BLENDING OF PLANNING AND OPERATIONS WITH AN INTEGRATED TRANSPORTATION SYSTEM

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Word Count: 5,776 words (including 171 word Abstract and References)
1,250 words (5 figures * 250 words per)
7,026 Total Words

ABSTRACT. Transportation engineers need a new set of tools to help ensure they are getting the best value and use of limited transportation monies. Agency officials have historically relied on various performance evaluation methods to assess roadway networks that have inherent limitations, which may not completely identify true causes and contributors of congestion.

Through application of technology and customized programming, Jacobs Carter Burgess has developed and applied an integrated system to evaluate congestion on regional networks, evaluate pavement roughness, estimate emissions, recommend mitigation measures, prioritize improvements, and update transportation travel demand model networks. The network conditions are evaluated using an in-vehicle setup including a PDA data collector, differentially correctable global positioning system (GPS), pavement sensor, and geo-referenced digital video system.

Components of this approach has been successfully applied on over 200,000 miles of roadways for MPO's across the country including Phoenix AZ, Nashville TN, Oakland CA, Savannah GA, Dallas TX, Denver CO, Tucson AZ, McAllen TX, Harlingen TX, Corpus Christi TX, Birmingham AL, Columbia SC, San Francisco CA, and Los Angeles CA.

INTRODUCTION

Beginning in 1997, the Federal Highway Administration (FHWA) implemented an initiative to require Metropolitan Planning Organizations (MPOs) to prepare a Congestion Management System (CMS)…most recently repackaged as a Congestion Management Process (CMP). MPOs view congestion management in the context of the overall transportation planning process. Metropolitan Planning Rules identify "the need to relieve congestion and prevent congestion from occurring where it does not yet occur." Further, the rule specifies that in the Transportation Management Areas (TMAs) (those planning areas with population greater than 200,000), the planning process must include the development of a CMP that provides for effective management of new and existing transportation facilities through the use of travel demand reduction and operational management strategies. The Federal Register, defines congestion as "the level at which transportation system performance is no longer acceptable due to traffic interference." The FHWA Safe Accountable Flexible Efficient Transportation Equity Act: A legacy for Users (SAFETEA-LU) requires the transportation planning process to address congestion management through a process that provides for effective management and operation. The Long Range Transportation Plans (LRTP) shall contain operational and management strategies to improve the performance of existing transportation facilities.

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This paper will first discuss from the agencies/MPOs side, how an integrated system can, has, and will lead to better management, fiscal responsibility, and better organization of the overall system. The TMAs shall assemble a CMP that is developed, established and implemented as part of the metropolitan planning process and shall include:

1. **Area of Application and System Definition** - Methods to monitor and evaluate the performance of the multimodal transportation system, identify the causes of congestion, identify and evaluate alternative actions, provide information supporting the implementation of actions, and evaluate the efficiency and effectiveness of implemented actions;
2. **Performance Measures** - Definition of parameters for measuring the extent of congestion and for supporting the evaluation of the effectiveness of congestion reduction and mobility enhancement strategies for the movement of people and goods. Since levels of acceptable system performance may vary among local communities, performance measures and service thresholds should be tailored to the specific needs of the area and established cooperatively by the State, affected MPOs, and local officials in consultation with the operators of major modes of transportation in the coverage area;
3. **Performance Monitoring Plan** - Establishment of a program for data collection and system performance monitoring to define the extent and duration of congestion, to help determine the causes of congestion, and to evaluate the efficiency and effectiveness of implemented actions. To the extent possible, existing data sources should be used, as well as appropriate application of the real time system performance monitoring capabilities available through the Intelligent Transportation System (ITS) technologies;
4. **Identification and Evaluation of Strategies** - Identification and evaluation of the anticipated performance and expected benefits of appropriate traditional and nontraditional congestion management strategies that will contribute to the more efficient use of existing and future transportation systems based on the established performance measures. The following categories of strategies, or combinations of strategies, should be appropriately considered for each area: Transportation demand management measures, including growth management and congestion pricing; traffic operational improvements; public transportation improvements; ITS technologies; and, where necessary, additional system capacity.
5. **Implementation** - Identification of an implementation schedule, prioritization, implementation responsibilities, and possible funding sources for each strategy (or combination of strategies) proposed for implementation; and
6. **Management** - Implementation of a process for periodic assessment of the efficiency and effectiveness of implemented strategies, in terms of the area's established performance measures. The results of this evaluation shall be provided to decision makers to provide guidance on selection of effective strategies for future implementation.

Many MPOs initially prepared a CMS to meet the regulations as mandated through ISTEA in 1997 but for various reasons have not made it an active partner in the planning process. These reasons vary from lack of funding for updates to a sense that the approach they followed to evaluate their network produced limited data useful in their planning process.

