Improving resource allocation through layered data analysis

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Improving resource allocation through layered data analysis

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Executive Summary

Decision makers, elected officials, and the public are looking for ways to understand resource allocation choices and the effect of investments and financial constraints. While the details are complicated, many of these needs can be satisfied by simply organizing information that is already used for analysis and displaying it on a map. This project report demonstrates the concept with map layers showing information about congestion, safety, pavement condition, bridge quality, and freight value. These maps can be visually stacked to provide analysts with consistent information on several important topics in one view. This is similar to the way that diners get the taste of many flavors in a tostada, a regional dish that layers many different food ingredients—vegetables, meat, cheese, etc.—on top of a tortilla. They experience all of the ingredients and flavors in each bite—thus, the TOol using STAked DAta – the TOSTADA.

The report describes the concept; the remaining development steps in the project involve adjusting the maps to exactly match road segments and to layer all the data categories into one roadway segment picture. Policy makers and transportation professionals can use the project results to understand transportation problems and economic effects. The maps can form the basis of a common dialogue to identify appropriate improvements and illustrate investment costs and benefits. The maps, and associated data layers, will improve the ability to compare a variety of data sets and elevate the discussion of transportation problems and opportunities.

Background

The TOSTADA project utilizes geographic information system (GIS) tools—computer systems designed to analyze, store, and manipulate geographical data—to demonstrate the individual data map layers. Each map has a color scale showing performance. Data from 2012 for each factor were used in this concept demonstration. The following is a quick summary of each factor:

- **Congestion** – Congestion levels on the road segments in the selected area are compared on a scale of good to bad. One can find the most congested roads within a small urban area or see congestion compared to the most congested roads in Texas.

- **Safety** – A comparison between crash rates (crashes per mile traveled) on each road segment and the average of similar road segments from across Texas is provided in the safety map layer.

- **Pavement condition** – TxDOT’s statewide grading scale for pavement quality is used.

- **Bridge condition** – The bridge condition comparison uses the bridge with the worst TxDOT condition rating within a road segment (the performance of the entire segment is “only as good as its weakest bridge”).

- **Truck commodity value map** – The value of truck commodities carried on road segments within each county was estimated using a combination of national and state sources.
Using the TOSTADA Maps

The TOSTADA stacked data report contains preliminary results that are only for demonstration of the concept. The final TOSTADA product would show all of the information on one coordinated map, but more work is required to integrate all the map layers on the same base map. In the ultimate model, a road link could be chosen and all of the pertinent information—congestion, safety, pavement quality, bridge quality, and truck freight value—and performance metrics would be shown. If factors were weighted or prioritized, an index could be created to show the combined performance metric of each road segment.

The TOSTADA could be rolled out in two phases:

- Phase 1 – Use the information to describe all the effects of projects and programs. A pavement project, for example, may also have safety benefits. Construction to reduce congestion also frequently improves safety and pavement condition and allows increased freight movement. Benefit discussions, however, are often focused on the original intent of the project or are related to the funding category. The TOSTADA will allow a fuller accounting of the benefits of transportation investments.

- Phase 2 – Project prioritization and selection can be informed by a much broader set of effects. Funding can be directed toward the projects that offer the most return on investment across a broad set of categories. Instead of pavement projects being graded only on how well the pavement and ride quality are improved, they could also receive credit for the safety effects and the increased amount of freight moved on the smoother road surface. A project that increases the freight carrying capacity of a bridge and improves the pavement surface while adding capacity might appear to be a much better investment than if the discussion focused only on eliminating a structurally deficient bridge from the needs list.

The TOSTADA is part of a growing set of tools and techniques that allow the general public and decision makers to understand the full effects of transportation spending. Too often these discussions have focused on engineering evaluations when there are important economic development and quality of life concerns addressed by the projects, programs, and policies being enacted. The integrated maps will provide a comprehensive and consistent level of information for informed project comparison and selection, improved public engagement, and awareness of the relationship of transportation concerns. The project demonstrates the visualization power of displaying the layered information and having these data in one location.
Introduction

For some time, transportation decision-makers have been faced with limited available resources for transportation programs and projects. Decision-makers, elected officials, and the public are looking for ways to understand the resource allocation choices and the effect of financial constraints. The demand for transparency and accountability in the transportation project/program decision-making process can be at least partially satisfied by data-driven or data-facilitated tools.

An element of the Texas Department of Transportation’s (TxDOT’s) 2011 appropriations passed by the Texas Legislature was predicated on a list of the most congested road sections in Texas. Rider 42 of TxDOT’s appropriation in the General Appropriations Act (H.B. 1, 82nd Legislature, Regular Session) also required that transportation improvement projects have the greatest possible impact (i.e., increased economic benefits, safety, and pavement quality; decreased user costs) (1).

This report describes and demonstrates a process to provide a spatially-comprehensive and visually-consistent level of information. This mapping process informs project comparison, project selection, improved public engagement, and awareness of the relationship of transportation costs and benefits. This project report incorporates map layers with congestion, safety, pavement quality, bridge quality, and freight value moved as an initial step toward and demonstration of this visual comparison effort; however, many more data elements can be included as map layers.

Policy-makers and transportation professionals can use the project results to understand transportation problems and economic effects. Transportation professionals can use the maps as a form of common dialogue with decision makers to “make the case” for appropriate improvements based on objective information. The maps and associated data layers can increase the ability to compare a variety of datasets and elevate the discussion of transportation problems and opportunities (2).
The Concept

A good illustration that demonstrates the concept behind the stacked data layers is a tostada. A tostada is a regional dish that layers many different food ingredients—vegetables, meat, cheese, etc.—on top of a tortilla so that as you bite into it, you experience all of the various ingredients and flavors in each bite. The research team termed this stacked data-layer study the “TOSTADA project” (TOol using STAcked Data) because analysts will be able to understand a variety of project factors in one “visual bite.”

Figure 1 demonstrates the TOSTADA concept using transportation data from a short segment of US-281 just north of Loop-1604 in San Antonio. Five data types—congestion, pavement condition, bridge condition, safety, and freight value—are shown for this location. The congestion, safety, and freight value have high factor scores, meaning that the location experiences congestion, has a history of crashes, and has a significant amount of freight movement. The pavement and bridge conditions have average scores, which indicate they are in fairly good condition. The Map Layers section describes the process to grade and color code each map layer.
**Background**

The data layers included in this discussion (congestion, safety, pavement condition, bridge condition, and freight value) are important, readily available, and beneficial for project prioritization. The literature is fairly sparse on discussions of state departments of transportation (DOTs) or Metropolitan Planning Organizations (MPOs) creating visual tools for project prioritization using many data elements. This is not to say that such tools do not exist—they just may not publish much information on their existence and their usage. It is possible these tools are used “behind the scenes” to facilitate data-driven decision-making.

