Performance Measurement Framework and Congestion Management Update

Performance Measurement Framework

Prepared For:
Maricopa Association of Governments

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Acronyms

AADT – Average Annual Daily Traffic
AASHTO – American Association of State Highway and Transportation Officials
ADMS – Archived Data Management System
ADOT – Arizona Department of Transportation
AMPO – Association of Metropolitan Planning Organizations
BRT – Bus Rapid Transit
Caltrans – California Department of Transportation
CDW – Central Data Warehouse
CMAQ – Congestion Mitigation and Air Quality
CMP – Congestion Management Process
CMS – Congestion Management System
CTOC – Citizens Transportation Oversight Committee
DOT – Department of Transportation
FHWA – Federal Highway Administration
FSP – Freeway Service Patrol
FTA – Federal Transit Administration
GP – General Purpose Lanes
HOV – High Occupancy Vehicle Lanes
HPMS – Highway Performance Monitoring System
ITS – Intelligent Transportation Systems
KPI – Key Performance Indicator
LOS – Level of Service
LRP – Long Range Plan
M&O – Management and Operations
MAG – Maricopa Association of Governments
MPH – Miles Per Hour
MPO – Metropolitan Planning Organization
MTP – Metropolitan Transportation Plan
NTOC – National Transportation Operations Coalition
PM – Performance Measurement
RCTO – Regional Concept of Transportation Operations
RTP – Regional Transportation Plan
SAFETEA-LU – Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users
TAG – Technical Advisory Group
TCRP – Transit Cooperative Research Program
TDM – Travel Demand Management
TIP – Transportation Improvement Program
TRB – Transportation Research Board
TTI – Travel Time Index
US DOT – United States Department of Transportation
V/C – Vehicle-to-Capacity Ratio
VMT – Vehicle Miles Traveled
WSDOT – Washington State DOT

1. Introduction

This memorandum represents the results of research conducted as part of the second Phase of the Maricopa Association of Government's (MAG) Performance Measurement Framework and Congestion Management Process Update (PM/CMP) Project. The primary objectives of this project are as follows:

- Develop a framework and prototype report as a tool for evaluating the effectiveness of regional strategies for moving people, goods, and services in relation to costs and time.
- Update MAG regional congestion management strategies to facilitate system evaluation based on performance measures developed as part of the study.
- Comply with Proposition 400 audit requirements as well as federal requirements set forth as part of the Safe, Accountable, Flexible, Efficient, Transportation Equity Act - A Legacy for Users (SAFETEA-LU).

Phase I (**complete**) of this project included the development of a best practices memorandum and the initiation of the Technical Advisory Group (TAG).

Phase II (**underway**) includes the development of a framework for performance measurement strategies and the development of implementation plans and reporting methodologies for multi-modal transportation systems at the regional and corridor level.

Phase III will incorporate the results of the performance measurement framework developed in Phase II into the congestion management process update. This update is needed to comply with federal requirements in SAFETEA-LU regarding the Congestion Management Process (CMP). The update will include development of evaluation tools that will allow for a multi-modal transportation system analysis, as well as strategy identification and analysis techniques, and reporting methodologies for disseminating the results.

It is anticipated that the successful implementation of this project will result in MAG achieving the following goals:

- Move toward scientific program development based on objectives-based, performance driven planning
- Enhance the TIP and other program planning decision-making processes to enable MAG to better evaluate and prioritize both existing and proposed projects
- Provide the tools necessary to support Proposition 400 audit requirements
- Enable MAG to better meet regional congestion mitigation objectives

The MAG PM/CMP Project is designed to be consistent with guiding principles adopted during the 2003 Regional Transportation Planning (RTP) process and will seek to revisit the strategies and goals in the RTP as they relate to new Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) guidelines for the development of Metropolitan Transportation Plans. These guidelines place a greater emphasis on the strategic integration of MAG's CMP into the multimodal regional transportation system plan. Furthermore, transportation system management and operations components are to be directly linked to improving the performance of the existing and planned surface transportation system. This project will seek to develop solutions for this integration, through the development of a performance measurement program and its comprehensive application to the CMP.

The content of this memorandum begins with an overview of the goals and objectives and performance measures included in existing planning-related documentation applicable to the MAG. This is followed by a discussion regarding how effective performance measures are developed, an overview of the process to follow in developing a regional concept of congestion, and the presentation of the proposed Preliminary Performance Measures Framework. It concludes with a discussion of the availability of data for use in supporting MAG's performance measurement efforts and a synopsis on linking performance measures to an agency's CMP.

1.1. Background

The Maricopa Association of Governments is the designated metropolitan planning organization (MPO) for transportation planning for the metropolitan Phoenix area. MAG's membership consists of the 25 incorporated cities and towns within Maricopa County and the contiguous urbanized area, the Gila River Indian Community, the Salt River Pima-Maricopa Indian Community, Fort McDowell Yavapai Nation, Maricopa County, the Arizona Department of Transportation (ADOT), and the Citizens Transportation Oversight Committee (CTOC). ADOT and CTOC serve as ex-officio members for transportation-related issues.

The RTP, adopted in 2003, is a performance-based comprehensive Regional Plan that covers all major modes of transportation. The plan was adopted in conjunction with Proposition 400 - a voter-approved extension of a half-cent sales tax for transportation improvements in the region. One of the key purposes of the plan is to establish and implement processes to examine and address expected congestion during the next twenty years, as well as to determine overall revenue and cost estimates for the program. Pursuant to Arizona statues, Proposition 400 requires the establishment of performance measures for all major transportation modal categories and requires performance audits of proposed transportation projects and systems starting in 2010. This audit will examine the RTP projects scheduled for funding within each transportation mode and evaluate them using a specific set of performance measures as part of a Performance Monitoring Program. In addition, it will review past expenditures based on the RTP and examine the performance of the transportation system in relieving congestion, and in improving mobility and accessibility. The audit is also required to provide recommendations regarding whether further implementation of a project is warranted, warranted with modifications, or not warranted.

1.2. Next Steps

The overall goal of Phase II of MAG PM/CMP Project is to review and enhance the tools that currently support MAG's existing performance monitoring program, facilitating the integration of performance measurement data into MAG congestion management process (Phase III), thereby improving its usefulness as a decision-making tool in the multimodal regional transportation planning and programming process.

Future activities to be carried out as part of this Phase will include:

- Finalize selection of performance measures that can be consistently applied across transportation modes and communicated to decision makers, stakeholders, and to the public on a periodic basis.
- Development of strategies and a methodology to analyze and evaluate various performance measures as they relate to the RTP, and to objectives established by the legislative mandate of Proposition 400.
- Development of reporting and visualization tools to communicate results of the performance measurement process to the public. The reporting function of this project will provide decision makers and the public in general with a better understanding of the progress that is being made in the implementation of the RTP and Proposition 400, and how these investments are improving the overall performance of the system.

2. MAG's Existing Goals, Objectives, and Performance Measures

The most effective performance measures are those that are consistent with the goals and objectives of the agency(s) for which they are being employed. Consequently, one of the first steps in developing a performance measures program should be to evaluate pertinent goals and objectives, linking them to any existing performance measurement programs currently in use or planned for implementation by the agency(s) involved. Based on this need, a mapping of existing performance measures and requirements to MAG's regional goals and objectives was conducted in order to identify those goals and/or objectives not currently being addressed through one or more performance measures. Exhibit 2.1 depicts how existing performance measures programs align with MAG's regional goals and objectives.

The first step in the process was to identify goals and objectives for the MAG region. Four overarching regional goals were identified as part of the MAG Regional Transportation Plan:

- **System Preservation and Safety.** Transportation infrastructure that is properly maintained and safe, preserving past investments for the future.
- **Access and Mobility.** Transportation systems and services that provide accessibility, mobility, and modal choices for residents, businesses, and the economic development of the region.
- **Sustaining the Environment.** Transportation improvements that help sustain our environment and quality of life.
- **Accountability and Planning.** Transportation decisions that result in effective and efficient use of public resources and strong public support.

Through a review of the following regional transportation planning documents, these goals were subsequently translated into 23 specific objectives as depicted in Exhibit 2.1:

- MAG Regional Transportation Plan
- Proposition 400 Legislation
- MAG Regional Concept of Transportation Operations
- MAG Regional Transit Framework Study
- Valley Metro Efficiency and Effectiveness Study

The results of this effort serve to indicate areas where existing performance measures efforts adequately align with regional goals and objectives, as well as any areas that need to be addressed as part of future performance measures development efforts.

Exhibit 2.1 – Existing MAG Region Goals/Objectives & Performance Measures

Vision	Core Goals	Objectives	Performance Measure Category	Relevant Planning Documents and Existing Performance Measures				
				MAG Regional Transportation Plan	Proposition 400 Performance Variables (A.R.S. 28-505)	MAG Regional Concept of Transportation Operations	Valley Metro Efficiency and Effectiveness Study	MAG Regional Transit Framework Study
System Preservation and Safety	Transportation infrastructure that is properly maintained and safe, preserving past investments for the future	• Provide for the continuing preservation and maintenance needs of transportation facilities and services in the region, eliminating maintenance backlogs. (RTP Objective 1A) • Provide a safe and secure environment for the traveling public, addressing roadway hazards, pedestrian and bicycle safety, and transit security. (RTP Objective 1B) • Reduce the number of crashes that involve bicyclists or pedestrians, by educating bicyclists on road safety; and promoting bicyclist training programs in coordination with Coalition of Arizona Bicyclists (Strategic Transportation Safety Plan) • Improve safety on access routes to schools, by establishing recommended walk or bike routes to school and promoting Safe Routes to Schools programs. (Strategic Transportation Safety Plan) • On arterials, implement a multi-jurisdictional arterial incident management program (based on outcomes of feasibility study) (MAG Regional Concept of Transportation Operations) • Ensure adoption of the emergency vehicle signal preemption (EVSP) standard by each of the MAG member agencies, and implement the standard on 100 percent of signals with EVSP (MAG Regional Concept of Transportation Operations)	System Preservation		• System Preservation variable (e.g., pavement condition rating)			
			Safety	• Accident rate per million miles of passenger travel	• Safety variable (e.g., accident rate per 100k vehicle miles traveled)		• Safety Incidents per 100k vehicle miles • Security Incidents per "x" boardings	• Frequency of evening bus service at major passenger facilities • Proximity of passenger facilities to popular destinations • Percent of park-n-Ride or station/stop locations that are isolated, stand alone facilities • General level of potential integration of stations and stops into surrounding land uses (High, Medium, Low) • Off peak average passenger loads • Percent of trips requiring one or more transfers
Access and Mobility	Transportation systems and services that provide accessibility, mobility, and modal choices for residents, businesses and the economic development of the region.	• Maintain an acceptable and reliable level of service on transportation and mobility systems serving the region, taking into account performance by mode and facility type. (RTP Objective 2A) • Provide residents of the region with access to jobs, shopping, educational, cultural, and recreational opportunities and provide employers with reasonable access to the workforce in the region. (RTP Objective 2B) • Maintain a reasonable and reliable travel time for moving freight into, through and within the region, as well as provide high-quality access between intercity freight transportation corridors and freight terminal locations,	Travel Time and Delay	• Travel time between selected origins and destinations • Peak period (other) delay by facility type and geographic location • Peak hour speed by facility type and geographic location • Extent of Congestion (LOS Measures) - Congested freeway lane miles/VMT - Congested arterial intersections • Location and Extent of Congestion (based on Speed) • Duration of Congestion (LOS Measure) - Vehicle hours of delay	• Congestion Relief variable (e.g., travel time and delay)	• Peak/non-peak period average travel speed and travel time by freeway segment • Peak/non-peak period average travel time by arterial • Average travel time on Bus Rapid Transit routes where Transit Signal Priority has been implemented		• Average travel speed – system/by mode

Vision	Core Goals	Objectives	Performance Measure Category	Relevant Planning Documents and Existing Performance Measures				
				MAG Regional Transportation Plan	Proposition 400 Performance Variables (A.R.S. 28-505)	MAG Regional Concept of Transportation Operations	Valley Metro Efficiency and Effectiveness Study	MAG Regional Transit Framework Study
		including intermodal facilities for air, rail and truck cargo. (RTP Objective 2C) • Provide modal options necessary for people of the region to carry out their essential daily activities and support equitable access to the region's opportunities. (RTP Objective 2D) • Address the needs of the elderly and other population groups that may have special transportation needs. (RTP Objective 2E) • Reduce incident duration on freeways by 20 percent (MAG Regional Concept of Transportation Operations) • On freeways, limit the percent increase in average travel time to less than the percent increase in traffic volume. (MAG Regional Concept of Transportation Operations) • On arterials, continue to limit the percent increase in average travel time to less than the percent increase in traffic volume (MAG Regional Concept of Transportation Operations) • On arterials, update the traffic signal coordination within/between cities every two years or when traffic volumes through the intersection change by more than five percent. (MAG Regional Concept of Transportation Operations) • Establish integrated freeway-arterial corridor operations on three corridors. (MAG Regional Concept of Transportation Operations) • Where beneficial, deploy transit signal priority (TSP) to all Express and Bus Rapid Transit (BRT) routes (MAG Regional Concept of Transportation Operations)	Reliability	• On-time performance (transit)		• Transit schedule adherence • Freeway and Arterial incident response and clearance times	• On-time performance	
			Mobility (Throughput)	• Number of major intersections at LOS "E" or worse • Miles of freeways with LOS "E" or worse during peak period • Average Daily Traffic on freeways/highways and arterials • Total transit ridership by route and transit mode • Per Capita Vehicle Miles of Travel (VMT) by facility type and mode • Transit share of travel (by mode) • Estimated number of persons/amount of freight transported • Number of miles traveled • Number of vehicles & estimated capacity of those vehicles • Transit focus: - Total boardings - Boardings per revenue mile • Demand Measures: - VMT (freeway/arterial)		• Percentage of traffic signals optimized within a city • Percentage of inter-jurisdictional traffic signals optimized between cities • Percentage of traffic signals with emergency vehicle signal preemption that are operating according to the established regional standard	• Total Boardings • Boardings – avg. weekday, Saturday, Sunday • Boardings per revenue mile • Boardings per revenue hour	• Average wait time for transfer • Percent of system with transit signal priority • Percent of system with express service • Percent of system with dedicated guideway or exclusive lanes • Ridership • Vehicle revenue miles of service per resident • Miles of express bus/freeway BRT service per employee in regional CBD • Percent of passenger hours of travel spent in stopped vehicles • Percent of system miles with dedicated guideway

