The ENTERPRISE Pooled Fund Program

Travel Time Research Project

Deliverable #1 – Travel Times Best Practices Manual

Final Report

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1. Executive Summary

1.1 Introduction

The ENTERPRISE Travel Time Best Practices Research Project involved contacting numerous State Department of Transportation (DOT) representatives to discuss best practices for travel time data collection, processing, and information reporting. This document summarizes the results of the conversations and lessons learned.

In addition to simply documenting the practices implemented in each state, research was also conducted on the specific approaches used for monitoring and reporting information. Therefore, there are a number of matrices in this deliverable, each one presenting a different perspective on the topic of travel time prediction and reporting.

The intent of this research was not to develop a lengthy white paper on the topic of travel time reporting, but rather to present quick facts in an easily referenced format to support ENTERPRISE member agencies in understanding what has worked and what has not worked in the field of travel time reporting.

1.2 Conclusions of Best Practices Study

In general, those agencies delivering travel times to their local travelers have had very successful results. Most often, the traveling public has responded positively to the travel time reports and has found them to be of significant value.

The matrices in Section 3 of this report describe details from many successful travel time systems throughout North America. Without repeating all of Section 3 in this brief Executive Summary, a few highlights of best practices are summarized as follows:

- North Carolina has implemented a low cost system based on solar powered Doppler based speed detectors reporting over wireless communications. This implementation met their specific needs and the low costs allowed for maximum coverage to be served by minimum costs;

- Seattle, Washington and Minneapolis, Minnesota both had extensive loop detector coverage and established communications. This infrastructure enabled them to build in-house travel time systems with minimal outside contracted services and operate these with existing staffing resources, providing accurate and useful results; and

- Chicago Illinois and the Bay Area represent areas where existing AVI tags on vehicles and a network of sensors allowed for hybrid approaches to data collection. These data are fused together through travel time algorithms developed by private contractors to deliver information using a combination of inputs.

The intent of this study and report is not to judge or assess any technologies, products, or approaches; but rather to document and summarize the experiences of public agencies that are operating travel time reporting systems. Therefore, this report specifically avoids promoting (positively or negatively) any specific vendor, technologies or systems. Any references to contractor/vendor names and/or products are included in order to describe sufficient details about the deployments to allow readers to understand the approaches and have the background needed should they decide to seek additional information.

1.3 Decision Factors for Travel Time Calculations

While this best practices report summarizes many aspects of travel time data collection and reporting, the three most critical decisions facing travel time deployments were observed to be:

- The travel time reporting needs (e.g. geographic coverage, information needed);
- The ownership and responsibility of the data collection equipment and algorithms; and
- The approach towards data collection and calculation.

1.3.1 Travel Time Reporting Needs

Based on discussions with many states performing travel time reporting, the recommendation of this report to any state deciding to pursue travel times is to begin by developing a Concept of Operations that defines how the travel times will be used, as a driving factor in determining the best approaches. The minimum factors addressed in this Concept of Operations should be the intent of travel time reporting and the desired geographic coverage of travel time reporting. Each of these factors is discussed below:

- The intent of travel time reporting:
    - For states wishing to provide travel time information along freeways to inform travelers of their expected time along the current route, then data collection and calculations for these select isolated routes and segments might be appropriate, and there might not be a need to collect and report travel times for alternate routes.
    - For states wishing to provide travel times (either on DMS, 511 or the Internet) to key destinations, together with alternate route travel times, then a more diverse network of travel time data collection is needed, possibly even including the arterial network;
    - For states wishing to include a form of automated incident detection or alert functionality or to consider traffic volumes and density in controlling

ramp meters, then the data collected should include volume and occupancy data (and not be solely limited to speed data);

    - For states ultimately wishing to disseminate travel time information for a number of destinations (e.g. related to an ‘Access and Destinations’ approach), then connector travel times (i.e. ramps, feeders) may also be needed to describe a complete travel time picture

    - For states wishing to disseminate historic travel time information on the Internet site or use the raw data (speed, volume, occupancy) for other calculations or analyses, then the agency should pursue an approach where they ‘own’ the data and are allowed to archive and use the data for other purposes.

- The geographic coverage where travel time reports are needed:

    - For sites that decide the primary travel time needs are on one or two isolated routes, then an approach similar to that used in North Carolina where solar powered speed sensors and wireless communications might be the most appropriate solution;

    - For sites that decide the travel time reports should cover the primary freeway network that is already monitored with fixed sensors communicating back to a management center, then an in-house State DOT owned travel time algorithm complemented by supplemental sensors added in the field might make the most sense;

    - For sites that decide to offer travel times over large areas, supporting numerous destinations, with a mixture of freeways and arterials and/or wish to expand the travel time reports to corridors or rural areas of the state, then the best approach might be to contract services from a private company that either collects and generates information with their own sources or through a combination of public and private data collection points.

1.3.2 Options for Ownership and Responsibility

In talking with state agencies performing travel time reporting, the largest difference in the approaches to travel time calculation and reporting throughout North America was observed to be in the ownership and responsibility of the data collection and travel time calculation algorithms. Some states have deployed and own all data collection equipment and software, and also have developed and own all algorithms. Other states, purchase a service that either collects and provides the data, processes existing data and computes travel times, or both. Finally, some states operate a hybrid approach, where much of the equipment is owned by the state, and a private contractor accesses the data to compute and disseminate travel times. Some observations of each approach are summarized as follows:

Observations about the ***states that own and operate the data collection equipment*** (traffic sensors) and travel time algorithms are summarized as follows:

- Often states that have a network of existing sensors to support real-time ramp meter algorithms have sufficient coverage to perform successful travel time calculations without additional sensors;

- The ownership of sensors requires ongoing maintenance and operations costs, however many states perform this maintenance with in-house operations staff and the true costs to maintain the sensors specifically for travel time are seldom fully understood;

- States operating travel time algorithms developed in-house typically feel a good deal of ownership in the system and regularly tweak and modify the algorithm with internal staff;

- There are a number of very successful locations where state DOTs operate effective in-house travel time systems, experiencing minimal contracted expenses. These sites deliver a highly valued service almost exclusively with in-house staffing resources.

- In situations where the geographic demand for travel time reports continues to increase (further in to the suburbs or along additional second tier highways that may or may not be operated by the state DOT), eventually the costs to continuously maintain and operate the growing number of sensors may create delays in expanding travel time delivery or eventual cost impediments to maintaining the network of sensors.

Observations about the ***states that contract services for data collection, travel time calculation, or both*** are summarized as follows:

- There are numerous success stories where contracted services use privately collected data, process publicly collected data, or combinations of both to generate travel times;

- One observation is that those approaches that do not require fixed physical infrastructure solely dedicated to traffic detection offer a very long term solution to providing travel times over increasingly larger geographic areas more efficiently than would be possible with fixed detectors;

- However, one observed challenge facing the contracted services is the need for ongoing contracted and outsourced service delivery, and the periodic re-negotiation of such services that might be required; and

- It appears that the market for travel time service delivery is still evolving and the business models, prices and service agreements may continue to change as different companies establish their services. At some point, the contractors offering the travel time service delivery will reach a stable price for delivery (or maybe have already) and it will be interesting to observe whether this price is a cost that State DOTs can justify in regards to the benefits to travelers and the available funding sources.

Recommendations

The opinions of this research project are that the selection of approach to ownership and responsibility of travel time calculation and delivery is dependent upon the local situation within each state.

For example, state DOT ownership and operation of fixed sensors for traffic detection and in-house travel time calculations appears to be most suited to situations such as:

- States with in-house IT staffing and resources to maintain the field equipment and software without considerable burden;
- States with an existing network of data collection for ramp meters, where minimal new infrastructure is needed to monitor traffic flows to calculate travel times;
- States with funding allocations and approaches where it may be challenging to outsource or administer continuous operations contracts (and where the use of internal staff is preferred).

In contrast, state DOT outsourcing or contracting of services to provide travel time information (or portions of the service) appear to be most suited to situations such as:

- States where a comprehensive network of fixed traffic sensors does not exist (and would essentially need to be created solely for travel times);
- States where a combination of freeway and arterial travel times is desired;
- States where the need for travel time calculation extends beyond the metropolitan area and there is a strong desire to report suburban or rural travel times in an extended area.

1.3.3 Approaches for Data Collection

An additional key decision facing states wishing to implement travel times is the data collection method. This decision is most often faced by those states performing travel time calculations in-house, but also may be relevant if services are contracted (depending upon the service agreement). The discussions with states in this project (summarized in the tables in Section 3) have presented four options for data collection:

- Fixed detection of traffic volume and occupancy;
- Fixed detection of speed;
- Detection of travel times using approaches such as toll readers; and
- Proprietary approaches, such as probes and or communication monitoring.

Fixed Detection of Traffic Volume and Occupancy

Some observations about those states using fixed detection of traffic volume and occupancy are:

- Most typically, inductive loops, radar or other sensors provide the volume and occupancy reports;
- There are a number of commercial products that offer comparable performance and well documented success in terms of reliability and accuracy;
- The costs per observation site and the need for many observations sites creates cost impediments to monitoring large areas. Many sites with large networks monitored have grown the system over many years, and have a routine for replacement of a percentage of sites each year.

Fixed Detection of Speed

Some observations about those states using fixed detection of speed are:

- Speed monitoring provides the needed information to calculate travel times often at a low cost, however these approaches lack traffic counting capabilities;

- North Carolina is a good example of a state that reached a decision to implement speed sensors along a freeway route to gather the information needed to report travel times.