**Congestion**

The addition of a congestion data layer to the Tostada, on top of the safety layer, helps pinpoint the cause of some safety issues. The process works both ways—congestion sometimes causes safety problems, and in some cases safety problems cause congestion. As an example, reducing traffic congestion could improve driver safety by decreasing the opportunity for stop-and-go, rear-end crashes.

**Safety**

Driver safety is a predominant goal for transportation systems; safety information can be divided into two major factors: crash frequency and crash severity. Minimizing both of these elements is optimal, and the process must recognize that there are many factors that ultimately lead to crashes. Clearly, hazardous roadway conditions are a major cause of concern and generally bubble to the top of lists for roadway improvement projects.

**Pavement Condition**

Pavement condition studies also show ties to safety. Quality pavement gives drivers better traction and control of their vehicle while on the road. Pavement condition has shown to be a significant safety factor during precipitation as better pavement reduces the risk of hydroplaning and losing control of vehicles. Pavement ride quality can also be improved with smoother roads to improve driver satisfaction and overall safety.

**Bridge Condition**

There is very little literature concerning the role that bridge conditions play in overall transportation improvement decision-making (that is, beyond the typical bridge improvement funding category). Bridge quality is a concern because of the aging U.S. roadway system. There have been several instances in recent years of bridge collapses; this is an important issue to factor into roadway improvement projects (3, 4).
Freight Value

Tracking the value of commodities trucked over roadways allows decision-makers a quantifiable (albeit surrogate) understanding of the economic impact of one road relative to another when deciding on potential projects. A road transporting more commodity value may have more economic significance than another and ultimately might be more appropriate for improvements to help economic conditions in the state.

Literature Review

As mentioned, none of the literature researched has the exact model that we are presenting, however there are some similar characteristics discussed in many articles. Much of the literature has ties to safety. Safety is clearly the main focus; however, a few articles use a multi-criteria analysis that includes safety concerns. Many of the articles tie in one additional element beyond safety and discuss how this additional element affects crash rates and severity (e.g., congestion and safety, crash frequency and pavement condition). None of the papers include bridge condition and truck commodity value.

Using Weights to Score Road Segments

One paper discusses alternative roadway improvement projects and prioritizes each project by a score (5). The study used a multi-criteria analysis (MCA) approach that incorporates some cost-benefit analysis (CBA) elements. This was done by converting the monetary results from a CBA into MCA scores through the definition of a benefit-cost ratio threshold. The factors used (and associated percentage weight they carry) were:

- Environment (10 percent)
- Safety (10 percent)
- Economy (35 percent)
- Integration (35 percent)
- Accessibility (10 percent)

The authors noted that the weights were given in collaboration with multiple decision-makers. Assessing weight for each category plays a major role in the outcomes and should be evaluated by several people. The study demonstrates the importance of and methods to weight multiple data types for scoring road segments and identifying a cost-effective way to improve our roadways.

Pavement Condition and Crash Frequency Link

The relationship between pavement condition and crash frequency was the focus of another project to develop pavement management strategies to reduce the amount of pavement-related crashes. Pavement conditions have been linked to road safety, and this study focused on the
parameters of Rut Depth (RD), International Roughness Index (IRI), and Present Serviceability Index (PSI) to measure pavement and match this with crash information. The results showed that the PSI models statistically outperformed the models based on the other pavement measures on a regular basis. Improving the PSI score was the focus of the study because improving the PSI would ultimately improve traffic safety and provide a better ride quality for drivers (6).

**Congestion and Crashes**

The relationship between congestion and crashes was the focus of another study that used econometric methods and crash modeling to research major roads in the U.K. It was found that increased congestion has a negative impact on crash frequency, but does decrease crash severity. However, the effect on crash severity is relatively small; the broad takeaway is that congestion has a negative effect on safety (7).

**Crash Risk Estimation Model**

Another study discusses a crash risk estimation model (CREM) to find which segments of roads are the most hazardous. The study looks at the effects that road geometry, congestion, and ambient weather and road conditions have on safety. Among the findings is an increase in congestion decreases the effects of horizontal geometry on crashes, while the influence of vertical geometry on crash risk becomes more substantial. They also find that nighttime and holiday driving increases crash risk. The discussion also recommends variable message signs could help to warn drivers when dangerous road conditions exist and could potentially help improve safety (8).

**Using Safety Data Alone to Find and Correct Problem Areas**

Another example of a safety-driven approach discusses an integrated decision-support outline to help agencies recognize high crash-risk roads and develop cost-effective enhancement plans. Projects are ranked using life-cycle safety benefit evaluations and ideal resource allocation models. They also propose an efficient solution algorithm to the optimization model. They use a web-based GIS tool to look at the crash information. The tool gives them the ability to view the information via tables, charts, and color-coded maps to help agencies know where to locate projects to most effectively reduce fatalities. This study attempts to determine problem areas but only uses the safety data to pinpoint trouble areas whereas the concept demonstrated in this paper attempts to look at a multi-factor approach (9).

**Fund Allocation for Road Maintenance and Improvement**

A study discusses financing road maintenance based on trying to efficiently allocate resources by focusing on four parameters: asset value preservation, improvement of road safety, minimization of driver costs, and improvement of customer satisfaction. The basic concept is similar to the multi-factor approach described in this effort; however, this effort was only focused on fund allocation for pavement improvements (10).
Performance Measurement-Based Sustainability Evaluation Methodology for TxDOT

One project for the Texas Department of Transportation (TxDOT) developed a performance measurement-based sustainability evaluation methodology for the TxDOT strategic plan. A set of objectives was defined along with performance measures that addressed the five goals of TxDOT’s strategic plan, as well as sustainable transportation concerns. A multi-criteria decision-making methodology was developed to evaluate, benchmark, and aggregate the performance measures into a set of “sustainability index” values. The methodology, applicable at the highway corridor level, was integrated into a user-friendly, spreadsheet-based analysis tool that provided the sustainability index values (for current and future scenarios) as an output for a particular corridor (11). This sustainability methodology is applicable only at the corridor level. For the TOSTADA to have maximum usefulness, any data/information incorporated into the methodology needs to function at the roadway segment level, so this sustainability methodology, in its current form, does not apply.
The Map Layers

The purpose of the TOSTADA project is to discuss the ramifications and policy effects of creating a database consisting of multiple map layers (e.g., traffic congestion, safety, pavement quality, bridge quality, freight value) and overlaying them, so that all information is available statewide for decision makers determining problem locations, and to make the data readily available for evaluation of solutions. Eventually, a single “Index” or “Score” could be created to grade all of the various data elements at one time and create a ranked list. However, for demonstration purposes in this project, only the data types (layers) are shown, and these map layers are demonstrated individually within this report. Prior to the eventual creation of an overall “Index” or “Score,” it is important to understand the types of data used, what they can show, and the limitations of a one-number approach to complex problem and strategy evaluations.

