Analysis of Congestion Scenarios in Long Range Plans Using Travel Forecasting Models

OCTOBER 2017

U.S. Department of Transportation
Federal Highway Administration

TMIP
Better Methods. Better Outcomes.

FHWA-HEP-18-030

1. Report No.
FHWA-HEP-18-030

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Analysis of Congestion Scenarios for Long Range Plans Using Travel Forecasting Models

5. Report Date
October 30, 2017

6. Performing Organization Code

7. Authors
Thomas A. Williams, AICP
Hao Pang

8. Performing Organization Report No.

9. Performing Organization Name and Address
Texas A&M Transportation Institute
505 E. Huntland Drive, Suite 455
Austin, Texas 78752

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFH61-15-C-00029

12. Sponsoring Agency Name and Address
United States Department of Transportation
Federal Highway Administration
1200 New Jersey Ave. SE
Washington, DC 20590

13. Type of Report and Period Covered
June 2015 to October 2017

14. Sponsoring Agency Code
HEPP-30

15. Supplementary Notes
The project was managed by Sarah Sun, COR for Federal Highway Administration. Special thanks to the Capital Area Metropolitan Planning Organization (CAMPO) for use of the regional travel demand model.

16. Abstract

This report describes the process of developing, analyzing, and displaying results of a scenario forecasting process using travel demand models. A Travel Time Index (TTI) is the ratio of travel time without congestion (called free flow) and congested travel times, usually during a peak period. With this common measure, planners can compare and contrast the various levels of congestion between urban areas, scenarios within urban areas, and track congestion levels over time. This report is a guide for forecasting TTI using traditional travel demand models to analyze relative impacts of various trip reduction and modification scenarios from long range planning models. The TTI is used in this context as a measure to indicate the reasonableness of asserted changes made to a trip-based travel demand model that reflect the behavioral changes that could be brought about as a result of specific congestion reduction strategies.

17. Key Words
Scenario planning, travel demand modeling, travel forecasting, long range transportation planning

18. Distribution Statement
No restrictions.

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
51

22. Price
N/A

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Analysis of Congestion Scenarios in Long Range Plans using Travel Forecasting Models

Federal Highway Administration

Table of Contents

List of Figures

List of Tables

1.0 Introduction

1.1 Disclaimer

The views expressed in this document do not represent the opinions of the Federal Highway Administration (FHWA) and do not constitute an endorsement, recommendation or specification by FHWA. The document is based on research conducted by Texas A&M Transportation Institute.

1.2 Report Purpose

This report was funded by the Broad Area Agency research program by FHWA. The purpose of the report is to inform state departments of transportation and metropolitan planning organizations (MPOs) on scenario building methods using the Travel Time Index (TTI) and regional long range planning models.

The purpose of this study was to develop a method to assert changes to a travel model in response to the question, “what would it take to not let congestion get worse?” Many strategies to address this question could not be tested with a regional trip-based travel demand model (TDM). However, elements of trip-based TDMs that can be changed—trip reduction by trip purpose or geography, trip length changes, intrazonal trip capture, and mode shifts—can reflect the types of travel behavior changes that would result from the introduction of specific congestion reduction strategies.

Trip based TDMs are not detailed enough to be used for analysis of specific policies and strategies that are aimed at reducing congestion. However, changes to TDMs can be asserted that reflect the results of such policies. The question then becomes one of how the model is being used—either as a predictive tool or as an exploratory/experimental tool. In the case study presented, the method of using the TDM is the latter.

In this study, TTI—the ratio of peak travel time to free flow travel time—is used as a measure to indicate the reasonableness of asserted changes made to a trip-based TDM that reflect the behavioral changes that could be brought about as a result of specific congestion reduction strategies.

1.3 Report Organization

This report is organized into the following sections:

- *Planning, Forecasting, and Uncertainty* – This section discusses long range planning, the use of TDMs, uncertainty in forecasting, the purpose of calibration, and scenario based planning.
- *Application of Congestion Scenarios Process* – This section discusses the methods used to adjust models to reflect various potential changes in the transportation system.
- *Step-by-Step Guide to Forecasting Congestion Scenarios* – This section details the steps needed to produce the calculations using a trip based model.

2.0 Planning, Forecasting, and Uncertainty

2.1 Why We Use Models in Planning

Transportation planning is the process of collaboratively using existing information and future goals and objectives to develop a future transportation system. Forecasting models are used to describe the transportation system, both in the existing condition and in various future conditions. Models are used to predict, to the best of planners' knowledge, the impacts of growth, travel behavior, and system performance in various future forms. In metropolitan cities, a regional long range transportation plan, required by federal law, describes these elements and their expected trends. Models are used to measure the impacts of the long range transportation plan, including the impact of the planned projects on vehicle emissions.

Forecast models are developed from data that describe the physical transportation system (roads, transit, etc.) and data that describe how people use the system, also called behavioral data. Travel surveys of households and workplaces give planners data about behavior of people using the system, such as when they travel, how often, where they go, the purpose of the travel, and the mode and route they usually take.

A well-calibrated model is effective in assessing impacts of future capacity additions, given that the calibration target of measured behavior remains consistent in the forecast year. The accuracy of the model forecast is only as good as the accuracy of the forecasted inputs, and it is only as good as how well the data used to calibrate the model describe future travel behavior and choices. If travel behavior changes, the assumptions about trip rates, trip lengths, and other constants may become less accurate in describing future travel choices.

Experience tells modelers that travel behavior changes very slowly over time in response to economic, social, or physical changes. Economically, transportation cost can play a role in people's travel choices and economic conditions have an impact on mobility needs such as getting to jobs, making deliveries, and other travel activities. Transportation behavior can also be impacted by social changes over time, such as household size and the number of workers in a household compared to the number of vehicles available. Physical changes to the transportation system can also have an impact. The addition of a new roadway may provide a faster route for some trips.

These slow moving economic, social, and physical changes to the transportation environment are well known to planners because they can be tracked over time, and the trend can be anticipated to continue, reasonably, into the future. Models that are calibrated to recent past conditions are very useful in predicting future travel behavior in this type of slow-changing transportation and urban activity system.

But what if slow, steady change is not what is expected? What if the future was expected to be different in some significant way? What if planners wanted to provide forecast models of a shifting course away from trending travel behavior? Is there a disruptive change that is expected to dramatically alter travel behavior, such as the advent of automated transportation and services?

2.2 Two Ways to Use a Travel Model

The typical way that a model is applied to make a forecast is to simply change the input population and employment growth and apply the calibrated model using the new growth (and usually, growth distribution around a region). This type of typical application is done to show what will happen if travel behavior—the choices about frequency, mode, route, and location of trip making—stays consistently at the level measured in travel surveys. This type of model application is directed at showing the impact of continuing trends.

We can say that a model used in this manner is being applied in a *predictive* way. The objective performance question that is being posed is: "What outcomes can we expect if we continue with business as usual?" The resulting question about accuracy for this type of forecast is, "Will trends continue as they have been, well into the future?"

A model can also be used to forecast a shift away from trends. In this type of modeling, the analyst may change the frequency of trip making for a particular purpose, or change the trip length, time of day, mode, or routing choices. Using a model in this way can be thought of as *exploratory.* The objective of this type of modeling is to forecast the outcomes as if a change in behavior was going to take place. The question would be, "What if we changed travel behavior in a significant way?" The resulting question about accuracy for this type of forecast is, "Are the shifts imposed on the model reasonable and consistent with known conditions?"

In addition to application of models with different objectives in mind, modeling analysts may wish to also find out the level, or quantity, of travel behavior change that it would take to reach a specific system performance condition. The objective question here would be, "What would it take to yield a condition of *x*," where *x* is the system performance condition desired. Table 1 lists the context for different methods of applying travel models.

This report presents one method to produce a reasonable experimental forecast using long range TDMs to achieve a specific performance objective. While reasonableness is a subjective decision, the use of a calibrated speed model to calculate a TTI provides a basis for assessment of reasonableness in exploratory modeling.

Table 1. Context of Model Application Types

Type of Model Application	Objective	Measured Outcomes
Predictive	What will the future be?	System condition if current behavior and trends continue
Exploratory: Scenario Analysis	What impacts will these scenarios have?	System condition if these scenarios come to be
Exploratory: Experimental Analysis	What will it take to achieve x performance condition?	How much change in behavior will be needed to achieve desired outcome

2.3 Trends, Alternatives and Scenarios: What's the Difference?

The use of the word *trend* in transportation forecasting refers to the patterns of growth and travel behavior that have been observed over time. An alternative is an application of a transportation system within a transportation plan. A scenario is not an alternative and usually differs from the trend, although the trend can be considered one of the scenarios for thinking about the future (Bauer, Ange, & Twaddell, 2015).

Scenario planning is a method used in strategic planning to make significant changes to aspects of future forecasts so that decisions, plans, policies, and alternative solutions can be tested under a variety of conditions. Scenarios are often described in narratives, as a what-if condition for the future.

For most of the latter half of the 20th century, the technology available for transportation remained fundamentally unchanged. Most people used private automobiles as massive levels of investment in highways, parking, and urban arterials spread across the world. Where the automobile could not keep up with demand due to limited space, mass transit systems were put in place. Most of the technology in use was invented in the late 1800s and early 1900s and remained relatively unchanged.

The stable transportation technology environment meant that transportation planners could calibrate models to existing travel choices people were making, using cars, buses, trains, walking, and biking to meet their daily activity needs. Planners and modelers could look at the existing system performance, add expected growth in population and employment, and evaluate the needs to inform the decision making process.

However, late in the 20th century the introduction of mass personal communication through use of the internet began to transform how people satisfied their daily activities, such as going to work or buying a needed household item. Personal communication devices penetrated almost every home, empowering people to work remotely and shop remotely. Computer robotics has now become a reality, in a testing prototype environment as of 2016, to create cars that drive themselves. These advances could bring about changes in the way people satisfy their daily activity needs.

Transportation planners, collaborators, stakeholders, and decision makers are increasingly faced with the proposition that the future will be different from the past. The stakes have changed for planners and modelers. In the past, during a time of slow moving change, modelers were able to survey choices people were making, add growth, and relatively accurately predict the impacts into the future.

Modelers are now faced with more uncertainty about the future than they were in the recent past. Models that are calibrated to existing conditions and observed travel choices may not be reflective of a future where communication is easily accomplished through personal communication devices and efficient portable computer platforms. Robotics and automated systems may transform how we use the transportation system to go to work, collaborate, share ideas, and access goods and services. In this planning environment, modelers will need to work with planners and decision makers to go beyond the simple growth-plus modeling practices of the past. Modelers will need to adjust parameters and methods to account for the impacts of new technology on travel behavior and system performance, in addition to growth.

2.4 Transformational Change and Uncertainty

In times of slow moving change, long range travel models have been very useful in showing the impact of continuing the trending pattern of usage of the transportation system. This type of forecasting is useful to display the impact of business-as-usual travel behavior when future growth in population and employment is added. When an unexpected event happens, such as an economic downturn, these business-as-usual forecasts will probably still be plausible, but simply have a reduced impact as the event slows growth over time.

Another type of unexpected event is one where a *transformational* event occurs. Transformational events are significant events that cause a change in the characteristics of the urban region to the degree that negates the use of business-as-usual forecasting. An example of this type of event was Hurricane Katrina in 2005 that transformed the region of New Orleans to an extent that recent forecasts could not be used because of the significant changes the catastrophe had to the metropolitan region. Significant urban planning and urban redevelopment has occurred since the event, which puts New Orleans on a path to growth, but significantly changed from the trend expected before the hurricane.

Another type of change is one that is not related to a single catastrophic event but is expected to transform the patterns of growth and behavior in a metropolitan region. This type of change is impactful over time to a degree that people begin to transform their choices made about urban travel. This type of change is occurring now across the world in response to advancements made in communications and transportation technologies.

A recent report from the Transportation Research Board Executive Committee's Task Force on Transformational Technologies listed eight broad areas of transformational change currently impacting transportation:

1. Policy development.
2. Vehicles.
3. Infrastructure.
4. Personal technology (tech).
5. Communications, computation, and big data.
6. Insurance, standards, and security.
7. Mobility services.
8. Convening, deployment, and evaluation (Mohaddes, 2016).

2.5 Performance Based Planning and Programming and the TTI

Performance Based Planning and Programming (PBPP) is described in several reports and in federal legislative requirements for long range plans, including Metropolitan Transportation Plans (MTP). PBPP can be described as follows:

> PBPP is a data-driven, strategic approach, providing for public and stakeholder involvement and accountability, in order to make investment and policy decisions to attain desired performance outcomes for the multimodal transportation system.
> *(Grant, McKeeman, & et.al., 2014)*

Long range MTP, historically, have not been subject to performance management. Recent federal transportation legislation has made PBPP a required core element of the metropolitan transportation planning process.

Essentially, PBPP is a way to monitor implementation of a transportation plan, adjust it as necessary, to tie activities to plans and ensure performance goals are met. The technique described in this document is one method to measure overall traffic congestion impacts of long range transportation plans through the use of TDMs in common usage across the United States.

