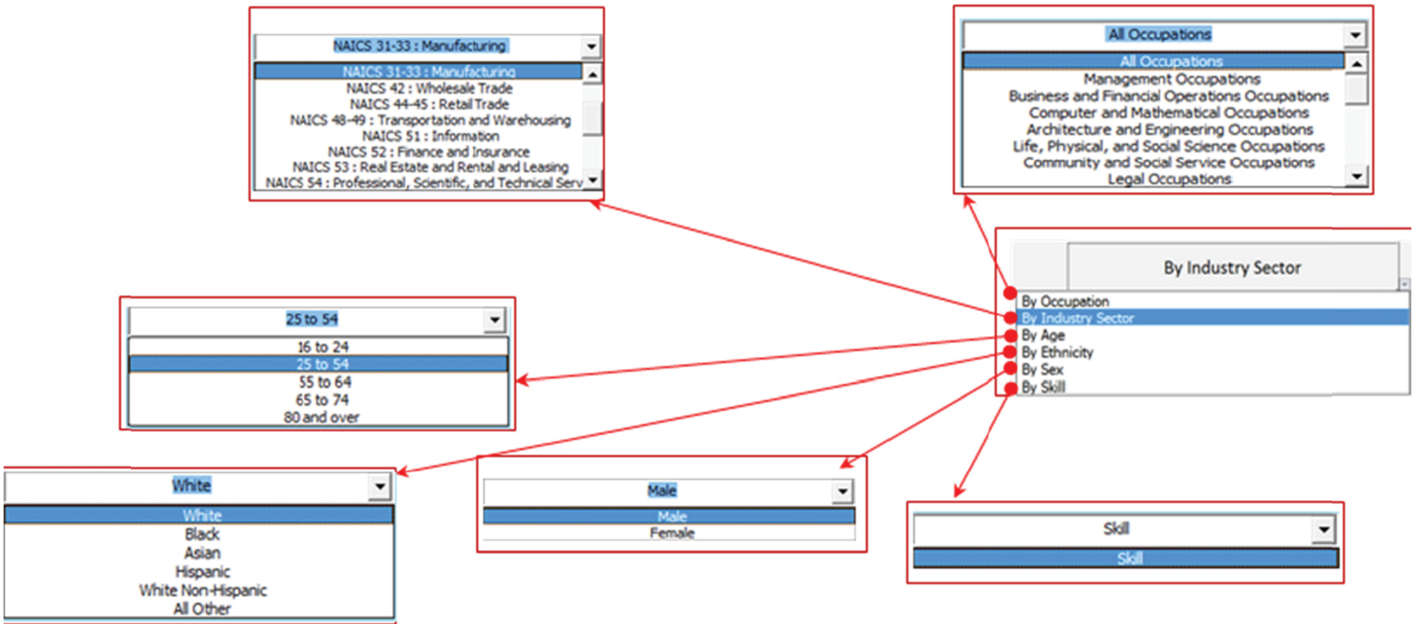


Figure 5.24. Combined screenshots of all options for labor force categorization.

Figure 5.25. Enter threshold value.

Figure 5.26. Enter inputs for commuter cost calculations.

Figure 5.27. Choose type of commuter trip.

Figure 5.28. Enter wage rate.

Figure 5.29. Percentage of wage rate for valuation of time costs.

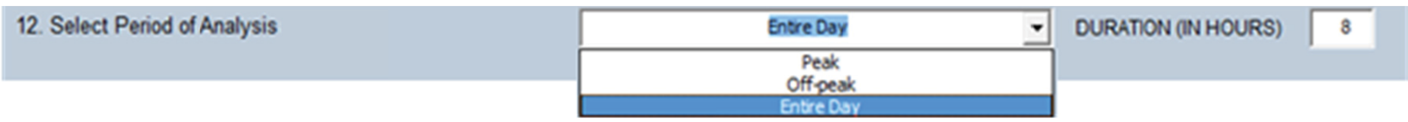


Figure 5.30. Selection of time period of analysis of changes in specialized labor markets.

Day analysis. These periods correspond to the time periods (or slices) from which the travel demand model skims (travel time) and trip tables are obtained and for which the analysis needs to be carried out. In most cases, the selection is **Entire Day.** However, in specific conditions, such as assessing the effects of congestion, entering the specific time-of-day may be required.

13. Enter the average speed for all the links in the network if threshold/impedance table input is in miles (see Figure 5.31). This allows the tool to convert the impedance tables into hour units of time for commuter cost calculations. The default value for the average speed is 55 mph. Users may override this by inputting more appropriate values.
14. Save and close the above settings and selections using the dialog box as shown in Figure 5.32. This option allows you to save all entries and automatically transfer them to another worksheet (Tab 3) (see Figure 5.33).

The overall process is laid out in Figure 5.34. The toolkit currently allows for a maximum of 30 centers to be analyzed at the same time. For the sake of simplicity, if the number of centers and zones are less than or equal to 10, use the path identified in the left column of Figure 5.34. If, on the other hand, the number of centers exceeds 10, use the path identified in the right column of Figure 5.34. When the study area is large, such as several counties or metro region, the number of zones could exceed 30 very quickly.

Entering Employment Centers (Tab 2 and Tab 7)

Enter the list of zones as employment centers in the desired box or print directly into the worksheet on the tab labeled 7–INPUT EMPLOYMENT CENTERS (see Figure 5.35). Enter data only in the required boxes; entering data in other boxes will result in error for the outputs. Note that the employment centers selected should be within the zones that are used within the tool. Use the user interface box (shown in blue on the screen) only when the zone size is less than or equal to 10.