Vision	Core Goals	Objectives	Performance Measure Category	Relevant Planning Documents and Existing Performance Measures				
				MAG Regional Transportation Plan	Proposition 400 Performance Variables (A.R.S. 28-505)	MAG Regional Concept of Transportation Operations	Valley Metro Efficiency and Effectiveness Study	MAG Regional Transit Framework Study
			Accessibility and Modal Choice	• Percentage of persons within 30 minutes travel time of employment by mode • Jobs and housing within one-quarter mile distance of transit service • Percentage of workforce that can reach their workplace by transit within one hour with no more than one transfer • Households within five miles of park-and-ride lots or major transit centers • Households within one-quarter mile of transit • Supply Measures: - Freeway lane miles - Number of arterial intersections	• Accessibility variable (e.g., transit vehicle revenue miles of service per resident of the MAG region) • Integration and connectivity with other modes variable (e.g., percentage of Park-and-Ride facilities in use)		• Percentage of paratransit "No shows"	• Percent of trip requiring one or more transfers • Distribution of routes stratified by weekday span of service • Distribution of routes stratified by weekend span of service • Distribution of routes by peak period headway • Distribution of routes by base period headway • Percent of population residing within ¼ mile of local bus or ½ mile of LRT/Express route • Percent of region's employment located within ¼ mile of local bus or ½ mile of LRT/Express route • Percent of Population within 2.5 miles of a Park-n-Ride Facility • Percent of total MAG region population within one-fourth mile of local bus or one-half mile of express bus/LRT • Percent of total MAG region employment within one-fourth mile of local bus or one-half mile of express bus/LRT • Number of major activity centers served

Vision	Core Goals	Objectives	Performance Measure Category	Relevant Planning Documents and Existing Performance Measures				
				MAG Regional Transportation Plan	Proposition 400 Performance Variables (A.R.S. 28-505)	MAG Regional Concept of Transportation Operations	Valley Metro Efficiency and Effectiveness Study	MAG Regional Transit Framework Study
Sustaining the Environment	Transportation improvements that help sustain our environment and quality of life	• Identify and encourage implementation of mitigation measures that will reduce noise, visual and traffic impacts of transportation projects on existing neighborhoods. (RTP Objective 3A) • Encourage programs and land use planning that advance efficient trip-making. (RTP Objective 3B) • Make transportation decisions that are compatible with air quality conformity and water quality standards, the sustainable preservation of key regional ecosystems and desired lifestyles. (RTP Objective 3C)	Quality of Life				• Complaints per "x" boardings • Customer Satisfaction	• Average load factor on express bus/freeway BRT services (1.0 or less is good) • Percent of sheltered bus stops with seating • Number of timed transfers available system wide • Percent of trips requiring one or more transfers • Percent of peak period local bus and LRT runs with extreme crowding (load factor greater than 2.0) • Number of shaded spaces at park-and-ride lots
			Environmental Preservation		• Air Quality and other environmental impacts variable (e.g., air quality index)			
Accountability and Planning	Transportation decisions that result in effective and efficient use of public resources and strong public support.	• Make transportation investment decisions that use public resources effectively and efficiently, using performance-based planning. (RTP Objective 4A) • Establish revenue sources and mechanisms that provide consistent funding for regional transportation and mobility needs. (RTP Objective 4B) • Develop a regionally balanced plan that provides geographic equity in the distribution of investments. (RTP Objective 4C) • Recognize previously authorized corridors that are currently in the adopted MAG Long-Range Transportation Plan; i.e., Loop 303 and the South Mountain Corridor. (RTP Objective 4D) • Achieve broad public support for needed investments in transportation infrastructure and resources four continuing operations of transportation and mobility services. (RTP Objective 4E) • Determine which investments will allow transit to capture the most market share of all transportation users. (MAG Regional Transit Framework Study)	Cost Efficiency	• Cost effectiveness: trips served per dollar invested • Transit focus: - Farebox recovery ratio - Operating cost per boarding - Cost per revenue mile	• Economic Benefits variable (e.g., commodity flows from, to, within, and through the region) • Cost-effectiveness of a project or service variable (e.g., trips served per dollar invested) • Operational Efficiency variable (e.g., operating cost per user or rider) • Project Readiness variable (e.g., schedule adherence)		• Farebox Recovery Ratio • Operating cost per boarding • Subsidy per boarding • Cost per revenue mile • Cost per revenue hour • Average Fare • Miles between Mechanical Failure	• Land-use synergy - adjacent street patterns (grid/suburban) • Transit friendly land use policies or zoning in place along majority of route • Service characteristic compatibility with local plans • Coordination between the planned service and economic development plans of local communities • Transit investments have the support of all local agencies • FTA New Starts, ARS 28-505, and BQAZ Consistency

3. Development of a Performance Measures Program

This section of the memorandum provides an overview of the process underlying the development of an effective performance measurement program.

3.1. Characteristics of Effective Performance Measures

Successful performance measurement programs typically encompass most (if not all) of the following characteristics[1]:

- **Stakeholder acceptance** - Stakeholders include agency management and staff, elected officials, other agencies, and the general public. A system initiated without broad stakeholder input and support is likely to fail or, at a minimum, operate below expectations.

- **Linkage to goals** - It is essential that performance measures be consistent with the goals and objectives of the agency for which they are being employed.

- **Understandable** - The program's intended audience should clearly understand how the measures are to be used.

- **Reasonable number of measures** - The array of measures being used must be balanced against the need to avoid overwhelming users with excessive amounts of data that may obscure important results.

- **Level of detail** - Measures should be sufficiently detailed to accurately identify areas where improvement is needed, but should not be more complex than necessary.

- **Flexibility -** The system should be capable of changing over time as agency goals and other needs evolve.

3.2. Overview of an Effective Performance Measures Program

Initiating a performance measures program requires a strategic approach to ensure that the information it provides can be used to support high-level policy and resource allocation decisions, to evaluate and compare solutions at a corridor and project specific level, as well as to support daily operations.

Performance measures are based on clearly stated performance objectives, which in turn derive from the mission, vision, and goals of an organization. In the case of

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[1] Nakanishi, Yuko J. and G.F. List, Regional Transit Performance Indicators: A Performance Measurement Model, Rensselaer Polytechnic Institute, Troy, NY, 2000.

transportation measures, the mission, vision, and goals are expressed in the Regional Transportation Plan. In addition to their basis in performance objectives, performance measures should be "SMART" – that is, they should be specific, measurable, attainable, reliable, and time-bound. There are other characteristics of good performance measures as well:

- Usefulness of measures: performance measures should be:
  - Tied to making specific decisions
  - Action oriented – helpful in identifying where action is required and improvements can be made
  - Clearly demonstrate progress and results
  - Related to what is truly important
  - For outcome measures, reflective of what higher level goal will be achieved (success of the system)
  - For output measures, reflective of what level of activity is being achieved

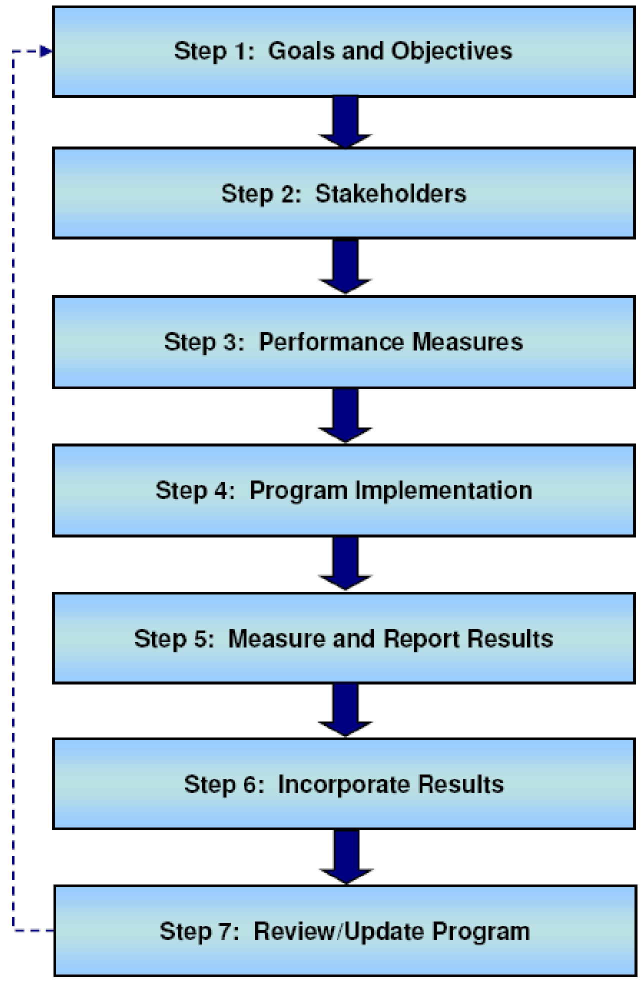
- Quality of measures: measures should have the following characteristics:
  - Accessibility – managers should be able to readily access information for informed decisions
  - Clarity – measures should be both understandable, and presented in a clear way
  - Accountability – it should be clear who obtains and maintains the data
  - Availability – data is readily available as input to the measure, and it is clear how the data is or will be collected
  - Reliability – input is dependable and will yield consistent results
  - Directional – measures should confirm that you are on track to meet goals
  - Achievable – the target is achievable, realistic, yet a stretch
  - Objective – measured and interpreted in an objective way
  - Qualitative – measure ensures that not only is something being done right, it is being done well
  - Quantitative – shows what has been achieved and how much more is left
  - Timely – information is provided at an appropriate time
  - Trustworthy and valid – the measure yields results that are credible
  - Worthwhile – measures add more value than the cost to collect and use

The process described below provides an overview of the steps that should be taken in order to help ensure program success.

Step 1: Define goals and objectives

Integration of the performance measurement program with agency goals and objectives is essential to ensuring the effectiveness of the program.

Exhibit 3.1 – Process to Develop a Performance Measures Program



- Actions:
    - Review agency (and other relevant) goals and objectives
    - Link selected performance measures to the goals and objectives
    - Review the performance-measurement program over time to ensure it reflects updates to agency goals

Step 2: Identify anticipated audience(s) for the program and other stakeholders who should be involved in program development

A program's characteristics can vary substantially depending upon the anticipated audience. For example, performance measures intended primarily for communicating with local elected and appointed officials and the public should be fairly straightforward and easy to understand, whereas performance measures intended for system management can be more technically oriented.

- Actions:
    - Identify and include likely users of the performance measures program or resulting data
    - Develop an understanding of different stakeholders' priorities

Step 3: Select performance measures and develop consensus

Select measures that are linked to the agency's goals and objectives.

- Actions:
    - Determine categories of performance measures to be implemented (e.g., Mobility, Reliability, and Safety)

  - Select performance measures for program inclusion
  - Identify data collection requirements for performance measures, taking into consideration data limitations and potential impact on the program
  - Develop consensus among the key stakeholders

Step 4: Test and implement the program

It is recommended that agencies implementing a performance measures program for the first time consider deployment of a pilot project to test the extent to which program objectives are met and potential problems and limitations can be uncovered.

- Actions:
  - Design and implement a pilot of the performance-measurement program
  - Assess data collection and analysis capabilities and limitations
  - Implement the performance-measurement program based on the pilot, including development of additional data collection programs
  - Review technological developments that may facilitate improved data collection capabilities over time.

Step 5: Monitor and report results

Once an agency has implemented its performance-measurement program, the next step consists of monitoring and reporting upon the system's performance. Different audiences will need to have information communicated in a way that is easy to understand for that them.

- Actions:
  - Develop a schedule for performance reporting
  - Develop a performance measures reporting format
  - Monitor and report on performance at pre-determined intervals
  - Review results

Step 6: Incorporate program results into the agency's decision making processes

An agency should have policies and procedures in place to guide how they will make adjustments to their programs based on the results of the performance measures program. Over time, implementing agencies should consider establishing performance "targets," generally associated with regional goals and objectives, for use in comparing the measured effects of their mitigation strategies (both planning and operations-oriented) against previously established policy-related objectives.

- Actions:
  - Develop policies for integrating program results
  - Identify activities and actions for improving performance (For measures not meeting their goals)

- For measures exceeding their goals (over multiple reporting periods), consider increasing performance targets (if cost-effective)

Step 7: Review & Update the program

It is important to remember that the performance measurement process is inherently evolutionary. This ensures positive feedback into the performance measures process as data availability and analysis capabilities improve and agency goals and objectives change. As a result, for a performance measurement program to be effective, it must be periodically reviewed over time.

- Actions:
    - Periodically evaluate the performance measurement program
    - Based upon results of the evaluation, make a determination regarding whether a program update is necessary
    - Return to Step 1, above, and repeat the process.

4. Defining and Reporting Congestion

This section of the memorandum provides an overview of the options available for monitoring and reporting on traffic congestion as part of a performance measurement framework. It summarizes a technical working paper that can be found in Appendix A of this document.

4.1. Background

The basic concept behind the creation and operation of a congestion management program is to provide regional planning agencies with the ability to better identify the portions of a region's transportation system that are not functioning as intended or desired so they can prepare and implement necessary improvements. This task is complicated by the fact that insufficient resources exist to make the transportation system perfect. As a result, not only must the "problems" be identified, they must also be prioritized in order to better differentiate between those that require immediate attention, those that are to be addressed in the near versus long term as additional resources become available, and those that may need to be accepted as beyond the available resources to resolve.

For roadways, one measure of poor performance is "congestion." This section discusses how congestion can be measured and reported within the framework of the regional performance measurement system. Unfortunately, congestion is not a "yes or no" condition. Congestion (delay, or conditions that result in slower than desired or intended travel speed) varies in its location, duration, intensity, extent, and frequency of occurrence. As a result, a robust roadway performance measurement system makes use of a number of different performance measures to identify where, how often, for how long, and how intense the congestion is.

In addition, roadway agencies and travelers tend to view congestion differently. Agencies are generally more concerned about where and when congestion occurs; while travelers are more concerned about the overall effect congestion has on their travel mobility. (That is, how long does it take them to reach their destination, and how long do they have to plan for that trip to take if they need to be at that destination at a specific time?) A robust performance measurement system includes statistics that meet both groups' needs. That is, the selected measures describe where, when, and how badly congestion affects specific roadway segments, and it includes travel time measures that describe the overall effects those congestion points have on both average travel conditions and the reliability of those travel times. Finally, most performance measurement systems produce aggregated summary statistics that are used to describe overall regional trends.

4.2. Alternative Congestion Measurement Statistics and Definitions

4.2.1. Point Measures

Point measures are useful for describing roadway performance conditions at specific locations. Most of the traditional roadway performance measures are point measures. Key point measures include

- Delay (vehicle-hours, person-hours)
- Speed (mph)
- Queue Length (feet or number of vehicles)
- Signal Cycle Failure (arterials only)
- Lost Efficiency
- Level of Service (LOS)
- Volume-to-Capacity
- Volume

Detailed descriptions of these statistics can be found in the full paper on congestion measurement options that is available in the appendix to this report.