TTI is described in detail the next chapter. TTI is a measure that is used as the common basis for defining the performance of the existing transportation systems in metropolitan regions across the United States. Each year, since 1982, the Texas A&M Transportation Institute has published the Urban Mobility Report, recently in cooperation with the INRIX Corporation (Schrank, Eisele, Lomax, & Bak, 2015).

TTI is measured for 471 urban areas in the United States and provides an annual measure of congestion for each metropolitan region. This information tracks the performance of the urban area according the measured travel times comprising the TTI. However, there is not an equivalent document that indicates the expected performance of long range transportation plans through a common measure, such as the TTI.

This report provides a detailed description on how a TTI can be calculated using long range TDMs in common usage in the United States. The index is calibrated to the base condition of travel times measured and published each year in the Urban Mobility Scorecard. By using the methodology in this document, planners and modelers can determine the impact that long range plans, such as the MTP, will have on travel times and overall congestion. Using the index as a common measure allows for comparison with the base year, existing, condition and can also be used to compare plan impacts across metropolitan regions.

3.0 Application of the Congestion Scenarios Process

3.1 TTI

TTI is the ratio of peak period travel time to free flow travel time, resulting in a measurement of an average congested condition across AM and PM peak periods. Because it is a ratio, the value does not include the mileage of trip and can therefore be used to compare different cities. The measure is either derived from weighted speed models based on the Highway Performance Monitoring System or it is calculated directly using speeds gathered passively through cellular and/or global positioning system (GPS) data.

The annual Urban Mobility Scorecard is produced by the Texas A&M Transportation Institute in cooperation with INRIX. INRIX provides GPS/cellular speed data. The speeds are weighted by vehicle miles of travel (VMT) on segments of roadway. FHWA's Urban Congestion Reports are produced in a similar manner using Highway Performance Monitoring System data on a quarterly basis. Both reports produce TTI rankings of metropolitan areas across the United States.

A forecasted TTI can be used in several ways, including:

1. Comparison of a no-build future with the MTP.
2. Comparison of various scenarios of trip reduction, mode shift, time of day of travel.
3. Measuring congestion for regional analysis and corridor specific analysis.

Another source of TTI is the quarterly published Urban Congestion Report, produced by FHWA's Operations Performance Measurement Program, https://ops.fhwa.dot.gov/perf_measurement/ucr/index.htm.

3.2 Building Strategic Congestion Scenarios in a Trip Based Model

We will use the Capital Area MPO (CAMPO) model (2010–2035) as a case study to explain how the calibrated forecasted TTI can be used to build scenarios for a long range transportation strategy. This process asserts various changes to parameters and outputs of the TDM to show the impacts of trip reduction, mode shift, time of day shift, and a land use scenario on regional travel times and congestion.

Figure 1 is the overall process used to build congestion scenarios and measure their impact using a regional TDM and a forecasted TTI. This process will be described in detail in coming chapters.

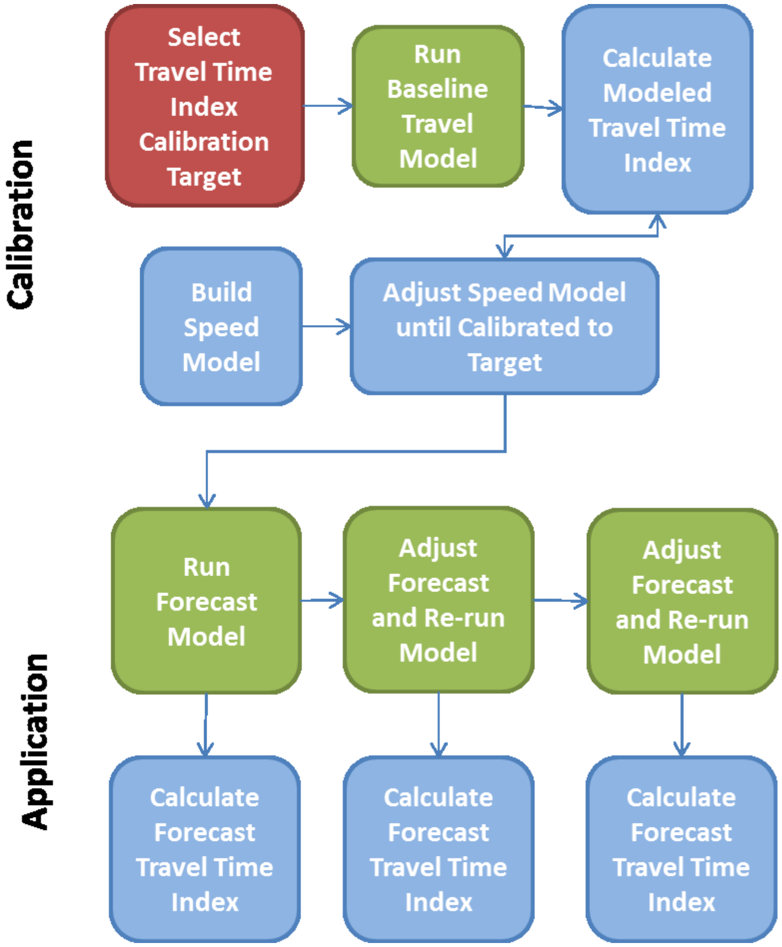


Figure 1. Congestion Scenario Process

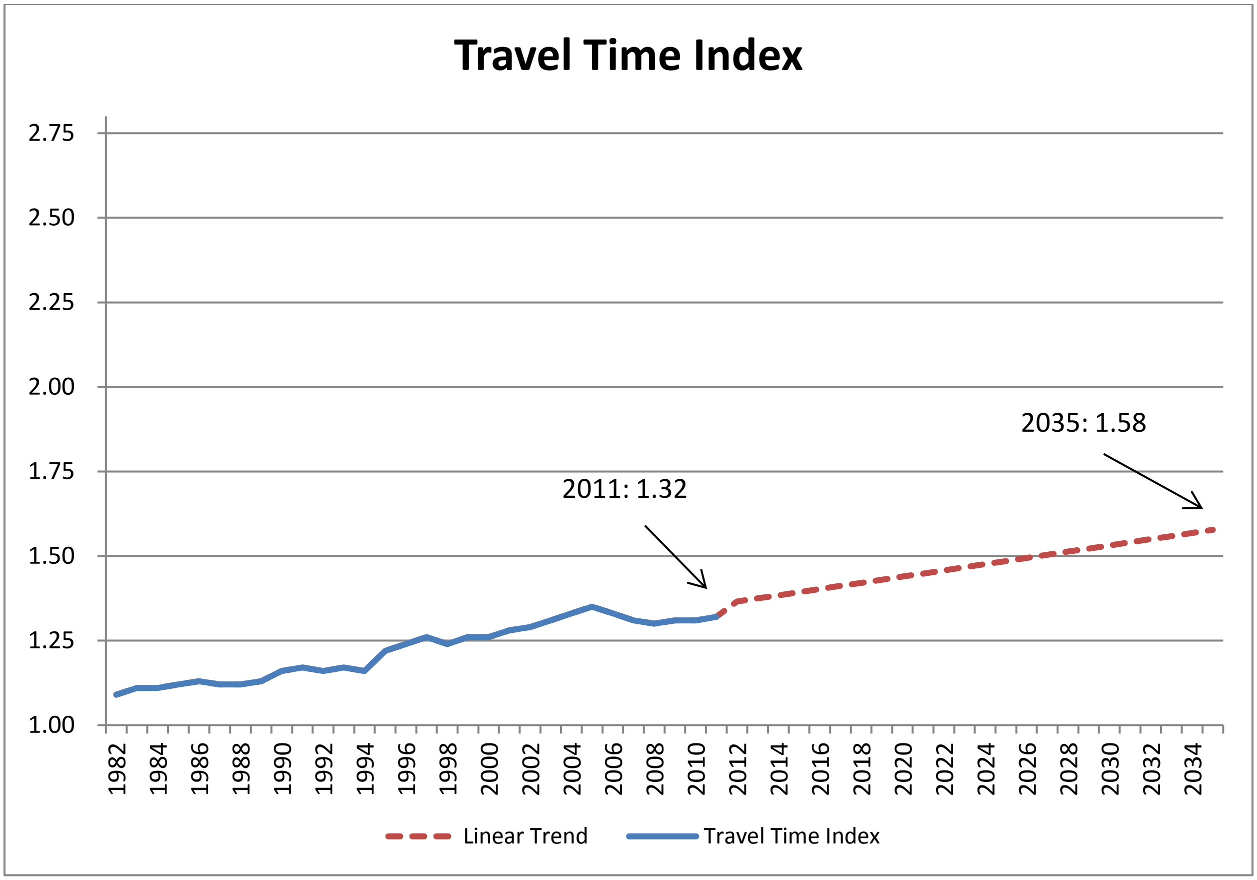
3.3 Alternative Strategies and Measurement

Given the forecast population and vehicles in the region, researchers identified strategies to address the congestion problems related to the rapid growth.

Six transportation strategies were framed for evaluation. The impact of not building any additional capacity (no build) and adding the capacity from the CAMPO 2035 Regional Transportation Plan were the first two strategies tested. The other strategies included telecommuting, peak shift, mode shift, and a land use change strategy based on concentrating population and employment in activity centers.

Each of the strategies, including the CAMPO Plan strategy, was measured for its impact on travel times and congestion in the region. All strategies were tested using the TTI as the performance measure. While there are many aspects to each strategy, this study focused exclusively on the impact each strategy was likely to have on congestion, as measured by the TTI.

Figure 2 depicts the Austin area’s actual and trend TTI.



Source: Lomax and Shrank, 2012

Figure 2. Austin Area TTI—Actual and Forecast Trend

For each of the alternative scenarios, researchers used the 7 a.m. to 9 a.m. peak period because it is readily available in the CAMPO model. The quantification of values in each strategy is not predictive in this study, but instead were imposed. It is simply a what would it take or what-if type of analysis. **The charts offered do not predict levels of participation in each strategy. The assumptions of the level of participation are just that—assumptions. However, the impact on congestion and the related TTI allows an apples-to-apples comparison of the relative impact of each. These examples are showing the use of a trip-based TDM in an exploratory manner.**

3.4 Strategies Examined

Six strategies were examined using the 2035 long range travel demand forecasting model from CAMPO. These strategies were examined in a cumulative manner, with the effects of one strategy building upon the congestion reduction impacts of the others.

The experiments examined in this study were performed by asserting changes to the trip-base CAMPO regional TDM. Taken individually, they are called strategies; taken cumulatively they form a future scenario—a scenario that meets the goals of the experiment. In this case study, the objective of the scenario was to bring the TTI down to a 1.20 value.

Table 2 shows the method of representing each strategy in the CAMPO trip-based TDM.

Table 2. Trip-based Model Adjustments for Transportation Strategies

Transportation Strategy	Model Adjustment Method	Potential Refinements
Build the Plan	Added capacity	Add or delete large expensive highway or transit projects
Telecommuting	Reduce Home Based Work (HBW) productions/attractions	Stratify by income, limit to service employment, add HNW trips as replacement
Peak Shift	Adjust diurnal factors for AM peak period	Adjust for PM periods; limit to HBW trips; limit to congested trips
Mode Shift	Reduce SOV trip table for transit-accessible TAZs	Limit to short trips in accessible bike/ped TAZs; adjust for high-occupancy vehicle (HOV) also; vary by trip purpose
Centers Plan	Increase intrazonal capture in Centers TAZs; reduce trip lengths	Adjust employment/housing distribution; vary by Center type, trip purpose; additional mode shift

3.4.1 CAMPO Plan

The CAMPO Plan strategy is a program of roadway and transit improvements. The CAMPO Plan also includes various other non-capacity strategies, but for this study, the CAMPO Plan refers only to the capacity improvements (roadway and transit). Researchers also added managed lanes on I-35 to the roadway network, which were not in the adopted plan because of funding constraints.

3.4.2 Telecommuting

The telecommuting strategy is designed to represent a 10 percent level of telecommuting, on average, throughout the five-county CAMPO region. While named telecommuting, there are demographic changes that could contribute to this level of trip reduction, such as a higher number of retirees in the region or fewer workers being added to the total regional workforce. For example, a 10 percent level of telecommuting equates to every second worker in the region taking one day a week to work at home, on average. No trips were added to reflect travel on days where a worker did not commute; the assumption was that all travel generated by each worker telecommuting was eliminated.

3.4.3 Peak Shift

This strategy assumes shifting 12 percent of travel from the AM peak period (7 a.m. to 9 a.m.) to pre-peak and post-peak periods. To accomplish this, a 5 percent shift in total travel to earlier hours and a 7 percent shift of trips to between 9 a.m. and 11:00 a.m. was assumed.

3.4.4 Mode Shift

This strategy represents increasing use of alternatives to the single-occupant vehicle (SOV), through more transit, biking, and walking trips in the AM peak period. No detail on which alternative mode was chosen is specified. SOV trips are simply taken out of the regional trip table.