Use of GIS Tools

A Geographic Information System (GIS) is a computer system designed to analyze, store, and manipulate geographical data to inform decision-making. The TOSTADA project utilizes GIS tools to demonstrate the individual data map layers. The GIS tools allow the information to be viewed through color-coded maps. Each map color scale shows performance or condition scaled from poor condition (low performance) to good condition (high performance). The color display changes between map layers and shows a variety of factor-specific elements; with more research and use-case discussions, these might be harmonized.

Spatial Geography of Source Data

The map layer scales might change if one looked at more than one county at a time (rather than the single county displays of Bexar or Tom Green County); some of the scales would remain consistent even if the comparison was made across all Texas counties. Bexar County (San Antonio) was chosen for this demonstration to represent a large metropolitan county. Tom Green County (San Angelo) was chosen to characterize smaller metro regions. For user application and understanding of transferability, the spatial geography of the source data for each TOSTADA county map is as follows:

- **Congestion** – shows a comparison of congestion levels on the road segments. The scale of bad/good and the color assigned to each roadway segment will change as the geographic coverage is adjusted.

- **Safety** – shows a comparison of crash rates on the road segments against similar-type road segments from across the state of Texas. The color assigned to each roadway segment will not change if the geographic coverage is adjusted.
• Pavement condition – shows a comparison of the pavement condition using the statewide grading scale. The color assigned to each roadway segment will not change if the geographic coverage is adjusted.

• Bridge condition – shows a comparison of the worst condition bridge within a given road segment based on the statewide grading scale. The color assigned to each roadway segment will not change if the geographic coverage is adjusted.

• Truck commodity value – shows a comparison of truck commodity value carried on the road segments within each county. The values assigned to the trucks will vary from county to county across the state depending on several factors. The colors assigned to each roadway segment will change as the geographic coverage is adjusted.

Roadway Network and Data Coverage

The roadway network and data coverage varies for each of the map layers. The roadway network is determined by the entity, which requires the performance reporting. Most of the data is based on the TxDOT Roadway/Highway Network (RHsNo) geo-database (J2) roadway network. However, the data coverage may not extend beyond TxDOT-maintained roadways. Congestion layer data is dependent on where speed data are available. Speed data are provided on the traffic message channel (TMC) network—the industry standard geographic scale for traveler information reporting. The TMC level is too short for general congestion reporting; the TMCs are combined into longer ‘sections’ for these maps. Therefore, the segmentation of the road networks can vary.

For the TOSTADA project demonstration, it was not necessary to conflate (or match) all of the networks onto the same scale since the layers were shown separately. The final conflation of all of the map layers will place them onto the same network segmentation.

The following sections discuss the individual data layers and give a demonstration of the type of information that each layer provides. Several of the data layers (congestion, safety, pavement, bridge) use information already compiled in other databases maintained by TxDOT. In other cases, such as the truck commodity value, some discussion is provided to demonstrate the methods used to create the information included in the map layer.
### Congestion

#### Data Sources

The traffic congestion information comes from the Texas 100 Most Congested Roadway Segments (TX100) study performed annually by the Texas Department of Transportation (TxDOT) and the Texas A&M Transportation Institute (TTI) (2). The TX100 analysis combines traffic volume data from TxDOT’s Roadway/Highway Network (RHiNo) geo-database and speed data from INRIX, which is a private-sector company that collects speed data on over one million miles of U.S. roadway. It should be noted that each year TxDOT releases a Request for Proposal (RFP) to determine the supplier of the speed data for TX100. INRIX won the solicitation for the data presented in the version of the TOSTADA (2012 data) described in this report. The TOSTADA can incorporate data from any speed provider.

#### Methodology

The statistics for the TX100 analysis are calculated at the individual link level using the segments in the RHiNo database. The TX100 report combines the RHINO database links into logical reporting segments. However, for the TOSTADA report, the statistics will be reported at the individual link level rather than at the TxDOT-TX100 reporting segment level. The other measures shown in the TOSTADA report are reported at the link level for consistency through the map layers.

#### Interpretation of the Map Layer

The key congestion measure for reporting in the TX100 analysis is annual person-hours of delay per roadway mile. This is the measure shown in the maps to demonstrate the congestion layer (Figures 2 and 3). Delay per mile allows for comparison of different lengths of roadway. The figures for traffic congestion are shown with a continuous color scale such that the darkest segments (shown in red) have the highest levels of delay per mile and the brightest segments (shown in yellow) have the lowest values of delay per mile.

Figures 2 and 3 show traffic congestion levels on roadways in Bexar and Tom Green Counties. Comparisons cannot be made between the two graphics because the congestion information is scaled according to congestion levels in the individual county. The most congested roadway segment in Tom Green County will show up as very congested for that region but might only be in the middle congestion levels in Bexar County.

#### Bexar County

Bexar County congestion levels are shown in Figure 2 on roadways where the INRIX speed data are available. Many of the roadways with greater delay per mile are the freeways such as IH-35,
IH-10, IH-410, and Loop-1604. But some arterial streets, such as Huebner Road, Blanco Road, and S.W. Military Drive, also show higher delay per mile values.

**Tom Green County**

Figure 3 shows the congestion data for Tom Green County. There is less INRIX speed data available in San Angelo for the congestion analysis, although the speed data network coverage is improving each year. Some of the worst congestion levels are on US-87 near downtown San Angelo and on W Avenue North near Angelo State University.
Figure 2. Traffic Congestion on Road Segments in Bexar County.

Figure 3. Traffic Congestion on Road Segments in Tom Green County.
Safety

Data Sources
The crash information used in this analysis is provided for over 100,000 main lane roadway segments of the Texas highway system (13). Each segment is a section of continuous traveled roadway that is not interrupted by a major intersection, and consists of homogenous geometric and traffic control features, such as the number of lanes, median type, speed limit, traffic volume, and cross-sectional widths. The segments are not of equal lengths, and traffic volumes vary greatly between segments. For each segment, severe injury crashes, possible injury crashes, property-damage-only crashes, and the total number of crashes are reported. The crash rate based on the total crash frequency and length and volume of traffic on that segment is also provided.

The information on roadway segments was extracted from TxDOT’s RHino database for the year 2012 (12). A roadway segment begins at the center of an intersection and ends at either the center of the next intersection, or where there is a change from one homogeneous roadway segment to another homogenous segment. Only state-maintained highways are considered in this safety analysis. The database was filtered to include main lane segments only (i.e., no frontage roads, ramps, etc.).

Methodology
After the roadway segments were identified, crashes were assigned to each individual segment. The TxDOT Crash Records Information System (CRIS) maintains a statewide database for all reported motor vehicle traffic crashes (13). The 2012 crash data were considered for the TOSTADA report. Only those crashes that were coded as “TxDOT Reportable” are considered. A crash is considered “TxDOT Reportable” if it occurs on a roadway and results in an injury or a property damage greater than $1,000.