4.2.2. Travel Time[2] (Segment) Based Measures

Much of the current research related to congestion reporting is focused on the use of travel time-based statistics. The intent is to measure and report travel times for roadway corridors and segments that correspond to trips that travelers routinely make. Because travel times (and congestion conditions) vary both by time of day and from day to day, reporting travel times often includes reporting not just the average or mean travel time for a given trip or roadway segment, but also some measure of the distribution of travel times that can be expected for that trip or segment.

By reporting on the reliability[3] of a specific travel time, as well as its mean condition, the congestion reporting process gives a more robust description of travel conditions actually experienced by travelers. Reporting on travel time variability and reliability also has the benefit of identifying the impacts that unusual occurrences (e.g., crashes) have on travel times, as well as the effects that transportation agencies' mitigation efforts (e.g., incident response programs) have on those "unusual" travel conditions.

To date, most published travel time reporting describes the performance of freeways, but the same statistics and measures can also be used to assess performance along arterials. Among the most commonly reported travel time measures are:

[2] Travel time (minutes for a given trip) can also be reported as a "Travel Rate" in units of miles per minute in order to make trips of different lengths directly comparable. Thus, all "travel time" statistics can be reported as travel rate statistics.

[3] The amount of variability present in the trip that makes the prediction of the expected travel time by a traveler more difficult.

- Mean travel time
- 95th percentile travel time
- The relationship between the 95th percentile and free flow or mean (average) travel time (i.e., the Buffer Time Index, Planning Time Index, and Travel Time Index[4])
- On-time percentage
- 80th percentile travel time
- Median (50th percentile) travel time

4.2.3. Area and System Measures

Both point sources and travel times are useful for describing specific congestion problems and for tracking changes in that congestion. That is, they are good at answering questions such as, "How congested is I-10, and how has it changed over the past three years?" However, it is also important for the congestion management process (CMP) to answer questions such as, "How is congestion throughout Maricopa County changing?"

To answer such higher level questions, area-wide statistics are needed. Generally, these statistics are created by either aggregating the point and travel time statistics described above, or by using systems such as that developed by the Texas Transportation Institute (TTI) for its Federal Highway Administration (FHWA) annual Urban Mobility Report. In most cases, area-wide congestion is reported in terms such as

- Person-hours of delay
- Delay per person
- Percentage of congested lane-miles.

Metropolitan Atlanta's MPO, the Georgia Regional Transportation Authority (GRTA), developed a single "transportation performance index" that combines a series of other indices which cover four basic topics: roadway services, roadway safety, roadway emissions, and transit service. Twelve inputs are combined as part of this process to produce a single index which can be used to judge the relative change in the performance of the metropolitan transportation system across multiple modes, and relative to key policy objectives (e.g., congestion relief, air quality improvement, and safety.)[5]

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[4] The Buffer Time Index is computed as the 95th percentile travel time minus the average travel time, with the resulting quantity divided by the average travel time and then multiplied by 100. It is a measure of how much "extra" time must be added to the "normal" or "expected" travel time if the traveler wanted to arrive on time 95 percent of the time (that is, late to work only once per month).
The Planning Time Index is computed as the 95th percentile travel time divided by the free flow travel time. It reflects the amount of time that travelers must include in their trips above the expected off-peak trip travel time if they want to arrive on time 95 percent of the time.
The Travel Time Index is the ratio of peak period travel time to free flow travel time. The TTI expresses the average amount of extra time it takes to travel in the peak relative to free-flow travel.

[5] The exact formula that weighs the different indices that make up the overall GRTA index are currently being reconsidered. The formula incorporates the travel time index, planning time index, daily vehicle miles traveled, two types of transit revenue service hour measures, transit passenger miles traveled, transit passenger boardings, vehicle based NOx emissions, vehicle based VOC emissions, vehicle based PM2.5 emissions, traffic crash fatality rates, and pedestrian and bicyclist fatality rates per 100,000 population.

4.3. Reporting Statistics

There are two basic types of congestion reporting statistics. The first simply uses select performance measures to report on current conditions. The second grades that performance against some adopted set of standards or performance objectives. Many agencies initially select performance measures and report on them for a few periods before setting a standard or threshold.

The first of these reporting techniques, performance reporting, is essential for evaluating the status of the roads being monitored. When a new version of the congestion report is produced, a comparison of this year's report with previous years' reports allows a region to track how roadway performance is changing over time.

The Washington State Department of Transportation (WSDOT) presents a considerable amount of this type of data in its Grey Notebook[6] (GNB). The GNB contains a variety of tables and graphics and includes many of the statistics described above, including mean and 95th travel times (see Figure 4-1).

Figure 4-1: Travel Time Table from WSDOT's GNB

***EVENING*: Key Commute Routes: Changes in Travel Time Performance, 2003 to 2005**

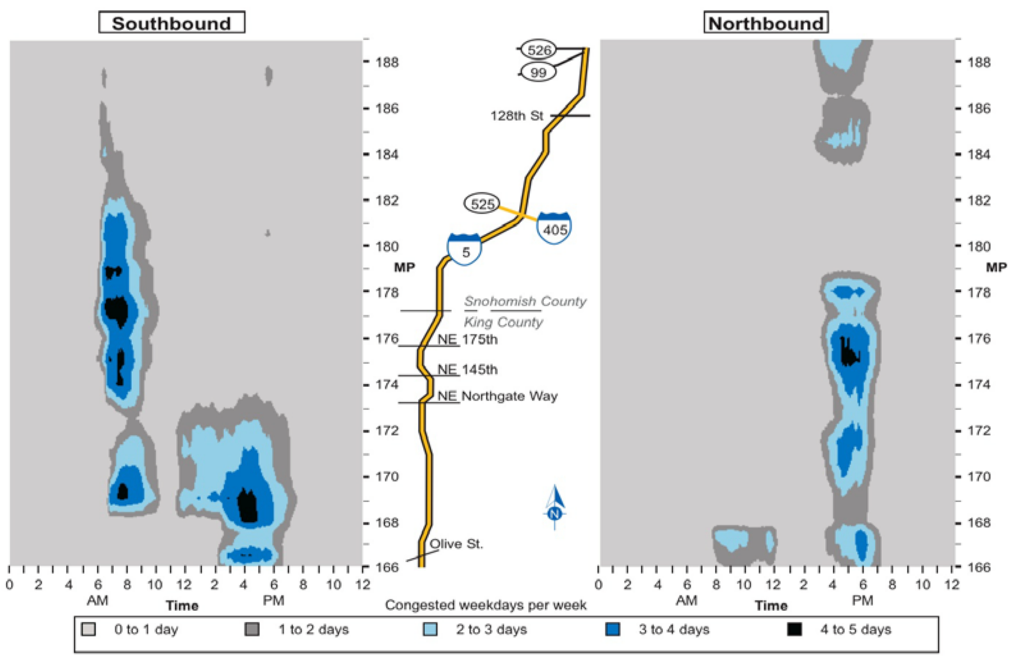
				Travel Time (in minutes)	Average Peak Travel Time (in minutes)			95% Reliable Travel Time (in minutes)			Ratio of Peak Travel Time to Maximum Through-put Travel Time		Traffic Volume Peak Hour	Duration of Peak Period (hours and minutes that average speed falls below 70% of posted speeds)		
Route	Route Description	Peak time	Length (Miles)	At Posted Speeds	2003	2005	Change (%)	2003	2005	Change (%)	MT^3I 2003	2005	Change (%)	2003	2005	change (in minutes)
From Seattle																
I-5	Seattle to Everett	5:20 PM	23.7	24	42	46	10%	60	68	13%	1.5	1.7	-2%	3:05	3:30	25
I-5	Seattle to Federal Way	5:15 PM	22.1	22	34	37	9%	51	55	8%	1.3	1.4	-2%	1:40	2:05	25
I-5/I-90	Seattle to Issaquah	5:25 PM	15.7	16	22	24	9%	32	36	13%	1.2	1.3	5%	*	0:15	*
I-5/SR 520	Seattle to Redmond	5:25 PM	14.7	16	27	30	11%	37	43	16%	1.5	1.6	0%	2:05	3:15	70

The second style of report, objective attainment reporting, both identifies how effectively the region is meeting its goals and objectives and sets a minimum list of "regional needs" for the congestion management process. That is, it identifies the facilities that do not currently meet the performance objectives or regional needs. As a first step towards setting these objectives, many agencies have adopted "reporting standards" as opposed to adopting specific "performance policies" or criteria. For example, WSDOT reports how frequently major freeway corridors operate below an average of 35 mph. Although the agency has not adopted 35 mph as a specific policy objective, it has informally adopted the 35 mph statistic as "the point at which congestion is bad enough to be worth noting."

[6] http://www.wsdot.wa.gov/accountability/

Another technique for displaying data is through use of a contour graphic (as in Figure 4-2), which presents both the time and location of congestion along I-5.

Figure 4-2 – Contour Map Illustrating the Frequency with which I-5 Fails the Selected Performance Standard



These same types of statistics can be shown in tabular format and with specific numeric values, rather than as colored graphics. The choice between these two display techniques is simply a function of the level of detail and precision that it is needed versus the visual simplicity desired.

5. Preliminary Performance Measures Framework

This section of the memorandum presents the proposed Preliminary Performance Measures Framework, including:

- A table of proposed measures arrayed by mode of travel
- A table linking the proposed measures selected back to the regional goals and objectives outlined in section 2
- Details concerning the performance measures being proposed, including:
    - Definition of the measure
    - Reporting Criteria
    - Geographic Scale
    - Units of Measurement
    - Data Needs
    - Description of Use

The primary objective of this effort is to provide a technical basis for depicting performance across the region.

5.1. Categories of Performance Measures

The proposed framework will focus on the following general categories of performance measures: a) Travel Time and Delay, b) Reliability, c) Mobility, d) Safety, e) System Accessibility, f) System Preservation, g) Environmental Preservation, h) Quality of Life, and, i) Cost Effectiveness. The initial priority should be on measures related to Travel Time and Delay, Reliability, Mobility, and Safety, since these are the most critical to the development of MAG's Congestion Management Process. These categories of performance measures are described in more detail below, and example measures within each category are provided.

5.1.1. Travel Time and Delay

Travel Time and Delay describe the amount of time and related delay incurred in traversing parts of the transportation network and can be applied for specific roadways, corridors, transit lines, or at a regional level. Travel time is reported as the amount of time for a vehicle to traverse between two points on a corridor. Although this may be defined as the time to travel the entire study corridor length, intermediate starting and ending points should be used, if needed, to illustrate specific traffic conditions in a corridor. Delay is defined as the total observed travel time minus the expected travel time under uncongested conditions. Congestion measures related to delay can be used to address both its **spatial** and **temporal** extent (duration). Depending on how these measures are defined and the data that are collected, these measures may focus on recurring and/or non-recurring congestion.

- Recurring congestion occurs in roughly the same time and place on the same days of the week. It results when travel demand exceeds freeway design capacity, and vehicular speeds drop below a pre-determined threshold speed on a "typical" incident-free weekday.
- Nonrecurring congestion is caused by unpredictable or unplanned occurrences, such as crashes, special events, severe weather, or short-term construction.

5.1.2. Reliability

Reliability captures the relative predictability of travel time**.** Unlike mobility, which measures the number of people moving at a certain rate, reliability focuses on assessing variations in travel time and their impact on travel predictability.

It is recommended that the "buffer index" be used to estimate reliability, rather than other measures, such as the standard deviation of travel time. The buffer index expresses the extra time that travelers must add to their average travel time when planning a trip in order to ensure on-time arrival 95% of the time.

5.1.3. Mobility

Mobility describes how well the system moves people and freight. Measures used to describe mobility are typically volume based, including: traffic volume (by person or vehicle), Level of Service (LOS), and Vehicle Miles Traveled (VMT)

5.1.4. Safety

Safety captures the safety characteristics of a portion of the network. It is recommended that safety performance measures focus primarily on crash and fatality rates. Rates can be measured at a link, corridor, and/or regional level.

5.1.5. System Accessibility

Accessibility quantifies how the transportation system facilitates access to different opportunities such as jobs, a transit station, and other land use or trip attractors of interest. Availability of modes or the ability to serve a particular user group (e.g., a disadvantaged segment of population or type of freight) can also be treated as accessibility measures.

5.1.6. System Preservation

System preservation measures the condition of the transportation system and actions to keep the system in a state of good repair. Measures are often specific to the type of asset and could be expressed by physical condition (e.g., extent or severity of distress) or by indices that combine a number of condition measurements or that relate to user perceptions of condition (e.g., pavement condition index or rating).

5.1.7. Environmental Preservation

Environmental Preservation measures the effects on the environment, including air quality, groundwater, protected species, noise, and natural vistas. Output-based performance measures may also be defined for actions critical to mitigating the above impacts (i.e., protecting wetlands, constructing wildlife passages across transportation facilities, and monitoring and controlling hazardous materials).

5.1.8. Customer Satisfaction & Quality of Life

Customer satisfaction is a measure of public perception regarding transportation facilities and the quality of the travel experience, including the efficiency of system management and operations, in a region. Many agencies now conduct regular customer satisfaction surveys and incorporate the results into their performance measure programs.

5.1.9. Cost Effectiveness

Cost effectiveness measures the effectiveness and efficiency of transportation investment decisions. Example measures include trips served per dollar invested, as well as time savings per dollar invested.

5.2. Measures Proposed for the Preliminary Framework

This section provides an overview of the performance measures recommended for use as part of MAG's Preliminary Performance Measures Framework. The complete list of recommended performance measures is presented in Exhibit 5.1, arrayed according to category of performance measures and mode of travel to which it is being applied.

Performance measures are often described as output or outcome measures.

- Output measures look at the products or services delivered (e.g., miles of roadway covered by ITS infrastructure and number of service patrol responses).

- Outcome measures look at the impact of the products on the goals of the agency (e.g., roadway travel times and measures of roadway congestion).

Outcome measures are preferred because they directly link the agency's goals to the results of the activities undertaken to achieve them. At the same time, outcome measures are more difficult to define and measure. In deciding which measures to use, the agency needs to consider whether enough data can be collected to allow a measure to be calculated with sufficient accuracy for it to be a useful tool in guiding decision-making. Almost all of the measures proposed for use as part of this framework are outcome oriented.

Both Valley Metro/Regional Public Transportation Authority (RPTA) and MAG are currently carrying out studies related to the development of transit-oriented performance measures. Consequently, the reader should keep in mind that the transit-oriented performance measures included in the framework are proposed for use as supplements to the measures contained in those transit-specific studies, not as alternatives or replacements.

5.3. Availability of Data

Performance measurement is all about data – in particular quality and geographic scope. It does little good to specify a comprehensive set of performance measures if the data needed to assess conditions is not available. In the short term, the availability of data will directly reflect on what performance measures can be computed and reported, as opposed to what performance the agency or region would like to compute and report. Depending upon the performance-related objectives developed for the region, and the resulting performance measures selected, it may be necessary to propose new data collection efforts, or changes to existing data collection methods and systems, to obtain the information needed to effectively track performance.