3.4.5 Centers Plan

The Centers Plan strategy represents adding more population and employment to areas, similar to the centers concept included in the CAMPO Plan, as well as assuming a reduction in trip lengths by 25 percent for all home-based trips. Through the assumption of more population and employment in these activity centers, the desired outcome is both fewer and shorter vehicle trips. The CAMPO Plan has a goal of 31 percent and 38 percent of population and employment, respectively, being located in activity centers. These are the levels that this strategy used in this study.

3.5 Comparative Analysis of Strategies

Recognizing that no one scenario will meet the challenge, the goal was to build a collection of scenarios that together might achieve a substantial impact on TTI. Figure 3 represents the cumulative impact of all of the scenarios and depicts the contribution of each. Researchers realize that full scenario implementation results will likely not happen. However, knowing the assumptions of each of the scenarios provides an understanding of the relative impact each strategy can have.

Wedge graphics can be very informative. First, it is easy to depict the relative impact of various strategies in one graphic—by showing their total impact in the horizon year (2035). But far more telling is the size of each wedge, which indicates that each strategy is, in reality, implemented over time in an incremental fashion. As a planning tool, this shows that to achieve the total benefits of each strategy, it is necessary to start today and incrementally build up the total benefits over time.

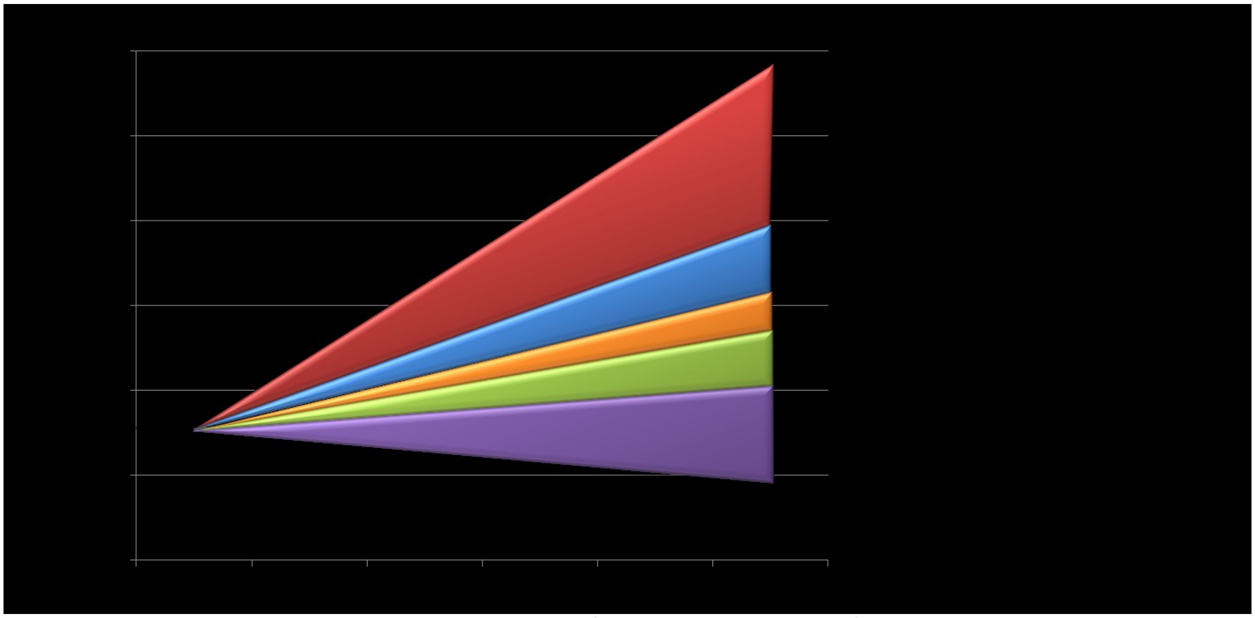


Figure 3. Austin Regional Congestion Reduction Strategies

As noted in Figure 3, if there is no additional project implementation prior to 2035, the modeling quantifies the daily TTI to be 2.17—or 66 percent more than the 2010 congestion levels. But, by adding the improvements included in the CAMPO Plan (plus the managed lanes on I-35), the index is reduced to 37 percent more congestion than today.

The impact of the additional scenarios brings those totals down further, with the total of all scenarios coming to 10 percent less congestion than today. The assumptions included in each scenario present significant challenges as well. This analysis can be a tool to mix and match, add and subtract, and feed the ongoing process of making transportation decisions.

3.5.1 The CAMPO Plan Strategy

The CAMPO Plan is a program of roadway and transit improvements totaling $26.8 billion, with about $9.6 billion in new projects. Using the CAMPO modeling networks, researchers calculated the planned roadway network in the CAMPO Plan will add 1,958 additional lane miles—a 17 percent increase in lane miles over the 2010 level. Researchers also added one managed lane in each direction on I-35, adding about 55 lane miles to the total. Those additional I-35 managed lanes added a 4 percent reduction in the regional TTI.

The CAMPO Plan, with the I-35 managed lanes, offers an 18 percent reduction in the TTI by 2035 as compared to the no build condition (Figure 4). This strategy is not a given; to build the projects in the CAMPO Plan will require the region to secure funding, execute contracts, and develop the projects in the plan incrementally over the next 25 years.

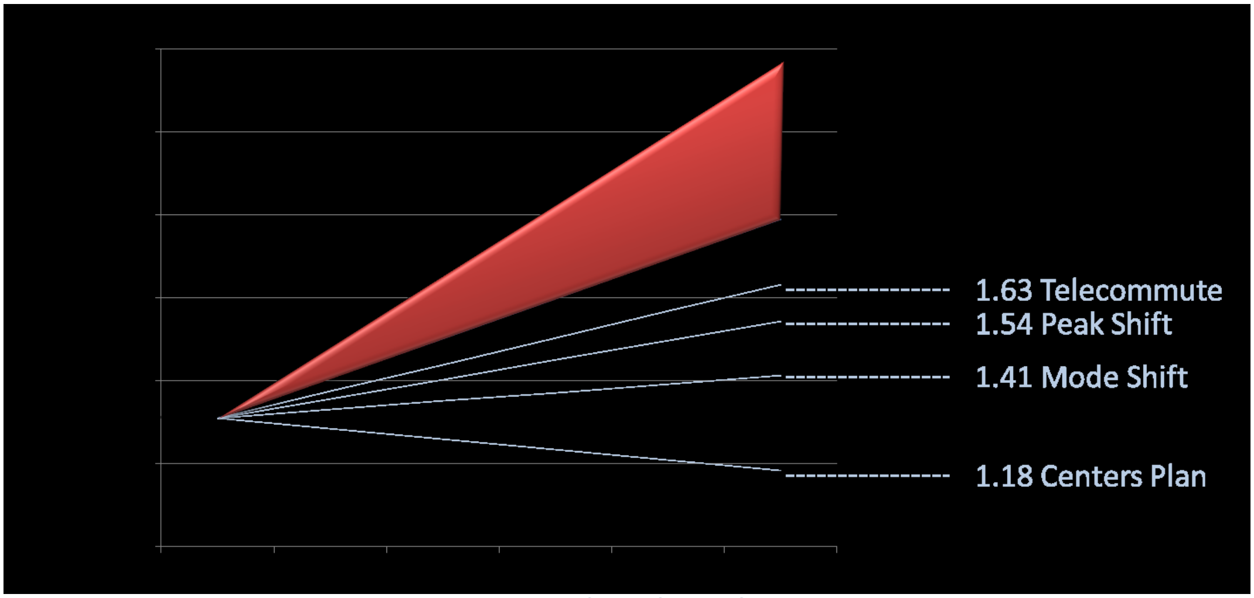


Figure 4. The CAMPO Plan Strategy

3.5.2 The Telecommuting Strategy

The telecommuting strategy was fashioned to represent a 10 percent level of telecommuting, on average, throughout the five-county region. Researchers reduced the total number of home-based work trips by 10 percent to model the strategy. Although the scenario is named telecommuting, there are other actions that could produce similar reductions, such as demographic changes in the workforce. An increase in the proportion of retirees in the region or fewer individuals in the total regional workforce could have the same impact.

If 10 percent of the workforce telecommutes—the equivalent of every other worker choosing to work at home one day a week—or some other comparable demographic change occurs, then an additional 9 percent reduction in the TTI results by 2035 (Figure 5).

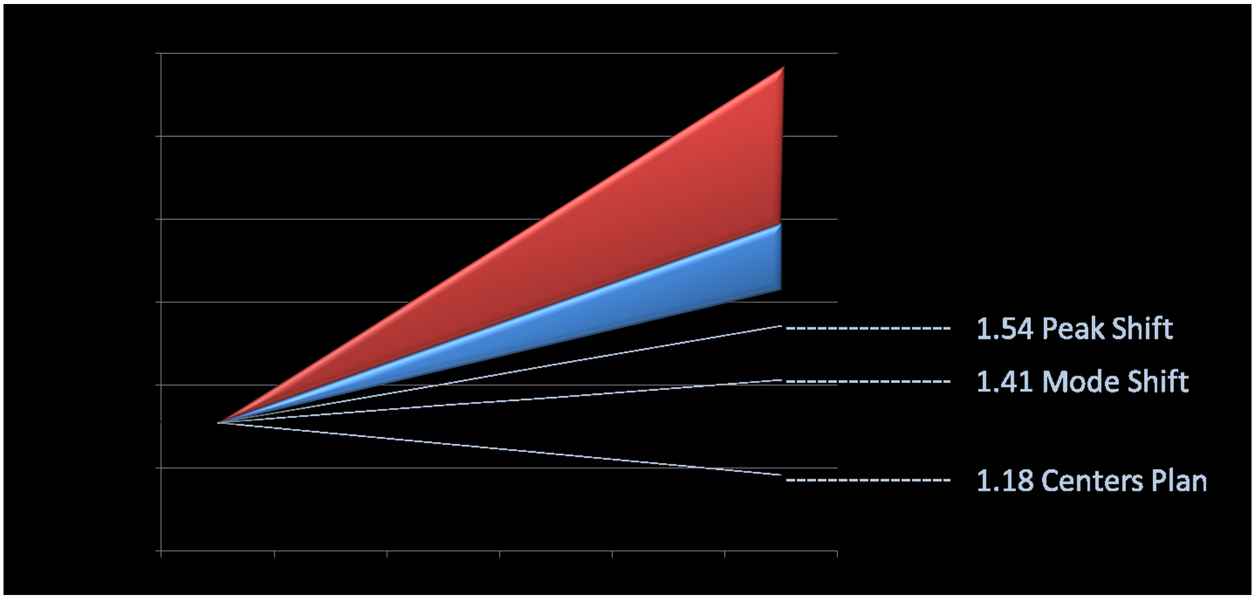


Figure 5. The Telecommuting Strategy

3.5.3 The Peak Shift Strategy

The peak shift scenario is designed to represent commuters and other AM peak-period travelers making the choice to travel before or after the 7 a.m. to 9 a.m. period. This scenario assumes that 12 percent of the drivers make that decision, with 5 percent traveling before 7 a.m. and 7 percent traveling between 9 a.m. and 11 a.m. Note that in this strategy, SOV travel is not reduced, they simply travel at different times than in today's pattern.

Thus, if there was such a shift, the result would be an additional 5.5 percent reduction in the TTI (Figure 6).

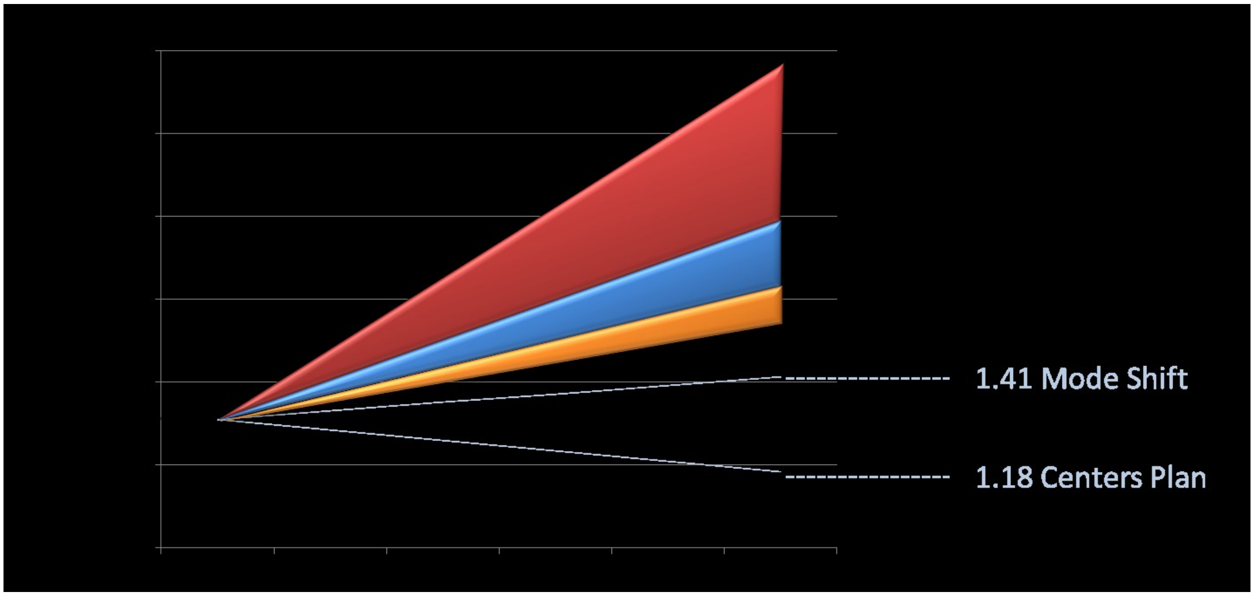


Figure 6. The Peak Shift Strategy

3.5.4 The Mode Shift Strategy

Shifting trips from personal SOVs to public transportation, biking, and walking during the AM peak travel period is represented by the mode shift strategy. Researchers assumed 11 percent fewer SOVs that would instead be taking transit, riding a bike, or walking to and from work. Researchers did not estimate the impact to the transit system or additional needed transit facilities required to achieve this level of increased activity. Researchers also did not assume which mode the trips would shift to—that would be dependent on choices made by commuters and other travelers in the AM peak period.