The number of crashes on any segment is due to a number of factors, but the length of the segment and traffic volume (which combined are known as “exposure”) have an influence on the number of crashes. The roadway segments in the RHino database have different lengths and traffic volumes. Therefore, it is desirable to know the crash rate to better understand the safety performance of each segment and to allow for comparisons between segments.

The crash rate on each roadway segment is calculated by dividing the number of crashes in any crash category by the product of the length and traffic volume (also called the vehicle-miles of travel). Because the number of crashes, relative to the number of vehicle-miles traveled, is very small, the rates are expressed per million vehicle-miles of travel.

Crash rates may be interpreted as the probability (based on past events; in this case what occurred in 2012) of being involved in a crash per instance of the exposure measure. Observed crash rates are often used as a tool to identify and prioritize sites in need of modifications and for evaluation of the effectiveness of potential treatments. Typically, those sites with the highest...
crash rate or perhaps with rates higher than a certain threshold (e.g., the average crash rate for all similar segments) are analyzed in detail to identify potential modifications that would reduce crashes.

**Method Limitations**

The rankings in the TOSTADA safety analysis that are based on crash rates are subject to a number of limitations. First, the crash rate method depends on the observed crash data, in this case from law enforcement reports submitted to TxDOT. The issue of data quality and accuracy arises due to the limitations in recording, reporting, and measuring crash data with accuracy and consistency (e.g., every crash may not result in a report). Secondly, crash rates presume a linear relationship between crash frequency and the measure of exposure, which is typically not true. This means that there are proportionally less (or more) crashes per passing vehicles as the traffic flow increases and thus the crash risk per vehicle diminishes (or increases) when traffic flow increases. These effects are lessened due to the approach taken in this effort to categorize risk (see Appendix B for more details).

Lastly, the method is affected by the limitations associated with natural variations in crash data (i.e., randomness in the data). The natural variations in the crash data results in the regression-to-the-mean (RTM) bias. According to the RTM phenomenon, when a period with a comparatively high crash frequency is observed, it is statistically probable that the following period will be classified as a relatively low crash frequency. Therefore a database with only one year of data, such as the one used in the TOSTADA analysis, must be analyzed with caution. It is best to use several years of data to help guard against the possibility any given year of crash occurrence is not representative of the overall crash experience in the segment. Because the TOSTADA safety analysis only utilized one year of crash experience for demonstration purposes, the results must be viewed with caution. For more details on the methodology utilized for the TOSTADA safety analysis, please see Appendix B.

**Interpretation of the Map Layer**

In examining the safety map layer, the width of the bar equates to the severity of the crash problem while the length of the bar shows the length of the roadway section. Very thin lines or slivers equate to very short segments on the roads. On arterial streets these short segments may be intersections. For freeways it is important to note that crashes on the frontage roads are included with the mainline crashes.

The identification of crash risk for each segment is based on a comparison to all the other segments in Texas that match its area type (urban or rural), functional class (freeway, arterial, collector, local) and volume category (low, medium, high) relative to all others in the same setting and functional class. Any roadway segment which is identified as having a high crash risk bears further examination.
**Bexar County**

The crash rates for Bexar County are shown in Figure 4. There are many road segments throughout the region that score a Very High based on crash rates. The US-281 corridor north of Loop 1604 has several occurrences of Very High crash rates which might indicate the need for further investigation of that facility.

**Tom Green County**

Figure 5 shows the crash risk results for Tom Green County. The data show that even small urban areas like San Angelo still have issues with crashes. There appears to be several occurrences of Very High crash rates along US-67. This might be expected because this is one of the higher volume facilities in the region, but it does warrant further investigation.
Figure 4. Crash Rates on Road Segments in Bexar County.

Figure 5. Crash Rates on Road Segments in Tom Green County.
Pavement Condition

Data Sources

The pavement condition information comes from TxDOT’s Pavement Management Information System (PMIS) database (14). The condition score on a continuous scale from 0 to 100 is reported for each roadway segment in TxDOT’s RHINO database.

Interpretation of the Map Layer

The following grade scale (and colors) is applied to the pavement condition score for grouping segments into related quality levels:

- Very Good (“A”) – Over 90 [Green]
- Good (“B”) – 71 to 90 [Yellow]
- Fair (“C”) – 51 to 70 [Light Orange]
- Poor (“D”) – 35 to 50 [Dark Orange]
- Very Poor (“F”) – Under 35 [Red]

The condition score information utilized from the PMIS database is already calculated and stored in that dataset. Because no additional effort was performed to create the values, there is no discussion of a methodology included in this section. For more information on the condition score, see the reference to the PMIS (14).

Bexar County

The pavement condition scores for road segments in Bexar County are shown in Figure 6. Some of the worst local pavement conditions appear on SH-368 in central San Antonio with several sections of road in the Very Poor condition. There appears to be long stretches of FM-1976 and FM-1346 that are either in Poor or Very Poor condition.

Tom Green County

Overall pavement conditions appear to be better in Tom Green County than in Bexar County. Figure 7 shows the pavement condition scores in the San Angelo region. Portions of US-67 and Knickerbocker Road have some scores in the Very Poor category. There are very few road segments in the region with pavement condition scores in the Poor and Very Poor categories.
Figure 6. Pavement Condition of Road Segments in Bexar County.

Figure 7. Pavement Condition of Road Segments in Tom Green County.
Bridge Condition

Data Source
The bridge condition information comes from the Bridge Inspection Database maintained by TxDOT in the Bridge Inventory File database for each bridge on a public roadway in Texas (15). The variable chosen from this source for this demonstration is the bridge deck condition score.

The bridge deck condition score utilized TxDOT’s Bridge Inventory File database that was already calculated and stored in that dataset. Because no additional effort was performed to create the values, there is no discussion of the methodology included in this section. For more information on the bridge deck condition score, see the reference to the Bridge Inventory File (15).

The bridges in the inventory file were matched to the TxDOT RHiNo segments used in the other layers. Each RHiNo segment has a list of the bridges that fall within its limits. For this demonstration, the bridge with the lowest score is used to report the bridge score for the entire RHiNo segment. This score represents the bridge within the segment that is in the worst condition, so the performance of the entire segment is held to the standard of the worst bridge (read as “a segment is only as ‘strong’ as its weakest bridge”).