BENENFITS OF INTEGRATED TRANSPORTATION SYSTEM

A popular congestion performance measures used by agencies/MPOs routinely is travel time and speed. GPS probe car technology has been widely utilized as a flexible and versatile ground truth data collection. In North America, Lexington, Kentucky measured day-to-day travel time variability using GPS data from 100 households [1]; Utah Department of Transportation (DOT) and Louisiana DOT have intensively utilized GPS probe vehicles in measuring travel time and delay[2]; North Carolina DOT used GPS travel time data to measure delay and actual speed between intersections[3]. However, when thousands miles of segments' travel time and speed data are collected from a large metropolitan network, traditional analytical method becomes incapable of handling such massive volume of data. Following the completion of multi-source data surveys, agencies/MPOs are challenged in efficiently creating a geographically based warehouse. In the past, survey results were stored in MS access database and manually cross referenced in transportation model network for generating multiple scenarios or validations. When various sources of travel time and speed data are brought together for trend and characteristic analysis, the complexity of maintaining different version or year of data is very considerable. The tedious and time-consuming manual work of linking diverse data sources to a planning network is the main weakness of traditional CMP procedures. This paper presents a new procedural method to help agencies/MPOs obtain and analyze traffic data from intersection delay to average speed of the corridor to system-wide travel time patterns. An added benefit of this method is its ability to establish user-defined spatiotemporal coverage (i.e. delay by time of day or season) and trend analysis.

A concept recently being applied is the use of a Linear Reference System (LRS). The implementation of a LRS allows the roadway network links to serve as a data-bank of attributes and performance measures, enables changes and updates to be incorporated and reflected in the system instantly, and merges various data sources together for better management. A LRS is designed to better address various isolated regional transportation planning needs and standardizing a wide variety of data formats with its object-oriented programming structure. Many successful examples of LRS application in MPO planning level include: Puget Sound Regional Council developed a LRS to generate modeling scenarios from Transportation Improvement Plan (TIP) updates; Denver MPO utilized a LRS to merge and maintain three centerline files and route system into transportation network used by three departments; San Francisco Bay MPO incorporated transit planning into an unified LRS system shared by twelve counties; Dallas MPO used a LRS as solution to streamline the maintenance and editing of multi-year networks[4].Other applications include: managing and automatically updating Highway Performance Management System (HPMS) oriented LRS data for FHWA data processing reported by state DOTs [5]; Georgia DOT and Georgia Tech recently developed a pavement structure profile information system using a LRS[6]; FHWA and University of North Carolina also built a LRS application to address the needs of managing safety issues such as crash zone, pedestrian and bicycle routes [7].

From an agency/MPO's point of view, GIS-based LRS is the perfect answer for the question of how to intelligently and efficiently manage all types of planning data sources, varying from dynamic traffic condition measures to pavement management assessments. By introducing GIS for Transportation (GIS-T), this paper addresses this issue from a new and comprehensive angle that includes both planning and operations in the same platform. With a common platform, it becomes much more efficient and thorough to perform analytical studies of trends and patterns. For example, Maricopa Association of Governments (MAG), Phoenix, Arizona has developed a prototype GIS-T application [8] that includes different modules to manage various planning and operation projects such as traffic counts, travel time and speed [9], intersection delay [10], performance measurements, and TIP updates. The seamless connection between GIS-T and travel demand and air quality models enhances model updates' accuracy and processing speed in addition to increased speed in reflecting trend and pattern analyses results in models via calibration.

Overall, this paper elaborates on a complete kit of methodology for blending planning and operations based on previous experiences. A guideline is presented to help agencies/MPOs improve capability of managing regional planning and operation needs efficiently which leads to considerable benefits for the public as the development needs and issues are being monitored and addressed in the most cost effective manner.