Entering Desired Specialized Labor Market Segment Data (Tab 2 and Tab 4)

Enter total employment in all industries and for the segment selected earlier (Step 7). See example shown in Figure 5.36. Use the user interface box (shown in blue on the screen) only when the zone size is less than or equal to 10. You will be required to provide activity inputs for both the base period and the reference period for all zones in your study area.

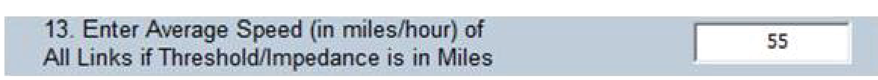


Figure 5.31. Enter average speed.

Figure 5.32. Save and close the inputs and parameters.

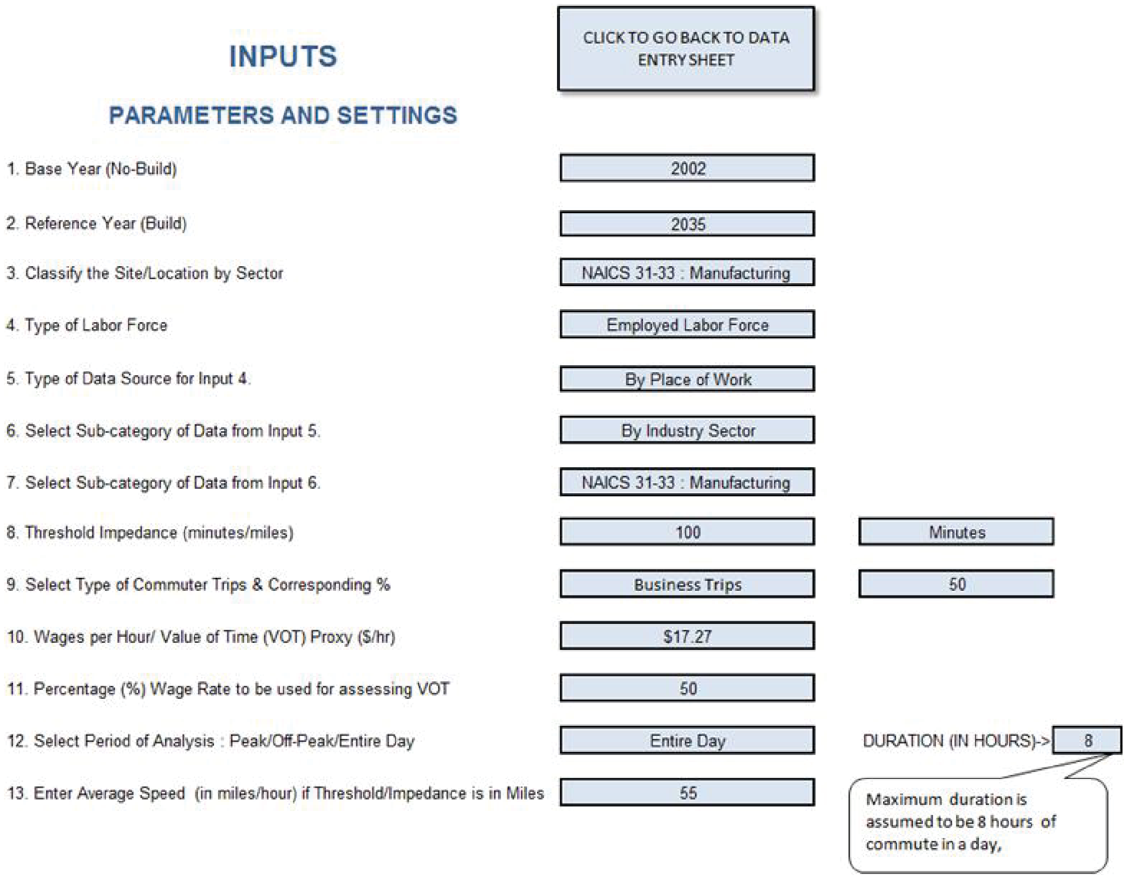


Figure 5.33. The final saved inputs and parameters and settings.