Direct Detection of Travel Times

Some observations about those states using travel time measurements with toll readers are:

- There were some experiences of delays in calculation time to determine travel times using toll reader information, depending upon the algorithm and overall approach;
- The accuracy when toll readers (or additional travel time centric readers) are spaced relatively close together can be very high;
- There are also some institutional issues regarding the use of toll reader information for travel time reporting, related to the data ownership and the use of the data.

- Many sites are using toll tags for travel times and reporting very accurate results with minimal additional investment required. Additionally, as the number of electronic toll users increases, the accuracy and time to calculation may also improve.

Private Sector Proprietary Travel Time Services

Some observations about those states contracting proprietary approaches are:

- Some approaches depend upon existing services of third party companies (e.g. cellular phone providers or fleet vehicles) and these approaches may require various levels of participation by these third parties. Therefore, while there is an advantage to using other existing networks of either fixed infrastructure or mobile devices (and therefore eliminating the need for new infrastructure) this also implies either a direct or indirect reliance on these other networks or systems. The needed commitments of these other systems should be understood and considered before reaching final decisions;

- The demonstrations and deployments that have already occurred have shown great success, and seem to demonstrate the long-term potential for approaches that can be reproduced nation-wide very quickly. For these reasons, these approaches appear to have the strongest long term potential for truly nation-wide service delivery.

2. Summary / Purpose of Matrices

The following section presents four matrices of information gathered from contacts with representatives in the various states, and through Internet searches. The intent of each matrix is summarized as follows:

- **Summary matrix of Travel Time Deployments.** This matrix presents general information about each location contacted and/or researched within this project. The information is intended to give readers an understanding of the approaches utilized, the ownership of equipment and data, and the feedback/findings on the quality of the reports.

- **Travel Time Data Collection Matrix.** This matrix presents additional details (based on discussions with state representatives as well as additional research) into the data collection approaches, products available, and findings on performance and lessons learned.

- **Travel Time Calculation Matrix.** This matrix presents different approaches towards calculating travel times based on the data collected. Again, information in this matrix is a combination of insight gathered in conversations with state representatives as well as additional research.

- **Travel Time Reporting Matrix.** This matrix presents different approaches used for the dissemination of travel time reports on DMS and the Internet. Where available, lessons learned and feedback on the approaches is also included.

3. Summary Matrix of Travel Time Deployments

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Seattle, Wa	- Loop detectors - Record occ. / vol. - Spacing ¼ - ½ mile - 20 sec. polling **- WSDOT owned and operated loops**	- From occupancy calculate speed - Use speeds and segment lengths to sum up a travel time - Expanding to consider historic travel time at location and time to predict trends. - Expanding to consider elements such as rain and snow - Planning to add an incident module to consider queue dissipation **- WSDOT developed algorithm**	- Reported on DMS as time to reach city (vs. a route) - Shorter distances, better feedback from travelers (more reliable) - Change every 2 minutes or longer (not change message every 20 seconds) - Also disseminated on web **- WSDOT owned and operated signs and website**	- Test show accuracy greater than 90% - Confirmed with camera tracking and customer feedback

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Twin Cities, MN	- Loop detectors (occupancy and volume / calc. speed) - ½ mile coverage - Each lane measured, averaged across all lanes in field and station reports transmitted to RTMC - 30 second polling **- Detectors owned and maintained by Mn/DOT**	- Modified mid-point algorithm - Each influence area divided into 3 regions (center region uses speed of detector within the region, each side region uses average of the two adjacent detectors **- Algorithm developed by Mn/DOT (with input from University of Minnesota)**	- Reported on DMS signs - Times reported to roads or key landmarks (ie. 'River') **- TMC software to control signs (IRIS) developed and maintained by Mn/DOT**	- Internal testing shows travel times accurate most of the time - Inaccuracy reports tend to be when conditions are changing from one steady state to another - Favorable public response - Favorable trials and reporting by local media

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Chicago, IL (IDOT)	- Loop detectors (Vol. & Occ.) - ½ mile coverage - 20 second polling - **Detectors owned and maintained by IDOT**	- Speeds calculated based on Vol./Occ. At each station - Speed used for ½ mile distance covered by station - All speeds summed to calculate travel time over route - Algorithm includes a fudge factor for times when occupancy exceeds 95% - Cap speed calculations at 55mph when computing travel times **- Algorithm written and maintained by IDOT**	- DMS signs - website (GCMtravel.com) - Website graphically displays current travel time, average travel time, and the typical ranges of travel times for each route	- Anecdotal feedback and experiences of IDOT staff. - Most travel time reports tend to be within +/- 2 minutes of actual - Have had good luck with travel time calculations during incidents

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Illinois State Toll Highway Authority (ISTHA)	- Initially used only IPASS ETC toll plazas and AVI tags - Long distances resulted in delays of capturing changes to travel times - ETC supplemented with approx. 100 RTMS detectors **- RTMS installed and maintained by Traffic.com** **- IPASS readers maintained by Transcore**	- Travel time algorithm combines ETC data and RTMS data to generate travel times. - Includes an automated section creator to be used with portable DMS to temporarily calculate travel times to be posted on portable DMS **- Travel time calculations performed by Delcan (NET) system.**	- Reporting possible on both permanent and portable DMS signs **- Travel Time Reporting on website is limited to calculations based solely on IPass ETC readers (contractual restrictions to not allow RTMS data to be used for web display. This results in a discrepancy between DMS and website reports** - Additional ETC readers are being considered	- Accuracy tested initially through ride-along drives to measure travel times - Annual tests of accuracy - Additional tests if reports of discrepancies - RTMS addition has improved travel time over ETC along - Quicker response to maintain accurate travel times in changing conditions - Better performance during incidents

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
San Francisco, CA (Bay Area)	- Loop detectors - AVI Toll Tag readers - Spot speed loop sensors owned by public agencies - Spot speeds also recorded by speedinfo sensors - MTC subscribes to data from about 300 sensors. Speedinfo does all O&M, the public agency pays only for the data stream	- Travel time algorithm compares the three data sources (loops, radar, AVI) and fuses the data together to predict travel times. - When one data feed appears to be inaccurate or is not available, the other data sources are used exclusively. - Some stretches of road have all data sources available, others do not. - Travel time predictions are performed by a contractor (design, build, operate, maintain – DBOM). - Travel time algorithm is the responsibility of contractor (Telvent Faradyne) and they deliver the travel time values as the deliverable to the project, therefore they maintain and update the algorithm.	- Travel times are disseminated via. DMS, web and 511 telephone system.	- A 3rd party performs monthly ground truth drivetime verifications of 30 miles each month. - Portions of the contractor payments are tied to the accuracy reported by the 3rd party evaluator. - Errors may be caused by sensor reading problems - Bigger incidents cause more error in travel time reporting - Feedback is that travel time reports are still accurate when traffic speeds dip down to 15-20 mph. **- Estimated that 90% of all travel time reports have greater than 80% accuracy.**

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Toronto CA	- Loop detectors every 1/3 mile - 20 second polling rate - Detectors owned and operated by MTO	- Internal travel time algorithm developed by MTO - Initial algorithm computed travel times by averaging recorded speeds over distances between sensors. - Early algorithm resulted in errors during start and end of peak period (when conditions were changing rapidly) - Revised algorithm applied rule-based decision logic to consider impacts of changing conditions. Factors included: • Queue growth and dissipation patterns • Correlation between actual travel times and locations of queues • Time of day that typically outline the start & end of peak period traffic • Impacts of driving behavior and selected lane of travel - Revised model was proven accurate and effective even during start and end of peak periods	- Reporting over DMS signs - Travel times presented in ranges of time. - 13-20 min - use 3 min. range (e.g. 15-17 min) - 21-30 min. – use 4 min. range (e.g. 23-26 min) - 31-40 min. – use 5 min. range (e.g. 32-36 min) - Travel time appended to end of congestion message - Under free flow conditions travel time calculations assume speed limit (100km/hr) - When travel times exceed 40 minutes, DMS displays 'Stop and go conditions'	- Current performance (with adjusted algorithm) produces accurate results and the traveling public has been pleased. - Additional research for more complex freeway systems (with express and collector systems) is being researched.