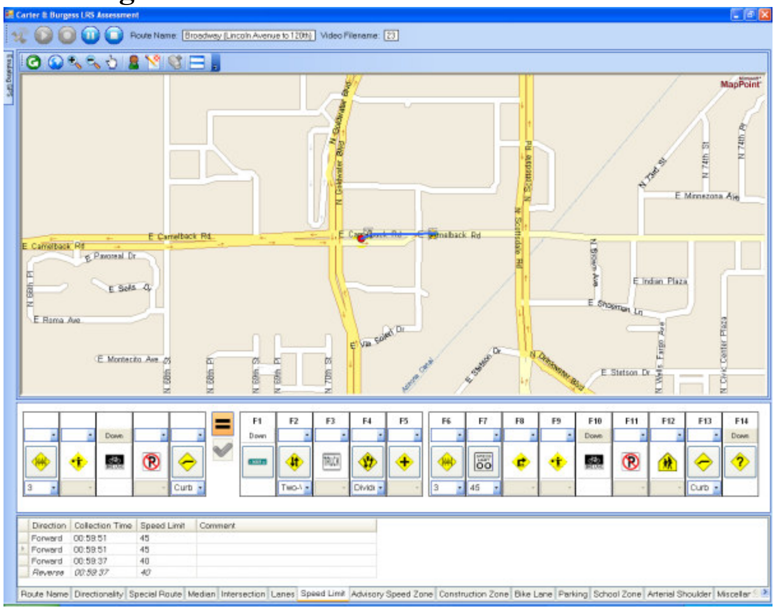
SYSTEMATIC AND INTEGRATED APPROACH

In response to the initial FHWA requirements, many MPOs followed the path of using their existing planning model to identify congested areas now and in the future. This has led to mixed results and many conclusions not field verified. The model attributes (lanes, speed limits, signal locations, etc) used by MPOs are at times populated with default or assumed values based on functional class and area types. These characteristics then lead to results that are not site specific or even corridor specific. They do not take into account the various approaches local municipalities follow to set speed limits or install school zones, and in some cases may not represent the actual number lanes or locations of traffic signals and stop signs. These are attributes that play a big role in the model assigning trips to each link.

Many MPOs have benefited over the 7 years with the development of an approach that addresses these shortcomings. The system includes the following steps:

1. Define CMP network
2. Geo-code network attributes through field surveys and create LRS in a GIS
3. Perform a statistically significant number of travel time runs using GPS [11]
4. Filter out non-recurring congestion (construction, accidents, weather, etc)
5. Calculate performance measures
6. Define local congestion thresholds and identify congested segments
7. Develop recommendations for mitigation of congestion and prioritize improvements
8. Incorporate currently programmed planned improvements
9. Perform historic comparisons (when available)
10. Incorporate network improvements since last assessment
11. Provide pavement condition assessment and emission estimates
12. Integrate CMP with Transportation Improvement Program (TIP)
13. Integrate other MPO responsibilities (GIS, Socioeconomic, Environmental, ITS, Safety, Regional Transportation Plan, and HPMS)

Defining CMP Network



The methods used to define the limits of the network to be evaluated follows various paths. For some jurisdictions, they are required by State law to include all functionally classified roadways from collectors to freeways, while others have more flexibility. For those MPOs that are able to exercise some judgment in selecting the network, the primary element they are advised to consider is the planned frequency of CMP updates. If they plan to perform updates on a regular basis, it may be suggested they do a comprehensive evaluation the first time and then revisit selective corridors each time while the others are included every other time.

Geo-code Network Attributes and Create Linear Reference System

The roadway mapping is done in-vehicle using the GPS equipment and custom software as shown in Figure 1. The software collects the roadway attributes as points and continuous/discontinuous segments.

Figure 1: Linear Reference Field Application

Traffic elements recorded include intersection control, speed limits, number of lanes, school zones limits, construction areas, and parking conditions. Other elements that are observed or coded in GIS using data provided by the MPO include: city limits, area type, and facility type. This information is used later to determine the segment lengths and theoretical travel times, and to provide better insight into the resulting travel time runs and improvement recommendations.

The roadway segments are videotaped during the mapping process in order to provide a reference of the conditions. The digital videos are later linked to the GIS. This provides a video log of the CMP network roadways. These video logs can be invaluable for future tasks such as asset management where all traffic signals, signs, sidewalks, and other items can be easily inventoried and mapped. All roadway attributes are then incorporated in GIS through the creation of a LRS.

All of the automated QA/QC methods are possible due to the use of a LRS. The routes are measured polyline features with one route for each travel direction. Dynamic segmentation allows the display and analysis of route events: points or line segments along a route. Route events are stored in a tabular format. A point event (speed limit sign) is represented in the LRS with a route identifier and measure along the route. A line event (speed limit zone) is represented with a route identifier, a start measure and an end measure.

Figure 2 illustrates a typical LRS application. The route, 1st Ave – NB, has a route identifier of 2049. Point events along the route in the northbound direction include the intersection at Main St (Measure = 101607.9), a speed limit change to 35 mph (Measure = 102332.9) and the intersection at Broadway Blvd (Measure = 103672.1). Line events are created from the point events using database programming since the points are stored as a table of events. The 45 mph speed limit segment is created by setting the start measure equal to the first speed limit point on the route (45 mph at Measure = 100000) and the end measure equal to the next speed limit event in the route direction (35 mph at Measure = 102332.9). The intersection segment events provide the best way to summarize the GPS point data from a traffic analysis standpoint. The intersection segments have start and end measures of consecutive intersection point events along the route. One advantage of storing data in a LRS is the speed limit within an intersection segment; the weighted average speed limit is calculated based on the location of the speed limit change within the intersection segment. The speed limit change is independent from the end points of the intersection segment; speed limit changes do not always occur at an intersection. Other independent line event data is also used to analyze or summarize the GPS point data, advisory speeds, school zones, construction zones, number of travel lanes, area type, and functional class.