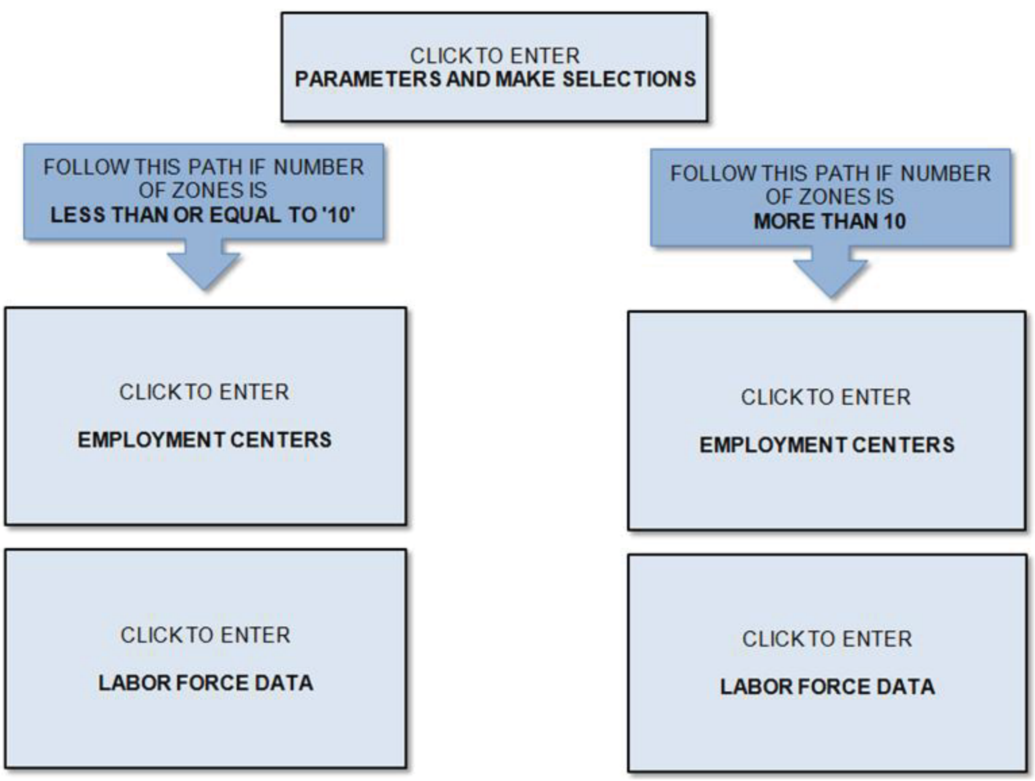


Figure 5.34. Select the path based on number of employment centers.

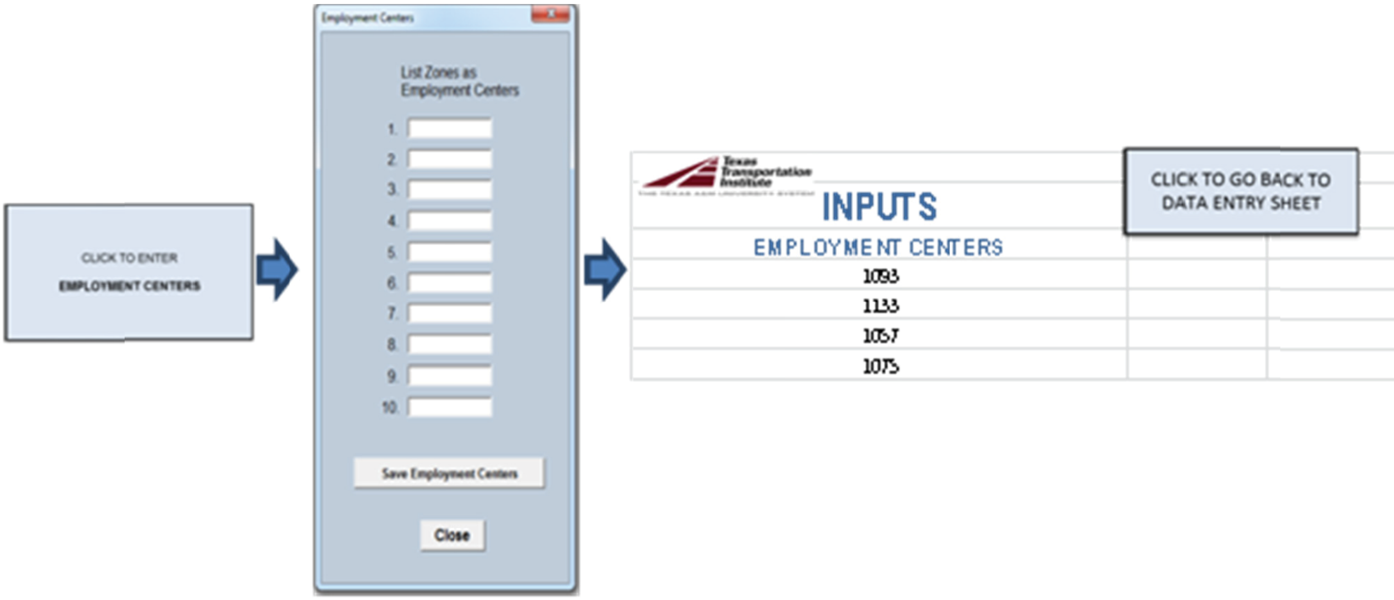


Figure 5.35. Entry of list of employment centers (identified by zones)—Tab 7.

Entering Impedance Matrix Data (In Minutes or Miles) (Tabs 2, 5, and 6)

Enter impedance matrix data both for the No Build and Build scenarios, as shown in Figure 5.37. Note that these data need to be entered within the assigned cells of the spreadsheet to avoid error flags. Use the user interface box (shown in blue on the user's screen) only when the zone size is less than or equal to 10. Note that this is the impedance matrix for the entire study area.

Entering Trip Table Matrix Data (Optional) (Tabs 2, 8, and 9)

Use this exercise only when you want to calculate the commuter costs.

Enter trip flow matrix data both for the No Build and Build scenarios, as shown in Figure 5.38 for the entire study area. Note that these data need to be entered within the assigned cells of the spreadsheet to avoid error flags. Use the user interface box (shown in blue on the screen) only when the zone size is less than or equal to 10. Since the user market is labeled as "work commute," it is appropriate to enter the home-based work trip purpose category origin–destination daily trip volumes for the duration selected. The more appropriate user class segmentation may be entered if available. In this case, the analysis is only as good as the data provided. These data along with the skims are to be obtained for both the Build and No Build scenarios from the travel demand model. For peak-period analysis, a peak-period trip table is appropriate.