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Milwaukee, WI	- Loop detectors spaced every half mile in the metro area (some as close as every ¼ mile. - Suburbs (outside core metro) spacing is longer (as much as 3 mile spacing) - Loops augmented with some microwave detectors	- Travel time calculated by known distance and averaged speed based on detector data - Detector data brought back to Freeway Management System (FMS) for calculation and posting - Algorithm averages the speed of all lanes of traffic at a specific location - Averaged speed is assumed over a predefined link, and travel time is calculated using the distance of the link. - If more that 1/3 of detectors are not operational, the travel time calculation will not be performed - if less than 1/3 of detectors have failed, system will still produce travel times, and will fill in missing data using data from surrounding detectors.	- Trans-suite software (Transcore) operating in center to compute and post travel times - Travel times updated on DMS every minute - Travel times updated on web page every 3 minutes. - DMS relays travel time to different destinations based on time of day, (for example during AM peak downtown destinations are reported).	- Once a month WisDOT performs drives to verify travel times - Travel times found to be accurate within a few minutes - Public has been happy with performance - Public notices travel time errors and reports them - Most errors are found to be result of bad data (e.g. loops not operating) - System has been operational since late 1990's (part of Y2K software upgrade)

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Houston, TX	- AVI (toll tag) transponders - 232 supplemental reader stations in addition to toll facilities - Over 2 million EZ Tag customers driving the roads	- Initially one operated performed manual posting of travel times to DMS (proved too time consuming) - Texas Transportation Institute (TTI) developed a travel time processor, and Southwest Research Institute (SwRI) developed an automated sign posting interface - Now travel times are automatically posted to over 80 DMS every 10 minutes - Recommendation is for agencies to take ownership of software and other systems and materials whenever possible.	- Reporting on over 80 DMS, updated every 10 minutes between the hours of 5:30-7:30 (some updated more frequently) or when travel times differ from free flow - Travel times also posted to web (helps inform travelers about system) - DMS messages include time of calculation (to address latency issues) (e.g. Travel Time to IH 45 11 min. at 4:40pm)	- System highly accepted by travelers - Travel times reported to be accurate - A survey of drivers revealed that 85% changed their route of travel based on messages on the signs

SITE LOCATION	DATA COLLECTION	ALGORITHM / CALCULATIONS	REPORTING	PERFORMANCE
Nashville, TN	- RTMS sensors located at ¼ mile intervals - TMC software polls sensors every 2 minutes - RTMS sensors are regularly maintained and calibrated to ensure they are accurate.	- Average speeds are used to calculate travel time (using distance between sensors and average speed of sensor) - MIST system operates in the TMC.	- Travel time reported only to destinations that are no more than 5 miles from the DMS - Distance to destination also posted on DMS - Travel times posted as ranges of 2-3 minutes - Posting of incident information takes priority over travel time postings.	- Public response has been very positive -Public prefers travel time postings to blank DMS signs - Regular calibration of RTMS helps ensure accuracy - TDOT regularly tests travel time accuracy using CCTV for manual verification

4. Travel Time Data Collection Matrix

DETECTION METHOD	LOCATIONS REVIEWED	PERFORMANCE FEEDBACK	M & O REQUIREMENTS	NOTES
Wavetronix Smart Sensor	MN Non-intrusive testing (NIT)[1] MN Tiger Project	- Volume error 1.4% - 4.9% - Speed error 3.0% - 9.7% - Effective at monitoring up to 8 lanes with one deployment - Increased errors at speeds below 3 mph	- Initially auto configuring feature aids calibration - Ongoing calibration needed (weather related) - Ongoing calibration requires radar detector	- Typical costs < $10,000 per site
EIS RTMS	MN Non-intrusive testing (NIT)[1]	- Volume error 2.4% - 8.6% - Speed error 4.4% - 9.0% - Effective at monitoring up to 8 lanes with one deployment - Increased errors distinguishing vehicles at speeds below 5 mph.	- Initially auto configuring feature aids calibration - Ongoing calibration needed (weather related) - Ongoing calibration requires radar detector	- Typical costs < $10,000 per site
SmarTrek SAS-1	MN Non-intrusive testing (NIT)[1]	- Volume error 1.4% - 4.9% - Speed error 3.0% - 9.7% - Effective at monitoring up to 8 lanes with one deployment - Increased errors undercounting vehicles at speeds below 30 mph.	- Initially auto configuring feature aids calibration - Ongoing calibration needed (weather related) - Ongoing calibration requires radar detector	- Typical costs < $10,000 per site

[1] Kotzenmacher, Jerry (Minge & Hao); "Evaluation of Portable Non-Intrusive Traffic Detection System", Minnesota Department of Transportation Report No. MN-RC-2005-37, September 2005.

DETECTION METHOD	LOCATIONS REVIEWED	PERFORMANCE FEEDBACK	M & O REQUIREMENTS	NOTES
SpeedInfo Sensors	North Carolina San Francisco, CA	- All tests in N.C. showed travel times accurate to within 1-2 minute of ground truth using data output. - Solar powered detectors mounted on existing poles report data over GSM cellular connections. - Data is transmitted to SpeedInfo operations center and raw data is converted to single speed calculations - Only time where NCDOT has noticed unusual reports is during the first 1-2 minutes of a rainfall, when speed detection varied, then it stabilizes. - Readings currently limited (in NC) to only speed (i.e. no volume counts).	- SpeedInfo performs all O&M and delivers data to NCDOT. - Calibration is needed every 2 years (provided by SpeedInfo contract). - Speed is measured using Doppler technologies. - One deployment sensor can monitor both directions of travel. - SpeedInfo offers partnerships were they own the equipment and clients buy the data (approximate costs estimated at $100/mo. per site)	- NCDOT costs were $150,000 for 40 sensors, including 3 years O&M

DETECTION METHOD	LOCATIONS REVIEWED	PERFORMANCE FEEDBACK	M & O REQUIREMENTS	NOTES
AVI Toll Tag Transponders / Readers	Illinois Tollway San Francisco, CA Houston, TX San Diego, CA	- Spacing of Readers is largest factor on performance (e.g. errors and/or delays in accurate reports happen with long distances between readers) - Number of AVI tags is another factor, Illinois has 1.5 Million active users; Houston has 2 Million users. - Anecdotal feedback suggest maximum of 5 miles between readers (either toll plazas or supplemental AVI readers for Travel Time) - AVI readings often subsidized with loops or spot sensors (fusing data from all sources)		- Offers reliable reporting of travel times - Delays in reports was the most often expressed concern

DETECTION METHOD	LOCATIONS REVIEWED	PERFORMANCE FEEDBACK	M & O REQUIREMENTS	NOTES
Private Proprietary Approaches	Inrix Traffic.com	- Each system uses a number of data inputs and proprietary approaches for calculating travel times - Inrix hired an independent analysis of travel time accuracy in 3 cities, the results showed that Inrix and Traffic.com had basically the same accuracy (while Inrix had considerably larger coverage). The study presents results in a variety of measures. Overall accuracy rates ranged from 71% - 74%.[2]	- Typically a service contract is signed where the provider delivers travel time reports to the DOT; all O&M performed by the service provider	- Offers a solution with limited in-field new deployments of systems - Contract restrictions prohibit Illinois tollway from displaying travel time information gathered from private sources on Web (can only display results of AVI measured travel times – Web and DMS differ in reports)

[2] Frost and Sullivan Report "Real-Time Traffic Flow Ground Truth Testing Methodology Validation and Accuracy Measurement", September 2006.

DETECTION METHOD	LOCATIONS REVIEWED	PERFORMANCE FEEDBACK	M & O REQUIREMENTS	NOTES
Loop Detectors	Minnesota Seattle Illinois DOT Portland	- Reliable and proven technology for measuring occupancy and volume (speed can be inferred) - Measurements tend to break down at 95% occupancy - Spacing of detectors is key. Some success stories with .5 mile spacing. Closest is .25 mile spacing in Milwaukee, WI.		- Loops deployed to support ramp metering responsive control are typically close enough to support accurate travel time predictions.

5. Travel Time Calculation Approaches

OWNERSHIP / DEVELOPMENT APPROACH	LOCATIONS IN USE	GENERAL DESCRIPTION OF ALGORITHM
Agency developed (internal) algorithm	Seattle, WA Twin Cities, MN Chicago (IDOT) Portland, OR	- Midpoint Algorithm is common (speed is recorded at point and assumed to be speed over entire segment – segments are summed together to calculate travel times. - Modified algorithm (MN) divides segments into thirds (center is speed at sensor, sides are averaged speeds with neighboring sensor readings). This approach improved performance of MN travel time calculations considerably. - San Antonio has a modified approach where the segment travel speed is taken as the lesser of the speeds at either the upstream or downstream locations (segment defined as from one reading point to the next) - Toronto, Canada modified the basic average speed algorithm to include rule-based parameters intended to improve performance during transition times, when queues are building or dissipating.
Contractor developed algorithm	Milwaukee, WI Illinois Tollway Bay Area, CA	- States have benefited from contractors who have developed algorithms and gained experiences supporting multiple states. - Typically the contractor performs maintenance on the algorithm. - The algorithm may be developed and delivered to the DOT, or the contractor may operate the algorithm, delivering travel time reports in real-time as contractual deliverables.

6. Travel Time Reporting Matrix

TYPES OF REPORTING	SAMPLE LOCATIONS	THOUGHTS AND LESSONS LEARNED FROM SITE OPERATIONS
DMS – Travel Time to Road or Landmark	Twin Cities, MN Milwaukee, WI Bay Area, CA Houston, TX Kansas City, KS	- Most common DMS display - Minnesota posts two destinations on same sign phase - Kansas City posts 3 destinations on each sign phase (bottom-most destination is furthest away and travelers will typically see it on next sign as well
DMS – Travel Time to city	Seattle, WA	- The display of travel times to cities is sometimes used to display simpler information understood by more people, and to improve perceptions of accuracy
DMS – Travel Time and Distance to Destination	Nashville, TN	- Display of distance gives unfamiliar drivers an idea of speeds to destination
DMS – Travel Time and Time of Calculation	Houston, TX	- Display of time stamp is a way of handling any latency in the data processing and/or acknowledging that travel times may have changed slightly
DMS – Event Description and Travel Time	Toronto, Canada	- Toronto, Canada uses this to inform drivers of the event and then the impacts (travel time). - Messages are posted on the same sign phase, travel time on lowest line of display
DMS – Travel Time Reported in 2-3 minute ranges	Nashville, TN	- Range of travel time posted on the DMS to address potential accuracy concerns and report a range of expected travel.