Due to the importance of this topic, section 6 of this memorandum will focus on the availability of data for use in supporting MAG's performance measurement efforts.

Exhibit 5.1 - Preliminary Performance Measures Framework

Measure/Mode	Highways (GP)	HOV Lanes	Arterials	Transit	Freight	Bicycle/Pedestrian (Non-Motorized)
Travel Time and Delay	Mean and 80th-95th Percentile [Peak / Off-Peak]	Mean and 80th-95th Percentile [Peak / Off-Peak]	Mean and 80th-95th Percentile [Peak / Off-Peak]	Point-to-Point Travel Times	Point-to-Point Travel Times	
	Point-to-Point Travel Times	Point-to-Point Travel Times	Point-to-Point Travel Times	Congestion Delay – Spatial & Temporal		
	Congestion Delay – Spatial & Temporal	Congestion Delay – Spatial & Temporal	Congestion Delay – Spatial & Temporal			
Reliability (Predictability of Travel)	Travel Time Reliability Index [Buffer Index]	Travel Time Reliability Index [Buffer Index]	Travel Time Reliability Index [Buffer Index]	On-time Performance		
	Roadway Clearance Time		Roadway Clearance Time			
Mobility – Throughput (People/Freight)	Volume (Person and/or Vehicle)	Volume (Person and/or Vehicle)	Volume (Person and/or Vehicle)	Ridership – by mode (Peak Period and Total)	Freight Volume	LOS on Bicycle and Pedestrian Facilities
	On-Ramp Ramp Queue Size		Intersection LOS – based on V/C	Peak Hour Load Factor (Average Load Factor on Express bus/freeway BRT)	Commodity flows from, to, within, and through the region, by mode	Per capita VMT
	Lost Capacity		Signal Cycle Failures / Intersection Queue Size	Per capita VMT		
	Per Capita VMT		Per Capita VMT	Transit share of travel (by mode) – miles traveled or trips taken		Bicycle/Pedestrian share of travel
				Boardings per revenue mile		
Safety	Accident Rate/Fatality Rate	Accident Rate/Fatality Rate	Accident Rate/Fatality Rate	Accident Rate	Accident Rate/Fatality Rate	Accident Rate/Fatality Rate
				Transit Crime Rate (Safety Incidents per 100k vehicle miles)		Percent of Schools participating in Safe Routes to Schools program
System Accessibility		Percent of Park and Ride Capacity Used		Percent of Park and Ride Capacity Used	Percent of freight terminals / intermodal facilities (air, rail, and truck cargo) located within 5 miles of a freeway	Sidewalk and/or Bicycle Network Completeness
				Vehicle Revenue Miles of Service per Resident of MAG Urbanized Area		
System Preservation	Bridge/Pavement Condition Rating	Bridge/Pavement Condition Rating	Bridge/Pavement Condition Rating			
Environmental Preservation	Air Quality Index	Air Quality Index	Air Quality Index	Air Quality Index	Air Quality Index	
Customer Satisfaction/Quality of Life	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction
		Percent of Employers with a Trip Reduction Program		Percent of Employers with a Trip Reduction Program		
Cost Effectiveness	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested

- It is recommended that performance metrics in cells with no shading should be reported on a regular basis (depending on availability of data)
- It is recommended that performance metrics in shaded cells should only be reported on infrequently for the purpose of assessing behavioral and systemic changes occurring over time.

5.4. Alignment of Performance Measures with MAG Regional Goals and Objectives

It is essential that performance measures selected for use in the region be consistent with the goals and objectives of the agency(s) for which they are being employed. Consequently, a mapping of the preliminary performance measure framework to MAG's regional goals and objectives was conducted to identify where goals and objectives were not being met, and to identify additional performance measures needed to measure progress toward these goals. Exhibit 5.2 depicts how the performance measures identified in the preliminary framework in Exhibit 5.1 are aligned with MAG's regional goals and objectives.

The first step in the process was to identify goals and objectives for the MAG region. Four overarching regional goals were identified as part of the MAG Regional Transportation Plan:

- **System Preservation and Safety.** Transportation infrastructure that is properly maintained and safe, preserving past investments for the future.
- **Access and Mobility.** Transportation systems and services that provide accessibility, mobility, and modal choices for residents, businesses, and the economic development of the region.
- **Sustaining the Environment.** Transportation improvements that help sustain our environment and quality of life.
- **Accountability and Planning.** Transportation decisions that result in effective and efficient use of public resources and strong public support.

Through a review of the following regional transportation planning documents, these goals were subsequently translated into 23 specific objectives as depicted in Exhibit 5.2:

- MAG Regional Transportation Plan
- Proposition 400 Legislation
- MAG Regional Concept of Transportation Operations
- MAG Regional Transit Framework Study
- Valley Metro Efficiency and Effectiveness Study

Finally, a review was conducted to ensure that the preliminary framework was aligned with and could adequately measure progress towards regional goals and objectives.

Exhibit 5.2 - How Proposed Performance Measures Align with MAG Regional Goals and Objectives

Vision	Core Goals	Objectives	Performance Measure Category	Performance Measure by Modal Group					
				Highways (GP)	**HOV Lanes**	**Arterials**	**Transit**	**Freight**	**Bicycles and Pedestrians**
System Preservation and Safety	Transportation infrastructure that is properly maintained and safe, preserving past investments for the future	• Provide for the continuing preservation and maintenance needs of transportation facilities and services in the region, eliminating maintenance backlogs. (RTP Objective 1A) • Provide a safe and secure environment for the traveling public, addressing roadway hazards, pedestrian and bicycle safety, and transit security. (RTP Objective 1B) • Reduce the number of crashes that involve bicyclists or pedestrians, by educating bicyclists on road safety; and promoting bicyclist training programs in coordination with Coalition of Arizona Bicyclists (Strategic Transportation Safety Plan) • Improve safety on access routes to schools, by establishing recommended walk or bike routes to school, promoting Safe Routes to Schools programs, training crossing guards, encouraging safe driving near schools, and sponsoring new legislation. (Strategic Transportation Safety Plan) • On arterials, implement a multi-jurisdictional arterial incident management program (based on outcomes of feasibility study) (MAG Regional Concept of Transportation Operations) • Ensure adoption of the emergency vehicle signal preemption (EVSP) standard by each of the MAG member agencies, and implement the standard on 100 percent of signals with EVSP (MAG Regional Concept of Transportation Operations)	System Preservation	Bridge/pavement condition rating	Bridge/pavement condition rating	Bridge/pavement condition rating			
			Safety	Accident Rate/Fatality Rate	Accident Rate/Fatality Rate	Accident Rate/Fatality Rate	Accident Rate	Accident Rate/Fatality Rate	Accident Rate/Fatality Rate
							Transit Crime Rate (Safety Incidents per 100k vehicle miles)		
Access and Mobility	Transportation systems and services that provide accessibility, mobility, and modal choices for residents, businesses and the economic development of the region.	• Maintain an acceptable and reliable level of service on transportation and mobility systems serving the region, taking into account performance by mode and facility type. (RTP Objective 2A) • Provide residents of the region with access to jobs, shopping, educational, cultural, and recreational opportunities and provide employers with reasonable access to the workforce in the region. (RTP Objective 2B) • Maintain a reasonable and reliable travel time for moving freight into, through and within the region, as well as provide high-quality access between intercity freight transportation corridors and freight terminal locations, including intermodal facilities for air, rail and truck cargo. (RTP Objective 2C) • Provide modal options necessary for people of the region to carry out their essential daily activities and support equitable access to the region's opportunities. (RTP Objective 2D) • Address the needs of the elderly and other population groups that may have special transportation needs. (RTP Objective 2E) • Reduce incident duration on freeways by 20 percent (MAG Regional Concept of Transportation Operations) • On freeways, limit the percent increase in average travel time to less than the percent increase in traffic volume. (MAG Regional Concept of Transportation Operations) • On arterials, continue to limit the percent increase in average travel time to less than the percent increase in traffic volume (MAG Regional Concept of Transportation Operations) • On arterials, update the traffic signal coordination between/within cities every two years or when traffic volumes through the intersection change by more than five percent. (MAG Regional Concept of Transportation Operations) • Establish integrated freeway-arterial corridor operations on three corridors. (MAG Regional Concept of Transportation Operations) • Where beneficial, deploy transit signal priority (TSP) to all Express and Bus Rapid Transit (BRT) routes (MAG Regional Concept of Transportation	Travel Time and Delay	Mean and 80^{th}-95^{th} Percentile [Peak / Off-Peak]	Mean and 80^{th}-95^{th} Percentile [Peak / Off-Peak]	Mean and 80^{th}-95^{th} Percentile [Peak / Off-Peak]			
				Point-to-Point Travel Times	Point-to-Point Travel Times	Point-to-Point Travel Times	Point-to-Point Travel Times	Point-to-Point Travel Times	
				Congestion Delay – Spatial & Temporal	Congestion Delay – Spatial & Temporal	Congestion Delay – Spatial & Temporal	Congestion Delay – Spatial & Temporal		
			Reliability	Travel Time Reliability Index (Buffer Index)	Travel Time Reliability Index (Buffer Index)	Travel Time Reliability Index (Buffer Index)	On-time Performance		
				Roadway Clearance Time		Roadway Clearance Time			
			Mobility (Throughput)	Volume (Person and/or Vehicle)	Volume (Person and/or Vehicle)	Volume (Person and/or Vehicle)	Ridership – by mode (Peak Period and Total)	Volume (Freight)	
				Per Capita VMT		Per Capita VMT	Per Capita VMT	Commodity flows from, to, within, and through the region, by mode	Per capita VMT
				Lost Capacity		Signal Cycle Failures / Intersection Queue Size	Peak Hour Load Factor (Average Load Factor on Express bus/freeway BRT)		
				On-Ramp Ramp Queue Size		Intersection LOS – based on V/C	Boardings per revenue mile		

Exhibit 5.2 - How Proposed Performance Measures Align with MAG Regional Goals and Objectives

Vision	Core Goals	Objectives	Performance Measure Category	Performance Measure by Modal Group					
				Highways (GP)	**HOV Lanes**	**Arterials**	**Transit**	**Freight**	**Bicycles and Pedestrians**
		Operations)	Accessibility and Modal Choice		Percent of Park and Ride Capacity Used		Percent of Park and Ride Capacity Used		Sidewalk and/or Bicycle Network Completeness
							Vehicle Revenue Miles of Service per Resident of MAG Urbanized Area		
							Transit share of travel (by mode) – miles traveled or trips taken		Bicycle and Pedestrian share of travel
Sustaining the Environment	Transportation improvements that help sustain our environment and quality of life	• Identify and encourage implementation of mitigation measures that will reduce noise, visual and traffic impacts of transportation projects on existing neighborhoods. (RTP Objective 3A) • Encourage programs and land use planning that advance efficient trip-making. (RTP Objective 3B) • Make transportation decisions that are compatible with air quality conformity and water quality standards, the sustainable preservation of key regional ecosystems and desired lifestyles. (RTP Objective 3C)	Quality of Life	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction	Customer Satisfaction
					Percent of Employers with a Trip Reduction Program		Percent of Employers with a Trip Reduction Program		
			Environmental Preservation	Air-Quality Index	Air-Quality Index	Air-Quality Index	Air-Quality Index	Air-Quality Index	
Accountability and Planning	Transportation decisions that result in effective and efficient use of public resources and strong public support.	• Make transportation investment decisions that use public resources effectively and efficiently, using performance-based planning. (RTP Objective 4A) • Establish revenue sources and mechanisms that provide consistent funding for regional transportation and mobility needs. (RTP Objective 4B) • Develop a regionally balanced plan that provides geographic equity in the distribution of investments. (RTP Objective 4C) • Recognize previously authorized corridors that are currently in the adopted MAG Long-Range Transportation Plan; i.e., Loop 303 and the South Mountain Corridor. (RTP Objective 4D) • Achieve broad public support for needed investments in transportation infrastructure and resources four continuing operations of transportation and mobility services. (RTP Objective 4E) • Determine which investments will allow transit to capture the most market share of all transportation users. (MAG Regional Transit Framework Study)	Cost Efficiency	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested	Trips served/Time Savings per dollar invested

5.5. Details Concerning the Performance Measures Proposed for Use by MAG

This section provides details related to the characteristics of the performance measures being proposed for use, including information regarding:

- Definition of the measure
- Reporting Criteria
- Geographic Scale
- Units of Measurement
- Data Needs
- Description of Use

See Exhibit 5.3, below, for a breakdown of the characteristics of the proposed performance measures.