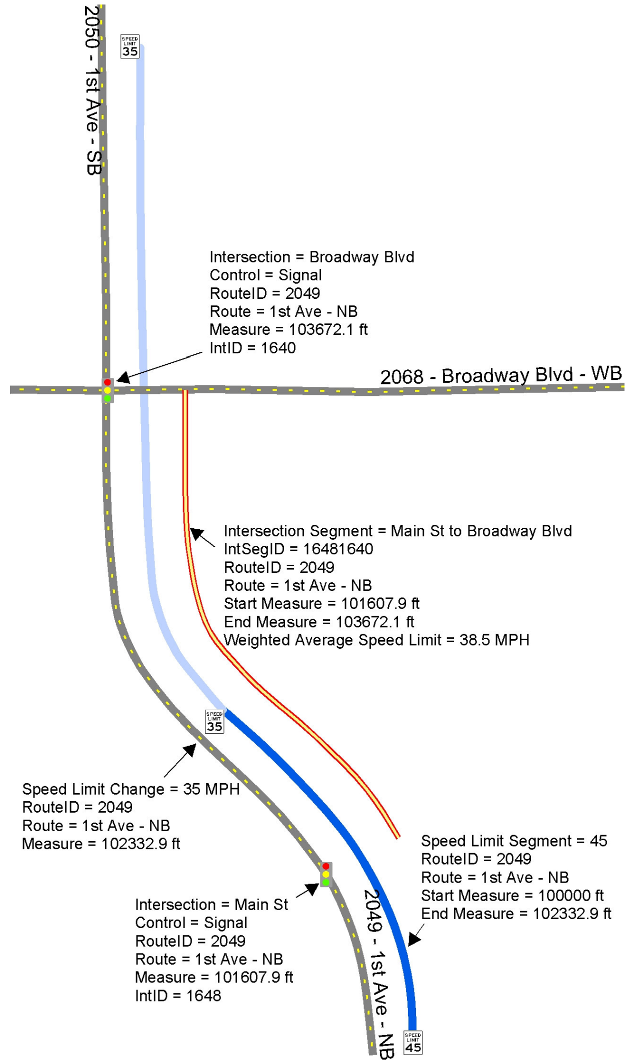


Figure 2: Linear Reference System Example

Travel Time Runs

Travel time runs are conducted using the floating car method. In the floating car method, the driver of the test vehicle "floats" with the traffic by attempting to safely pass as many vehicles as pass the test vehicle, thus representing the "average" vehicle in the traffic stream. Travel time runs are conducted during the morning and afternoon peak periods on all roadway segments. Multiple runs are made depending on the desired statistical requirements and budget. The runs are made in each direction during each peak period. During the travel time runs, the GPS equipment records position and time at one-second intervals as shown in Figure 3. The driver of the test vehicle drives the speed limit if no other cars are present and at the school zone speed limit if a school zone speed limit is in effect at the time of the travel time run.

The power of the system is the ability to process millions of GPS points through the LRS efficiently. Without the programs in place to do this on a weekly basis, any project that requires more than a few drivers or more than a couple weeks would be overwhelming and cost prohibitive. That is what sets this approach apart. Historically, it has not been cost effective to perform large scale travel time studies and thus MPOs were forced to rely on traditional speed-flow curves to estimate congestion and delay within urban planning model networks.