TYPES OF REPORTING	SAMPLE LOCATIONS	THOUGHTS AND LESSONS LEARNED FROM SITE OPERATIONS
ATIS Website (Map display of signs,click to view travel time report)	Nashville, TN Houston, TX	- Map display of area allows clicks to view DMS displays of travel times - Information provided on location of DMS signs
ATIS Website (Tabular display of travel times – often with typical travel times reported)	Seattle, WA Milwaukee, WI Chicago (GCM)	- Allows travelers to quickly view regular routes and see current travel times (often accompanied with typical travel times
ATIS Website (Graph displaying current, Average, and range of travel times, based on historic information	Chicago (GCM)	- Effective for allowing visitors to view a typical range of travel times on a stretch of road at a given time of day. - Information may be confusing to someone not familiar with travel time reporting.
ATIS Website (Point and click selection of origin and destination)	Bay Area, CA Central Florida	- Map interface allows visitors to select an origin and destination, results present alternate route travel times - Interactive and very effective at allowing visitors to view conditions on multiple routes - Requires travelers to select start and ending points, rather than simply viewing information on a page.

Appendix A
Example Images and Pictures of Travel Time Messages Displayed on DMS Signs

A-1. Introduction

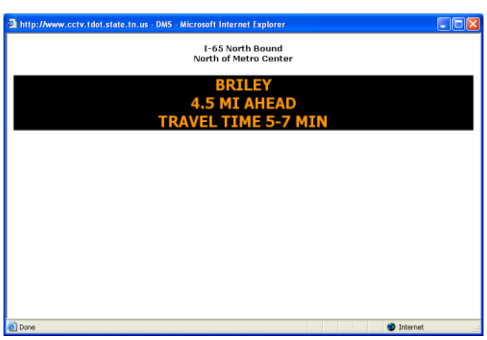
This Appendix supplements the ENTERPRISE Travel Time Best Practices Manual. The intent of this Appendix is to include photograph or web generated images replicating DMS displays of travel time reports. All images have been obtained from either the respective State Department of Transportation or downloaded from their website. The different approaches to travel time dissemination on DMS include such things as:

- Display of travel time to one or multiple destinations;
- Display of travel time and distance to the destination;
- Display of travel time and time stamp marking the time at which data was collected;
- Display of travel time together with an incident/event summary; and
- Display of travel times to either roadways, cities or both.

Following this brief introduction, the remainder of the document is comprised of brief bullets of information and accompanying images, intended to give the readers of the Travel Time Best Practices Manual a graphic understanding of the different approaches.

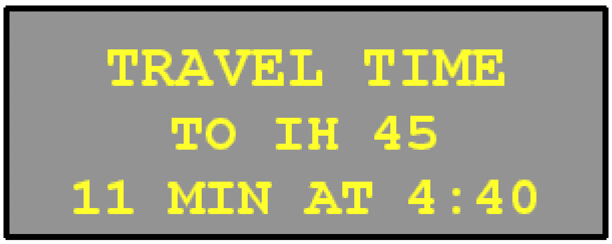
A-2. Nashville, Tennessee

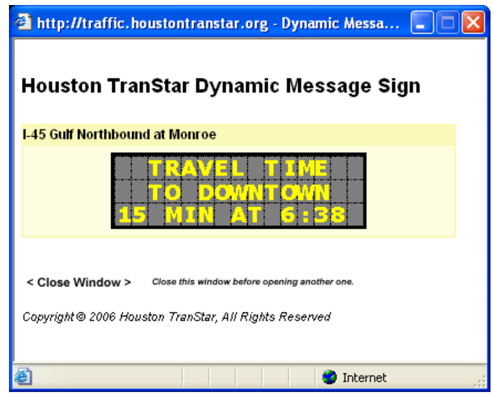
- Travel times posted on DMS
- Website displays DMS locations and current sign content
- Example of travel time and distance on same sign phase
- Images below show web page map pop-up and picture of actual sign (both courtesy of the Tennessee DOT traveler information website)



A-3. Houston Texas

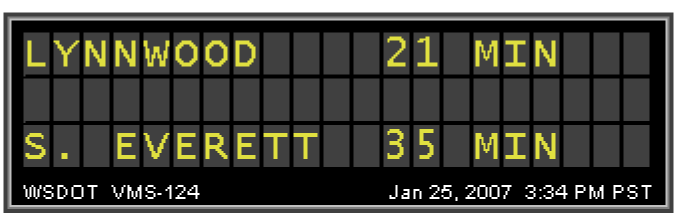
- DMS displays travel time to destination together with time stamp from when data was collected





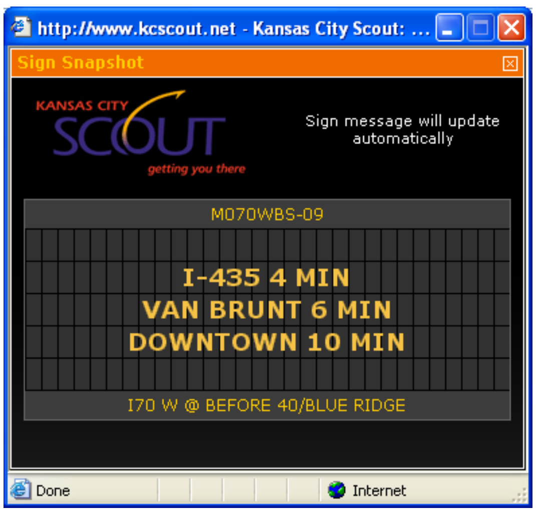
A-4. Seattle, WA

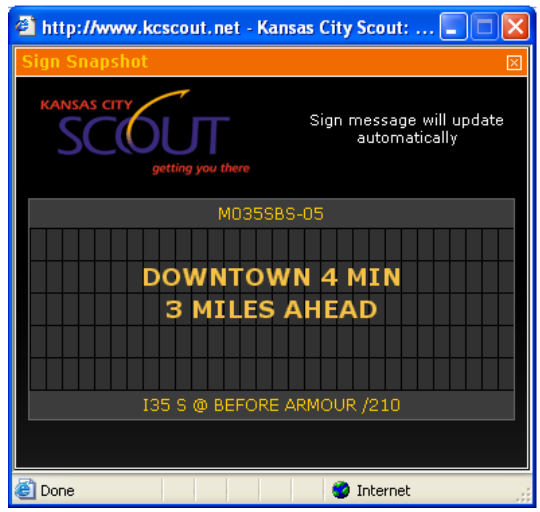
- Typically two destinations per sign
- Often use city as destination



A-5. Kansas City Scout Project (Kansas City Kansas and Missouri)

- As many as three destinations posted on a sign phase
- DMS images replicated on web site (web site images below were captured during evening commute time)
- Bottom-most row destination is furthest away and typically appears on another sign downstream
- Some DMS locations include distance to destination





A-6. Minnesota

- Destinations include highway names or landmarks (e.g. 'River' shown below)

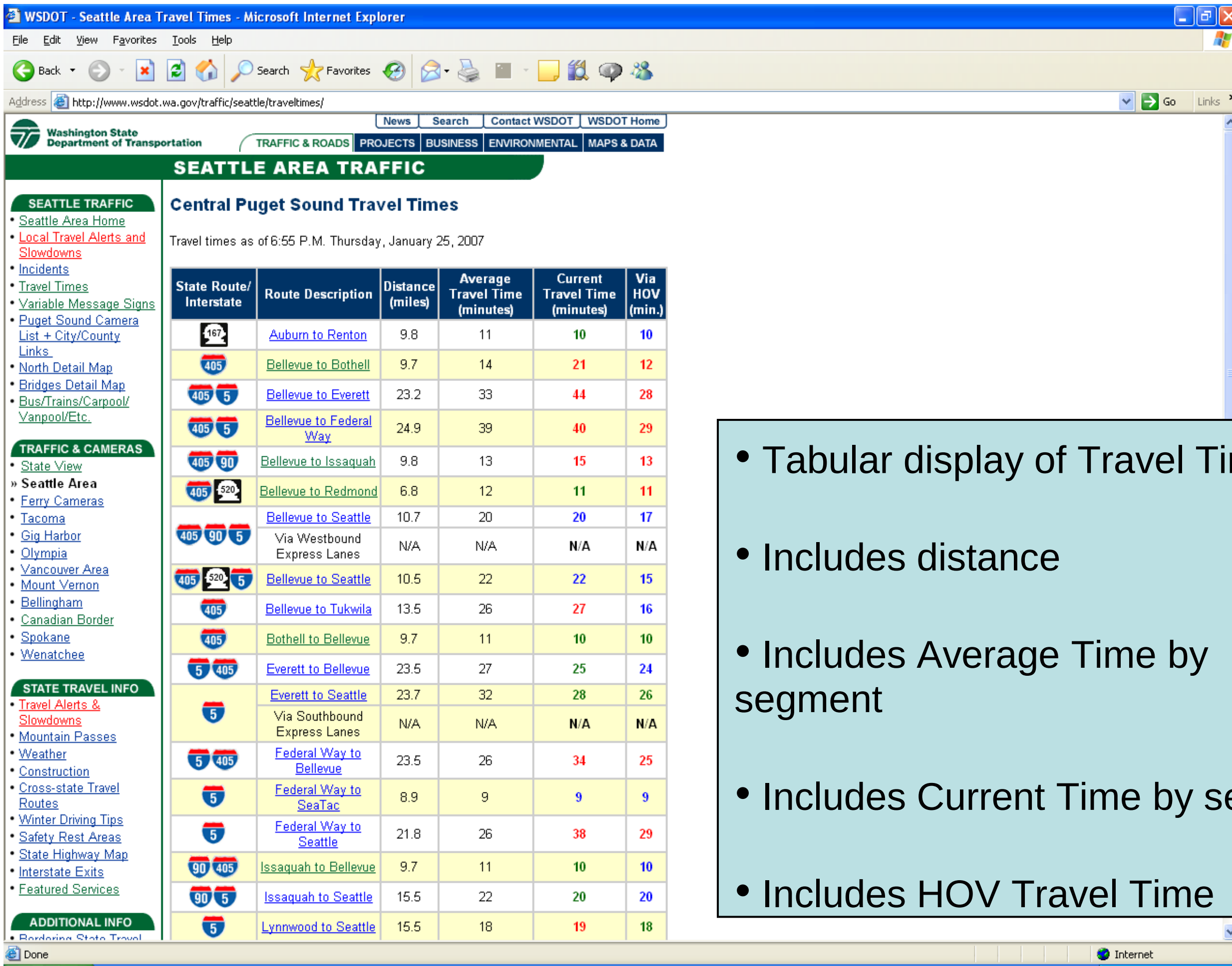
Appendix B – Snapshots of Travel Time Displays on the Internet