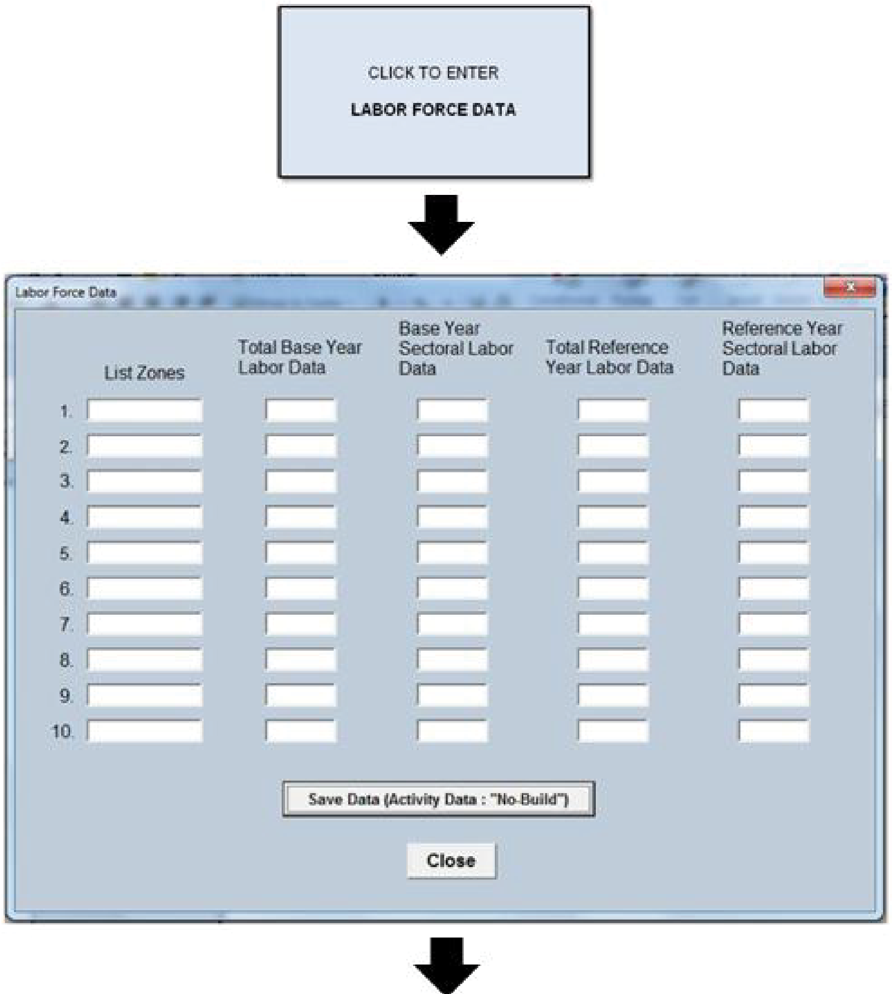
Obtaining Results

Obtaining Desired Outputs (Market Area/Labor Access/CI) and Commuter Costs (Tabs 2, 10, and 11)

Use one of the selections shown in Figure 5.39 to perform the task of calculating the Zone Accessibility, Employment Accessibility, and CIs. You can use any of the options to fulfill your requirements. The CIs are provided at the employment center level. A higher value in Build relative to No Build suggests enhanced concentration of workers of the specified category at the center. Ultimately, some centers may gain more, relative to the others, based on how transportation actually changes access to those centers; the average effect on all centers is important in the study area.

Outcome Measures

The toolkit measures the change in market area or trade area for work sites as the first outcome measure. This measure refers to the ease with which labor can access the work sites with given travel time or distance budgets. The change in the trade area is what is made possible due to transportation improvements. In the toolkit, this outcome measure is called *zone accessibility* (market area, trade area, or effective market area). The second related outcome measure is the expanded labor pool (additional opportunity) that is made available due to the larger trade area, referred to as employment accessibility. Both of these outcome measures are often used by businesses and industries to ascertain their reach to key markets, consistent with travel budgets. A third outcome variable is an index that measures the change in concentration of a specific labor pool type or