Interpretation of the Map Layer
The bridge deck condition score is coded on a continuous scale from 0 to 9. A grade scale was applied to the condition score to group bridges into related quality levels. This scale and the associated colors used on the map are listed below:

- Good – 7 to 9 [Green]
- Fair – 5 to 6 [Light Orange]
- Poor – 3 to 4 [Dark Orange]
- Critical – 0 to 2 [Red]

Bexar County
The bridge condition scores for Bexar County are shown in Figure 8. There is only one road segment in Bexar County containing a bridge that scores in the Poor category (on Walters Street). There are about an even amount of road segments that contain bridges scoring in the Good and Fair categories.
**Tom Green County**

The same holds true in Tom Green County (Figure 9), there is about an even split between Good and Fair categories for bridge condition. In Tom Green County, no road segments have a bridge scoring in categories less than Fair.
Figure 8. Bridge Condition on Road Segments in Bexar County.

Figure 9. Bridge Condition on Road Segments in Tom Green County.
Truck Commodity Value

Methodology

As a surrogate to assess the relative economic significance of the Texas transportation system, a methodology was developed for estimating the value of truck commodity movements throughout Texas. This methodology was developed specifically for demonstration in the TOSTADA project. Methodology refinements are possible as data improve and updates are made to the Freight Analysis Framework (FAF) database. This approach represents one way of estimating the freight values, but there are many other methods and associated assumptions that could be made to obtain similar values.

This is a brief overview of the methodology and demonstration of its application to Bexar and Tom Green Counties.

The Federal Highway Administration’s FAF contains the value and tonnage of commodities shipped by truck between 123 regions throughout the United States (16). Utilizing FAF datasets and the FAF Traffic Analysis Model, route assignment was predicted between all 123 regions to estimate the value of truck commodity movements through Texas. The FAF regions for Texas (from the 123 regions) include:

- Austin.
- Beaumont.
- Corpus Christi.
- Dallas-Fort Worth.
- El Paso.
- Houston.
- Laredo.
- San Antonio.
- Remainder-of-Texas.

The data for Bexar County are based on the San Antonio FAF region. The data for Tom Green County come from the Remainder-of-Texas FAF region, which includes all of Texas not included in the eight FAF metro regions listed.

A value of about $2,000 per ton was calculated for trucks moving through Texas on the Interstate Highway system. See Appendix B for more information on the methodology used to calculate the truck commodity values.
The value per ton of the remainder of truck trips (non-through trips) for a given FAF region was calculated using the trips originating and ending in the region, as well as the truck trips moving only within the region. The value for the truck movements within Bexar County was calculated at about $700 per ton. The $700 figure takes into account that more trucks are dead-heading in a local region, are carrying less-than-truck-load amounts while making regional deliveries, and are hauling less valuable cargo, on average, than the long-haul, national trips.

In Tom Green County, which does not have an Interstate Highway, through truck movements were given the same value per ton as regional movements—$900 per ton—since many of the through movements in the area may not be going across country. Tom Green County and San Angelo fall in the Remainder-of-Texas FAF Region because it is a much smaller urban area. Thus, many of the smaller urban regions within Texas will have the same value per ton as what was used for Tom Green County.

The final key assumptions were the weights (tonnage) assigned to individual trucks. If a heavily loaded truck is approximately 80,000 pounds, and the weight of the truck and trailer could be 15,000 to 20,000 of those pounds, then that leaves about 60,000 pounds for payload. It was assumed that through truck trips were going longer distances and would be loaded more heavily to make the trips cost effective, so through trips were given a weight of 25 tons of payload (50,000 pounds per truck). Non-through trips were given an average payload weight of only 15 tons (30,000 pounds of payload) because they include shorter delivery trips, which often have less-than-truckload amounts.

**Interpretation of the Map Layer**

The figures for truck commodity value are shown with a continuous color scale such that the darkest segments (shown in red) have the highest truck commodity values and the lightest segments (shown in yellow) have the lowest values of truck commodity value.

**Bexar County**

Figure 10 displays the truck commodity values for Bexar County. The highest freight values are on the freeways of IH-35, IH-10, IH-37, IH-410, Loop-1604, and portions of US-281. This is somewhat expected because the through trip traffic is assigned to those facilities and is valued at the higher rate.

**Tom Green County**

The freight values for Tom Green County are shown in Figure 11 with the greater freight values occurring on portions of US-67 and US-87, which gets some of the through trip assignments for the San Angelo region.
Figure 10. Truck Commodity Values on Road Segments in Bexar County.

Figure 11. Truck Commodity Values on Road Segments in Tom Green County.
Demonstration of TOSTADA

As discussed previously, the TOSTADA stacked data concept brings all of the available data together to allow for more informed decision-making. A demonstration of this is shown here for Bexar and Tom Green Counties. Figure 12 displays information on a short segment of US-281 just north of SL-1604 in San Antonio, while information for US-87 near FM-2105 in Tom Green County is shown in Figure 13. Depending on local policy in the area, the data displayed in these examples could be used to decide if this is a location that warrants further investigation and possible funding for solutions.

Limitations to Consider

To reiterate, the information reported in this section is DEMONSTRATION ONLY—the preliminary results are not fully vetted for local decision-making. Please refer to the maps in each data layer in the previous section for the color-code scales corresponding to each map in Figures 12 and 13.

Additionally, the examples shown in Figures 12 and 13 are not all synchronized to the same base map. More work is required to get all the map layers on the same base map. Since this report only demonstrates the concept, the additional mapping work was not performed. The greatest difference in maps is in the pavement map, which shows the pavement quality for each direction of travel, as opposed to information along the roadway centerline. Thus, there will be two lines on the pavement map (showing each direction of travel) for every centerline of travel on each of the other maps.

Bexar County Example

The example from Bexar County (Figure 12) shows:

- Bridge condition – good/fair.
- Congestion – high.
- Freight – medium/high.
- Pavement condition – very good/good.
- Safety – Very high/high.

The infrastructure on US-281 (pavement and bridge condition) appears to be in fairly good condition. The performance of the roadway at this location warrants some additional investigation. Delay per mile (congestion) at this location is on the high end of the scale. The crash frequency (safety) at this location shows a couple of road segments that are very high. Crashes along this stretch of roadway may contribute to the road performance and increase congestion, almost certainly lowering the travel reliability in the area. In addition, this is an
important corridor for freight, so the congestion and safety issues are costing the private sector and the state of Texas in terms of economic productivity.

**Tom Green County Example**

The example from Tom Green County (Figure 13) shows:

- Bridge condition – good.
- Congestion – medium.
- Freight – medium/high.
- Pavement condition – very good/good (very poor on FM-2105 at the intersection).
- Safety – medium high/high.

The infrastructure on US-87 (pavement and bridge condition) appears to be in good condition with the exception of the pavement condition on the approach from FM-2105. The performance of the roadway at this location warrants some additional investigation. Congestion does not appear to be a huge problem; however, the crash frequency (safety) at this location shows a couple of segments that are very high. One of these segments is the intersection of US-87 with FM-2105. Crashes along this stretch of roadway do not appear to create an inordinate amount of delay, but they probably lower the travel reliability in the corridor. Since this appears to be an important corridor for freight in the region, safety improvements to the corridor would have a positive impact on economic activity.