Appendix B supplements the ENTERPRISE Travel Time Research Project's Best Practices Manual with screen shot images from Travel Time displays presented on sample Internet travel information dissemination systems throughout the United States. These are only a sample of the states performing travel time reporting on the Internet. These selections were chosen to present as wide a range of different approaches as possible.

For many of the sites featured in this Appendix, a blue-green text box has been added describing the unique features of the specific site. For each site, the website address is included at the top of the site. Scaling has reduced the visibility of each site and readers are encouraged to visit the sites to view the actual operating systems.

Washington State

http://www.wsdot.wa.gov



WSDOT - Seattle Area Travel Times - Microsoft Internet Explorer

Address: http://www.wsdot.wa.gov/traffic/seattle/traveltimes/

Washington State Department of Transportation

News | Search | Contact WSDOT | WSDOT Home

TRAFFIC & ROADS | PROJECTS | BUSINESS | ENVIRONMENTAL | MAPS & DATA

SEATTLE AREA TRAFFIC

SEATTLE TRAFFIC
- Seattle Area Home
- Local Travel Alerts and Slowdowns
- Incidents
- Travel Times
- Variable Message Signs
- Puget Sound Camera List + City/County Links
- North Detail Map
- Bridges Detail Map
- Bus/Trains/Carpool/Vanpool/Etc.

TRAFFIC & CAMERAS
- State View
- » Seattle Area
- Ferry Cameras
- Tacoma
- Gig Harbor
- Olympia
- Vancouver Area
- Mount Vernon
- Bellingham
- Canadian Border
- Spokane
- Wenatchee

STATE TRAVEL INFO
- Travel Alerts & Slowdowns
- Mountain Passes
- Weather
- Construction
- Cross-state Travel Routes
- Winter Driving Tips
- Safety Rest Areas
- State Highway Map
- Interstate Exits
- Featured Services

ADDITIONAL INFO

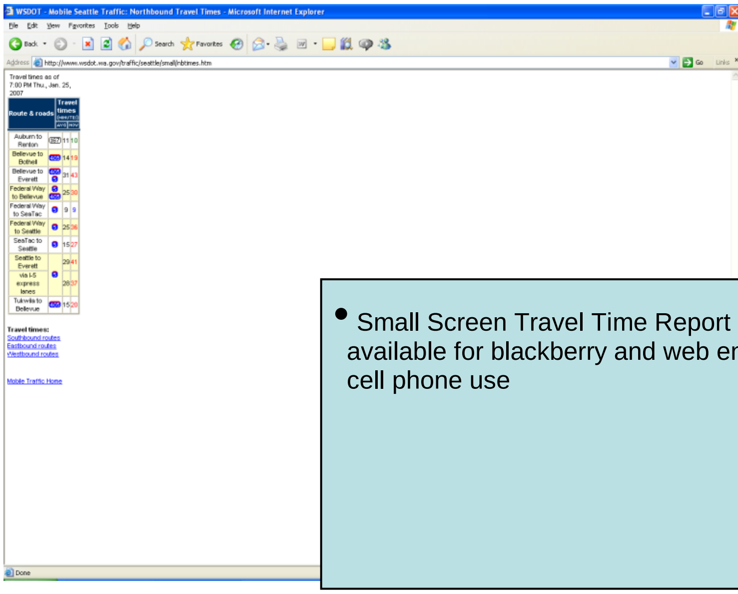
Central Puget Sound Travel Times

Travel times as of 6:55 P.M. Thursday, January 25, 2007

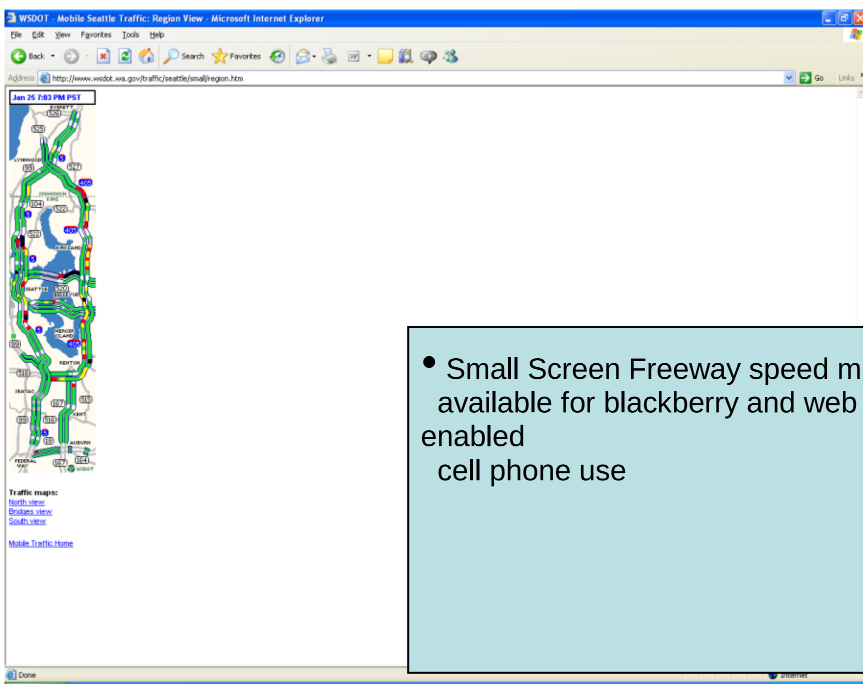
State Route/ Interstate	Route Description	Distance (miles)	Average Travel Time (minutes)	Current Travel Time (minutes)	Via HOV (min.)
167	Auburn to Renton	9.8	11	10	10
405	Bellevue to Bothell	9.7	14	21	12
405 5	Bellevue to Everett	23.2	33	44	28
405 5	Bellevue to Federal Way	24.9	39	40	29
405 90	Bellevue to Issaquah	9.8	13	15	13
405 520	Bellevue to Redmond	6.8	12	11	11
405 90 5	Bellevue to Seattle	10.7	20	20	17
	Via Westbound Express Lanes	N/A	N/A	N/A	N/A
405 520 5	Bellevue to Seattle	10.5	22	22	15
405	Bellevue to Tukwila	13.5	26	27	16
405	Bothell to Bellevue	9.7	11	10	10
5 405	Everett to Bellevue	23.5	27	25	24
5	Everett to Seattle	23.7	32	28	26
	Via Southbound Express Lanes	N/A	N/A	N/A	N/A
5 405	Federal Way to Bellevue	23.5	26	34	25
5	Federal Way to SeaTac	8.9	9	9	9
5	Federal Way to Seattle	21.8	26	38	29
90 405	Issaquah to Bellevue	9.7	11	10	10
90 5	Issaquah to Seattle	15.5	22	20	20
5	Lynnwood to Seattle	15.5	18	19	18

- Tabular display of Travel Times
- Includes distance
- Includes Average Time by segment
- Includes Current Time by segment
- Includes HOV Travel Time