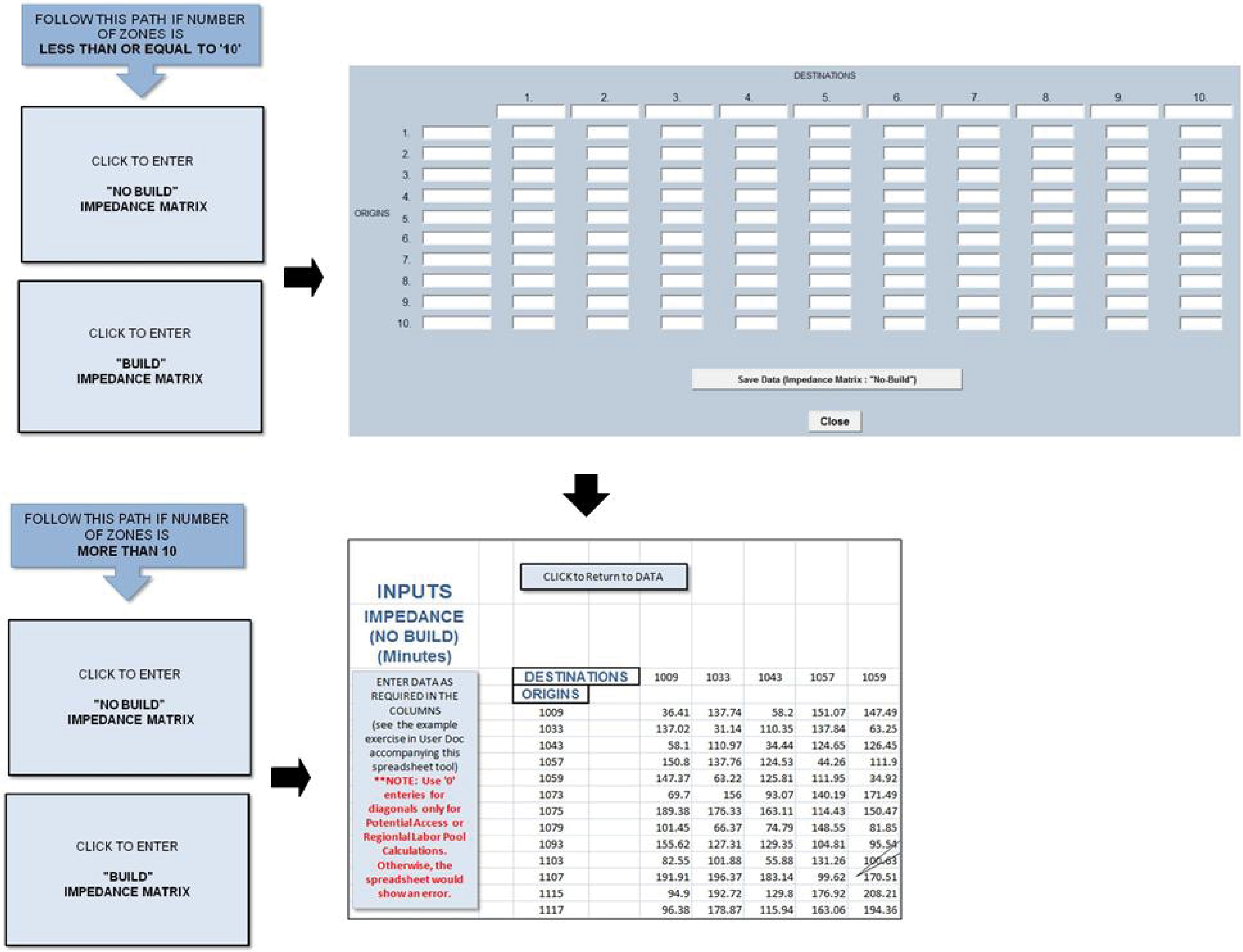


INPUTS

CLICK TO GO BACK TO DATA ENTRY SHEET

Year of Data ->>	2002		2035	
Industry Sector ->>	NAICS 31-33 : Manufacturing		NAICS 31-33 : Manufacturing	
Type of Labor Force ->>	Employed Labor Force		Employed Labor Force	
Type of Data for Labor Force ->>	By Place of Work		By Place of Work	
Sub-category of Data for Labor Force ->>	By Industry Sector		By Industry Sector	
Sub-category of Data for above ->>	NAICS 31-33 : Manufacturing		NAICS 31-33 : Manufacturing	
EMPLOYMENT CENTER	Total Labor Data	Sectoral Labor Data	Total Labor Data	Sectoral Labor Data
1009	8535	1801	24385	2853
1033	19256	4050	32730	6199
1043	25549	5544	39172	2676
1057	4999	1526	6412	1660
1059	9837	3816	14407	687
1073	362727	32879	556299	2056

Figure 5.36. Labor force data entry.



ORIGINS \ DESTINATIONS	1009	1033	1043	1057	1059
1009	36.41	137.74	58.2	151.07	147.49
1033	137.02	31.14	110.35	137.84	63.25
1043	58.1	110.97	34.44	124.65	126.45
1057	150.8	137.76	124.53	44.26	111.9
1059	147.37	63.22	125.81	111.95	34.92
1073	69.7	156	93.07	140.19	171.49
1075	189.38	176.33	163.11	114.43	150.47
1079	101.45	66.37	74.79	148.55	81.85
1093	155.62	127.31	129.35	104.81	95.54
1103	82.55	101.88	55.88	131.26	100.63
1107	191.91	196.37	183.14	99.62	170.51
1115	94.9	192.72	129.8	176.92	208.21
1117	96.38	178.87	115.94	163.06	194.36

Figure 5.37. Impedance matrix for No Build and Build scenarios.

category for an industry within a specific zone relative to the share of that same labor category across all sectors (k) and zone (j).