The final TOSTADA product would show all of the information on one coordinated map. A road link could be clicked on or chosen, and all of the pertinent information and performance metrics would be shown. An index or indices could be created that would weight all of the information and performance metrics together based on certain regional or statewide funding policies to generate one score or a small number of scores for the individual roadway segment. The scores from this roadway segment could be compared with scores from other roadway segments to find the greatest problem location or possibly determine the effects of a transportation project on that particular location.
Legend: green and yellow colors are indicative of better performance. Orange and red colors typically show poor or bad performance for that data type (for freight, orange and red show high freight value).
Conclusions

Project Overview

This report describes the development of a process to incorporate factors, such as congestion, safety, pavement quality, bridge quality, and truck freight value, to provide a comprehensive and consistent level of information for informed project comparison, project selection, improved public engagement and awareness of the relationship of transportation concerns. The TOSTADA project demonstrates the visualization and decision-making power of displaying the layered information and having these data in one location. Each map layer has a great deal of valuable data by itself, and the whole becomes greater than the sum of the parts when all of these data layers are combined to inform decisions. The project is not an exhaustive list of information because much more data can be added to the TOSTADA as they become available or are needed. Information that might be added includes:

- Right-of-way availability
- Environmental impacts
- Demographics
- Benefit-cost ratios for projects

The TOSTADA project is only a demonstration of the data layering concept. Work is needed to incorporate additional data and also to develop methods of linking all of the information together to simplify the results.

Benefits

- The project does show that there are opportunities for this type of tool to increase transparency for transportation improvement decisions.
- Policy-makers can use the project results to better understand transportation problems and their economic effects.
- Transportation professionals can use the maps as a form of common dialogue with decision-makers to make the case for improvements and potentially show the benefits of the improvements.
- The TOSTADA project reiterates that with data comes knowledge, and by increasing the amount of information made available through the TOSTADA in the visual format presented here, a broader understanding and discussion of transportation problems and possible investments can ensue.
<table>
<thead>
<tr>
<th>References</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Minnesota Department of Transportation. <em>Interstate 35W Bridge in Minneapolis.</em></td>
<td><a href="http://www.dot.state.mn.us/i35wbridge/">http://www.dot.state.mn.us/i35wbridge/</a></td>
</tr>
<tr>
<td>7. <em>The relationship between traffic congestion and road accidents: an econometric approach using GIS.</em></td>
<td><a href="https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/6207">https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/6207</a></td>
</tr>
</tbody>
</table>
15. TxDOT. Bridge Inventory Database. (http://onlinemanuals.txdot.gov/txdotmanuals/ins/bridge_inspection_database.htm)
Appendix A. Safety Layer Methodology

The crash information used in this analysis is provided for over 100,000 main lane roadway segments of the Texas highway system (13). Each segment is a section of continuous traveled roadway that is not interrupted by a major intersection, and consists of homogenous geometric and traffic control features, such as the number of lanes, median, speed limit, traffic volume and cross sectional widths. The segments are not of equal lengths and traffic volumes vary greatly between segments. For each segment, severe injury crashes, possible injury crashes, property-damage-only crashes, and the total number of crashes are reported. The crash rate based on the total crash frequency and length and volume of traffic on that segment is also provided.

How Roadway Segments Are Defined

The information on roadway segments was extracted from Texas Department of Transportation (TxDOT) Road-Highway Inventory Network (RHiNo) database for the year 2012 (12). A roadway segment is a section of continuous traveled way that is not interrupted by a major intersection, and consists of homogenous geometric and traffic control features. A roadway segment begins at the center of an intersection and ends at either the center of the next intersection, or where there is a change from one homogeneous roadway segment to another homogenous segment. Only state-maintained highways are considered in this safety analysis. The database was filtered to include main lane segments only (i.e. no frontage roads, ramps, etc.).

How Crashes Are Assigned to Roadway Segments

After the roadway segments were identified, crashes were assigned to each individual segment. The TxDOT Crash Records Information System (CRIS) maintains a statewide database for all reported motor vehicle traffic crashes (13). The crash data for the year 2012 were considered for the TOSTADA report. Only those crashes that were coded as “TxDOT Reportable” are considered. A crash is considered “TxDOT Reportable” if it occurs on a roadway and results in an injury or a property damage greater than $1000.

How and Why Crash Rates Were Developed

The number of crashes on any given segment are due to a number of factors, but the length of the segment and traffic volume (which combined are known as “exposure”) have a great influence on the number of crashes. The roadway segments in the RHiNo database have different lengths and traffic volumes. Therefore, it is desirable to know the crash rate in order to better understand the safety performance of each segment and to allow for comparisons between segments.

The crash rate at each roadway segment is calculated by dividing the number of crashes in any given crash category by the product of length and traffic volume, also called the vehicle-miles of travel. Because the number of crashes, relative to the number of vehicle-miles traveled, is very
small, the rates are expressed per million vehicle-miles of travel as the resulting values are more convenient to express and understand.

**How Crash Rates May Be Interpreted and Used**
Crash rates may be interpreted as the probability (based on past events; in this case what occurred in 2012) of being involved in a crash per instance of the exposure measure. Observed crash rates are often used as a tool to identify and prioritize sites in need of modifications and for evaluation of the effectiveness of treatments. Typically, those sites with the highest crash rate or perhaps with rates higher than a certain threshold (e.g., the average crash rate for all similar segments) are analyzed in detail to identify potential modifications that would reduce crashes.

**Why Crash Rates Should Be Used With Caution to Assess Risk**
The rankings in the TOSTADA safety analysis that are based on crash rates are subject to a number of limitations. First, the crash rate method depends on the observed crash data, in this case from law enforcement reports submitted to TxDOT. The issue of data quality and accuracy arises due to the limitations in recording, reporting, and measuring crash data with accuracy and consistency (for example, every crash may not result in a report).

Secondly, crash rates presume a linear relationship between crash frequency and the measure of exposure, which is typically not true. This means that there are proportionally less (or more) crashes per passing vehicles as the traffic flow increases, and thus the crash risk per vehicle diminishes (or increases) when traffic flow increases. These effects are lessened due to the approach taken in this effort to categorize risk.

Lastly, the method is affected by the limitations associated with natural variations in crash data, i.e., randomness in the data. The natural variations in the crash data result in the regression-to-the-mean (RTM) bias. According to the RTM phenomenon, when a period with a comparatively high crash frequency is observed, it is statistically probable that the following period will be classified as a relatively low crash frequency. Therefore a database with only one year of data, such as the one used in the TOSTADA analysis, must be analyzed with caution. It is best to use several years of data to help guard against the possibility any given year of crash occurrence is not representative of the overall crash experience in the segment. Because the TOSTADA safety analysis only utilized one year of crash experience for demonstration purposes, the results must be viewed with caution.