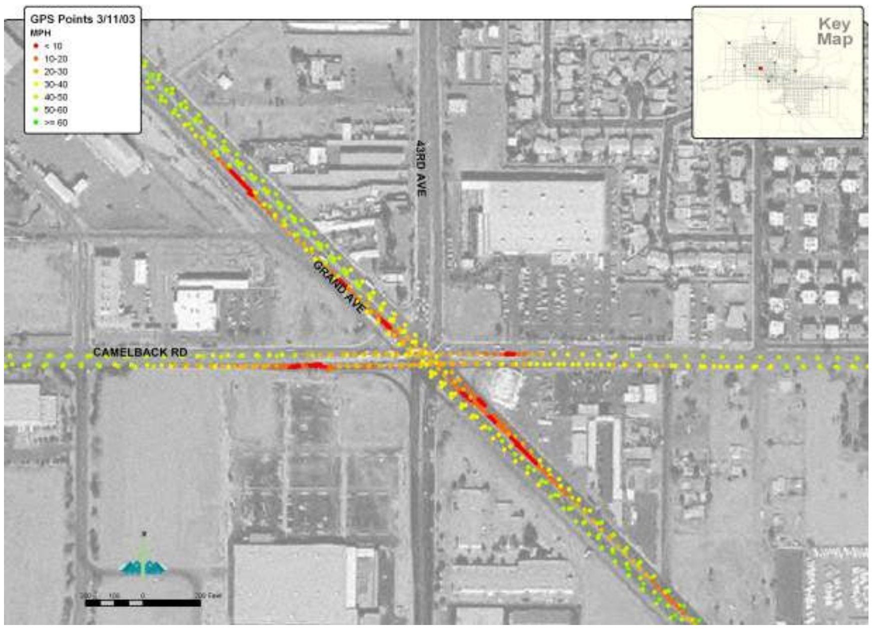


Figure 3: Raw GPS Data Points

Non-Recurring Congestion

A large part of the quality control is done automatically with computer algorithms and queries. In addition to the automated routines, the drivers play an important role in providing feedback on the observed conditions during their runs. Drivers carry a voice activated tape recorder on their travel time runs, and use them to note problem areas that may not be typical. While stopped, a driver would note the type of incident or problem, and the time it occurred. Examples of incidents or events that technicians record are: construction, accidents, school zones, trains, overflowing left-turn queues, school bus stops, emergency vehicles, weather, and signal preemption. The comments collected by the drivers are illustrated in GIS and differentiated by comment type. For example, those times when the drivers encountered an active school zone, is noted for the applicable speed limit. If the observation was determined to be non-recurring following further statistical analysis, the data from that run in that segment is flagged so that it was not included in the calculations.

Calculate Performance Measures

Capacity is the maximum hourly rate at which vehicles can traverse uniform section of roadway during a given time period under prevailing roadway, traffic, and control conditions.

The vehicle capacity of a roadway, and its operational characteristics, is a function of a number of elements including: the number of lanes, shoulder widths, roadway alignment, access, traffic signals, grades, and vehicle mix. Generally, roadways with wider travel lanes, fewer traffic control devices, straight alignments, etc. allow faster travel speeds and therefore greater vehicle flow per unit time.

The data analysis includes various levels of review, automated Quality Assurance / Quality Control (QA/QC), and manual QA/QC. Many of the primary steps taken to process the large amounts of data include:

- Assign segments for aggregation purposes
    - intersection segment
    - speed limit
    - school zone speed and limits (if applicable)
    - number of lanes
    - Area Type / Facility Type (Functional Class)
    - Jurisdiction
- Calculate average Space Mean Speed and Time Mean Speed
- Calculate the stop delay as the count of one second GPS points where the speed <=3 MPH
- Calculate the segment delay as the difference between travel time and theoretical travel time at the posted speed limit
- LOS (approach and intersection) based on delay and speed and volume parameters averaged by intersection segment

Typical attributes and performance measures include:

- Functional class and jurisdiction
- Travel Speed – average speed for all routes
- Speed Limit – weighted average speed limits for each run performed, may vary by time period depending on the number of runs on various routes
- Congestion Index (CI) or % Posted Speed Limit – represents the ratio of Travel Speed to Speed Limit
- Running Speed – Average speed for travel times > 3 mph
- Stop Delay – average amount of time spent < 3 mph per mile
- Segment Delay – Actual time to traverse a segment will all delay encountered less than the theoretical time to traverse the segment
- Control Delay – The delay encountered caused by intersection control [9]

The summary data has been aggregated on various levels including regional travel time contours as shown in Figure 4. Data can be viewed from levels as detailed as the raw 1-second point data to the intersection segments. This allows the data to be presented in various forms depending on the audience.