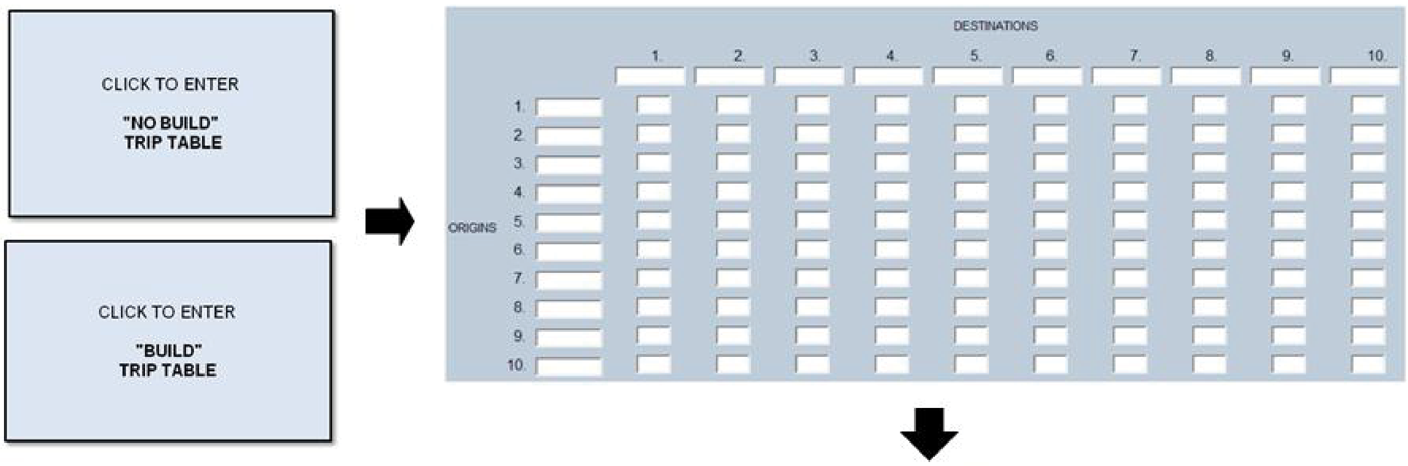
The tool also connects the suppliers (commuters) with the demand sites (work sites) so that it becomes possible to determine the economic implications in terms of commuter cost changes.

Zone Accessibility (Market Area/Effective Trade Area)

Zone accessibility is computed as the number of zones (which could be a TAZ, Block Group, or County) that are accessible before and after the investment for a given threshold distance from the employment centers. This is a set of all zones that are within equal time and/or distance from the work site. It is often visualized as a map of equal time or distance budgets and resembles a contour map. However, this toolkit provides a spreadsheet-driven preliminary approach determining this area at the zonal level before and after a transportation-related intervention. Most GIS tools can be directly used to provide this outcome measure as long as there are network and land use layers indicating zones or locations of work sites.

Employment Accessibility (Access to Additional Labor Pools)

Employment accessibility accounts for the total employment of the desired type within a given zone that becomes accessible before and after transportation investment. In principle, a large market area and access to a larger and/or thicker labor pool should allow for a better labor matching at the firm level and for reduced search costs for commuters (under the assumption that the firm is economically



INPUTS
TRIP TABLE

CLICK TO GO BACK TO DATA ENTRY SHEET

ZONE NAMES / ORIGINS	<<-DESTINATIONS->> 1009	1033	1043	1057	1059	1073	1075	1079	1093	1103
1009	62319.14	22.62	604.96	3.17	16.99	14.48	15.48	29.34	19.93	355.48
1033	24.33	78795.31	75.33	1.3	645.14	0	1.69	491.41	92.92	1.73
1043	612.91	74.07	116683.6	27.83	59.24	1.55	38.16	33.17	63.48	1682.62
1057	3.2	1.31	27.99	27327	0.82	0	45.53	3.89	3.79	23.03
1059	17.97	659.9	59.24	0.66	45256.5	0	2.14	238.22	237.51	6.48
1073	14.61	0	1.55	0	0	1685912	0	0.01	0	0.06
1075	15.61	1.74	35.46	45.78	2.13	0	22459.06	3.07	29.41	13.77
1079	30.03	494.61	34.26	3.9	237.08	0.01	3.06	44981.91	8.1	128.19
1093	19.63	93.02	61.45	3.79	236.29	0	29.39	7.87	43461.11	75.66
1103	360.96	1.94	1643.57	22.75	6.91	0.06	13.53	123.97	75.65	174459.8
1107	22.01	2.08	65.5	176.13	0.36	0	92.42	6.27	3.23	35.07
1115	43.65	32.09	172.09	5.34	14.64	1517.06	20.68	77.63	22.7	472.02

Figure 5.38. Enter the No Build and Build trip table (work trip).

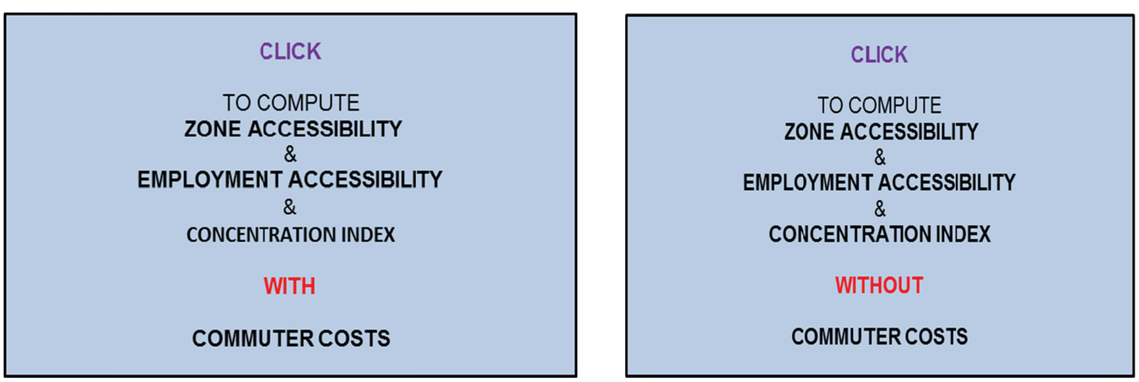


Figure 5.39. Selection of an option to obtain desired outputs.

able to use the additional labor resources that may become available).