Washington State
http://www.wsdot.wa.gov

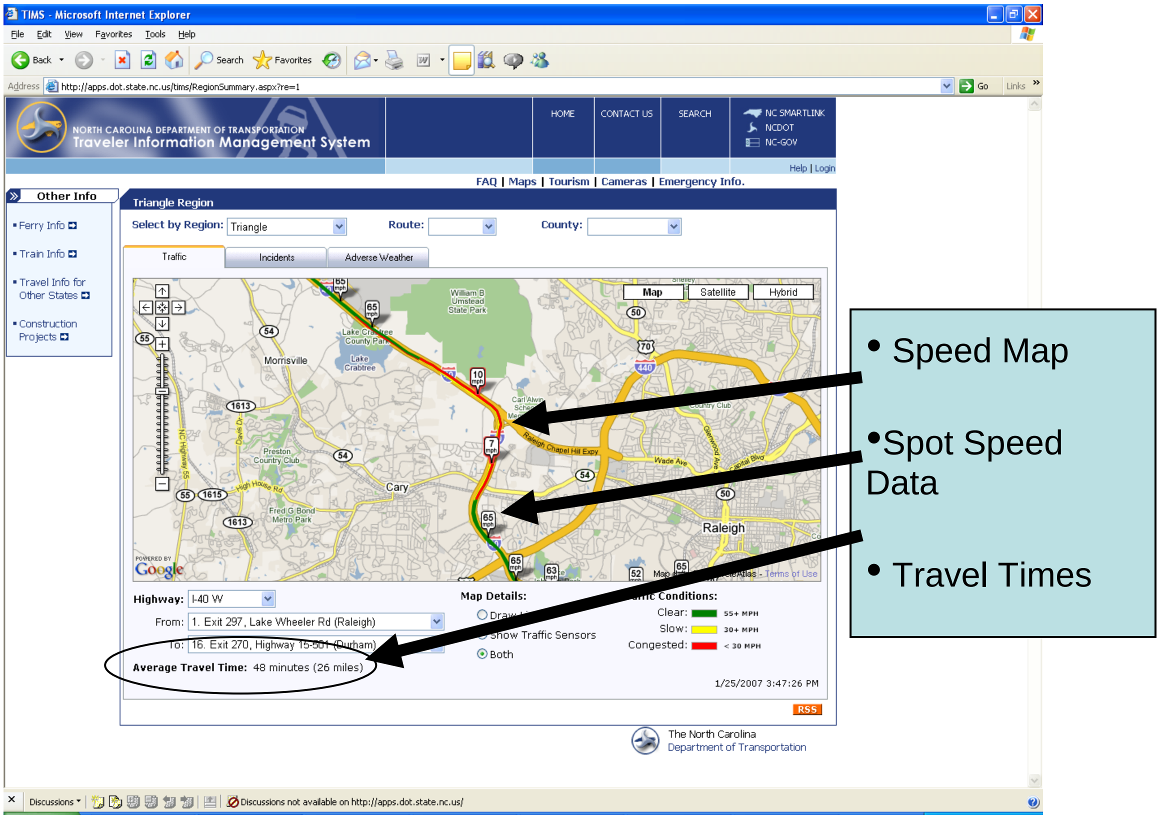


- Small Screen Travel Time Report available for blackberry and web enabled cell phone use

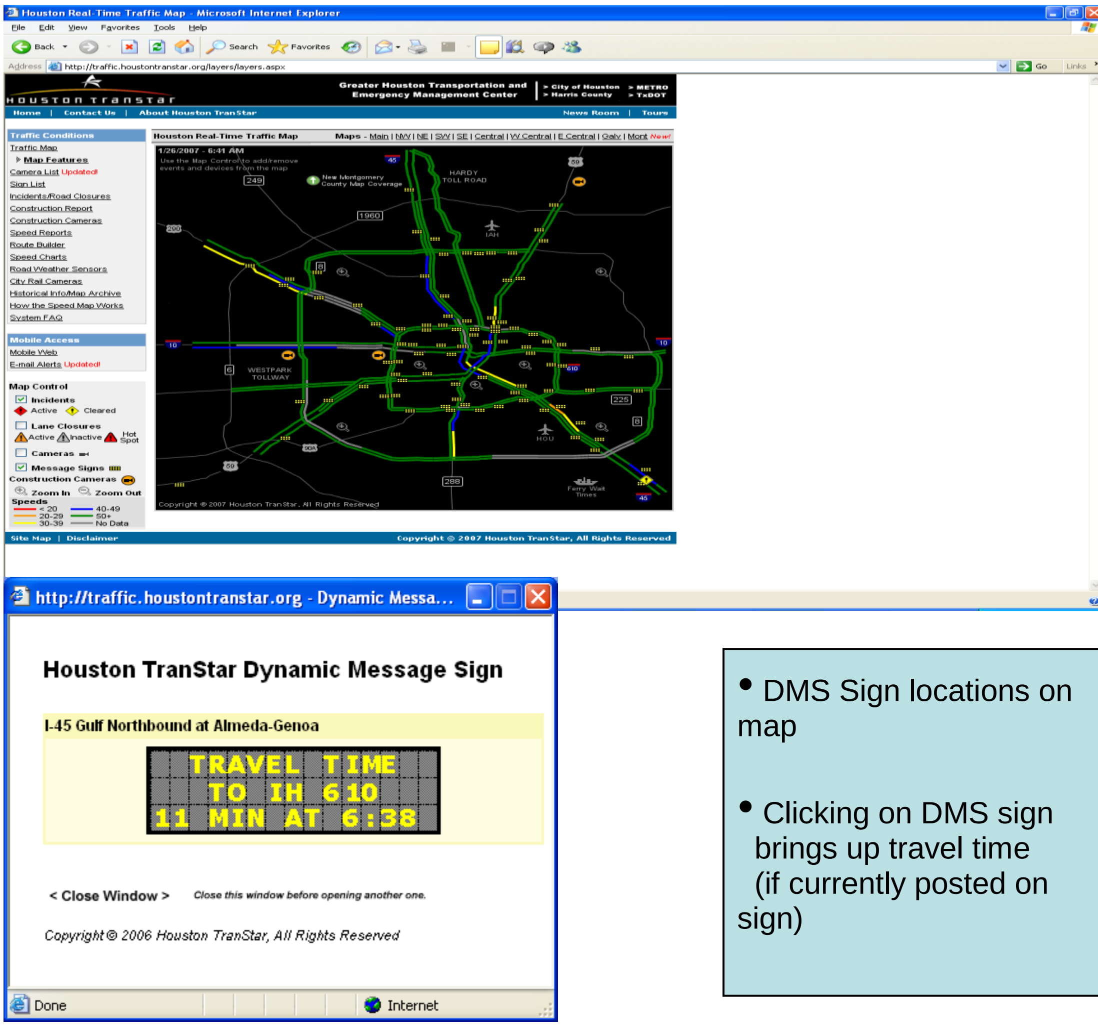


- Small Screen Freeway speed map available for blackberry and web enabled
  cell phone use

Raleigh, North Carolina
http://apps.dot.state.nc.us/tims/



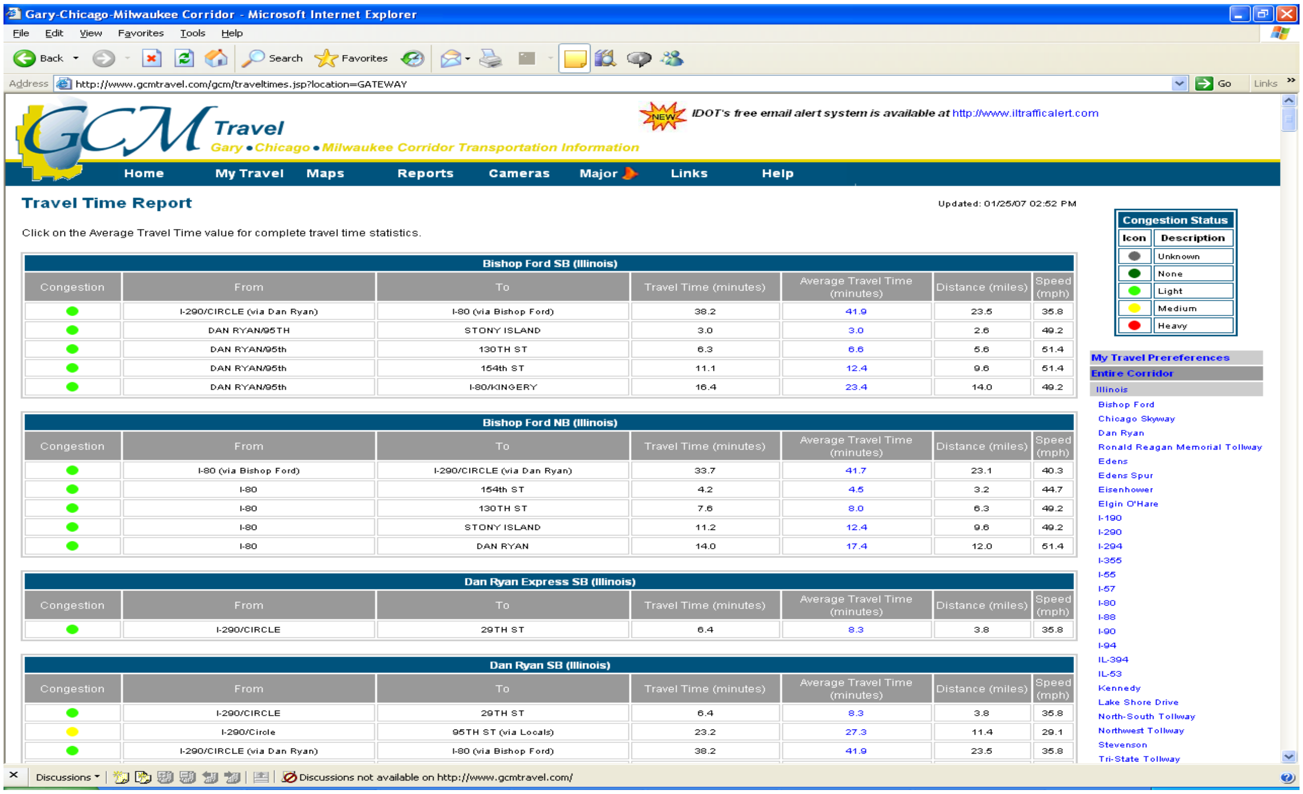
Houston Transtar
http://traffic.houstontranstar.org