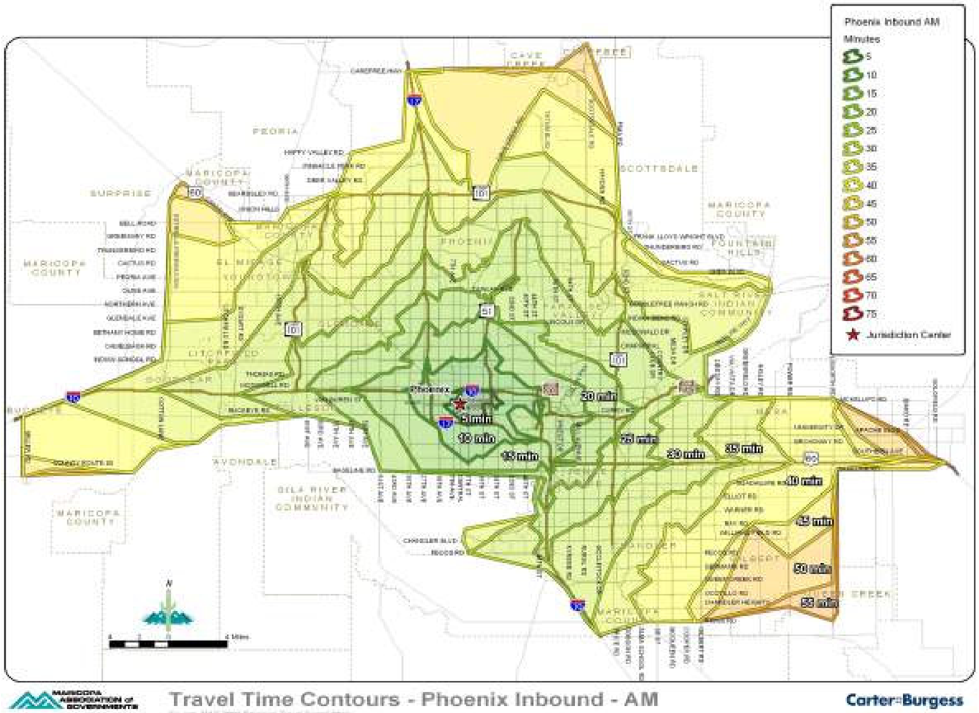


Figure 4: Travel Time Contours

Define Local Congestion Thresholds and Identify Congested Segments

FHWA allows the local MPOs to define congestion through public involvement. Congestion is viewed differently in each area of the country; therefore, using values shown in the Highway Capacity Manual (HCM) may not identify any Levels of Service (LOS) that are unacceptable on the national level. That does not mean that the local area does not have delays that are avoidable, it just means they may not be as bad as other more urban areas.

One popular performance measure has been Congestion Index (CI). CI is the ratio of the actual travel time to the theoretical travel time. Theoretical travel time is the time it would take a vehicle to traverse the segment distance at the posted speed limit without interruptions from other traffic or traffic control devices.

CI = Actual Travel Time / Theoretical Travel Time

CI = Congestion Index
Actual Travel Time = the recorded travel time for a given segment
Theoretical Travel Time = segment length / posted speed limit

Many smaller MPOs have defined congestion to be anything with a CI less than 0.75 (or 75% of the posted speed). A CI of 0.75 to 0.99 indicates a section of stable flow, and a CI greater than 0.99 indicates free flow conditions.

The travel speeds on congested segments are slower than drivers typically want to drive; therefore less opportunity for lane changing and maneuvering. Stable sections are accommodating volumes less than capacity. Travel speeds are somewhat slower than the speed limit, but generally acceptable to drivers. Lane changing and maneuvering is less difficult than in congested segments. Free-flow sections are operating well below capacity. Travel speeds equal or exceed the speed limit and traffic can maneuver without interference.

Develop Recommendations for Mitigation of Congestion

Recommendations are made to mitigate the congestion found according to the performance measures and thresholds assigned by the MPO. Recommendations are made that first attempt to mitigate congestion with management strategies prior to costly capital construction or adding capacity. Improvements include signal timing optimization, traffic signal progression, access management, intersection widening, roadway widening, and adding signals in place of stop signs. Benefits of these improvements are described below.

Many of the recommendations for surface streets include signal timing improvements. Signal timing improvements are a relatively inexpensive way to make significant improvements on a transportation network. Improved signal timing can decrease delay by appropriately allocating green time among competing phases. This allows more traffic to pass through the signal with less delay. By adjusting cycle lengths and offsets, drivers can travel longer distances along a corridor before having to stop for a red light. This decreases travel time and improves air quality. Both signal timing optimization and traffic signal progression are low cost improvements to make the best use of existing capacity and optimize allocation of funding. The cost for a signal timing improvement project varies depending on the number of traffic signals, the controller capabilities, the location of the traffic signals and adjacent signals, the number of timing plans required, and implementation and fine-tuning needs.

The U.S. Department of Transportation's Federal Highway Administration (FHWA) has produced a video showing that retiming traffic signals is one of the more cost-effective techniques available to state and local agencies in their efforts to manage congestion and growing travel demand. The video, "It's About Time, Traffic Signal Management: Cost-Effective Street Capacity and Safety," [12] demonstrates how signal timing on roads can improve air quality while reducing fuel consumption, decreasing traffic congestion, and saving time for commercial and emergency vehicles. Two-thirds of all highway miles in the United States are roads with traffic signals. According to the Institute of Transportation Engineers, the United States has about 300,000 traffic signals. It is estimated that the performance of about 75 percent of them could be improved easily and inexpensively by updating equipment or by simply adjusting the timing.