CI

The CI with respect to an employment center in any industry sector (j), zone (k), and commute threshold (threshold) is expressed by Equation 5.5 (shown in the technical guide at the beginning of this chapter).

Figure 5.40 shows the output for the four employment centers identified in the example for an assumed 100-minute commute threshold. These outputs are Zone Accessibility, Employment Accessibility, and CI, to which the user is automatically directed immediately after the calculations are done by the tool, once the accessible button of Figure 5.39 has been clicked. There are charts produced beneath each output item for quick and easy interpretation of results.

Commuter Costs

As mentioned earlier, in the technical guide at the beginning of this chapter, the standard rule-of-half from Benefit–Cost Analysis has been adapted to provide estimates of commuter cost savings for both passenger commute trips and business trips coming into the employment centers. For more information on commuter costs, refer to this chapter's technical guide. The Commuter Costs Change is calculated as shown in Equation 5.6.

Figure 5.41 shows the cost savings for the four employment centers and overall (in dollars).

Reset Data and Outputs

To reset the entered data or outputs for performing tasks, click any of the appropriate accessible buttons in Figure 5.42.

OUTPUTS

CLICK TO GO BACK TO DATA ENTRY SHEET	*ZA = Zones Accessible within Threshold*			*EA = Employment Accessible (sectoral) within Threshold*			*CI= Concentration Index*		
EMPLOYMENT CENTERS	ZA (No-Build)	ZA (Build)	Difference in ZA	EA (No-Build)	EA (Build)	Difference in EA	Base Year CI (No-Build)	Reference Year CI (Build)	Difference in CI
1093	6	8	2	35,109	28,418	(6,691)	1.26	1.39	0.14
1133	12	14	2	17,292	7,448	(9,844)	1.11	0.76	(0.35)
1057	17	20	3	20,447	11,565	(8,882)	0.67	0.50	(0.18)
1075	20	23	3	6,725	8,627	1,902	1.20	3.32	2.12
TOTAL	**55**	**65**	**10**	**79,573**	**56,058**	**(23,515)**	**4.24**	**5.98**	**1.74**

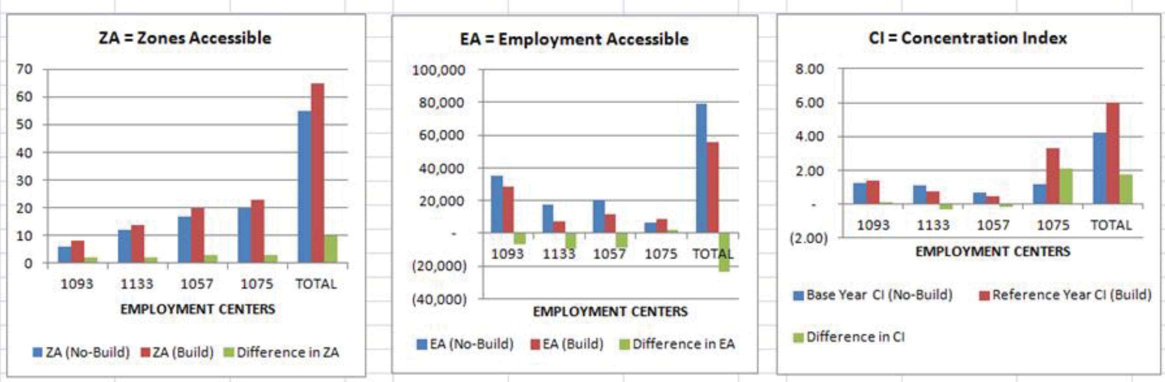


Figure 5.40. Sample outputs for the example.

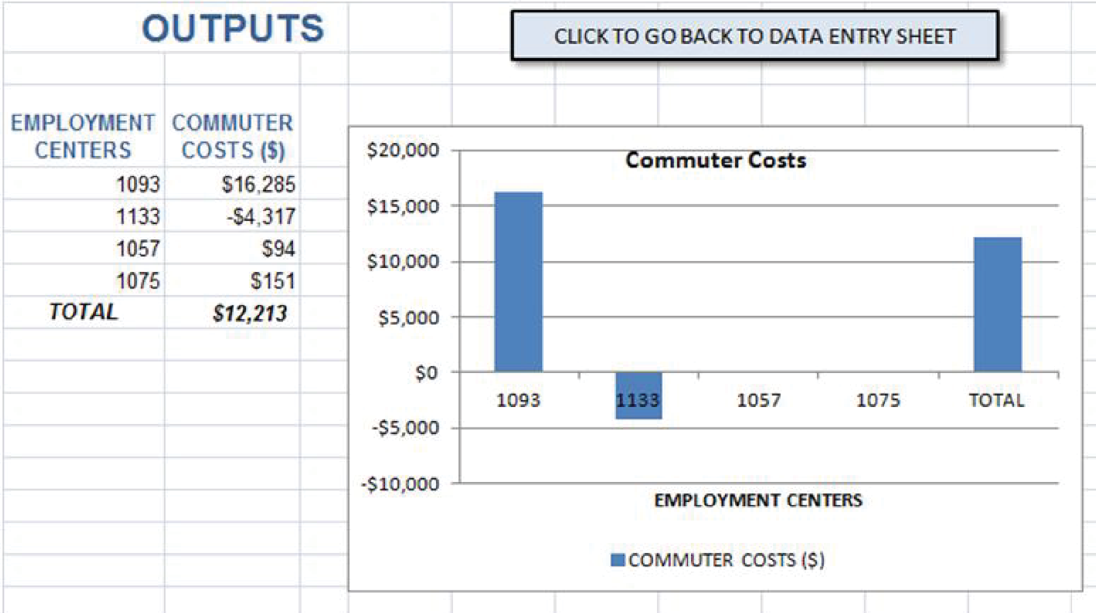


Figure 5.41. Sample output for commuter costs.