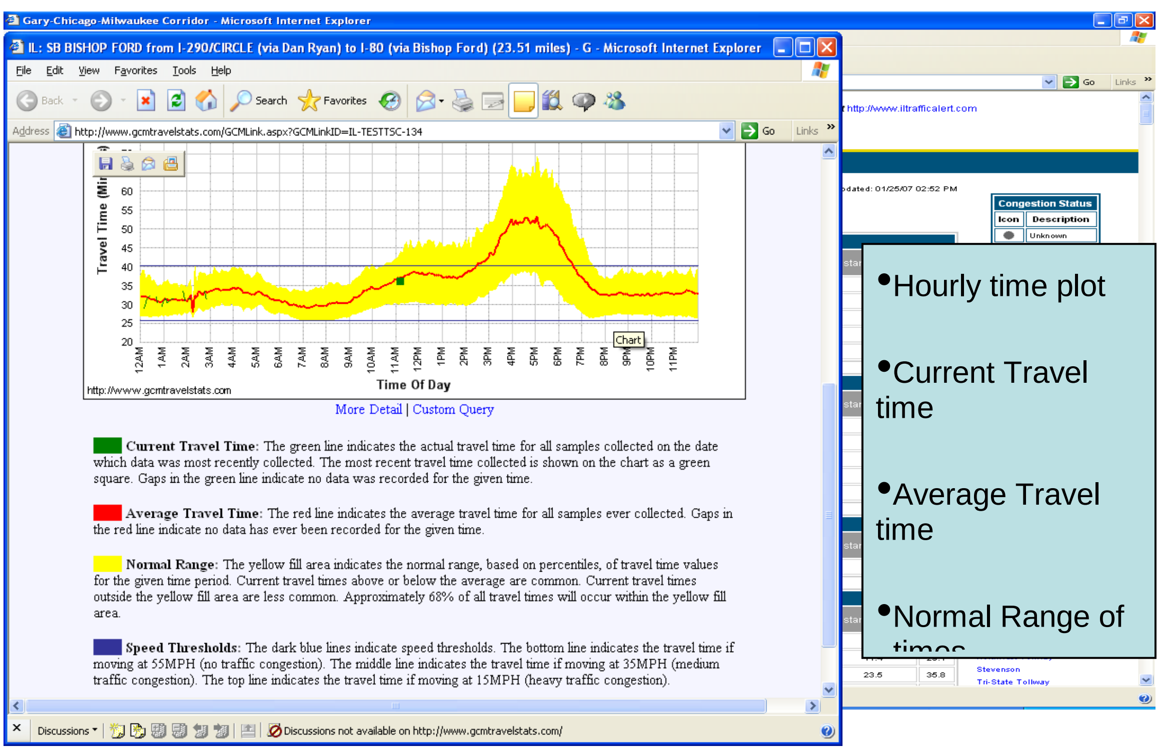


- DMS Sign locations on map
- Clicking on DMS sign brings up travel time (if currently posted on sign)