Exhibit 5.3 - Characteristics of Proposed Performance Measures

Measure	Definition	Mode(s) of Travel	Geographic Scale	Reporting Criteria	Units of Measurement	Data Needs	Description of Use
Travel Time and Delay							
Mean and 80th-95th Percentile	Indicators of nature of travel experience: average – worst case	Highways, HOV Lanes, & Arterials	Roadways or Segments of Roadway & System	A.M./P.M. Peak Periods, Off-Peak, Daily	Minutes/Percentile	Measured travel time data	Indicators of nature of travel experience: average – worst case
Point-to-Point Travel Times	The average time consumed by vehicles traversing a fixed distance	Highways, HOV Lanes, and Arterials, Transit, & Freight	Roadways or Segments of Roadway & System	A.M./P.M. Peak Periods, Off-Peak, Daily	Minutes	Measured travel time data	Basic measure of congestion and basis for reliability
Congestion Delay – Spatial & Temporal	Indictor of congestion by location, time, and intensity	Highways, HOV Lanes, and Arterials, & Transit	Roadways or Segments of Roadway & System	A.M./P.M. Peak Periods, Off-Peak, Daily	Distance and Time	Measured travel times/speeds and delay	Multi-dimensional assessment of congestion
Reliability							
Travel Time Reliability Index - [Buffer Index]	Difference between the average travel time and the 95th percentile travel time, normalized by the average travel time	Highways, HOV Lanes, & Arterials	Roadways or Segments of Roadway & System	A.M./P.M. Peak Periods, Off-Peak, Daily	Ratio or Percentage	95th percentile travel time and Average travel time	Indicator of variability in roadway congestion
Roadway Clearance Time	Difference between time of arrival of incident responders and time when a lanes cleared	Highways & Arterials	Roadway and System	A.M./P.M. Peak Periods, Off-Peak, Daily	Minutes	Traffic incident management records concerning roadway clearance activity	Impact of incidents (unplanned events) on roadway
On-Time Performance	Percentage of fixed route trips no later than 5 minutes late	Transit (by mode)	System (by mode)	A.M./P.M. Peak Periods, Off-Peak, Daily	Percentage	Performance data from vehicle management systems	Assess effectiveness of service being provided
Mobility							
Volume (Person and/or Vehicle)	Number of Persons or Vehicles Traversing an area or roadway	Highways, HOV Lanes, & Arterials	Roadway and System	A.M./P.M. Peak Periods, Off-Peak, Daily	Persons or Vehicles	Traffic count data	Indicator of movement of people
Per capita VMT	Estimate of daily mileage an average person travels by vehicle per day	Highways, HOV Lanes, Arterials, Transit, & Non-motorized	System	Annual	Distance traveled per Capita	Average Trip Lengths and Number of Trips	Description of modal use conducted on an annual basis
On-Ramp Ramp Queue Size	Average length of queues at on-ramps to ADOT roadways	Highways	Roadway	A.M./P.M. Peak Periods & Daily	Distance	Ramp metering system data	Indicator of delay at ramp meters and potential impact on arterial roads
Lost Capacity	Difference between measured volume on a freeway segment under congested flow vs. maximum capacity for that segment	Highways	Roadways or Segments of Roadway & System	A.M./P.M. Peak Periods, Off-Peak, Daily	Vehicles per hour	Traffic count data, estimated maximum capacity count data, and average speed	Indicator of "capacity lost" due to traffic congestion
Intersection LOS – based on V/C	Average vehicle control delay at signalized and unsignalized intersections	Arterials	Roadway Intersection, Roadway & System	A.M./P.M. Peak Periods, Off-Peak, Daily	Grade (A-F)	Traffic count data and estimated maximum capacity count data (alternatives – average speed or delay)	Measure of effectiveness in moving vehicles on arterials
Signal Cycle Failures	Indictor of whether all vehicles at an intersection approach served during one green cycle	Arterials	Roadway Intersection, Roadway & System	A.M./P.M. Peak Periods, Off-Peak, Daily	Percentage of time – Pass/Fail	Traffic signal system data	Indicator of congestion levels at intersections
Ridership (by Mode)	Total or average number of passengers carried during a certain time	Transit	Route and System (by mode)	Daily - Annual	Number of users	Transit system ridership data (by route and mode)	Determine usage of mode and quality of service provided
Peak Hour Load Factor (Average Load Factor on Express bus/freeway BRT)	Percentage of seats filled during peak periods	Transit	Route and System (by mode)	A.M./P.M. Peak Periods	Percentage	Transit system ridership data (by route and mode) and Ridership Capacity data	Determine usage of mode and quality of service provided
Share of travel (by mode)	Percentage of miles traveled or trips taken	Transit & Non-motorized	System (by mode)	Annual	Percentage (Miles traveled or trips taken)	Transit and Non-motorized system ridership data (by mode) and data for trips for all other modes	Determine share of all travel accounted for by transit and Non-motorized modes

Measure	Definition	Mode(s) of Travel	Geographic Scale	Reporting Criteria	Units of Measurement	Data Needs	Description of Use
Boardings per revenue mile	Number of transit boardings compared to total revenue miles driven	Transit	Route and System (by mode)	Daily	Ratio	Transit system ridership data (by route and mode)	Productivity measure to assess service utilization
Freight Volume	Volume of freight moving across the region	Freight	System	Annual	Tons	Estimates provided by US DOT	Assess commercial vehicle usage for roadways to help determine need for infrastructure investment
Commodity flows from, to, within, and through the region, by mode	Assessment of the movement of goods	Freight	System	1-5 years	Shipment Characteristics	Census survey data	Assess movement of goods to help determine need for infrastructure investment
Segments of Sidewalk and/or Bicycle Routes at or Over Capacity	Portion of non-motorized thoroughfares at or over capacity	Non-motorized	Sidewalks/Bike Path Segments	Annual	Percentage/Number (of a total)	Sidewalk/Bike Path Usage Numbers and Estimated Capacities (per segment)	Determine usage of mode and quality of service provided
Safety							
Accident Rate/Fatality Rate	Number of crashes/accidents or Number of crashes/accidents with at least one fatality	Highways, HOV Lanes, Arterials, Transit, Freight, & Non-motorized	Route and System (by mode)	Annual	Number per some pre-determined VMT	Accident Fatality Statistics Data from Law Enforcement and Transit Agencies	Assess crash/fatality rate against VMT
Transit Crime Rate	Safety Incidents per 100k vehicle miles	Transit	Route and System (by mode)	Annual	Safety Incidents per 100k vehicle miles	Safety data from transit agencies	Assess changes in crime rates
Percentage of Schools participating in Safe Routes to Schools program	Percent of Schools participating in Safe Routes to Schools program	Non-motorized	All schools within area being assessed	Annual	Percentage	Safe Routes to School participation rates assessment	Assess program participation
System Accessibility							
Percentage of Park and Ride Capacity Used	Percentage of Park and Ride Capacity Used	HOV Lanes & Transit	All Park and Ride Facilities within area being assessed	Annual	Percentage	Park-and-Ride usage assessment	Determine usage of facilities and quality of service provided
Vehicle Revenue Miles of Service per Resident of MAG Urbanized Area	Number of revenue miles of service provided per resident	Transit	System	Annual	Ratio	Transit system ridership data (by route and mode)	Productivity measure to assess service provision
Percentage of freight terminals / intermodal facilities (air, rail, and truck cargo) located within 5 miles of a freeway	Percentage of freight terminals / intermodal facilities (air, rail, and truck cargo) located within 5 miles of a freeway	Freight	System	Annual	Percentage	Survey	Access ease of access to limited access facilities for freight transport
Sidewalk and/or Bicycle Network Completeness	Portion of non-motorized thoroughfares completed	Non-motorized	System	Annual	Percentage	Survey of percentage of networks planned vs. completed	Assess completeness of non-motorized travel thoroughfares
System Preservation							
Bridge/Pavement Condition Rating	Ability of infrastructure to sustain traffic loads in a safe and smooth manner	Highways, HOV Lanes, & Arterials	Roadway (and sections of roadway), Bridges and System	Annual	Index/Rating	Survey data from infrastructure inspections	Assess overall condition of infrastructure
Environmental Preservation							
Air Quality Index	Modeled emissions attributable to transportation network	Highways, HOV Lanes, Arterials, Transit, & Freight	System	Annual	Index – based on VMT	Modeled data	Assess impact of transportation network on regional air quality

Measure	Definition	Mode(s) of Travel	Geographic Scale	Reporting Criteria	Units of Measurement	Data Needs	Description of Use
Customer Satisfaction/ Quality of Life							
Customer Satisfaction	Defined by Question Asked	Highways, HOV Lanes, Arterials, Transit, Freight, & Non-motorized	System	Annual	Rating/Score	Survey	Assess public perception regarding quality of their travel experience
Percent of Employers with a Trip Reduction Program	Percent of Employers with a Trip Reduction Program	HOV Lanes & Transit	System	Annual	Percentage	Survey	Assess usage of TDM programs
Cost Effectiveness							
Trips served/Time Savings per dollar invested	Effectiveness of funds spent on transportation investments	Highways, HOV Lanes, Arterials, Transit, Freight, & Non-motorized	System	Annual	Ratio	Comparison of investments made against operational improvements	Measure of efficiency/effectiveness

6. Overview of Data Status & Opportunities

Many of the data elements needed to support a robust Performance Measures Framework are already being collected on a routine basis in the MAG region, or have been collected as part of recent studies. While many of the data elements for reporting on system performance are currently available, issues regarding accuracy, data quality, and usefulness for on-going performance monitoring need to be addressed. This section describes the data elements available from a variety of sources in the MAG area and provides a preliminary assessment of data quality. These issues will be discussed in more detail in subsequent drafts of the Framework.

Volume

The ADOT Freeway Management System (FMS) provides count data on the mainline general purpose lanes and HOV lanes 24/7/365, and on ramps. Traffic counts are collected through in-pavement loop detectors and passive acoustic detectors (PADs). This data feeds directly to the Arizona AZ511 system, providing real-time traveler information. Data is also aggregated in periods from five minutes to 24 hours for weekdays and weekends. Of the over 200 detector stations throughout the system, 58 stations receive priority attention to ensure reliable counts. While the information provided by PADs is considered adequate for providing real time information to the public, the accuracy of these detectors for planning purpose is debatable. The different sensor technologies in use for the ADOT FMS have been assessed for accuracy and consistency in recent years. Loop detectors, microloop detectors, and passive acoustic detectors, the principle data collection technologies in use in the MAG region, have varied from 5% to 25% for volume counts, and from 11% to 14% for speed, based on recent analysis. While recalibration of detectors can increase accuracy, the inconsistency in results from prior studies presents some issues for making comparisons over time.

The ADOT Transportation Planning Division has implemented a system for collecting information from 12 dual-direction stations using high-accuracy microloop detectors. Information from these count stations is available for the mainline only, and is separate from the FMS. This information is also collected on a 24/7 basis, but data collection is “offline” (i.e., detector sites must be visited monthly to extract information from the controllers). The ADOT Transportation Planning Division also collects data every other mile on all regional freeways using loop data or portable automatic traffic recorders (ATRs). This data is collected at each location for 48 hours on weekdays each year.

The City of Scottsdale also maintains a traffic count station that uses wireless sensors at one location on the L101 at Shea Boulevard; this information is also available 24/7.

For the arterial system, MAG collects traffic data at over 770 stations using machine counts. Data is collected on weekdays every three to four years, over a 48-hour time period, and aggregated by 15 minute, hour, peak period, and 24 hours. Counts are conducted by direction at mid-block locations throughout the region. Data from the MAG count program undergoes a variety of data quality control checks; count data collected from other jurisdictions is usually subject to the same kind of quality control checks.

Traffic counts are also conducted by various cities and counties throughout the region. Like the MAG counts, data is collected over 48 hours, either annually or biennially, for weekdays. Machine counts are available for mid-block locations. In addition, data is available for some communities through either permanent count locations or through the traffic signal control system. The City of Scottsdale, for instance, has 60 loop detectors for traffic counts, and has 285 interconnected traffic signals that can provide counts of through traffic and turning movements.

Speed Data

The principal source of speed data is the MAG Travel Time and Speed Study, conducted in 2003 and 2007. This study used probe vehicles to collect travel times on freeways (including both general purpose and HOV lanes) and on arterials. Data was collected for the peak hours and mid-day for over 2,038 centerline miles. Roadways were divided into 7,492 segments for data collection and reporting purposes. In all, 71,841 miles of travel time runs were undertaken for the 2007 study. Speed data is also available through the ADOT FMS, the ADOT Transportation Planning Division traffic detector stations, as well as the Scottsdale wireless detector station at US 101 and Shea. Speed data was also collected using handheld speed radar detectors at sample locations for the 2007 MAG Vehicle Occupancy Study. The Travel Time and Speed Study also provided point-to-point travel time matrices for different locations throughout the region.

Vehicle Classification Data

Vehicle classification data is available from the ADOT FMS, from the ADOT TPD microloop system, from the MAG arterial traffic count program, and from the 2007 MAG Vehicle Occupancy Study. Vehicle classification is based either on vehicle length or axle count, or – in the case of the Vehicle Occupancy Study – on entries by trained observers at 119 sites throughout the region.

While vehicle classification data provides one dimension of freight movement, this information can be supplemented with freight data obtained through studies such as the Arizona Multimodal Freight Analysis Study. This study used proprietary data to model the major freight movements through the State of Arizona and the MAG region.

Congestion Reporting

MAG has used an aerial photographic method for determining level of service (LOS) for the region's freeway system. For the most recent study (data collected April 2006) aerial photographs were taken for peak period and midday conditions during weekdays. Interpretation of these aerial photographs provided information on traffic density and speed on general purpose lanes, HOV lanes, and ramps throughout the region. The aerial photography method was also used to measure queue lengths on ramps entering and exiting the freeway system. Queue lengths and intersection delay for arterials could also be imputed from the data collected in the Travel Time and Speed Study.

MAG has begun reporting on the temporal extent of congestion, tracking the percentage of weekdays where traffic conditions on freeway segments is considered congested. Freeway performance is graphed by hour, tracking the percentage of days during which traffic moves at less than 50 mph and less that 35 mph. Information from 2007 and 2006 is shown on the same graph to provide a perspective on year-to-year changes in congestion.

MAG has also started to report on "lost productivity for the freeway system." Freeways can carry the maximum amount of traffic (around 2000 to 2200 vehicles per lane per hour) when traffic is moving at roughly 45 mph. When more vehicles are traveling on a given roadway segment, however, traffic flow breaks down and moves more and more slowly, reducing the number of vehicles that can be accommodated on the roadway. The gap between the optimal capacity and speed on the one hand, and the volume under congested conditions, is considered lost productivity (the freeway is carrying less traffic than it could under ideal conditions). Data from the ADOT FMS is used for this measure.

Using data collected and reported by ADOT through the Highway Performance Monitoring System (HPMS - permanent count stations, usually loop detectors, along with PADs), the Texas Transportation Institute produces a Mobility Report each month, using three months' worth of data. This report provides a perspective on the long-term trends in congestion, since current data is "smoothed out" and compared with the previous year's data.

Intersection level of service, as mentioned above, is one measure of arterial performance. Another measure of arterial performance is intersection queue size and signal cycle failure (failure for a vehicle in the queue to clear the signal during a single cycle). It has not been determined how many of the jurisdictions in the MAG region are able to collect this type of information. It is anticipated that at least the City of Scottsdale would be able to obtain this information through their interconnected signal control system.

Incident delay is a key component of non-recurring delay. Incident duration or roadway clearance time is included as a potential performance indicator.

Travel Delay

Travel delay is derived from speed counts. Information for this measure is derived from the ADOT FMS and from the Travel Time and Speed Study. In general, travel delay is derived from the difference between free flow speeds and measured speeds. In the case of the Travel Time and Speed study, delay was based in part on observed travel speeds vs. posted speed limits. Currently collected data provides a good foundation for measures of travel delay such as the travel time reliability index.

Safety

Highway safety data is collected and reported through Arizona DOT's Accident Location Information Surveillance System (ALISS). Crash data, derived from the Police Accident Report (PAR) form, is entered into ALISS for fatality, injury, and Property Damage Only (PDO) crashes where property damage exceeds the $1,000 threshold. Information on the PAR form includes location, characteristics of vehicles and people involved in the crash, contributing factors, and other vital data.

MAG is currently developing the Regional Transportation Safety Information Management System or RTSIMS, which will contain an archive of crash data pertinent to the MAG planning region (it currently consists of all jurisdictions within Maricopa County plus Apache Junction). RTSIMS will rely principally on the ALISS crash database, together with other non-ALISS data useful for safety analyses such as traffic and socio-economic data. Once fully implemented, RTSIMS will integrate the additional crash data into the crash data archive and make the data available planning purposes. The primary users of the system will be MAG staff and MAG member agency staff that have a need to perform crash analyses to support regional planning discussions.

Some shortcomings exist in available crash data, including under-reporting of PDO crashes, and lack of data from some tribal areas. PAR forms sometimes lack sufficient data for ADOT staff to geocode the crash location. Furthermore, bicycle and pedestrian safety data is seldom reported unless a motor vehicle is involved.