In total, the CAMPO model forecasts 676,000 SOV trips in the AM peak period. This strategy assumed a reduction of 72,000 of those trips—shifting them to transit, walking, or biking.

Thus, if 11 percent of those individuals now driving to and from work each day made the personal decision to ride the bus or rail, bike, or walk instead, TTI would be lowered an additional 8.4 percent (Figure 7).

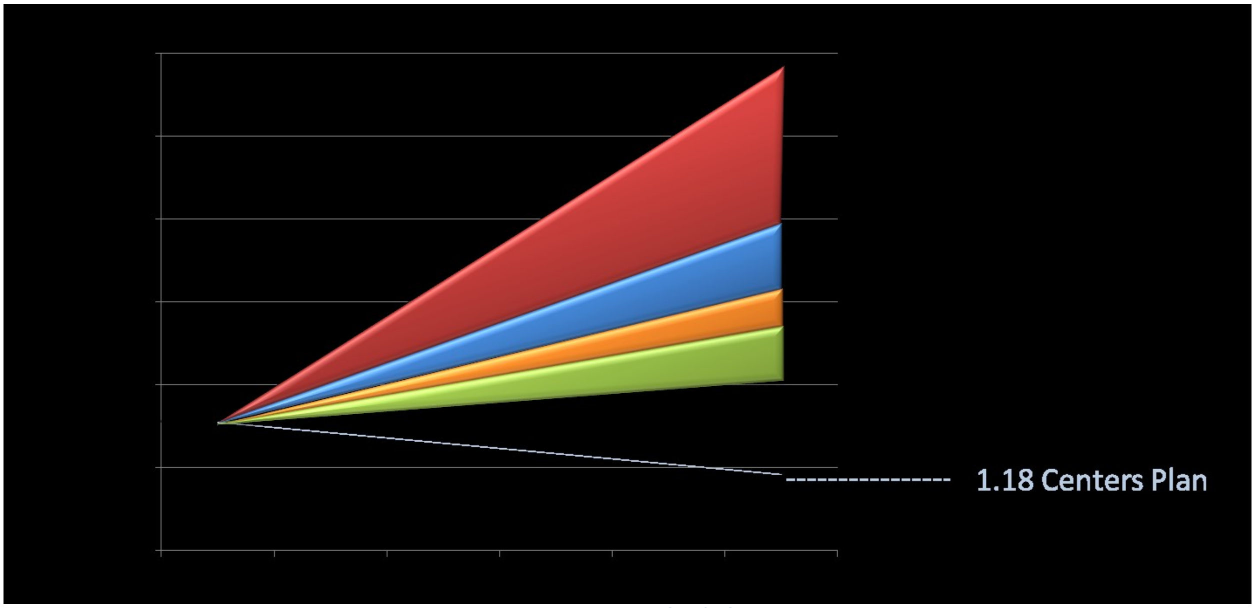


Figure 7. The Mode Shift Strategy

3.5.5 The Centers Plan Strategy

The Centers Plan strategy represents two sets of assumptions. First, researchers assumed a higher level of population and employment in the traffic analysis zones—matching areas representative of the CAMPO Plan's centers concept as assumed by TTI. Second, the length of all home-based trip making was reduced by 25 percent (for work, shop, and play). The outcome results in fewer and shorter auto trips since people living in centers could likely work, shop, and play in the same mixed-use area of their residence.

This is a substantial change in lifestyle decisions, as shown in Table 3.

Table 3. Percent of Regional Population and Employment in Centers

Plan or Analysis	Population Percent	Employment Percent
CAMPO Centers Plan Goal	31%	38%
TTI's Estimation in Center Areas in Model (2035)	14%	26%
Centers Plan Strategy—this study (2035)	31%	38%

The Centers Plan strategy would require an additional 550,000 people to move into activity center areas (as defined by this research as Traffic Analysis Zones in the CAMPO model), in addition to the 450,000 that were predicted to live in these areas in the CAMPO model. If this were to occur, the total TTI would be lowered an additional 16 percent (Figure 8). Also, an additional 200,000 employees would need to be located in center areas, on top of the already 400,000 predicted in the CAMPO model.

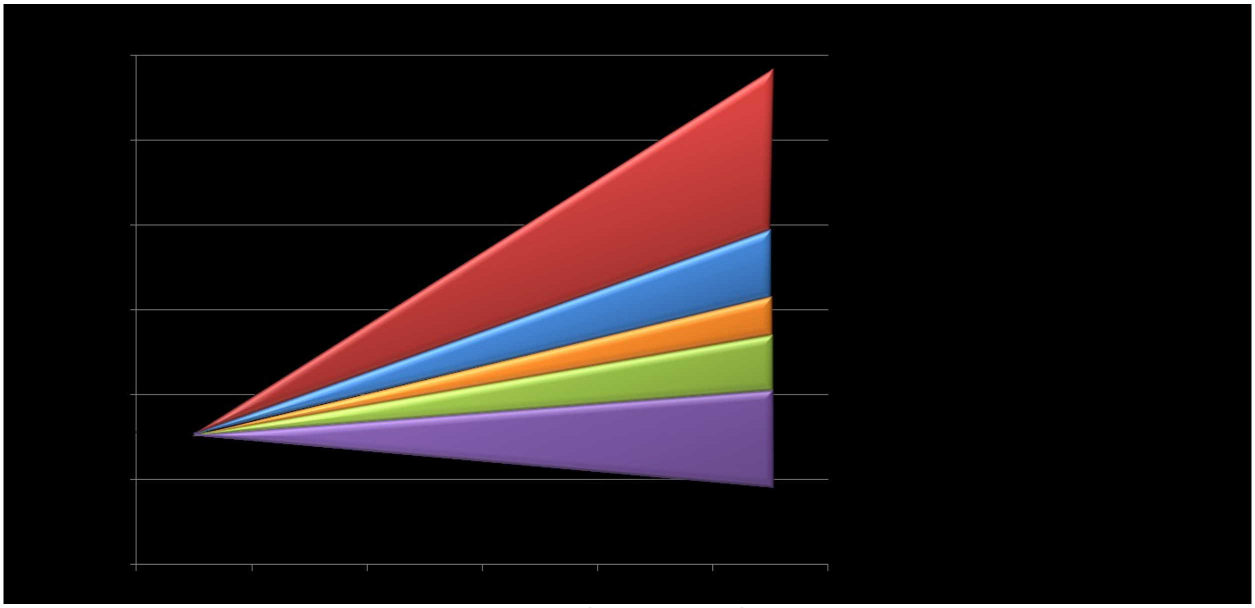


Figure 8. The Centers Plan Strategy

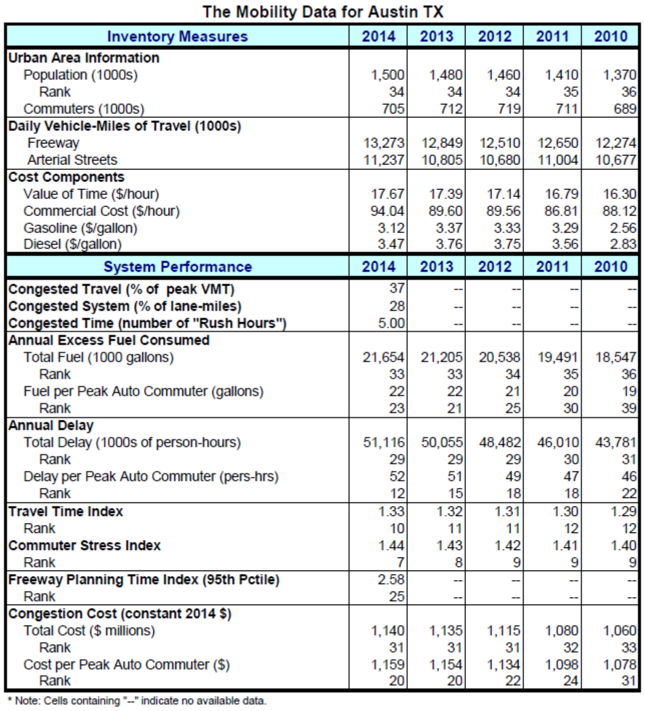
4.0 Step-by-Step Guide to Forecasting Congestion Scenarios

4.1 Background: Develop Baseline Forecast and Calibrate a Speed Model

4.1.1 Determine Model Baseline Year to Calibrate Speed Model

A model year that matches the data year in the UMR is necessary to calibrate a speed model and calculate a baseline modeled TTI. After the modeled TTI is satisfactorily close to the observed TTI from the UMR, then the model is considered calibrated and can be used to forecast a TTI value. The baseline year of the regional TDM may be either a calibration year or a validation year, but is most commonly the same year for both. For instance, if the model was calibrated in 2008 and has a validation year of 2014, either year is applicable for calibration of a speed model. The criteria for calibration will be that the modeled TTI matches to some degree the observed TTI from the UMR. A good rule of thumb is to choose the year of the model closest possible year to the present year.

The UMR can be found at http://mobility.tamu.edu/ums. The Urban Mobility Scorecard can be viewed and it can be seen that data for Austin, Texas, is available for 2010 through 2014. Previous years are also available in other reports. Since the regional model in Austin has a calibration year of 2010, and forecast years of 2020, 2030, and 2040, the 2010 year is most suitable for this analysis. TTI for Austin in 2010 was measured in the UMR to be 1.29, indicating that a peak-period trip under congested conditions will take 29 percent longer than if traveled under non-congested conditions.



The Mobility Data for Austin TX

Inventory Measures	2014	2013	2012	2011	2010
Urban Area Information					
Population (1000s)	1,500	1,480	1,460	1,410	1,370
Rank	34	34	34	35	36
Commuters (1000s)	705	712	719	711	689
Daily Vehicle-Miles of Travel (1000s)					
Freeway	13,273	12,849	12,510	12,650	12,274
Arterial Streets	11,237	10,805	10,680	11,004	10,677
Cost Components					
Value of Time ($/hour)	17.67	17.39	17.14	16.79	16.30
Commercial Cost ($/hour)	94.04	89.60	89.56	86.81	88.12
Gasoline ($/gallon)	3.12	3.37	3.33	3.29	2.56
Diesel ($/gallon)	3.47	3.76	3.75	3.56	2.83
System Performance	**2014**	**2013**	**2012**	**2011**	**2010**
Congested Travel (% of peak VMT)	37	--	--	--	--
Congested System (% of lane-miles)	28	--	--	--	--
Congested Time (number of "Rush Hours")	5.00	--	--	--	--
Annual Excess Fuel Consumed					
Total Fuel (1000 gallons)	21,654	21,205	20,538	19,491	18,547
Rank	33	33	34	35	36
Fuel per Peak Auto Commuter (gallons)	22	22	21	20	19
Rank	23	21	25	30	39
Annual Delay					
Total Delay (1000s of person-hours)	51,116	50,055	48,482	46,010	43,781
Rank	29	29	29	30	31
Delay per Peak Auto Commuter (pers-hrs)	52	51	49	47	46
Rank	12	15	18	18	22
Travel Time Index	1.33	1.32	1.31	1.30	1.29
Rank	10	11	11	12	12
Commuter Stress Index	1.44	1.43	1.42	1.41	1.40
Rank	7	8	9	9	9
Freeway Planning Time Index (95th Pctile)	2.58	--	--	--	--
Rank	25	--	--	--	--
Congestion Cost (constant 2014 $)					
Total Cost ($ millions)	1,140	1,135	1,115	1,080	1,060
Rank	31	31	31	32	33
Cost per Peak Auto Commuter ($)	1,159	1,154	1,134	1,098	1,078
Rank	20	20	22	24	31

* Note: Cells containing "--" indicate no available data.