Gary/Chicago/Milwaukee

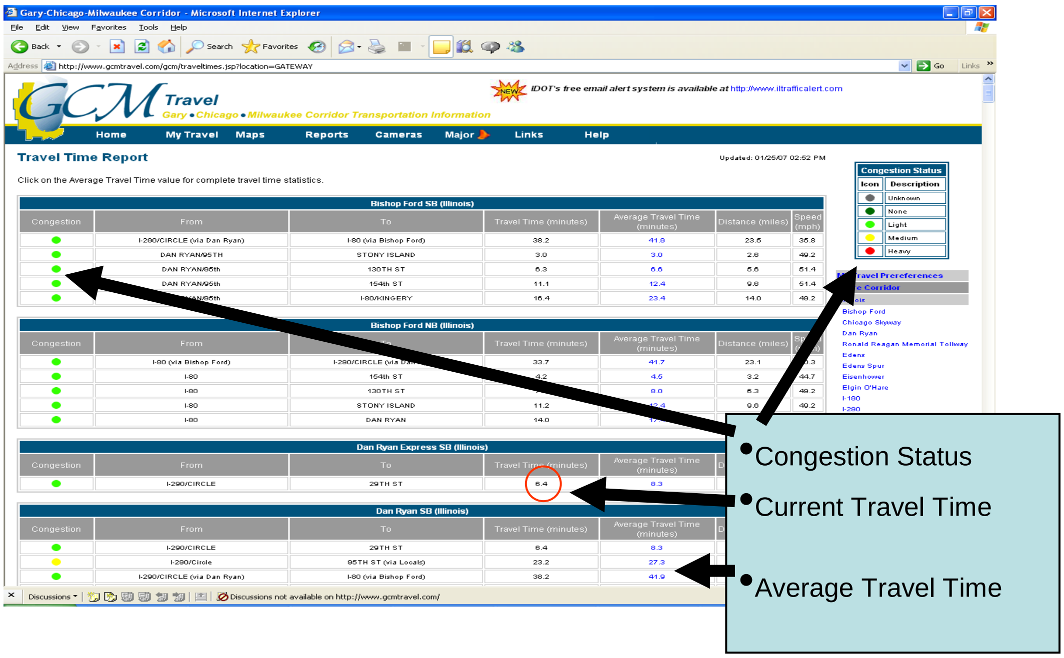
http://www.gcmtravel.com





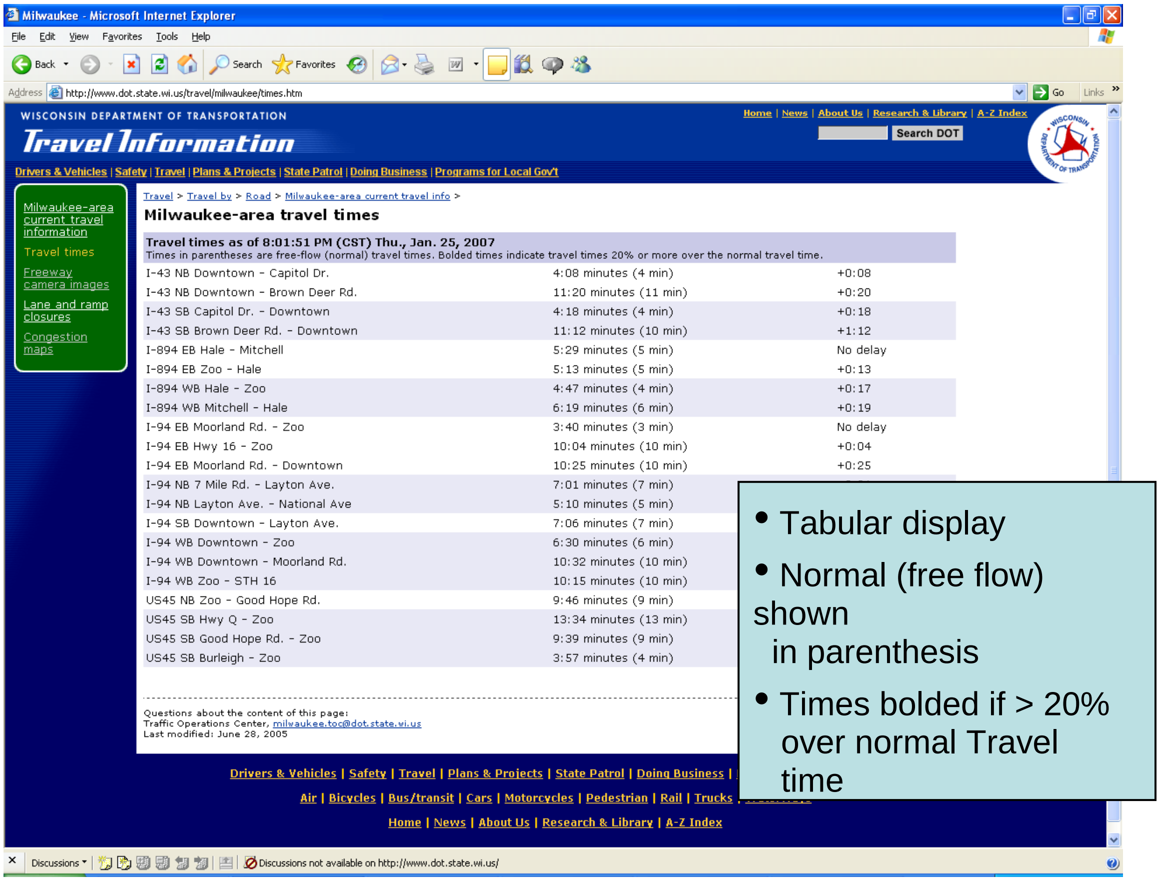
Gary/Chicago/Milwaukee

http://www.gcmtravel.com



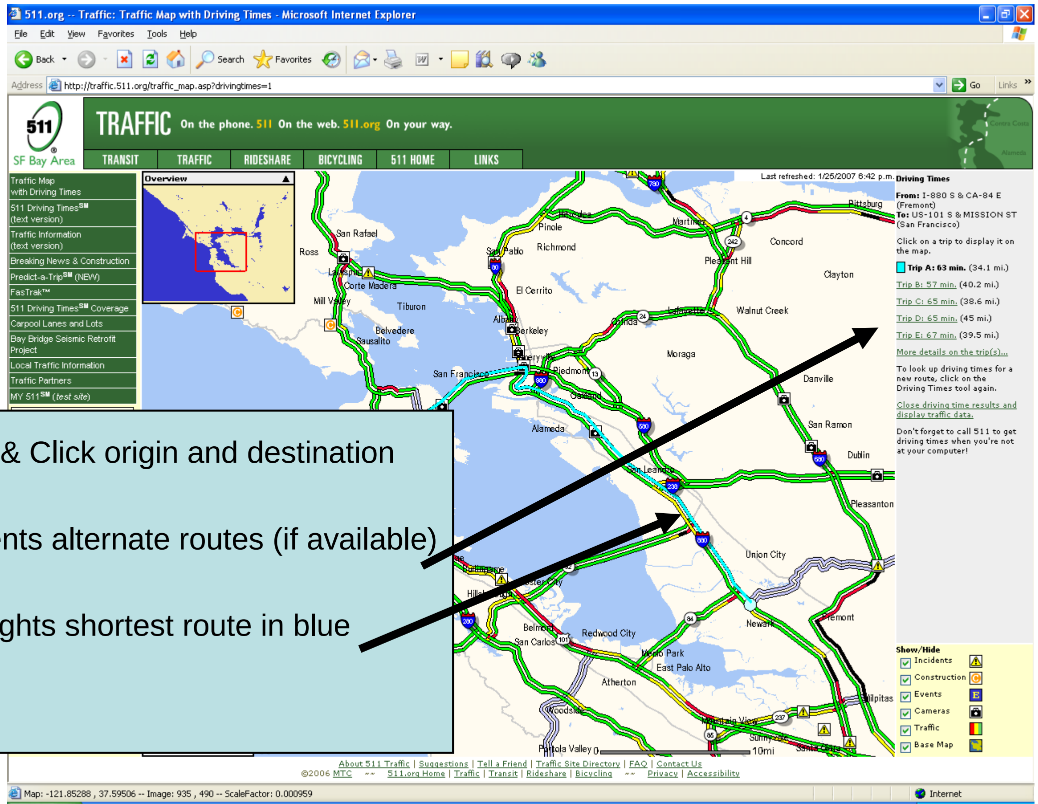
Milwaukee, Wisconsin

http://www.dot.state.wi.us/travel/milwaukee/times.htm



I-43 NB Downtown - Capitol Dr.	4:08 minutes (4 min)	+0:08
I-43 NB Downtown - Brown Deer Rd.	11:20 minutes (11 min)	+0:20
I-43 SB Capitol Dr. - Downtown	4:18 minutes (4 min)	+0:18
I-43 SB Brown Deer Rd. - Downtown	11:12 minutes (10 min)	+1:12
I-894 EB Hale - Mitchell	5:29 minutes (5 min)	No delay
I-894 EB Zoo - Hale	5:13 minutes (5 min)	+0:13
I-894 WB Hale - Zoo	4:47 minutes (4 min)	+0:17
I-894 WB Mitchell - Hale	6:19 minutes (6 min)	+0:19
I-94 EB Moorland Rd. - Zoo	3:40 minutes (3 min)	No delay
I-94 EB Hwy 16 - Zoo	10:04 minutes (10 min)	+0:04
I-94 EB Moorland Rd. - Downtown	10:25 minutes (10 min)	+0:25
I-94 NB 7 Mile Rd. - Layton Ave.	7:01 minutes (7 min)	
I-94 NB Layton Ave. - National Ave	5:10 minutes (5 min)	
I-94 SB Downtown - Layton Ave.	7:06 minutes (7 min)	
I-94 WB Downtown - Zoo	6:30 minutes (6 min)	
I-94 WB Downtown - Moorland Rd.	10:32 minutes (10 min)	
I-94 WB Zoo - STH 16	10:15 minutes (10 min)	
US45 NB Zoo - Good Hope Rd.	9:46 minutes (9 min)	
US45 SB Hwy Q - Zoo	13:34 minutes (13 min)	
US45 SB Good Hope Rd. - Zoo	9:39 minutes (9 min)	
US45 SB Burleigh - Zoo	3:57 minutes (4 min)	

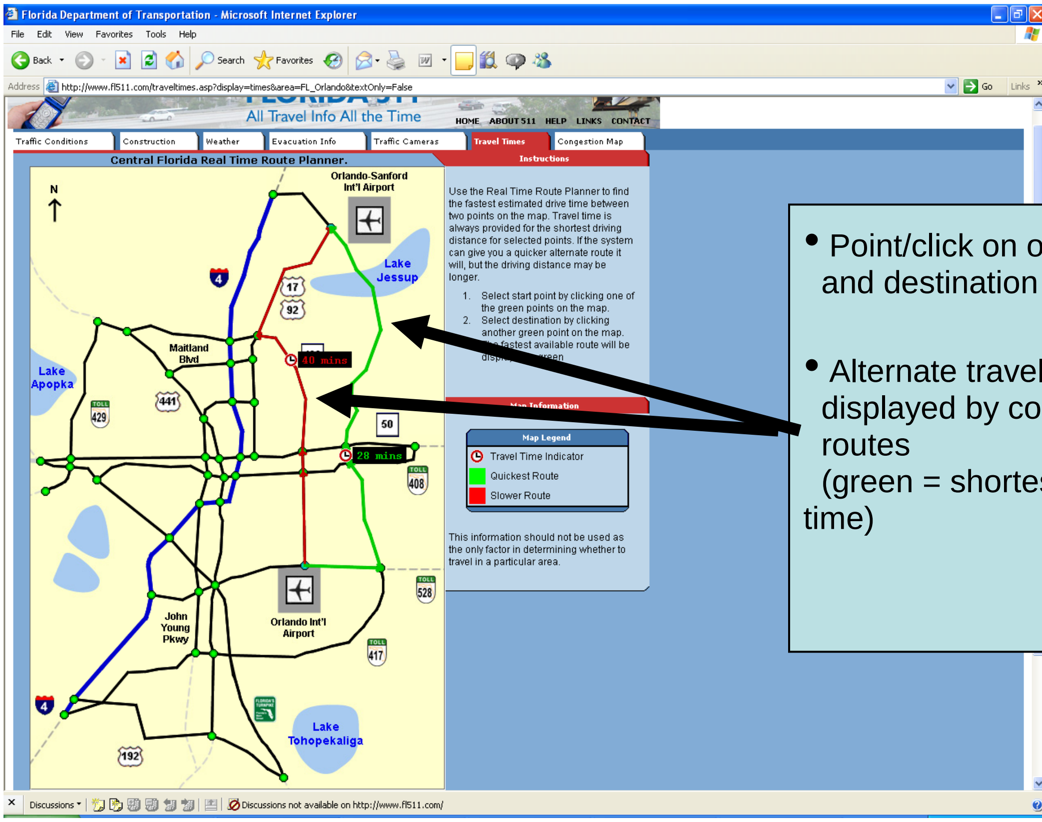
San Francisco Bay Area, CA
http://www.511.org



- Point & Click origin and destination
- Presents alternate routes (if available)
- Highlights shortest route in blue

Florida Travel Times on the Web

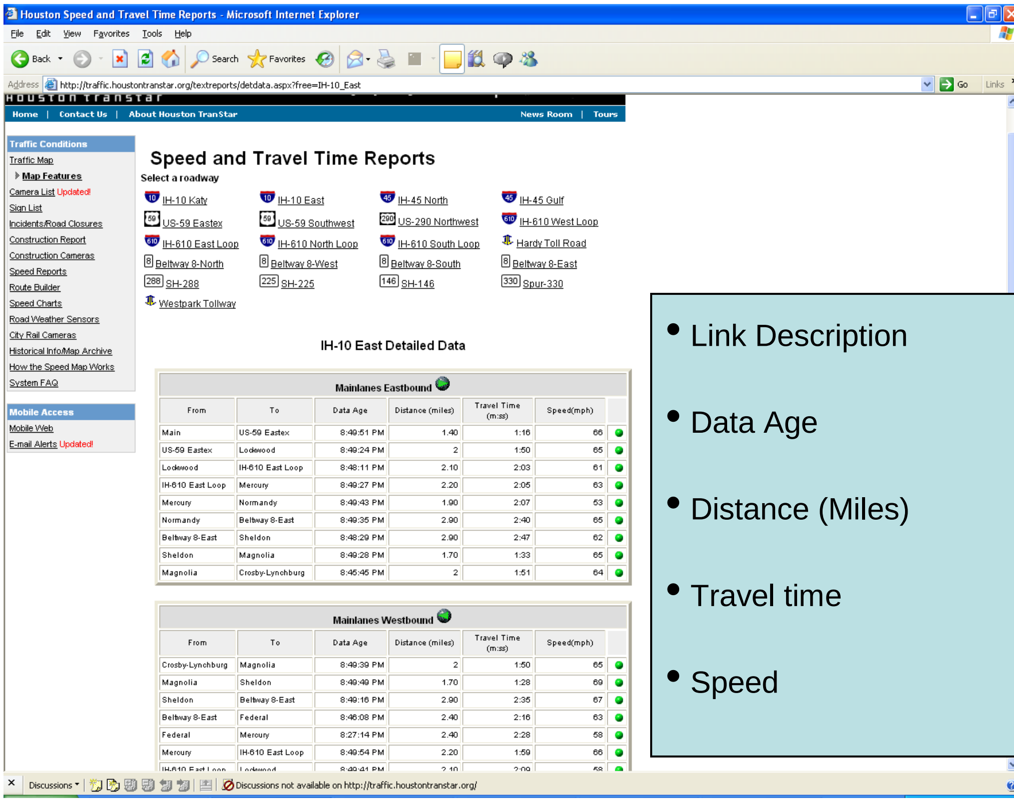
http://www.fl511.com



- Point/click on origin and destination
- Alternate travel times displayed by colored routes (green = shortest time)

Houston, TX (Transtar)

http://traffic.houstontranstar.org



- Link Description
- Data Age
- Distance (Miles)
- Travel time
- Speed