Transit Data

Transit data is derived from sources detailed in the MAG Regional Transit Framework Study and the Valley Metro/Regional Public Transportation Authority Efficiency and Effectiveness Study. Measures such as ridership, travel times, accessibility, safety and security, and comfort and convenience will be generated by Valley Metro. These measures, together with agency-centric figures such as farebox recovery ratio, cost per revenue hour/mile, cost per rider, on-time performance, and miles between mechanical failures, will be used to gauge transit performance. However, some aspects of transit system performance, such as mechanical performance, transit share of trips, and utilization of park-and-ride lots, are outside the scope of this study.

Bicycle and Pedestrian Data

Aside from bicyclist and pedestrian crash data, little information is currently available on the performance of non-motorized modes of travel in the MAG region. According to the Household Travel Survey conducted in 2001, about three percent of MAG region residents bicycled or walked to work, compared to four percent in the 1990 Census and three percent in the 2000 Census.

Local jurisdictions can request that studies be carried out for purpose of supporting improvements to pedestrian facilities. Pedestrian planning in the MAG region is based primarily on the use of two modeling tools:

The Pedestrian Latent Demand Model uses the following data elements for analysis:

- Land use, particularly the mix (if any) of residential densities, retail, office, public, quasi-public, and industrial
- Public schools and universities
- Public parks
- Urban trails
- Population density
- Income level
- Employment values within MAG’s traffic analysis zonal data
- Age demographics

The Roadside Pedestrian Conditions Model uses the following data elements:

- Lateral separation between pedestrians and motor vehicle traffic (including the presence, and width of sidewalks)
- Amount and speed of motor vehicle traffic
- Percentage of heavy vehicles (trucks)
- Number of travel lanes
- Presence of a paved shoulder, bike lane, or on-street parking
- Width of buffer between sidewalk and roadway
- Trees or other "protective" barriers in the buffer

Actual bicycle counts are included for some but not all of the MAG's arterial count station data, and are not included in data received from local jurisdictions. Otherwise, bicycle and pedestrian counts are generally obtained in the course of special studies or on a case-by-case basis. Efforts to develop measures for non-motorized travel will be coordinated with products of the Pedestrian Working Group and Regional Bicycle Task Force.

Infrastructure Condition

Bridge Management System

ADOT maintains a bridge management system to evaluate repair needs and coordinate repairs through the Highway Bridge Rehabilitation and Replacement Program. The purpose of the program is to provide dedicated construction funding to restore the structural integrity of a bridge or to replace it. Candidate repair or replacement projects are based upon the bridge sufficiency rating as determined through field inspections. Measurable objectives of the program include completing bridge rehabilitation and replacement projects on time and within budget.

Pavement Management System

The ADOT Materials Group maintains a pavement management system that contains information derived from highway condition surveys and tests about cracking, roughness, rutting, flushing, and friction on state roadways throughout Arizona. This information is used by a variety of departments throughout ADOT for planning and operations purposes.

Highway Performance Monitoring System (HPMS) Data

For the HPMS, ADOT collects a complete inventory of length (kilometers or miles) by functional system, jurisdiction, geographic location, (rural, small urban, urbanized, and NAAQS nonattainment areas) and other selected characteristics. Data reported includes measured pavement roughness (for the National Highway System and minor arterials).

HPMS Standard Sample Data consist of additional inventory, condition, use, pavement, operational, and improvement data that complement the universe data for those sections of roadway that have been selected as standard samples. When expanded through use of an appropriate expansion factor, the data represents the entire universe from which the sample was drawn, permitting evaluation of highway system performance. The sample sections form nominally "fixed" panels of road segments that are monitored on an established cyclical basis. Samples can be added or deleted from the sample panels as the need arises.

Panels of roadway sections are established using a statistically designed sampling plan based on the random selection of road segments at predetermined precision levels. The sample is stratified by area, by functional system, and by traffic volume group. Sample selection is done randomly within each stratum (a predetermined AADT volume group) for each arterial and major collector functional highway system in rural, and for each arterial and collector functional system in small urban and urbanized areas of the State. Pavement serviceability rating is reported for sample locations on rural major collectors and urban minor arterial and collectors.[7]

[7] Information on HPMS from **HPMS Field Manual,** Federal Highway Administration, 2005

7. Linking Performance Measures to MAG's Congestion Management Process

An agency's Congestion Management Process (CMP) is composed of a number of different elements that together add up to a coherent, objectives-driven, performance-based approach to solving congestion problems. These components are described in the Final Rule on Statewide and Metropolitan Transportation Planning, and include:

- Methods to monitor and evaluate the performance of the multimodal transportation system, identify the causes of recurring and non-recurring congestion, identify and evaluate alternative strategies, provide information supporting the implementation of actions, and evaluate the effectiveness of implemented actions.
- Definition of congestion management objectives and appropriate performance measures to assess the extent of congestion and support the evaluation of the effectiveness of congestion reduction and mobility enhancement strategies for the movement of people and goods.
- Establishment of a coordinated program for data collection and system performance monitoring to define the extent and duration of congestion, to contribute in determining the causes of congestion, and evaluate the efficiency and effectiveness of implemented actions.
- Identification and evaluation of the anticipated performance and expected benefits of appropriate congestion management strategies that will contribute to the more effective use and improved safety of existing and future transportation systems based on the established performance measures.
- Identification of an implementation schedule, implementation responsibilities, and possible funding sources for each strategy (or combination of strategies) proposed for implementation; and
- Implementation of a process for periodic assessment of the effectiveness of implemented strategies, in terms of the area's established performance measures. The results of this evaluation shall be provided to decision-makers and the public to provide guidance on selection of effective strategies for future implementation.[8]

Keeping the above in mind, a well-designed CMP should help an MPO to:

- Identify congested locations
- Determine the causes of congestion
- Develop alternative strategies to mitigate congestion
- Evaluate the potential of different strategies
- Propose alternative strategies that best address the causes and impacts of congestion
- Track and evaluate the impact of previously implemented congestion management strategies

The CMP is intended to be an integral part of the metropolitan planning process, rather than a stand-alone program or system. The CMP can be used to identify specific strategies that make

[8] 23 CFR 450.320(c)

the best use of new or existing transportation facilities, including but not limited to travel demand management, such as changes to land use, mode shifts, or changes to the time of day for travel; transportation systems management and operations, including approaches such as incident management through improved response to crashes, freeway management systems like ramp metering, improvements to arterial management such as traffic signal coordination, and improvements to transit operations; better travel information to help system users plan their trips in advance or respond to changing conditions; or capacity expansion through existing or new facilities as appropriate.

As a result, the Maricopa Association of Governments should seek to build upon the basic concepts of its existing CMS to develop a CMP that is:

- Objectives-driven
- Draws upon performance measures, operations data, and existing processes such as the regional Intelligent Transportation Systems (ITS) architecture

The establishment of regional congestion management-related objectives unsurprisingly leads to the need for performance measures that can be used to assess and track system performance. The following activities describe the manner through which data from a performance measurement program can be incorporated into an agency's CMP and through it, impact regional planning and decision-making:

a. Analyze Existing Conditions & Identify Problem Locations

Performance measures may be implemented on either a system-wide scale or at a corridor or transportation facility-level to determine where deficiencies exist and to facilitate the prioritization of strategies and funding. As part of the CMP, different measures of congestion may be used, addressing the scope, extent, or duration of congestion; recurring and nonrecurring congestion; and other related issues. Consequently, the existence of performance measurement data related to these issues can play an important role in determining the extent to which an agency examines and understands these conditions, as well as strategies (both operations and planning-related) for improving them. For example, once performance measures have been defined, they can be used to facilitate identification of those areas, roadways, and/or roadway segments that face the greatest congestion problems, thereby allowing the agency to more effectively target strategies (both operations and planning oriented) and funding to these areas.

b. Evaluate Operations-Related Programs for Improving Performance

As previously indicated, performance measurement programs can be developed so as to more effectively facilitate the identification, development, and implementation of strategies for improving system operation and reducing congestion. Efforts that focus on tracking and improving system performance can highlight the results of investments made in programs that increase system reliability, reduce delays, improve safety, and otherwise result in improved traffic flow and reduced congestion.

c. Analyze & Prioritize Congestion Mitigation Strategy Alternatives

Congestion mitigation strategies can be implemented over the short- to long-term. Such strategies include capacity improvement, operations-related improvements, and a wide-range of transportation management strategies. Using data from performance measurement programs as a baseline, public agencies can forecast the location and likely intensity of future congestion (both recurring and non-recurring) for everything from an entire region, down to segments of individual roadways. Using this data in conjunction with simulation models and other forecasting and sketch planning tools will enable an agency to evaluate future growth and planning needs, including the development of a prioritization framework of mitigation strategies. The objective of this prioritization framework can be to develop a roadmap for selection of the most appropriate projects and operational strategies for the region, including recommendations for modifications to previously proposed projects and strategies.

d. Monitor and Evaluate Strategy Effectiveness

Incorporating performance measurement-related data into the RTP development process can provide better information to decision-makers and other stakeholders concerning the progress being made toward an agency's desired goals and objectives, and can therefore, serve to make long-range plans more "real" users. Performance measures in the RTP can then be used by the MAG to report regularly on the performance of the metropolitan transportation system (e.g., via an annual performance report). Such reports inform transportation planning in a number of ways[9]:

- They provide a realistic view of system performance improvements achievable through management and operations investments

- They provide operations managers with guideposts and goals that provide some measure of how operations programs are contributing to the long-term goals of the system

- They support policy that is realistic about system constraints and that supports the role of management and operations in maintaining acceptable transportation performance

[9] Management and Operations in the Metropolitan Transportation Plan, Interim Draft, U.S. Department of Transportation, 2008, pg. 5-1.

Appendix A – Definition of Congestion[10] in a Congestion Management Program

This appendix is designed to help the reader better understand and evaluate their options for monitoring and reporting on traffic congestion as part of a performance measurement framework that supports an agency's congestion management process. That said, the reader should keep in mind that traffic congestion is only one aspect of roadway performance, and that roadway performance is only one component of a region's transportation system. Thus, additional measures, not discussed herein, are needed to effectively judge a transportation system's overall performance.

The appendix is structured into three subsections:

- The first section introduces how congestion is viewed by individuals and agencies and thus what is important in the definition of "congestion."
- The second section describes the types of statistics that are currently used to monitor and report on congestion and thus roadway performance. This section also briefly discusses the pros and cons of each of these statistics as potential performance measures.
- The third section presents how statistics such as these are used in a performance reporting system that describes congestion.

1. Background

The basic concept behind the creation and operation of a congestion management program is to provide regional planning agencies with the ability to better identify the portions of a region's transportation system that are not functioning as intended or desired so they can prepare and implement necessary improvements. An important question for such an effort is, "What measure(s) do we use to define and evaluate the segments that are functioning below the desired level?"

The answer to this question is complicated by the fact that insufficient resources exist to make the transportation system perfect. Therefore, not only must the "problems" be identified, but the significance of each problem must be determined in order to prioritize problems, which problems require immediate attention, which are to be addressed in the near and long term future as resources become available, and which may need to be accepted as beyond the available resources to resolve.

For roadways, one measure of poor performance is "congestion," a term with which the public is very familiar, and a term that most will support as a good means of identifying poorly performing roadways. As a result, the problem is in defining precisely what is meant by "congestion" and when it is bad enough to require the expenditure of scarce funds to make the roadway work better. This is because the definition of "bad congestion" differs widely from place to place and person to person. Like politics, "all congestion is local." That is, in places where traffic volumes are routinely high, speeds slow, and fixes to capacity limitations

[10] Congestion – a roadway operating condition that results in travel speeds that are slower than desired or intended by the operating agency, resulting in delay to the traveler.

expensive, the public accepts slower speeds, whereas in places where relatively little congestion occurs but improvements are not expensive to make, the public often expects improvements that result in improved mobility. For example, a higher level of traffic congestion is accepted in central cities than in growing suburban areas. This is in part due to the costs of resolving that congestion. In central, fully developed cities, little land is available for roadway widening, and yet increased or sustained activity levels are desired. Thus high levels of congestion are accepted. In growing suburban areas, roadway capacity can more often be expanded without compromising the surrounding land uses. In addition, added capacity is often viewed by the public as supporting continued growth, whereas in fully developed central areas, physical expansion of existing roadways can be viewed as taking away from the attractiveness of the area.

Another issue is that congestion is not really a "yes or no" condition. Congestion (delay, or conditions that result in slower than desired or intended travel speed) varies in its location, duration, intensity, extent, and frequency of occurrence. As a result, a robust roadway performance measurement system could potentially make use of a number of different performance measures to identify where, how far, how often, for how long, and how intense the congestion is. Traditional statistics used to report roadway performance, such as level of service (LOS) and volume-to-capacity ratios (v/c), while very useful measures of congestion, deal with only the location of congestion and its average intensity during a specific period. Therefore, most agencies now actively operating congestion management plans either use different measures or supplement LOS and v/c reports with additional statistics.

Although many traditional roadway congestion definitions and measures are point based, describing roadway performance at a specific location, travelers make trips, and trips experience congestion (or the lack of congestion) across a variety of locations. People (and freight shippers) plan their lives and businesses around the amount of time they expect a trip to take. They don't think about the amount of time they will spend in any specific congested location; they think about the entire trip. Therefore, in order to relate congestion conditions to the reality of travelers, many of the newer congestion definitions and statistics currently in use are based on the travel times experienced over longer defined roadway segments, not just conditions at specific locations.

2. <u>Alternative Congestion Measurement Statistics and Definitions</u>

This section of this working paper discusses the types of statistics that are used around the country to measure and report on congestion. They are presented here to illustrate the many ways that statistics can be used to describe roadway performance, and to give the reader the ability to examine alternatives to the statistics recommended by the project team for inclusion in the MAG Performance Measurement Framework.

The statistics described in this section are divided into three basic categories: point measures, trip or segment measures, and area measures. As freeway and arterial performance are intrinsically different (freeways being designed for free flow operation and subject to only small differences in speed limits from one facility to another, and arterials being designed for a variety of speed limits with widely varying traffic signal timing effects), statistics that are only applicable to arterials and/or to freeways are identified as such.

A. Point Measures

Point measures are useful for describing roadway performance conditions at specific locations. Most of the traditional roadway performance measures are point measures. Key point measures include:

- Delay (veh.-hrs, person-hrs)
- Speed (mph)
- Queue length (feet or number of vehicles)
- Signal cycle failure (arterials only)
- Lost efficiency
- Level of service (LOS)
- Volume-to-capacity
- Volume

Each of these measures and their definitions are discussed briefly below.