Source: http://mobility.tamu.edu/ums/congestion-data/central-map/

Figure 9. Urban Mobility Scorecard, Texas A&M Transportation Institute, 2015

4.1.2 Develop Baseline Model Run

Typically, the chosen baseline year model run will exist as part of the development of model calibration and/or validation. If the model for a baseline year is not available, the analyst will need to produce the year that matches the UMR data to calibrate a modeled TTI. The baseline year need only be very close to the existing year to get a resulting analysis that compares future conditions to today.

For instance, if the analyst chooses 2014, the latest available UMR year, to use as a baseline, the model would ideally represent data about 2014. This update would involve adding network capacity and new facilities to the modeling network and updating the demographics of the model at the TAZ level to include development up to 2014.

Alternatively, a short-cut method is to simply use the most recent model year, for instance, 2010, and then simply growth factor the resulting trip tables using growth by TAZ as an objective in a Fratar process. However, it is NOT recommended that this resulting demand be assigned to a 2010 network. The network capacity should always represent the year of the analysis—in this case 2014— to preserve the volume and capacity relationships upon which the speed model is based.

Another element that is needed for this process is a peak-hour or peak-period traffic assignment that represents the congested travel times in the regional model. Many trip based models for larger metro regions have peak period capability. If the region under analysis does not have a peak period modeling capability, then the analyst will need to develop this capability in the model before proceeding with this analysis. Typical peak travel factors and a suggested methodology can be found in *NCHRP 716 Travel Demand Forecasting: Parameters and Techniques.*

4.1.3 Determine Facilities Included in TTI Calculations

The analyst should determine the extent of network that is covered in the annual UMR report. Since the UMR analysis is based on INRIX speed data, the coverage of roadways that are measured is limited to larger facilities, usually freeways and major arterials. In Austin, Texas, the roadways covered by the INRIX data and used in the UMR are highlighted in red and are shown in Figure 10.

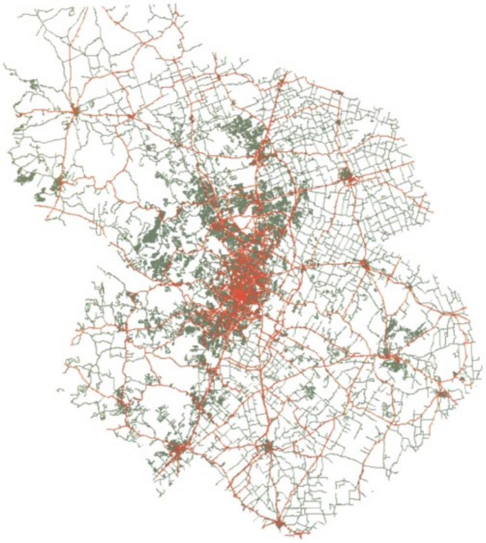


Figure 10. Facilities in Austin Region with INRIX Data

The analyst should also study the congestion trends in the region using the TTI. The purpose of this step is to assess what the target TTI should be for the analysis. Typically, a planning agency may set a performance goal of a TTI of 1.20 to 1.30, meaning peak period travel times are no more than 20 or 30 percent higher than free flow (off peak) travel times. This goal will be used to assess the level of trip demand reduction that is necessary, later in the process.

4.2 Calibrate a Speed Model to the Observed TTI

4.2.1 Overview of Speed Models and TDMs

The purpose of this step is to calibrate a speed model that uses the output of a regional TDM and network capacities to determine roadway speeds under congested and non-congested conditions. The speed model needs to be shown to replicate observed TTI measurements to be considered calibrated.

To perform the calculations for this step, use a spreadsheet or a program script outside of the existing model procedures. A speed model uses the V/C ratio, the relationship between traffic flow (volume) on a roadway, and the total available capacity as independent variables. The dependent variable is speed. These models are also referred to as volume delay curves. A regional model traffic assignment will provide the volumes for the speed model.

To calibrate a speed model to the observed TTI:

1. Extract link data (as input) for the analysis.
2. Choose the volume delay function for the speed model.
3. Calibrate the speed model on the baseline year.

4.2.2 Extract Link Data as Input for the Analysis

The procedure to extract link data as input for analysis is as follows. The purpose of this step is to get each link from the model, with traffic flow and capacity from a baseline validation year traffic assignment, and calculate a TTI.

Step	Description	Output of the TDM	Example Uses
1	Choose a representative time period from the model that best indicates the level of congestion at peak times in the region. The choices typically are: AM peak period or PM peak period.	Analysis of time of day factors tables	The AM peak period (6–9 a.m.).
2	Copy the following attribute fields to the speed model (spreadsheet): Link ID. Length. Functional classification. Area type, county, or any other Geo-ID (optional). Travel time resulting from the off-peak period. Total peak-period assigned flow. Total peak-period capacity.	Modeled volumes and coded capacities from the network link data for the calibration year	The NT (Night) period as the travel time resulting from the off-peak period. The AM period as the total peak-period assigned flow. AM period as the total peak-period capacity.
3	Calculate the TTI for a peak period using the following equation: $TTI = \frac{\sum(Peak\ Modeled\ Link\ Times)}{\sum(Free-Flow\ Modeled\ Link\ Times)}$ You can also use off-peak modeled link times instead of free-flow link times in this equation. TTI is the sum of peak modeled link times divided by the sum of the free flow modeled link times.	The network link data (excluding centroid connectors) for the baseline year	The network link data for the baseline year 2010.

4.2.3 Choose the Volume Delay Function for the Speed Model

Overview

The purpose of this step is to calculate a speed model (curve) that is used to determine speed (travel time) on each link from the peak and off-peak modeled traffic flows. The speed curve (volume-delay function [VDF]) is adjusted until the link travel times, peak and off-peak, result in a TTI value that matches the observed values from the UMR (or other data, described later in this report).

Because the speed model assumes that the peak speed is calculated by using the volume delay equation, the next step is to choose the VDF. This function relates speed (Y-axis) to the volume-to-capacity ratio (X-axis). The most common form is the Bureau of Public Roads form, but others are available that may be used. In this case, we chose the Akcelik Function for example.

Akcelik Function

There are many ways to choose the VDF, but we chose the Akcelik (1991) delay function. Specifically, we use the volume-to-capacity ratio and the capacity from the TDM for each link to estimate a speed.

Rationale for the Akcelik Function

Unlike the Bureau of Public Roads function, which uses two parameters (α and β), the Akcelik function only requires estimating one parameter (τ). The Akcelik function is a better choice for the speed model because we only have one indicator—the observed TTI from the UMR—for the calibration. The Akcelik function gives one solution instead of multiple solutions. The parameter (τ) is adjusted until the resulting TTI matches the target index value obtain from a published report, such as the UMR.

The Akcelik function's speed-VC curve is more appropriate for the speed model because it drops in a more intuitive way as traffic nears VC = 1.0.

Equation for the Akcelik Function

The Akcelik function can be written as:

$$t = t_0\left(1 + \frac{0.25T}{t_0}\left(\frac{V}{C} - 1 + \sqrt{\left(\frac{V}{C} - 1\right)^2 + \frac{8\tau\,(V/C)}{CT}}\right)\right)$$

Where:

t = average travel time per unit distance.
t0 = minimum (free-flow) travel time per unit distance.
V = demand traffic flow.
C = capacity.
T = flow (analysis) period (same unit as t).
τ = delay parameter.

In script, the equation is:
t = t(0) X (1 + 0.25T/t(0) X (V/C – 1 + SQR(V/C – 1) ^ 2 + (8 Tau(V/C)) /C X T))

4.2.4 Calibrate the Speed Model to the Baseline Year

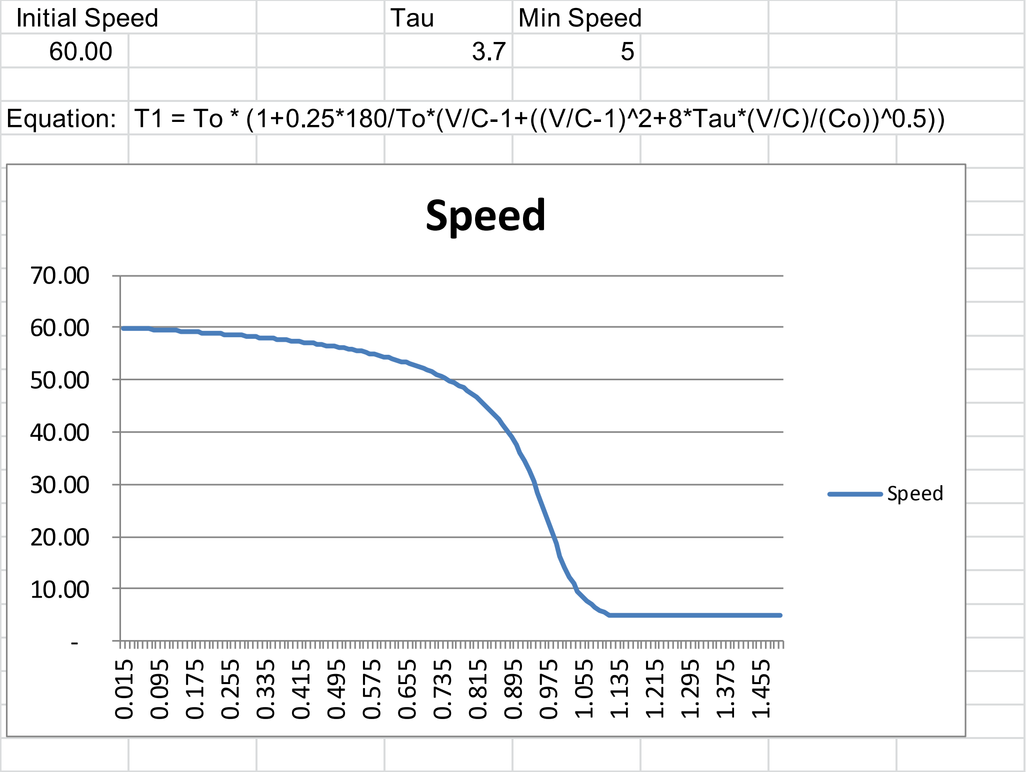
Procedure

The procedure to calibrate the speed model on the baseline year is as follows.

Step	Description	Example Uses:
1	Define a minimum speed, typically 5 to 10 mph, using the speed model. This reduces the subtle changes at lower speeds, which could cause noise in the analysis. Also, it is unlikely that traffic is ever completely stopped at 0 mph.	5 mph
2	Adjust the delay parameter of the VDF until the resulting TTI is close or equal to the chosen UMR observed TTI. This step is the process of calibrating the speed model.	The 2010 Austin UMR observed TTI: 1.29
3 (optional)	Select a subset of links based on area type, functional classification, or county or other boundary. The UMR observed TTI is based on each region's urbanized area. Therefore, as long as the most congested links in the region are within the chosen geographic boundary, the calibration should be valid.	

Example Speed Model

The following graph shows the estimated delay parameter (τ = 3.9) and calibrated speed-VC curve.



Initial Speed			Tau	Min Speed
60.00			3.7	5

Equation: T1 = To * (1+0.25*180/To*(V/C-1+((V/C-1)^2+8*Tau*(V/C)/(Co))^0.5))

The calibrated speed model was based on the following subset of links:

- Area type ≤ 4 (rural areas were excluded).
- Functional class ≤ 6 (only freeways and arterials were included).

At this point, the resulting TTI from the spreadsheet calculation should be close to the observed TTI derived from the UMR. The user must adjust the speed curve, which calculates the speed based on the volume-to-capacity ratio of the set of links copied into the spreadsheet from the TDM.

4.3 Develop Alternative Forecasts and Execute Models

4.3.1 Overview

Once the speed model is calibrated to a baseline condition, using a target TTI from the UMR, the TDM can be used to generate future scenarios. There are many future scenarios, the most common of which is the MTP scenario. The MTP scenario is mandated for MPOs to produce once every 4 or 5 years (depending on the MPO).

However, the MTP scenario is also required by federal rules to be a financially constrained scenario, in the effort to represent the effects of existing plans and probable funding levels. In regions with traffic congestion issues, the MTP scenario typically falls short of limiting future congestion to current conditions, and often shows growth in congestion. The growth in congested travel may be an accurate forecast given planned facilities for roadway and transit in the MTP under assumed funding levels.

But how well is an MTP performing, in terms of reducing growth in congestion that otherwise may occur without the planned facilities? Secondly, what additional measures could be taken to reduce future congestion, at least to a level equivalent to current conditions?

While specific plans and modifications to travel behavior are difficult to achieve, a measure of the magnitude of impacts from changes to travel choices and behavior could guide public policy toward more successful solutions. Without knowing the magnitude of such measures, it is difficult to explain how to achieve the solutions. For instance, given an MTP is implemented over 20 or 30 years, what levels of trip reduction, ride-sharing, trip length changes, land use changes, and other modals shifts would be needed to achieve the goal of keep current congestion levels constant over time, despite population growth in a region?

Trip based TDMs can be used to estimate scenarios beyond the MTP including trip reduction, time-of-day shifts, mode shifts, land use/urban form changes, and other scenarios.