**How Crash Risk Assessments Were Made for Each Segment**
Each roadway segment was assigned to a risk category (low, moderate, high, and very high) based on how its crash rate compares to the crash rates on all other roadways in the state within the same area type (rural or urban), functional class (freeway, arterial, collector, or local road), and volume range (low, medium or high). The following sections describe how these risk categories were developed.
Each homogenous segment is assigned a functional class in the RHiNo database. The functional classes are either rural or urban as shown in Table 1.

<table>
<thead>
<tr>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>Interstate</td>
</tr>
<tr>
<td>Principal Arterial</td>
<td>Other Freeway</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>Principal Arterial</td>
</tr>
<tr>
<td>Major Collector</td>
<td>Minor Arterial</td>
</tr>
<tr>
<td>Minor Collector</td>
<td>Collector</td>
</tr>
<tr>
<td>Local</td>
<td>Local</td>
</tr>
</tbody>
</table>

Table 1. RHiNo Segment Functional Classes.

For simplicity in comparing crash risk, these classes were combined into the categories shown in Table 2.

<table>
<thead>
<tr>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>Interstate and Other Freeways</td>
</tr>
<tr>
<td>Principal and Minor Arterials</td>
<td>Principal and Minor Arterials</td>
</tr>
<tr>
<td>Major and Minor Collectors</td>
<td>Collector</td>
</tr>
<tr>
<td>Local</td>
<td>Local</td>
</tr>
</tbody>
</table>

Table 2. Crash Risk Functional Classes

In order to mitigate the effects of assuming a linear relationship of crash rates over a wide range of traffic volumes, the crash rate per mile was plotted against the traffic volume (average daily traffic, or ADT) for each segment in a particular functional class. An equation was fitted to the data to visually examine how crashes vary across the range of traffic volumes. Figure 14 is an example of such a plot and the equation for rural interstate highways.

\[ y = 4.4821 \ln(x) - 39.697 \]

Figure 14. Crashes per Mile and Daily Traffic Volume for Rural Interstate Highways in Texas.
The fitted curve indicates that the relationship between crash rate per mile and volume varies across the range of average daily traffic volume values. However, the relationship is fairly constant over certain ranges of values. In this case, the relationships between 0 and 30,000 vehicles, 30,000 to 60,000 vehicles, and more than 60,000 vehicles are fairly stable and very nearly linear within these ranges. Therefore, the segments were further grouped by volume into low (less than 30,000 ADT), medium (30,000 to 60,000 ADT) and high (more than 60,000 ADT).

This analysis was performed for each functional class category (Table 3). All the functional classes were further refined into low, medium, and high traffic volume categories except for rural and urban local roads. The volume range is fairly narrow in those functional classes, the number of segments is small, and there is no advantage to creating the volume categories. The resulting 20 groupings and the number of segments in each grouping are listed in the following table.

**Table 3. Volume Ranges for Groupings by Area Type and Functional Classes.**

<table>
<thead>
<tr>
<th>Area Type</th>
<th>Functional Class</th>
<th>Volume Ranges (vehicles per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Urban</td>
<td>Freeways</td>
<td>Below 75,000</td>
</tr>
<tr>
<td></td>
<td>Arterials</td>
<td>Below 25,000</td>
</tr>
<tr>
<td></td>
<td>Collectors</td>
<td>Below 5,000</td>
</tr>
<tr>
<td></td>
<td>Local*</td>
<td>0 to 20,000</td>
</tr>
<tr>
<td>Rural</td>
<td>Freeways</td>
<td>Below 30,000</td>
</tr>
<tr>
<td></td>
<td>Arterials</td>
<td>Below 15,000</td>
</tr>
<tr>
<td></td>
<td>Collectors</td>
<td>Below 5,000</td>
</tr>
<tr>
<td></td>
<td>Local*</td>
<td>0 to 15,000</td>
</tr>
</tbody>
</table>

*Only one volume group.

Table 4 provides information on the number of segments, the total length of segments, and the total number of crashes for each area, functional class, and volume grouping.

**Table 4. Number of Segments, Total Length, and Total Crashes in Each Grouping for Assessing Crash Risk.**

<table>
<thead>
<tr>
<th>Area Type</th>
<th>Functional Class</th>
<th>Low Volume</th>
<th>Medium Volume</th>
<th>High Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Segments</td>
<td>Length (miles)</td>
<td>Crashes</td>
</tr>
<tr>
<td>Urban</td>
<td>Freeways</td>
<td>1,691</td>
<td>1,622</td>
<td>363</td>
</tr>
<tr>
<td></td>
<td>Arterials</td>
<td>24,704</td>
<td>16,782</td>
<td>18,809</td>
</tr>
<tr>
<td></td>
<td>Collectors</td>
<td>37,964</td>
<td>42,250</td>
<td>14,039</td>
</tr>
<tr>
<td></td>
<td>Local*</td>
<td>99</td>
<td>75</td>
<td>15</td>
</tr>
<tr>
<td>Rural</td>
<td>Freeways</td>
<td>4,311</td>
<td>1,550</td>
<td>16,991</td>
</tr>
<tr>
<td></td>
<td>Arterials</td>
<td>19,325</td>
<td>5,419</td>
<td>46,520</td>
</tr>
<tr>
<td></td>
<td>Collectors</td>
<td>2,273</td>
<td>760</td>
<td>1,167</td>
</tr>
<tr>
<td></td>
<td>Local*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Only one volume group.
Crash rates were compared between segments within the same setting, functional class, and volume grouping. In order to classify the crash risk, cumulative percentage graphs were plotted for each grouping, which depicts the percent of segments that have a particular crash rate or less. Figure 15 is an example of such a plot for rural interstates with medium traffic volumes (30,000 to 60,000 ADT).

![Cumulative Percentage vs. Crash Rate for Rural Interstate Highways in Texas](image)

Inflection points were identified for each plot. Inflection points are the percentile at which the relationship between cumulative percentages and crash rate changes. These were used to determine the categories. In this example, inflection points were noted at the 35th, 85th, and 95th percentiles. A low crash risk was assigned to segments from 0 to the 35th percentile. Segments with crash rates between the 35th and 85th percentiles (most segments fall into this category) were labeled as moderate. Between the 85th and 95th percentile, a high crash risk was assigned, and those segments with crash rates greater than the 95th percentile (i.e., the 5 percent of segments with the highest crash rates) were deemed as having a very high crash risk.

This method was repeated for each area type, functional class, and volume grouping and a risk assessment was assigned to each roadway segment. Therefore, there are low, moderate, high, and very high crash risk segments in each of 20 groupings. In addition, the crash risk is assessed for each group relative to all the segments in the entire state for that grouping.
Appendix B. Truck Commodity Values

As a surrogate to assess the relative economic significance of the Texas transportation system, a methodology was developed for estimating the value of truck commodity movements throughout Texas using the commodity flow data from the Freight Analysis Framework version 3 (FAF3) (17). The term “flow” refers to the movement of both tons of freight and value of freight between origin-destination (O-D) pairs within the United States.