Access management is a process that provides access to land development while simultaneously preserving the flow of traffic on the surrounding system in terms of safety, capacity, and speed. Access management is accomplished by controlling the design of access points, the location of access points, and the number of access points allowed within a given distance. Generally, the number of access points is minimized and distanced from each other so that conflict points are separated. Safety for turning movements may be improved by providing adequate storage bays or by prohibiting turns in key locations using a raised median. Access management can provide a number of benefits to the agency and to the traveling public. Capacity is preserved and safety is improved by minimizing slow moving turning traffic. In addition to safety and efficiency improvements, access management also provides environmental and financial benefits with reduced vehicle emissions and improved fuel economy.

On new roadways, or on undeveloped corridors, access management can be used to minimize traffic problems due to unmanaged development before the problems occur. In these cases, it is inexpensive and fairly easy to accomplish. The traveling public benefits from a safe and efficient corridor. Property owners benefit from safe access. The agency benefits from a low cost management plan from the onset rather than costly highway improvement projects once problems occur. Once corridors are developed, it is more difficult, expensive, and time consuming to retrofit managed access. Access management should be given high priority on undeveloped corridors. Access management is very challenging within a "built-up" corridor. Common issues include limited right-of-way and strong opposition by business owners. Still, retrofitting a corridor with access management can provide benefits. Possible retrofitting improvements include: combining and closing driveways, constructing raised medians, constructing turn lanes, providing regularly spaced traffic signals to encourage use of one major driveway, constructing (parallel) alternative routes, and providing internal access roads.

Consideration should be given to developing an access management program. The program development may include a comprehensive plan defining land patterns and traffic flow, program goals, policies, and implementation and financial strategies, and the development process should include public involvement. The program should result in a prioritized list of improvements and potential funding sources for developed corridors as well as a policy for developing corridors.

Roadway widening is necessary where traffic signal timing and access management are unable to provide enough capacity for heavy traffic volumes. Some segments may improve in the short term with optimized signal timing, but may ultimately warrant additional capacity through widening. Widening could include adding a through lane for a long section of road or providing turn lanes at intersections. Adding capacity through roadway widening is generally the most costly alternative.

Adding signals may be an improvement at four-way stop intersections or intersections with heavy major street and cross street traffic. This reduces delay for previously stop-controlled movements but may increase delay for movements that were not controlled. As traffic volumes increase, traffic signals are required to efficiently move traffic.

ITS technology has been a great help in relieving congestion where other solutions have failed. ITS including computers, communications, and displays have led to prompt removal of a disabled vehicle from travel lanes improves traffic flow.

The recommendations are prioritized based on the levels of congestion observed, duration of congestion, and frequency of congestion.

Incorporate Currently Programmed Planned Improvements

Following the initial development of recommendations to address the observed congestion, the existing Transportation Improvement Program (TIP) and Long Range Transportation Plan

(LRTP) are reviewed. This review will identify those programmed improvements throughout the network. By comparing the existing congestion with the programmed improvements, the MPO is able to determine if any adjustments are necessary. These adjustments may include shifting the timeline of improvements to better prioritize the changes to reallocating funds to other projects based on actual needs. This is a continuous process that is reviewed each time the CMP is updated.

Perform Historic Comparisons

For those MPOs that frequently update the status of the CMP, the LRS and GIS allow the historical trends to be monitored. This is very useful to see how the varying growth patterns are impacting the transportation network. At the same time, with all the roadway attributes in GIS, the MPO is able to compare and contrast the conditions of similar areas that may have different roadway cross sections such as a 2-lane undivided roadway vs. a 2-lane roadway with a continuous left turn lane vs. a 2-lane divided roadway.

Incorporate Network Improvements Since Last Assessment

As the MPO funds improvements through the TIP, the integrated GIS tracks those changes to the system and allows the MPO to validate the benefit of those improvements. The before/after comparison is a valuable tool and required in a CMP to not only project what congestion will be in the future but show the benefits of improvements.

Provide Pavement Condition Assessment and Emission Estimates

Additional performance measures incorporated into the CMP include an assessment of the pavement roughness and estimates of emission levels given the congestion levels. These two components are very unique and can be developed using much of the data generated through the travel time runs.

The pavement roughness is performed during the geo-coding process at which time a custom pavement sensor is attached to the axle of the vehicle and collects the movement of the vehicle 50 times a second. This road condition assessment provides a relative comparison of the roads within an study area. This has been a valuable tool as a criterion in the prioritization process. It is also used by the maintenance departments to highlight sections of the road that may benefit from local repairs.

On the emissions side of the assessment, using the 1-second GPS points and performance data, the estimated emissions of a "typical" passenger vehicle can be performed. This is done by using the speed, acceleration, and grade of the road to determine the load on the vehicle and therefore the emissions on a 1-second basis. These values are then assembled on a unit length basis (i.e. 0.1 mile) and accounting for the overall volume of the road, the relative impacts of delay on emissions are shown graphically in GIS.