The model can use any scenario that changes the level of flow across network links, resulting from a traffic assignment in this process. This includes major network changes, transit system changes, land use changes, anything that a TDM can model is suitable for performance analysis using this TTI method of evaluating performance.

This section gives examples of different scenarios you can use, including the MTP scenario, but also in addition to the MTP scenario (and no-build). In our example, we chose:

- Scenario for trip reduction (S1).
- Scenario for time-of-day shift (S2).
- Scenario for mode-share shift (S3).
- Scenario for land use and urban form changes (S4).
- Cumulative modeling of scenarios (S5–S7).

4.3.2 Scenario for a Trip Reduction Forecast (S1)

Methods of Trip Reduction

For our example, we will be using a method to reduce the number of home-based work trips in a model. This scenario could approximate a telecommuting idea. To be more accurate, the user may wish to add some level of trip making back into the model from the home end to reflect travel that might occur during a telecommuter's day, close to home, such as a trip to lunch.

You can develop trip reduction scenarios by using one of the following methods:

- Applying travel demand modeling scripts in the scripting language for the model software.
- Modifying the travel model data using a spreadsheet tool.
- Modifying the parameters of a travel model directly.

Modifications

Several methods could be used to produce a trip reduction scenario in several ways:

- Modify the trip rates, by trip purpose.
- Modify the productions, by trip purpose, and rebalance them to attractions.
- Reduce trips in the pre-assignment trip table.

Example

In the example, we modified the HBW productions, by trip purpose, and rebalanced the total attractions to the new production totals. This ensures that the trip distribution, mode choice, and traffic assignment steps are consistent because the CAMPO model has feedback loops from traffic assignment back to trip distribution, re-running the mode-choice step.

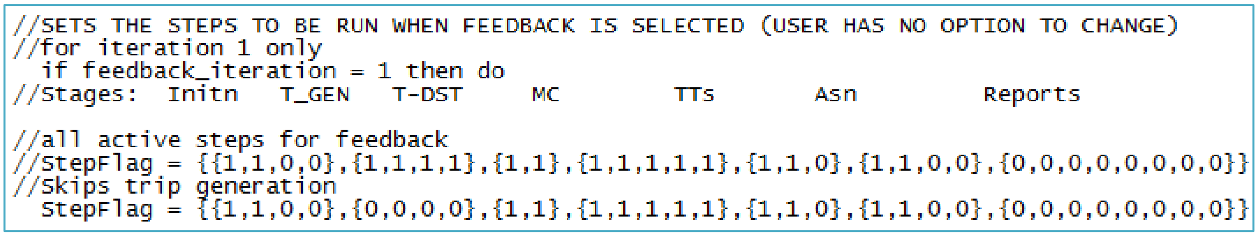
We reduced the productions for the HBW trip purpose by 10 percent. Since the work week is 5 days long, Monday through Friday, 1 day per week is equivalent to 20 percent of the work week. A 10 percent reduction in HBW trips represents 50 percent of the region's employees not commuting for 1 day per week.

For the CAMPO model, if the feedback loop run is selected, the model will automatically run the trip generation at the first iteration, and users have no options to change it. So in order to run the feedback loop from trip distribution, the user has to modify the programming coding of the CAMPO model.

Procedure Used for the Example

The procedure to develop the scenario for trip reduction (S1) for the example is as follows.

Step	Description
1	Use the input of CAMPO's 2040 forecast and run the trip generation in the CAMPO model.
2	Modify the balanced trip table after trip generation by: Reducing the trip productions for the HBW trip purpose by 10% for all TAZs. Rebalance the attractions.
3	Modify the GISDK coding of the CAMPO model to start the feedback loop from the trip generation. The modified and original coding is as follows.



```
//SETS THE STEPS TO BE RUN WHEN FEEDBACK IS SELECTED (USER HAS NO OPTION TO CHANGE)
//for iteration 1 only
  if feedback_iteration = 1 then do
//Stages:  Initn   T_GEN   T-DST     MC        TTs       Asn         Reports

//all active steps for feedback
//StepFlag = {{1,1,0,0},{1,1,1,1},{1,1},{1,1,1,1,1},{1,1,0},{1,1,0,0},{0,0,0,0,0,0,0,0}}
//Skips trip generation
  StepFlag = {{1,1,0,0},{0,0,0,0},{1,1},{1,1,1,1,1},{1,1,0},{1,1,0,0},{0,0,0,0,0,0,0,0}}
```

4	Test and compile the CAMPO model using the modified codes.
5	Copy and replace the balanced trip table with the modified trip table from step 2.
6	Do a feedback loop run using the modified model from step 3.
7	Copy the links to the spreadsheet for calculation of TTI. Collect input for the TTI calculation from the link table after the trip assignment at the last iteration.

4.3.3 Scenario for a Time-of-Day Shift (S2)

Methods of Time-of-Day Shift

The TTI is calculated based on roadway travel times using congested periods and free-flow conditions. One way to reduce trips in the congested peak period is to move trips out of the peak period(s) and into the off peak period(s). This may be a choice that travelers make when their trips become very time consuming.

Most trip based TDMs use diurnal factors that define the amount of VMT that occurs during each hour of a typical day. The factors are usually derived from household travel surveys and indicate a proportion of total daily trips, by trip purpose, that occurs during a peak period or hour.

Modifications

You can produce the time-of-day shift in several ways:

- Directly modifying the resulting time-of-day period trip tables.
- Simply modifying a file that represents the percent of daily trips by time of day, typically called the diurnals table.

The diurnal table contains the percentage values of trips by time of day for each trip purpose. These tables are developed from surveyed household travel. The values are typically used to factor a 24-hour trip table, post-mode choice, to one or more time periods. The resulting trip tables by time period of the day are then assigned to networks, reflecting capacity for that time of day.

Example

In the CAMPO model, in the steps after mode choice, the auto mode trip tables are disaggregated into four periods—AM peak, midday, PM peak, and night. Then the trips are assigned to networks with peak period capacities.

The disaggregation of the daily trip table from mode choice is based on the application of diurnal factors. In a time-of-day model, the trips are oriented into production-to-attraction (P to A) direction and attraction-to-production (A to P) direction. Thus, a factor could be 29.98 percent of the total daily trips in the P-A direction (from home to work) for HBW trips, and .28 of the daily trips in the A to P direction. The other proportion of trips occurs at other times of the day, for instance, on the return trip from work to home.

Procedure Used for the Example

The procedure to develop the scenario for a time-of-day shift (S2) used for the example is as follows.

Step	Description
1	Find the DIURNAL_PERIOD table for the TDM
2	Modify the diurnal factors to move 10% of trips into the off-peak periods for the specific purposes and directions, as shown in the following table. In the example, a total of 10% of the 6–9 a.m. trips for HBW are deducted from that period. 29.98 × 0.10 = 3.0 (approximately). Move 1.5% to the earlier period (1 a.m. - 6 a.m.) and 1.5% to the later period (9 a.m.–4 p.m.). The choice to move half earlier and half later is assumed, but the analyst can move any proportion that is reasonable to assume.

Period Time-of-Day Factors by Direction (Original)

HOUR	HBWPA	HBWAP	HBOPA	HBOAP	HBED1PA	HBED1AP	HBED2PA	HBED2AP	UTPA	UTAP	NHBW	NHBO	TRK	EXT
0-6	**3.07**	1.45	0.38	4.24	0.13	0.24	0.00	0.00	0.00	0.00	0.00	0.62	0.89	0.89
6-9	**29.98**	0.28	4.66	1.53	**14.06**	5.29	**10.25**	0.00	**10.25**	0.00	1.70	2.04	8.16	8.16
9-16	**13.20**	11.92	23.89	12.38	**21.27**	17.53	**26.46**	15.19	**26.46**	15.19	29.93	27.12	19.14	19.14
16-19	2.50	25.32	7.99	9.39	10.21	18.55	8.13	12.29	8.13	12.29	11.60	9.58	10.59	10.59
19-24	1.25	11.04	13.08	22.46	4.32	8.39	5.16	22.52	5.16	22.52	6.77	10.64	11.22	11.22

Period Time-of-Day Factors by Direction (Modified)

HOUR	HBWPA	HBWAP	HBOPA	HBOAP	HBED1PA	HBED1AP	HBED2PA	HBED2AP	UTPA	UTAP	NHBW	NHBO	TRK	EXT
0-6	**4.57**	1.45	0.38	4.24	0.13	0.24	0.00	0.00	0.00	0.00	0.00	0.62	0.89	0.89
6-9	**26.98**	0.28	4.66	1.53	**12.65**	5.29	**9.22**	0.00	**9.22**	0.00	1.70	2.04	8.16	8.16
9-16	**14.70**	11.92	23.89	12.38	**22.68**	17.53	**27.48**	15.19	**27.48**	15.19	29.93	27.12	19.14	19.14
16-19	2.50	25.32	7.99	9.39	10.21	18.55	8.13	12.29	8.13	12.29	11.60	9.58	10.59	10.59
19-24	1.25	11.04	13.08	22.46	4.32	8.39	5.16	22.52	5.16	22.52	6.77	10.64	11.22	11.22

3	Copy and replace the DIURNAL_PERIOD table with the modified one.
4	Do a feedback loop run using the CAMPO model.
5	Collect input for the TTI calculation from the link table after the trip assignment at the last iteration.

4.3.4 Scenario for a Mode-Share Shift (S3)

Methods of Mode-Share Shift

Another method to reduce trips in congestion is to develop a scenario that specifies a certain amount of trip reduction for SOV or HOV trips. This method involves reasonably factoring post-mode-choice trip tables.

Modifications

These scenarios can be very specific and have varying effects on congested roadway performance. The TAZs that are selected for trip reduction due to a mode shift away from SOV or HOV use need to reflect both geography of the transit network and the trip purpose. Methods available to modify a TDM to reflect a mode shift include:

- Modifying the mode choice parameters, such as In-Vehicle Travel Time coefficients, and testing the effect on congestion of such a change using a forecasted TTI.
- Modifying the resulting trip tables to directly reflect a specific percentage shift from one mode to another mode.

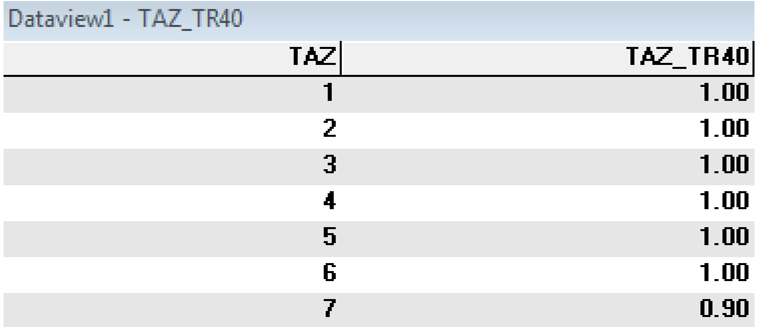
Example

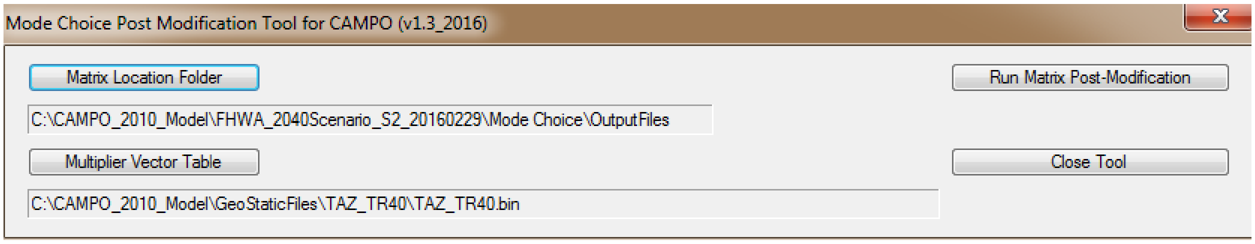
We developed a program using GISDK to post-modify the auto mode trip table. Software packages such as the commonly used TransCAD or CUBE have functions that the user can access to factor trips tables. If a feedback loop is part of the model stream, it may be necessary to modify the programming of the scripts for the model to incorporate a mode shift. It is necessary to only reduce auto trips in TAZs where transit is available, since transit is not accessible without a car in other parts of a region.

Procedure Used for the Example

The procedure to reduce trips due to mode shift is as follows.

Step	Description
1	Create a 1/4-mile buffer for all transit stops as the transit accessible areas.
2	Add one field to the TAZ geographic file, and select TAZs intersected with the transit accessible areas. We named the TAZ geographic file “TAZ_TR40” and used a default value of 1.
3	Code the selected TAZs with factor, TAZ_TR40 = 0.9, and export that table as a bin.file. This factor reduces the auto trips (SOV) by 10% in transit accessible zones. The following is an example.