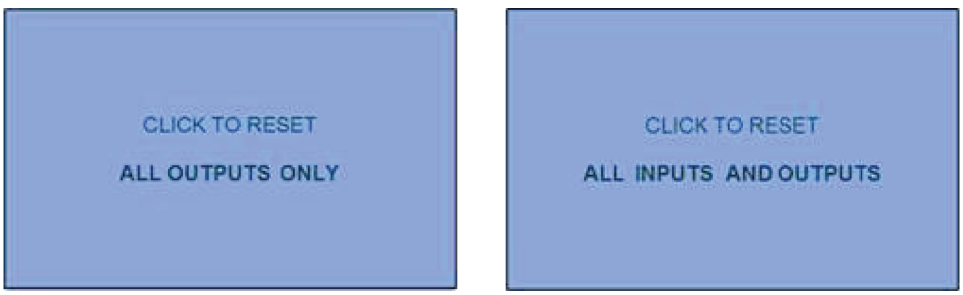


Figure 5.42. Resets for all outputs and for all inputs and outputs.

CHAPTER 6

Conclusions: Accomplishments and Needs

Accomplishments So Far

The spreadsheet tools developed by SHRP 2 Project C11 have five salient uses:

- They demonstrate that it is possible to estimate wider transportation impacts, including travel time reliability, intermodal connectivity, and market accessibility.
- They demonstrate that it is possible to calculate an economic value to households and businesses that are directly affected by those wider transportation impacts.
- They provide a set of ready-to-use tools that staff of any DOT, MPO, or consultant can use to estimate the above-cited effects.
- They generate transportation and economic metrics that can be used as input to multi-criteria, economic impact, or benefit–cost analyses.
- They provide a set of analysis steps that can potentially be incorporated into more complete and long-range transportation, land use, or economic forecasting systems.

These uses fall within the category of what are called "middle stage planning," which is a step beyond the simple viewing of comparable projects elsewhere (addressed by the T-PICS website of SHRP 2 Project C03), but short of the more sophisticated techniques incorporated into transportation, land use, and economic simulation and forecasting models. Yet it is clear that much more work remains to be done to improve these tools and their use.

Remaining Needs

The work accomplished by this project has shown not only (1) that it is possible to produce tools to assess wider transportation effects and their economic value but also (2) that there is significant need for future work to improve both the "state of the art" and the "state of the practice." These needs fall into four categories:

- *Alternative Measures of Transportation Impact.* The literature review has shown that for each of the dimensions of wider transportation impact (reliability, connectivity, and accessibility) there are multiple ways to measure the magnitude of effect. For example, reliability can be measured in terms of standard deviation around the mean, or schedule buffer time, and accessibility can be measured in terms of an effective density measure that is based on a decay function, or else in terms of the effective size of the market within defined boundaries. Each metric has advantages and disadvantages that vary depending on the intended use, though in some cases alternative metrics can yield similar findings regarding the relative impacts of a proposed project. More research is necessary to further illuminate similarities and differences among these metrics, and to guide future use of them.
- *Economic Valuation.* The economic valuation of these wider transportation impacts has been shown to vary widely depending on the type of transportation and industries that are involved or affected. For example, the benefits of timeliness and access to large-scale markets can depend on the type of product being shipped. The tools developed for this project distinguish between freight and passenger transportation, but do not distinguish impacts by industry. While those distinctions may be very important, the tools provided here were designed to illustrate how simple methods can be used in a straightforward manner without further data requirements. However, these tools can provide a basis for tools enhanced with further detail to improve the benefit estimation process, particularly when system-wide freight models and economic impact models are available.
- *Completeness.* The tools developed for this study illustrate how wider benefits can be incorporated into standard project evaluation procedures. But, they are still incomplete.

For instance, the business value of improved reliability has been calculated for freight deliveries, but is not yet operational for commuting trips. Furthermore, no effort has yet been made to assess the value of quality of life improvements that residents may realize because of better accessibility to shopping, recreation, and tourism opportunities. In addition, the three dimensions of impact that were addressed here are not the only dimensions of wider transportation impact. They were selected largely because they were the most commonly reported objectives of highway capacity projects in the T-PICS database, but obviously there are other, localized social and environmental effects that also occur and need to be addressed in future research.

- *Relationship to Productivity and Competitiveness.* These tools all attempt to measure impacts on households and businesses that directly make use of improved facilities, or are directly affected by their use (transporting workers, incoming supplies, or shipping products to customers). Yet there are also broader economic effects that occur as secondary or indirect consequences, over a longer period of time. These include effects on business expansion and location patterns, supply and demand for labor, prices, and import and export patterns—all of which can also affect productivity, competitiveness, and economic growth. Further research is needed to better distinguish productivity gains attributable to transportation system improvements.

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Related SHRP 2 Research

A Framework for Collaborative Decision Making on Additions to Highway Capacity (C01)

Interactions Between Transportation Capacity, Economic Systems, and Land Use (C03)

Pilot Testing of SHRP 2 Reliability Data and Analytical Products (L38)