Delay – Delay is defined as the time lost as a result of speeds being lower than a selected value or standard. It is a measure of the time lost because of congestion by travelers passing a particular point or using a section of road. Delay is computed by measuring the speed of vehicles or the time spent by those vehicles on a roadway segment and then computing the difference between that speed/time and the "desired" (or selected standard) speed/time. By measuring an average delay per vehicle and multiplying that value by the number of vehicles using that roadway, it is possible to estimate the total delay experienced on that roadway section. The result is often reported in terms of vehicle-hours or person-hours of delay.

Note that, by definition, some delay occurs on signalized arterials, no matter how optimally the traffic signals are timed. This specific kind of delay is called "control delay" and is minimized (but not eliminated) when traffic signal timing is optimized.

Delay is an excellent engineering variable, as it can be used to directly compare the relative impacts of one congested location to another. The major drawback to delay is that these measurements (often expressed in terms such as annual vehicle-miles of delay or peak hour vehicle-hours of delay) are not in units that are easily converted to an individual traveler's day-to-day experience. They are thus good engineering variables, but they are generally not as useful for reporting performance to the public.

Speed – Speed is the direct measure of vehicle performance on a roadway. It is a measure of congestion intensity, where "intensity" is defined as the amount that speed drops below an adopted standard. "Congestion" can be defined as either any speed below the posted speed limit, or a speed at some defined point below the posted speed limit. For example, on a freeway "congestion" can be defined as occurring only when speeds drop below the point at which maximum vehicle throughput occurs (~45 mph).

Speed is a good point measure for reporting congestion. It is easily understood by the general public. It can also be used to report travel conditions over a roadway segment and is therefore often used interchangeably with travel time or travel rate.

Queue Length – This measures the number of vehicles stored at a point. The length of a queue is a measure of the intensity of a given congestion point. It is a particularly good measure for defining the performance of approaches to signalized intersections, although it can be used to describe the congestion at any point at which queues form (e.g., queues on ramps between surface streets and limited access roads).

While this statistic is an excellent descriptor of the amount of traffic waiting at a given location, it is of less use to engineers than delay. The size of a given queue is important to track over time, but the comparison of one queue with another is less helpful without significant amounts of additional information. For example, it is good to compare queue lengths for a given approach to an intersection under two different signal timing plans because that comparison is instructive of the relative performance of those plans. However, when two different approaches are compared, issues such as the relative size of the different roadways and the amount of green time being provided at the intersection make the direct comparison of queue length less meaningful. As a result, this statistic is less useful for a regional performance monitoring system.

Signal Cycle Failure – This measure indicates whether vehicles that are stopped at an intersection when the green phase for that approach begins are unable to clear that intersection by the time that phase turns red (that is, a waiting vehicle is unable to pass through an intersection during one entire signal cycle). This is a binary (pass or fail) statistic that tracks when an intersection approach is unable to serve all of the traffic on a given approach. When tracked over time, it measures the frequency and duration of the times when an intersection approach is over capacity (congested). It is a particularly good measure of congested intersections, as cycle failure is readily noticed by motorists who are unable to progress through an intersection as desired.

This measure is extremely understandable to the public and is a superb measure of the level of frustration that the traveling public experiences on an approach to an intersection that is over-saturated (i.e., not performing well). However, this measure is not often used because it must be collected by the traffic signal system itself, and most signal systems are not currently set up to perform that function.

Lost Efficiency – This measure, initially adopted by Caltrans and subsequently adopted by other agencies, that describes the intensity of congestion in terms of the amount of roadway capacity lost as a result of congested conditions (that is, the difference between the number of vehicles actually served and the number of vehicles that could be served if the roadway operated at its stated capacity). It is a two-step measurement process: a) Step one requires an evaluation of average vehicle speed, and b) Step two tracks the difference between roadway capacity and actual measured vehicle volume, identifying this as “lost capacity,” during times when average speed drops below some pre-determined value (usually somewhere between 45 and 50 mph)

This is an excellent measure of the potential benefits that could be gained from operational improvements such as ramp metering, incident response, and various demand management strategies. However, to date it has been applied only to freeways. It is also a difficult concept to explain to the public and has therefore typically been applied as a "secondary" congestion measure, used mostly in instances where it can be effectively explained to a particular audience.

Level of Service – LOS has long been defined for different types of roadways by the Highway Capacity Manual. It is computed by using a variety of measures, including average speed, delay, and traffic density, depending on the type of roadway being examined. It is usually reported for a specific period of analysis.[11] Equations exist that allow its estimation on the basis of the traffic volume served by a roadway. It is descriptive of roadway performance up until LOS F conditions (basically the occurrence of stop and go conditions) on a freeway are reached, but it must be supplemented with other statistics to better indicate overall traffic conditions. The basic concepts it is intended to portray are reasonably well understood by most individuals (that is, LOS F is not good, while LOS C is better).

There are two significant drawbacks to the use of LOS. The first, as noted above, is that it refers to a specific volume condition, which is not indicative of many of the operating conditions at which a given roadway operates. Second, current LOS procedures are really designed to express the relationship between volume demand and geometric capacity. In cases where congestion is simply the result of there being a need for additional capacity, LOS works fairly well. However, LOS computations are less useful when the cause of congestion is not strictly volume based, but is instead the result of some other type of traffic disruption. In such cases, conventional LOS statistics will neither report the existence of actual congestion nor describe the benefits to be gained via improved operations or other activities designed to mitigate or eliminate the cause of that congestion.

Volume-to-Capacity Ratio (v/c) – Like speed, v/c is a reporting statistic that is often used as a direct measure of congestion. V/C is often used to compute LOS, and thus has many of the same attributes as described for LOS above.

Demand volumes generated by planning models are often reported and compared with theoretical roadway design capacity. In cases where traffic volume demand exceeds capacity, congestion can be expected to occur. The larger the ratio, the worse the congestion. However, as a direct measurement of congestion (that is, where "congestion" calculations are based on directly measured traffic volumes divided by theoretical roadway design capacity), v/c has a significant limitation, because when congestion occurs, actual traffic volume (throughput) declines[12], resulting in measured volumes which are below theoretical capacity, even though congestion exists.

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[11] California has used a variation of LOS reporting that appends a duration value to the LOS statistic to indicate the duration of an LOS F condition. So LOS_8 would mean 8 hours of LOS F conditions.

[12] Traffic volume is measured as the number of vehicles which pass a point in a given amount of time. An average freeway lane can move 2,000 vehicles per lane past the count location in an hour under "normal" conditions. In congested conditions, while there are a lot of cars on the roadway, they are moving so slowly that only 1,300 vehicles may move past that same data collection point during an hour. Thus, a traffic count based v/c computation shows v/c = 1,300 / 2,000 or 0.65. A v/c of 0.65 would indicate no congestion is present, when in fact the road is very congested.

Consequently, v/c is an excellent planning model tool, as well as an excellent measure for determining which sections of roadway are approaching congestion, but it is a less than perfect measurement statistic for actual roadway performance once congestion has occurred.

Volume – This measure, by itself, is not really a congestion measure, but it is an important statistic used to determine the relative importance of the delays being measured with other statistics.

B. Travel Time[13] (Segment) Based Measures

Much of the current research related to congestion reporting is focused on the use of travel time-based statistics. As previously indicated, the intent is to measure and report travel times for roadway corridors and segments that correspond to trips that travelers routinely make. Because travel times (and congestion conditions) vary both by time of day and from day to day, reporting travel times often includes reporting not just the average or mean travel time for a given trip, but also some measure of the distribution of travel times that can be expected for that trip.

By reporting on the reliability[14] of a specific travel time, as well as its mean condition, the congestion reporting process gives a more robust description of travel conditions. Reporting on travel time variability or reliability also has the benefit of identifying the impacts that unusual occurrences (e.g., accidents) have on travel times, as well as the effects that transportation agencies' mitigation efforts (e.g., incident response programs) have on those "unusual" travel conditions.

In many cases, travel decisions must be made with consideration of a trip's potential for very slow travel times because the consequences of being late may be onerous. For example, "When do I leave for the airport?" and "At what time does my just-in-time delivery have to leave the warehouse in order to be at the factory by 11:00 AM, 99 percent of the time?" Consequently, understanding the distribution of travel times for a given trip, and how that distribution has changed over time, is an important part of improving how roadway performance affects travelers.

If only the average travel time, and not the distribution of travel times is reported, the congestion levels reported only reflect the relative effect of traffic demand versus basic geometric capacity despite the fact that there are many additional sources of congestion (e.g., accidents, incidents, construction, bad weather, or special events). These periodic traffic disruptions are frequently what cause the severe, unexpected congestion that can so significantly affect the traveling public. As a result, if only average conditions are reported, then an inaccurate description of the congestion that travelers actually experience is used to make congestion management-related decisions.

[13] Travel time (minutes for a given trip) can also be reported as a "Travel Rate" in units of miles per minute in order to make trips of different lengths directly comparable. Thus, all "travel time" statistics can be reported as travel rate statistics.
[14] The amount of variability present in the trip that makes the prediction of the expected travel time by a traveler more difficult.

To date, most published travel time reporting describes the performance of freeways, but the same statistics and measures can also be used to assess performance along arterials. Among the most commonly reported travel time measures are:

- Mean travel time
- 95th percentile travel time
- The relationship between the 95th percentile and free flow or mean (average) travel time (i.e., the Buffer Time Index, Planning Time Index, and Travel Time Index which are explained further below)
- On-time percentage

Ongoing Strategic Highway Research Program (SHRP2) work has identified three additional statistics that MAG should consider:

- 80th percentile travel time
- Median (50th percentile) travel time
- The skew statistic

Mean or average travel time – This measure is usually reported by time period to describe the "routine" condition that can be expected for a defined trip. It is an excellent reporting statistic and is the type of travel time data most commonly used, as it can be estimated with reasonable accuracy using a variety of sampling techniques.

The 95th percentile travel time – This measure describes the "worst travel time experience for a given trip each month." It is an excellent measure of the amount of time required for trips for which the traveler would be highly penalized for being late, such as trips to the airport to catch a flight. It (or the indices based on it) has become the de facto standard measure of travel reliability. However, because it describes the "extreme" of the travel time distribution, it is more difficult to estimate reliably and therefore traditionally requires a substantial data collection program to measure accurately.

The Buffer Time Index – This measure is computed as the 95th percentile travel time minus the average travel time, with the resulting quantity divided by the average travel time and then multiplied by 100. It is a measure of how much "extra" time must be added to the "normal" or "expected" travel time if the traveler wanted to arrive on time 95 percent of the time (that is, late to work only once per month).

The Planning Time Index – This measure is computed as the 95th percentile travel time divided by the free flow travel time. It reflects the amount of time that travelers must include in their trips above the expected off-peak trip travel time if they want to arrive on time 95 percent of the time.

On-Time Percentage – This measure is the percentage of times that a trip can be completed within a specified amount of time or at a given average speed. It is particularly useful in reporting whether a roadway is meeting an adopted performance standard. (For example, an agency might adopt the standard that "a freeway is expected to average 45 mph during the AM peak period." This statistic would indicate the percentage of times that the performance standard was actually met.) It can also be reported as a failure rate (i.e., the percentage of trips that could not be made at an average freeway speed of 45 mph or faster).

This type of statistic can also be rephrased as "the amount of time a roadway is 'congested' or 'severely congested.'" In this case, the travel time or average speed adopted as a standard is used to report how frequently a roadway operates in that condition. For example, Caltrans has used 30 mph as their definition of severe congestion, and can track the amount of time a given roadway corridor operates below that standard ("in severe congestion.")

As with the 95th percentile travel time, this reporting measure describes the performance of a roadway in a manner easily understood by everyone. Similarly however, its limitation is the quantity and quality of data available for analysis, and thus the investment required to report it consistently.

80th percentile travel time – The SHRP2 L03 project has found that, in many cases, 95th percentile travel times are insensitive to many of the travel time improvements that have occurred as a result of operational strategies adopted by roadway agencies. For example, strategies such as quickly removing disabled vehicles from the roadway appear to substantially reduce travel times that are worse than "normal", but appear to have less impact on extremely long travel times caused by major events (e.g., heavy snow storms, major thunder showers that produce roadway flooding, etc.). As a result, reporting only the 95th percentile travel time may limit the ability of an agency to report on travel time improvements (congestion relief) that are occurring as a result of operational changes. In reaction to this finding, the Washington State Department of Transportation (WSDOT) has started to report on 80th percentile travel times.

Median – Preliminary SHRP2 L03 project results indicate that mean travel times can be adversely affected by a few very bad travel days. It has therefore been suggested that median or 50th percentile travel times might be a better statistic for reporting "routine" travel times (and thus routine congestion conditions). Early work has shown that this is true for larger reporting periods, but median values can be more unstable than mean values for shorter reporting periods (such as monthly peak period reporting). At this time, it is unclear whether the median is a better value than the mean.

Skew - Dutch researchers have suggested that another good "reliability" statistic is the skew statistic. The skew statistic measures the shape of the distribution curve. The larger the skew, the more extremes that exist in the distribution, and thus, the more unreliable the trip. Essentially, the larger the skew statistic, the greater the difference between the mean travel time and the extreme (e.g., 95th percentile) travel time. The SHPR2 L03 project team will be producing skew statistics as part of its research effort, but it is still unclear whether these statistics will be widely adopted, as their ability to describe travel reliability is not intuitive for either the public or most decision makers.

C. Area and System Measures

Both point sources and travel times are useful for describing specific congestion problems and for tracking changes in that congestion. That is, they are good at answering questions such as, "How congested is I-10, and how has it changed over the past three years?" However, it may also be important for the congestion management process (CMP) to answer questions such as, "How is congestion throughout Maricopa County changing?"

To answer such higher level questions, area-wide statistics are needed. Generally, these statistics are created by either aggregating the point and travel time statistics described above, or by using systems such as that developed by the Texas Transportation Institute (TTI) for its Federal Highway Administration (FHWA) annual Urban Mobility Report. TTI takes readily available, annualized volume data contained in the federal government's Highway Performance Monitoring System (HPMS) and applies generalized equations that predict the amount of congestion which will occur, given the volume-to-capacity ratios identified. Simple assumptions underlie the TTI equations to estimate the benefits resulting from implementation of various operational improvements.

In most cases, area-wide congestion is reported in terms such as

- Person-hours of delay
- Delay per person
- Percentage of congested lane-miles

These statistics are similar to those found in the point measures discussion above. The primary difference is that these computations usually rely on sparse data, to which very significant assumptions are applied. The outcome tends to be a useful number, but one that is more heavily influenced by the assumptions made than by the true performance of the roadway system.

To perform this system wide reporting task, Metropolitan Atlanta's MPO, the Georgia Regional Transportation Authority (GRTA), developed a single "transportation performance index" that combines a series of other indices which cover four basic topics: roadway services, roadway safety, roadway emissions, and transit service. Twelve inputs are combined as part of this process to produce a single index which can be used to judge the relative change in the performance of the metropolitan transportation system across multiple modes, and relative to key policy objectives (e.g., congestion relief, air quality improvement, and safety.)[15] However, due to questions related to the usefulness of this statistic in supporting transportation-related decision making, it will no longer be used as part of future GRTA performance reports.