Through Truck Trips for the State of Texas

The methodology was developed by using two different FAF components. First, origin-destination (O-D) commodity flow data for value and tonnage of truck freight flowing between 123 regions were obtained from the FAF Data Tabulation Tool (16). Each large metropolitan area in the United States is represented by an FAF region, with any remaining area within a state that is not included in a metro region grouped into a remainder-of-state region. The FAF regions for Texas (from the 123 regions) include:

- Austin.
- Beaumont.
- Corpus Christi.
- Dallas-Fort Worth.
- El Paso.
- Houston.
- Laredo.
- San Antonio.
- Remainder-of-Texas.

The data for Bexar County are based on the San Antonio FAF region. The data for Tom Green County come from the Remainder-of-Texas FAF region, which includes all of Texas not included in the eight FAF metro regions listed.

Second, the FAF3 Traffic Analysis Model (FAF Model), which applies a route assignment model to the origin-destination commodity flow data, was utilized (18). The FAF Model is calibrated to truck volumes provided by the Highway Performance Monitoring System (HPMS) to produce estimates for the total tonnage and value of freight along a specific highway segment (not value) and a series of state flow maps indicating high volume truck routes to/from and within Texas (see Figure 16).
The TOSTADA truck commodity value methodology applies a simplistic route assignment and summation procedure to estimate the contribution of individual origin-destination flows to the total freight flows provided in the FAF Model. The goal was to obtain total tonnages and values reasonably close to the aggregated tonnages and values from the FAF model. This is a necessary step in order to relate the value of estimated freight with actual “ground-truth” truck traffic provided by FAF.

A simplified highway network of prominent Texas freight corridors and eight corresponding points-of-entry (POE) and exit along the Texas state border was defined (see Figure 17). Using this defined network, all three types of truck trips (those originating or ending in, those going through, those traveling only within) are accounted for by assigning individual O-D flows to a specific route through Texas.
A route assignment is performed using two route-splitting factors, which account for alternative routes inside of Texas (e.g., IH-10 vs. IH-20) and outside of Texas (e.g., IH-70 vs. IH-40). To simplify calculations, all 123 FAF regions are grouped into 19 travel zones based upon similar state flow map densities (see Figure 18). Any FAF region O-D pairs sharing the same travel zone pair were assumed to have the same route choice through Texas. Cursory route assignments were made based on state flow maps, resulting in the proportion of freight flow (tons and value) moving through Texas along a particular route. Summation of all regional O-D pairs along a particular highway segment yields the total truck freight flow (value and tons) along a particular highway segment.

The estimated total tonnage and value were compared to total tonnages and values in the FAF3 traffic model, and route assignment factors were adjusted to be proportional to travel distance between alternative routes, beginning with the O-D pair with the highest individual contribution to total route tonnage. Route assignment factors were adjusted until estimated volumes were reasonably balanced with the FAF model across all POEs along the Texas border.
Several assumptions were key in producing the through truck trips for the State of Texas:

- Through trucks to the State of Texas will only use interstate highways and a limited number of major non-interstate highways and will remain on these highways while inside Texas.
- O-D pairs sharing the same travel zone pair are assumed to have the same route choice.
- The FAF state flow maps are assumed to have intuitive results for route assignment.

All of the methods used to estimate through truck movements allowed for the calculation of an average value per ton of freight moved through Texas. For the state of Texas, this value is $2,000 per ton of freight moved by truck. Since the methodology assumed that through truck trips in Texas would primarily be on the interstate highway system, this methodology only applied to truck value in Bexar County as Tom Green County does not have any interstate highways. Using the truck count information in TxDOT’s RHiNo database and reviewing these counts across entire interstate highway corridors through Bexar County, up to 40 percent of the trucks were labeled as through-Texas trips.

**Value for Non-Through Texas Movements**

The FAF database contains information on 123 regions within the United States. For each of these FAF regions, the tons and value of truck flows are reported for trips beginning or ending in each region and for trips beginning and ending inside a single region. This information was used to calculate the value per ton of regional truck cargo for Bexar and Tom Green Counties.

Some of the key assumptions in this methodology were the payload weights assigned to individual trucks. If a heavily loaded truck is approximately 80,000 pounds, and the weight of the truck and trailer could be 15,000 to 20,000 of those pounds, then about 60,000 pounds remain for payload. It was assumed that through truck trips were going longer distances and would be loaded more heavily to make the trips cost effective, so through trips were given a weight of 25 tons of payload (50,000 pounds per truck). Non-through trips were assigned an average payload weight of only 15 tons (30,000 pounds of payload) because they include shorter delivery trips, which often have less-than-truckload amounts.

For Bexar County, using the truck information in TxDOT’s RHiNo database, the through-Texas truck trips were pulled from the interstate highways and assigned an average weight of 25 tons to be valued at $2,000 per ton. Thus, each through-Texas truck received a payload value of $50,000.

The value of a ton of regional truck payload in the San Antonio FAF region was valued at approximately $700 per ton. All additional trucks in Bexar County—deemed to be regional trips—were assigned a weight of 15 tons and assigned the value of $700 per ton. Thus, more localized truck trips on Bexar County roads were valued at $10,500 per truck. The reason for the
lighter weight assumption is that more localized travel includes some dead-heading trips and a lot of less-than-truck-load delivery trips in the region.

The value per ton of regional truck payload in Tom Green County came from the Remainder-of-Texas FAF region as San Angelo did not have its own FAF region. The value of a ton of truck cargo for the Remainder-of-Texas FAF region is estimated to be $900. This value is used for all trucks in Tom Green County since it is located in the Remainder-of-Texas FAF region, whether the trips are deemed through trips or regional trips.

Even though through trips in Tom Green County probably are not going “through” Texas but are beginning or ending in Texas, there are through trips—generally long haul trips—using the San Angelo road network. The through trips for Tom Green County were assumed to be fifty percent of the travel on the U.S. Highways that cut through San Angelo based on observing the truck counts along these corridors in the RHINO database. These through trips were assigned a weight of 25 tons, just like the through-Texas trips. However, they are valued at the lower rate of $900 per ton of payload. The non-through or regional truck trips in Tom Green County were assigned a weight of 15 tons but were valued at $900 per ton rate. Thus, through trips in Tom Green County are given a value of $22,500, while regional trips are valued at $13,500.

The methodology for estimating the value of truck commodity movements throughout Texas was developed specifically for demonstration in the TOSTADA project. Refinements are possible to the methodology as data improve and updates are made to the FAF database. This approach represents one way of estimating the freight values, but there are many other methods and associated assumptions that could be made to obtain similar values.