<table>
<tr><td></td><td>
Dataview1 - TAZ_TR40
<table>
<tr><th>TAZ</th><th>TAZ_TR40</th></tr>
<tr><td>1</td><td>1.00</td></tr>
<tr><td>2</td><td>1.00</td></tr>
<tr><td>3</td><td>1.00</td></tr>
<tr><td>4</td><td>1.00</td></tr>
<tr><td>5</td><td>1.00</td></tr>
<tr><td>6</td><td>1.00</td></tr>
<tr><td>7</td><td>0.90</td></tr>
</table></td></tr>
<tr><td>4</td><td>Develop a dialog box using GISDK to reduce 10% of SOV and HOV trips for the TAZs with transit accessibility, and compile that in TransCAD. The following is the interface of the program.</td></tr>
</table>



Matrix Location Folder: C:\CAMPO_2010_Model\FHWA_2040Scenario_S2_20160229\Mode Choice\OutputFiles

Multiplier Vector Table: C:\CAMPO_2010_Model\GeoStaticFiles\TAZ_TR40\TAZ_TR40.bin

5	Do a feedback loop run, and then use the following folder as the "Matrix Location Folder" (shown above): "…\Mode Choice\Output Files."
6	Use the TAZ_TR40.bin file created in the third step as the "Multiplier Vector Table."
7	Click the "Run Matrix Post-Modification" button. The output of the mode choice is modified as the assumption.
8	Use the modified mode-choice output as the input for the rest of the steps of the CAMPO model.
9	Collect the input for the TTI calculation from the link table after the trip assignment.

4.3.5 Scenario for Land Use and Urban Form Changes (S4)

Methods of Trip Reduction

Urban form changes are the most difficult scenarios to impose in a trip-based modeling system. Several elements of a trip-based model can be modified to reflect changes in urban form. Typically, long-range plans can impact urban form by making destination activities, such as shopping or work locations, more concentrated into growth centers. The growth centers often include transit as a major component.

Growth centers (also called sustainable developments and planned use developments) can be designed to include residential development within walking or biking distance to work and shopping locations. Changes in municipal land use code may include a form-based design type of requirement, which allows for mixed uses to be built in a single area. Mixes of land use may include housing, shopping, and offices. Since the mixed uses are close together, it may be possible to reduce trip lengths (by auto mode) and incorporate more walking and biking to work and to shopping.

Land use codes (zoning) can be changed by cities to improve access to transit and to improve walking and biking facilities. These types of mixed-use developments encourage non-SOV use, shorter trip lengths, and greater internal capture of trips (trips that do not leave a TAZ).

Modifications

You can make these types of changes in TDMs in several ways:

- Moving forecast employment to designated growth center TAZs.
- Reducing trip lengths for HBW and HNW (work, school and/or shopping) trips.
- Increasing internal capture in growth center TAZs (trips that do not leave the TAZ).

Example

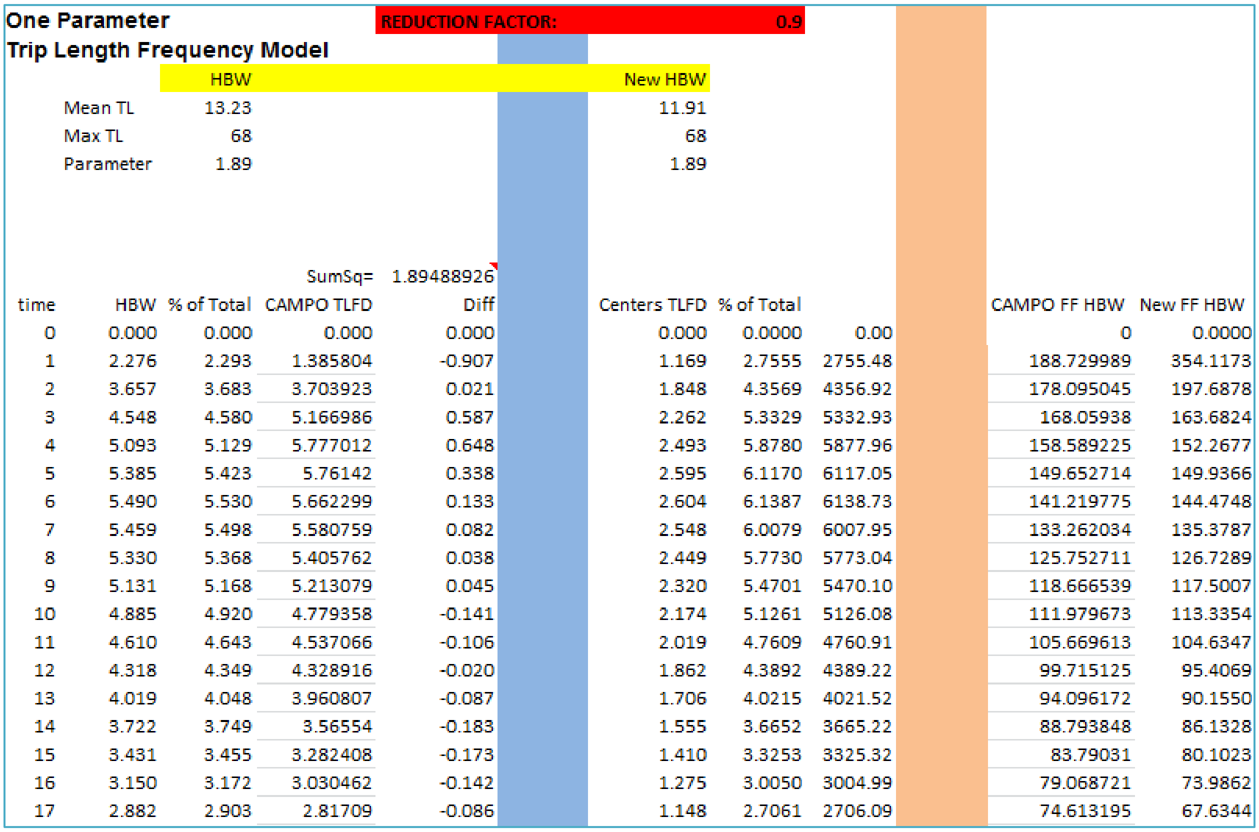
The example used the method of reducing trip lengths for HBW trips. We assumed that a 10 percent reduction in trip length is desirable. We modified the trip lengths to reflect greater satisfaction of work trips within a regional urban form that includes growth centers.

Reducing trip lengths in a gravity model formulation involves the modification of friction factor curves. Friction factor curves modify the travel times between TAZs within the gravity model formulation. A description of how a gravity formulation works with friction factors can be found in *NCHRP 716 Travel Demand Forecasting: Parameters and Techniques.*

Procedure Used for the Example

The procedure to reduce trips due to land use and urban form changes is as follows.

Step	Description
1	Find the friction factor table at "…\T_DIST\StaticFiles," and get one copy of the trip length distribution (TLD) of the baseline model (2010) for the HBW purpose.
2	Copy both the friction factor and baseline HBW trip length distribution to a spreadsheet. The following is an example.



One Parameter
Trip Length Frequency Model

REDUCTION FACTOR: 0.9

	HBW	New HBW
Mean TL	13.23	11.91
Max TL	68	68
Parameter	1.89	1.89

SumSq= 1.89488926

time	HBW	% of Total	CAMPO TLFD	Diff	Centers TLFD	% of Total		CAMPO FF HBW	New FF HBW
0	0.000	0.000	0.000	0.000	0.000	0.0000	0.00	0	0.0000
1	2.276	2.293	1.385804	-0.907	1.169	2.7555	2755.48	188.729989	354.1173
2	3.657	3.683	3.703923	0.021	1.848	4.3569	4356.92	178.095045	197.6878
3	4.548	4.580	5.166986	0.587	2.262	5.3329	5332.93	168.05938	163.6824
4	5.093	5.129	5.777012	0.648	2.493	5.8780	5877.96	158.589225	152.2677
5	5.385	5.423	5.76142	0.338	2.595	6.1170	6117.05	149.652714	149.9366
6	5.490	5.530	5.662299	0.133	2.604	6.1387	6138.73	141.219775	144.4748
7	5.459	5.498	5.580759	0.082	2.548	6.0079	6007.95	133.262034	135.3787
8	5.330	5.368	5.405762	0.038	2.449	5.7730	5773.04	125.752711	126.7289
9	5.131	5.168	5.213079	0.045	2.320	5.4701	5470.10	118.666539	117.5007
10	4.885	4.920	4.779358	-0.141	2.174	5.1261	5126.08	111.979673	113.3354
11	4.610	4.643	4.537066	-0.106	2.019	4.7609	4760.91	105.669613	104.6347
12	4.318	4.349	4.328916	-0.020	1.862	4.3892	4389.22	99.715125	95.4069
13	4.019	4.048	3.960807	-0.087	1.706	4.0215	4021.52	94.096172	90.1550
14	3.722	3.749	3.56554	-0.183	1.555	3.6652	3665.22	88.793848	86.1328
15	3.431	3.455	3.282408	-0.173	1.410	3.3253	3325.32	83.79031	80.1023
16	3.150	3.172	3.030462	-0.142	1.275	3.0050	3004.99	79.068721	73.9862
17	2.882	2.903	2.81709	-0.086	1.148	2.7061	2706.09	74.613195	67.6344

3	Model a typical trip length frequency distribution function around the mean trip length. Using such a formulation that creates a curve around a mean trip length will allow the user to modify the mean trip length and produce a new curve. This model can be calibrated to match the resulting trip length frequency distribution from a baseline (e.g., 2010) model run. We used the sum square of deviation to find the appropriate trip length frequency distribution function.
4	Using the spreadsheet model, create a reduced trip length frequency distribution (TLFD) curve. We assumed that a 10% reduction in trip length is desirable.
5	Calculate the difference between the adjusted TLFD and the original modeled TLFD, as a percent for each minute interval.
6	Apply the adjusted percent difference for each minute interval to the input friction factor curve from the TDM.
7	Copy and replace the fraction factor table with the new fraction factors estimated in step 6.
8	Do a feedback loop run using the CAMPO model.
9	Collect input for the TTI calculation from the link table after the trip assignment at the last iteration.

4.3.6 Cumulative Modeling of Scenarios (S5–S7)

Description

Besides independent modeling of scenarios (S1–S4), you can also cumulatively model the scenarios—make adjustments in order, with the first being applied to the baseline forecast, and then add others to the previous scenario to produce cumulative impacts.

Example

The table below summarizes the cumulative effects of all scenarios used in the experiment.

Scenario	Scenario for Trip Reduction (S1)	Scenario for Time-of-Day Shift (S2)	Scenario for Mode-Share Shift (S3)	Scenario for Land Use and Urban Form Changes (S4)
S5	✓	✓		
S6	✓	✓	✓	
S7	✓	✓	✓	✓

4.3.7 Displaying Results with a Wedge Chart

Description

The results of the scenario analysis need to be displayed to communicate the overall impacts of various trip reduction treatments in the forecast. One chart that will summarize each scenario and its impact on TTI is the wedge chart (Figure 11). This chart shows the baseline (2010) scenario, a no-build assumption, a scenario that includes the regional long range plan scenario, and the each of the alternative scenarios. This chart is best displayed with cumulative scenario analysis.

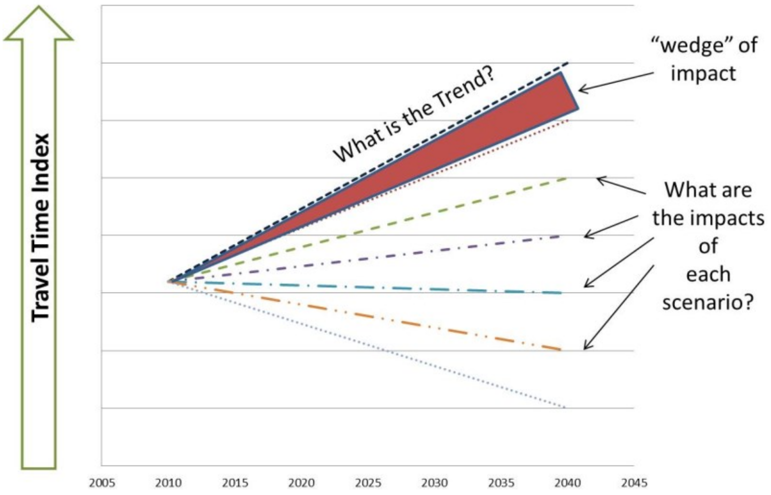


Figure 11. Wedge Chart Example

Other charts can also effectively show the results of the scenario analysis. Using results of the total number of trips from the ravel demand model, the analyst can create a chart showing the total number of SOV trips that are reduced in each scenario alongside the total congested VMT calculated from the scenario model runs.

4.4 Corridor (or Subarea) Analysis

Analysts may also want to examine the congestion status and the impact of different scenarios on major corridors or subareas. In order to compare those with the UMR observed TTI value for the region, the exactly same method used in UMR should be applied in the corridor (or subarea) analysis. Also the INRIX data should be used as the base for observed TTI estimation.