Integrate CMP with Transportation Improvement Program (TIP)

The final step of a fully integrated system is to tie the GIS network and supporting database design to the transportation planning model to support transportation planning and programming decisions. It is necessary for MPOs to maintain an accurate, up to date regional transportation model in order to conform to State and Federal regulations for air quality and transportation projects. MPOs update and calibrate their models using current information on the roadway network, area development, and other relevant characteristics such as travel time and speed data.

This is accomplished by providing a platform to assemble transportation related data, calculate various performance measures, document projects for the TIP, Arterial Life Cycle Program (ALCP) and Regional Transportation Plan (RTP), and include these projects in the various transportation modeling networks as depicted in Figure 5.

To accomplish this, the GIS must act as a central repository of information about existing transportation conditions on the multi-modal network. The information about existing conditions is accompanied by accurate information for improvement plans and projects. This information is available to the entire MPO staff, Information Technology (including the GIS and Socio-Economic modeling teams), and member agencies. The GIS, therefore, is able to 'round trip' data into and out of the demand model. MPOs commonly desire to compare current model results with historic and conditions in order to calculate performance measures for the existing and planned networks.

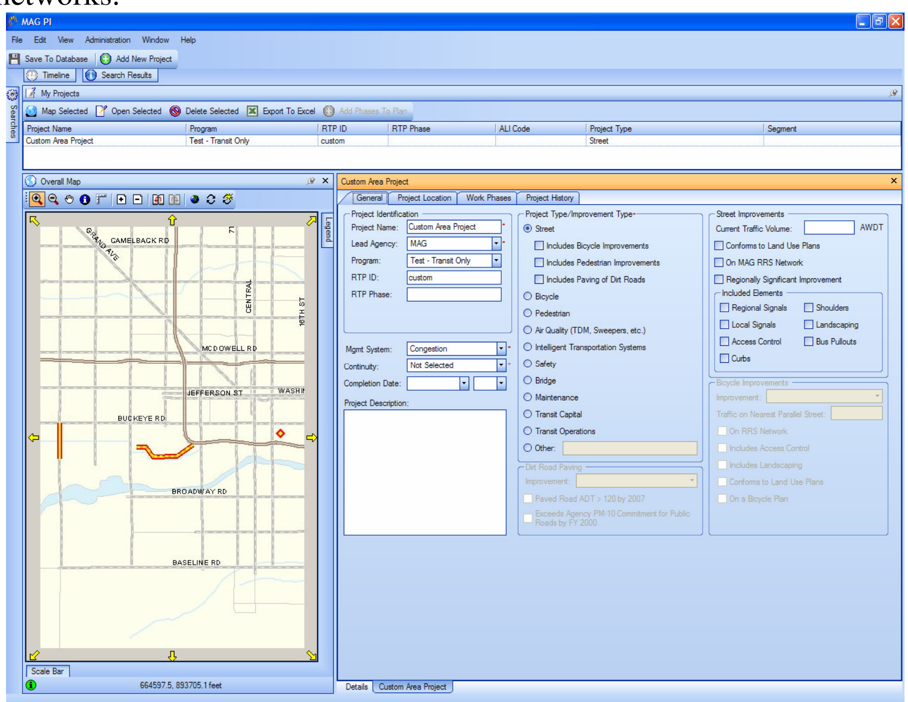


Figure 5: Integrated GIS-T Interface

Integrate Other MPO Responsibilities (GIS, Socioeconomic, Environmental, ITS, Safety, Regional Transportation Plan, and Highway Performance Management System (HPMS))

The most common issue faced by agencies undertaking new GIS-based initiatives is the collection, incorporation, and management of large amounts of data. This challenge has risen in a number of the case studies even when the project focus is limited to a single department. This challenge has been taken into consideration for the work plan recommendations resulting from this research. The integrated system is centered on the ability to:

1. Implement a central and GIS-enabled relational database using SQL Server and ArcSDE that serve as a repository for network information as well as program data for other aspects of the transportation program.
2. Focus on the creation of data layers that reflect the core activities supported by the new program and that can be maintained in the future, not on layers that would be created one time only.
3. Use a data model that simplifies the process of entering data through the use of a LRS. Linear referencing provides an organizational tool built to the MPOs needs and specifications that allow for a simple, non-spatial format around which many data sets can be organized and coded.

CONCLUSIONS

Innovative thinking, creativity, and technology have allowed engineers to develop a system that best utilizes an MPO's limited resources while significantly enhancing their CMP data collection and monitoring efforts. This system not only meets the goals of the federally mandated CMP, it adds accuracy and value to the analyses, and ultimately helps to better inform the MPO planning process. This integrated methodology continues to evolve to address each MPOs unique characteristics and needs, but at the same time, each public dollar spent by an MPO benefits the next through the lessons learned.

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