4.4.1 Estimate TTI Values for Corridors using INRIX Data

Description

In the INRIX data, all archived speeds for each 15-minute period each day for each road segment is calculated for each month (e.g., Monday from 06:00 to 06:15 for April 2015), and a calculated speed (CS) for each time slot is established for each road segment. Thus, each segment has 672 corresponding calculated speed values, representing four 15-minute time windows for all 24 hours of each day, multiplied by the seven days in a week.

Method

In this case, all major road segments of I-35 and Mopac Express (two major corridors in Austin metropolitan area) were extracted from the INRIX dataset with the following attribute fields:

a. Segment ID: unique value identifying the ID of the road segment represented.
b. Length: the length in mile for a given Segment ID.
c. Bin ID: the Bin ID in 15-minute increments throughout the day, 0 – 96 where 0=0:00 to 0:14 and 96=23:45 to 23: 59.
d. Day of Week: SU=Sunday, MO=Monday, TU=Tuesday, WE=Wednesday, TH=Thursday, FR=Friday, SA=Saturday.
e. Ref Speed: free-flow speed determined for each road segment using the INRIX Traffic Archive.
f. Speed: average observed speed (arithmetic mean) in MPH for a given Segment ID.
g. Total Travel Time in Seconds: total Travel time for all volume during the specific 15-minute slot for a given Segment ID in seconds.

Then, only the records within the peak-period (6 a.m.–9 a.m.) and within weekdays (Mon–Fri) were used to calculate the corridor TTI. Analysts can calculate (see below) volume, VMT, travel time, free flow travel time, and TTI for each segment for each specific 15-minute slot by using the attributes as above and the equation as below:

$$\begin{aligned}
&\text{Travel time} = \text{Length}/\text{Speed}\\
&\text{Free flow travel time} = \text{Length}/\text{Ref Speed}\\
&\text{Volume} = \text{Total Travel Time in Seconds}/(\text{Travel time} * 3600)\\
&\text{VMT} = \text{Volume} * \text{Length}\\
&\text{TTI} = \text{Travel time}/\text{Free flow travel time}
\end{aligned}$$

According to UMR, the TTI for each road segment in the region needs to be weighted by peak period VMT to calculate any area-wide average TTI. Specifically, the following steps were used in UMR to calculate region-wide average TTI and were also used in this study to calculate corridor average TTI:

1. For each 15 minutes within the peak period for the weekdays (Monday–Friday), the TTI were calculated for each road segment using the equation as above. Note that the free-flow speed is determined for each road segment using the INRIX Traffic Archive.
2. Those 60 TTI values (3 hours × 5 days × 4 15-minute periods) were then weighted by the VMT associated with each 15-minute period in the segment to get a peak-period average TTI value for that segment.
3. All of the segments (freeways and arterial streets) along the corridor were then weighted together by the peak period VMT in each segment to get a corridor average TTI value.

4.4.2 Calibrate Speed Model for Selected Corridors

Description

For each corridor (or subarea), the analyst then needs to re-calibrate the speed model to better describe the congestion status on baseline year for that corridor (or subarea). Instead of establishing an absolutely new model, the analyst can use the regional model but add one more criteria for selecting the subset of links within the study area (or corridor).

Method

In addition to attribute fields listed in 4.1.3, one more attribute needs to be coded in the link data to identify which links are within study area (corridor). That field can be added either in TransCAD or ArcGIS using queries on the highway network geographic layer:

- Corridor Flag: 1 – within study area (corridor) and 0 – not within study area (corridor).

For the regional model, as mentioned earlier, the calibrated speed model was based on the following subset of all links:

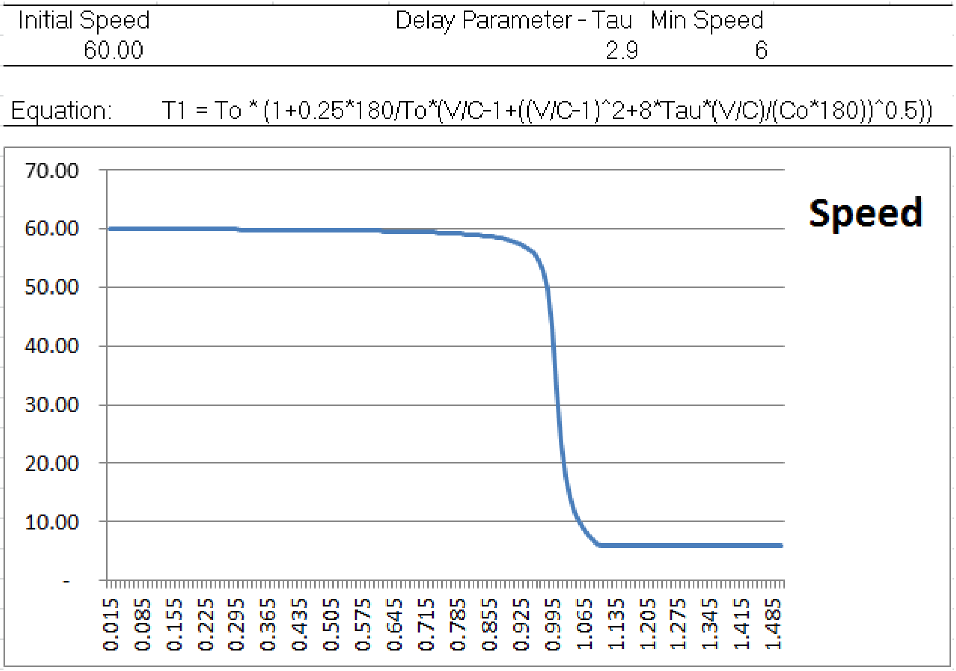
i.	Area Type ≤ 4	(Rural area was excluded)
ii.	Functional Class ≤ 6	(Only freeway and arterial were included)

For the corridor analysis, the analyst can add one more criteria:

iii.	Corridor Flag = 1	(Only links within study area [corridor])

Also by using the INRIX data and the methods mentioned in 4.3.1, we can estimate the observed TTI values for corridors: in this case, 1.26 for I-35 and 1.30 for Mopac Express. Then we can adjust the delay parameter for the new subset of links until the resulting corridor average TTI is close or equal to the observed TTI for that corridor. The following graphs show the estimated delay parameters and calibrated Speed-VC curves for the two corridors in this case:

<u>I-35 (τ = 2.9):</u>



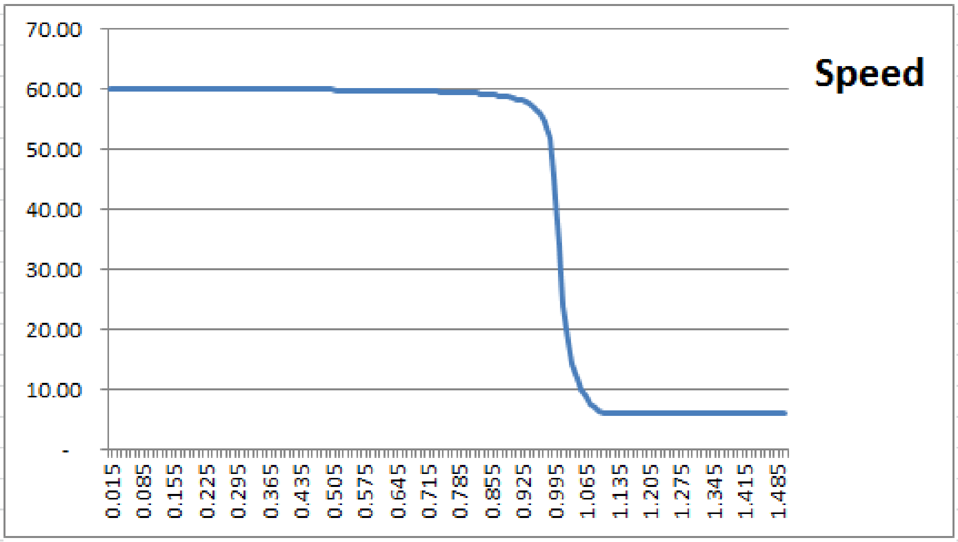
Initial Speed	Delay Parameter - Tau	Min Speed
60.00	2.9	6

Equation: T1 = To * (1+0.25*180/To*(V/C-1+((V/C-1)^2+8*Tau*(V/C)/(Co*180))^0.5))

Mopac Express (τ = 2.2):

Initial Speed	Delay Parameter - Tau	Min Speed
60.00	2.2	6

Equation: T1 = To * (1+0.25*180/To*(V/C-1+((V/C-1)^2+8*Tau*(V/C)/(Co*180))^0.5))



4.5 Execute Models and Calculate TTI

Once these adjustments are made, the TDMs are executed in the normal operating manner for a forecast application. Several methods may be used for this step:

1. Independent modeling of scenarios—make modeling adjustments to a baseline forecast (e.g., 2040) one at a time and analyze the effect of adjustments independently.
2. Cumulative modeling of scenarios—make adjustments in order, with the first being applied to the baseline forecast, then others are added to the previous scenario to produce cumulative impacts.
3. Aggregate modeling of scenarios—make all adjustments and run only one scenario that includes all adjustments in one model run.

Whichever modeling method is chosen, the results can efficiently be stored in a spreadsheet to calculate the resulting TTI for all scenarios.

4.6 Summarize Scenarios on Corridors

The purpose of the corridor analysis is to summarize the regional effect on the major corridors. For example, we are looking at the effect of the time of day shift on the whole region instead of only along the corridor. So the same scenarios were used for corridors as what were developed for the region. Also the analyst should use the same link data source as what we used in the regional model for each scenario. But for corridor analysis, the scenario results need to be summarized based on different delay parameters (shown in 4.3.2) and different subsets of links (also shown in 4.3.2).

5.0 Conclusions

This report presents a method of using common trip based TDMs for assessment of forecast assumptions that differ in significant ways from changes indicated by existing recent trends. While recent trends can be observed and surveyed and subsequently described by calibration in regional TDMs, the application of these calibrations may lose credibility for long term planning exercises. This context is brought on by experience—that the past is not a prologue to the future. The issue is expanded when rapid technological development is occurring and is intuitively expected to cause changes in travel behavior, such as with the advent of technological breakthroughs and investment in automated and connected vehicles.

This report presents one method to produce a reasonable experimental forecast using long range TDMs to achieve a specific performance objective. While reasonableness is a subjective decision, the use of a calibrated speed model to calculate a TTI provides a basis for assessment of reasonableness in exploratory modeling.

TTI is a measure that is calculated frequently across many regions and uses large quantities of passively collected speed data (from individual vehicle GPS and cellular locations). TTI has also been collected over several decades and thus provides a robust set of trend data. These trend data are used in this study as a reliable indication of the direction of change in congestion for a regional network. It therefore provides a suitable basis upon which analysts can subjectively assess the performance of modeling scenarios for long range regional TDMs.

Scenarios can be produced, models can assess impacts, but what defines the reasonableness of the model outputs, given that the model is calibrated to past conditions? TTI measures both demand and supply sides of a model in one measure.

While any modeling system can be improved by calibration to accurate data, the data and methods must also be put in the context of how sustainable it is related to variation in future scenarios. This report describes how the TTI can be used to assess the overall reasonableness of forecasted scenarios of congestion in a reliable manner.

6.0 Works Cited

Bauer, J., Ange, K., & Twaddell, H. (2015). *Advancing Transportation Systems Management and Operations through Scenario Planning.* Washington, D.C.: US DOT, Federal Highway Administration.

Cambridge Systematics. (2012). *NCHRP 716 Travel Demand Forecasting: Parameters and Techniques.* Washington, D.C.: Transportation Research Board.

Casavant, K. (2013). *Guidebook for Developing Subnational Commodity Flow Data* (Vol. 26). Transportation Research Board.

Castiglione, J. M. (2015). *Activity-based travel demand models: A primer. No. SHRP 2 Report S2-C46-RR-1.* USDOT, FHWA.

Grant, M., McKeeman, A., & et.al. (2014). *Model Long Range Transportaiton Plans: A Guide for Incorporating Performance-based Planning.* Washington, D.C.: USDOT, Federal Highway Administration.

Lomax, T. D. (2010). *Real-timing the 2010 Urban Mobility Report.* Washington, D.C.: US. DOT, University Transportation Center for Mobility, UTCM 10-65-55.

Mohaddes, A. a. (2016). *Transformational Technologies in Transportation: State of the Activities.* Washington, D.C.: Transportation Research Board.

Schrank, D., Eisele, B., Lomax, T., & Bak, J. (2015). *2015 Urban Mobility Scorecard.* College Station, Texas: Texas A&M Transportation Institute and INRIX Corp.

U.S. Government Accountability Office. (1996). *Executive Guide: Effectively Implementing the Government Performance and Results Act.* Washington, D.C.: U.S. GAO.

This report is being distributed through the Travel Model Improvement Program (TMIP).

U.S. Department of Transportation
Federal Highway Administration
Office of Planning, Environment, and Realty
1200 New Jersey Avenue, SE
Washington, DC 20590

October 2017

FHWA-HEP-18-030

U.S. Department of Transportation
Federal Highway Administration