Area-wide statistics are good for reporting simplified concepts to the press, but they are insufficiently accurate for making good congestion management-related decisions. Therefore, they play a key public information role. However, general public information should not be confused with providing key decision making support. Consequently, these statistics simply lack both the accuracy and precision needed to support congestion management decisions.

[15] The exact formula which weighs the different indices that make up the overall GRTA index are currently being reconsidered. The formula incorporates the travel time index, planning time index, daily vehicle miles traveled, two types of transit revenue service hour measures, transit passenger miles traveled, transit passenger boardings, vehicle based NOx emissions, vehicle based VOC emissions, vehicle based PM2.5 emissions, traffic crash fatality rates, and pedestrian and bicyclist fatality rates per 100,000 population.

3. <u>Reporting Statistics</u>

There are two basic types of congestion reporting statistics. The first simply uses select performance measures to report on current conditions. The second grades that performance against some adopted set of standards or performance objectives. Many agencies initially select performance measures and report on them for a few periods before setting a standard or threshold.

The first of these reporting techniques, <u>performance reporting</u>, is essential for evaluating the status of the roads being monitored. When a new version of the congestion report is produced, a comparison of this year's report with previous years' reports allows a region to track how roadway performance is changing over time.

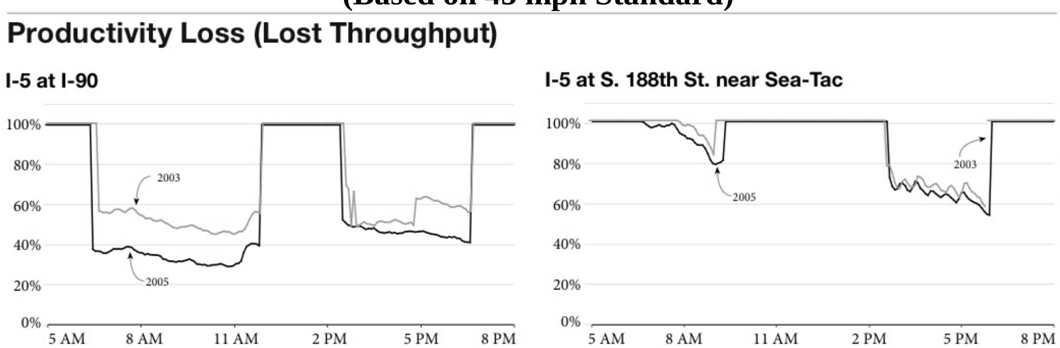
WSDOT presents a considerable amount of this type of data in its Grey Notebook[16] (GNB). The GNB contains a variety of tables and graphics and includes many of the statistics described above, including mean and 95th travel times (see Figure A-1) and lost productivity (see Figure A-2).

Figure A-1: Travel Time Table from WSDOT's GNB

***EVENING*: Key Commute Routes: Changes in Travel Time Performance, 2003 to 2005**

				Travel Time (in minutes)	Average Peak Travel Time (in minutes)			95% Reliable Travel Time (in minutes)			Ratio of Peak Travel Time to Maximum Through-put Travel Time		Traffic Volume Peak Hour	Duration of Peak Period (hours and minutes that average speed falls below 70% of posted speeds)		
											MT³I					
Route	Route Description	Peak time	Length (Miles)	At Posted Speeds	2003	2005	Change (%)	2003	2005	Change (%)	2003	2005	Change (%)	2003	2005	change (in minutes)
From Seattle																
I-5	Seattle to Everett	5:20 PM	23.7	24	42	46	10%	60	68	13%	1.5	1.7	-2%	3:05	3:30	25
I-5	Seattle to Federal Way	5:15 PM	22.1	22	34	37	9%	51	55	8%	1.3	1.4	-2%	1:40	2:05	25
I-5/I-90	Seattle to Issaquah	5:25 PM	15.7	16	22	24	9%	32	36	13%	1.2	1.3	5%	*	0:15	*
I-5/SR 520	Seattle to Redmond	5:25 PM	14.7	16	27	30	11%	37	43	16%	1.5	1.6	0%	2:05	3:15	70

Figure A-2: Example Lost Productivity Graphics from WSDOT's GNB (Based on 45 mph Standard)



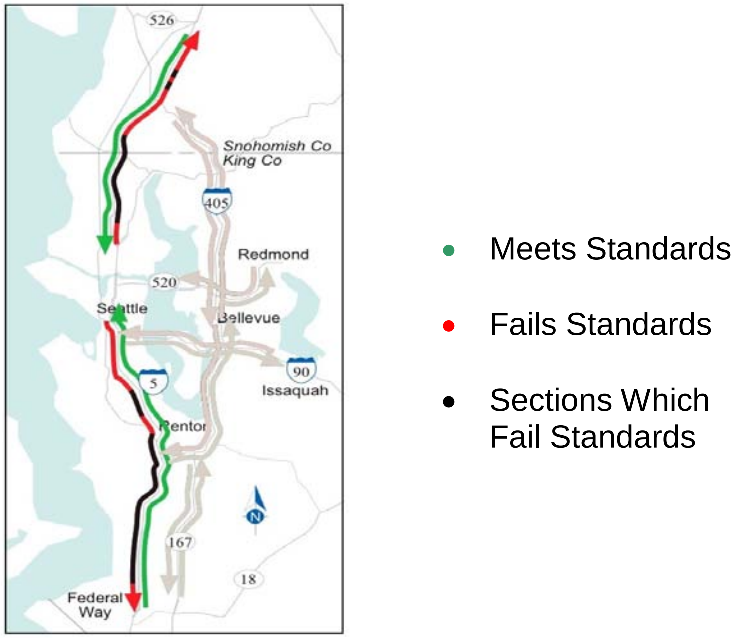
[16] http://www.wsdot.wa.gov/accountability/

If specific roadway performance objectives are adopted, in addition to being able to track changes in roadway performance, the region can determine how effectively the desired outcomes are being met. The second style of report, <u>objective attainment reporting</u>, both identifies how effectively the region is meeting its goals and objectives and sets a minimum list of "regional needs" for the congestion management process. That is, it identifies the facilities that do not currently meet the performance objectives or regional needs. As a first step towards setting these objectives, many agencies have adopted "reporting standards" as opposed to "performance policies" or criteria. For example, WSDOT reports how frequently major freeway corridors operate below an average of 35 mph. Although the agency has not adopted 35 mph as a specific policy objective, it has informally adopted the 35 mph statistic as "the point at which congestion is bad enough to be worth noting."

For arterials, the selection of a congestion threshold is further complicated by the fact that different arterials are governed both by different speed limits and by the effects of traffic signal timing. Setting arterial standards is further muddled by the very different expectations placed on them in different parts of the region. In ex-urban areas, roads are often expected to be less congested than in central core areas, if for no other reason than that they can often be expanded more readily in areas that have not been fully developed, whereas additional right-of-way is often not available in fully developed parts of the region. Therefore, a single "average speed" criterion for arterials is generally not applicable.

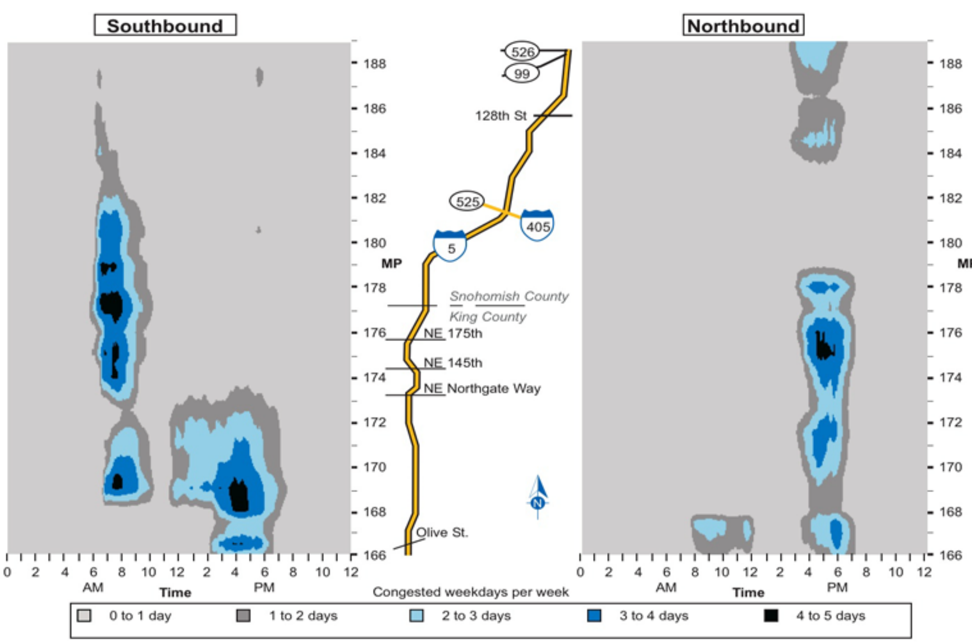
Once reporting standards, have been set, this approach to defining congestion has the advantage that simple, easily understood geographic representations of the existing failure points become possible. Figure A-3 (below) shows an illustration of where the Puget Sound region's I-5 HOV lanes fail their adopted performance standards. In this figure, the green lines indicate HOV corridors that meet the adopted standard (45 mph operation more than 90 percent of the time) during the PM peak period. The red lines show which I-5 HOV corridors fail that standard, and the black sections within the red lines indicate the locations of specific congestion points that cause the failure of the performance standard. As can be seen, a considerable portion of the two failing HOV corridors are congested. Thus, it is fairly easy to conclude that minor "fixes" to the I-5 HOV lanes will not restore these lanes to their desired level of performance.

Figure A-3: Performance of I-5 HOV Lanes, 2006 PM Peak Period



Another technique for displaying data is through use of a contour graphic (as in Figure A-4), which presents both the time and location of congestion along I-5.

Figure A-4 – Contour Map Illustrating the Frequency with which I-5 Fails the Selected Performance Standard



As shown in WSDOT's GNB tables, these same types of statistics can be shown in tabular format and with specific numeric values, rather than as colored graphics. The choice between these two display techniques is simply a function of the level of detail and precision that it is needed versus the visual simplicity desired.

4. Recommendations for Reporting Congestion

The previous section discussed the benefits that can be gained from setting standards and objectives that define when "congestion" has begun. This section summarizes what other regions and agencies have adopted in terms of a "definition of congestion" and makes recommendations about these concepts to MAG.

A. Freeways

Point Congestion

Freeway characteristics are such that freeways tend to operate at free flow speeds (LOS A, B, and C) until they near capacity. As they near capacity, traffic speeds drop to around 45 to 50 mph (LOS D and the E), depending on the geometry of the roadway. Under pressure from either additional traffic volume or some type of flow disruption, speeds then drop dramatically to essentially stop-and-go conditions (LOS F), after which speeds gradually recover as the disruption is cleared or traffic volumes decline.

This pattern leads to two simple "technical" choices for defining congestion. A freeway can be considered "congested" once enough vehicles are present to slow traffic below free flow levels (~55 mph), or it can be congested once traffic breaks down (below ~45 mph). Most regions use the 45 mph standard (or beginning of forced flow) as their definition of congestion at a point.

Travel Time-Based

For travel times, this same "congestion definition" can be used, but it lacks the theoretical underpinnings that exist for point locations. This is because a 10-mile trip that has one congestion point in it is likely to result in an average that is considerably faster than 45 mph. So, is such a trip a "congested trip" or not?

Most agencies that have adopted some type of freeway congestion definition have done so by first considering whether the definition would be used as a policy objective or simply a reporting standard. Where it is a policy objective, the specific intent of that objective will define the reporting standard used. If on the other hand, the congestion definition is simply for reporting purposes, the adopted reporting standard is generally viewed as an effort to identify specific conditions which the agency is interested in tracking. So, for example, in Washington, policy makers decided to identify any trip made at less than 35 mph for the entire freeway segment of the trip as "congested." Given that heavy congestion, even on short segments, may result in travel speeds of below 10 mph for that segment (and the Puget Sound region has many of these bottleneck locations), a standard set above 35 mph was thought to have the potential to make the roadways look “too congested” and might result in more harm being done than good in terms of public opinion.

However, for the HOV lane system, this standard was deemed too “lenient.” Because the transit systems in the region depend heavily on the HOV lane, they were interested in both a faster and more reliable travel time (because the reliability of the trip has a significant effect on the number of buses and drivers they must schedule). As a result, a policy objective was chosen stating that the HOV lane should operate at 45 mph, 90 percent of the time. This standard was then adopted as the reporting criteria for the HOV lane.

Given the significant level of congestion in the region, applying this criterion to the general purpose freeway lanes would mean that not only would most freeways in the region be considered to be out of compliance with the standard, but that they would have little chance of ever being brought into compliance given the geographic limitations in expanding the freeway right-of-way. As a result, the 35 mph speed criterion, described above, was selected for reporting general purpose freeway flow.

The HOV standard raises one other definitional issue, reliability. The HOV policy sets a congestion standard both for a single trip (45 mph) and for an annual condition (90 percent of trips). Many agencies are now starting to consider the use of reliability measures. However, outside of special cases like HOV lanes, few have adopted specific congestion standards that mention reliability.

Our initial suggestion would be for MAG to adopt a similar approach. Set a “reporting standard” and then measure and report both mean travel times, 80^{th} and/or 95^{th} percentile travel times, and the frequency with which monitored roadways fall below the given reporting standard (likely 45 mph). The exact reporting standard to be selected would require additional discussion.

B. <u>Arterials</u>

<u>Point Congestion</u>

Many jurisdictions around the country set intersection performance levels. Most commonly, those adopted performance objectives are expressed in terms of LOS. LOS is easily understood by traffic engineers and is easily computed for average conditions on the basis of commonly available volume statistics.

The primary limitation of LOS is that it does not address the day-to-day variation in intersection performance. When based on traditionally collected traffic volume statistics, LOS computations also do a mediocre job of describing how well actuated traffic control algorithms are working, as well as the effect of the various kinds of flow disruptions (incidents, accidents, construction, etc.).

A more robust point measurement of congestion is the number of signal cycle failures occurring during a specific time period. Similarly, the queue size being experienced on intersection approaches during those time periods can also be used. Unfortunately, these techniques for describing intersection congestion are only appropriate if an agency's traffic signal system can produce these types of statistics with existing traffic detection equipment.

Consequently, our initial recommendation is for MAG to report on intersection LOS on the basis of volume data, with the intent of adopting more robust and descriptive congestion measures as new data sources become available.

Travel Time-Based

Because of the effects of signal delay, travel times on arterials are far more variable than on freeways. It is therefore necessary to collect a considerable amount of travel time data on arterials in order to develop an "average" travel time that can be tracked to measure changes in performance with statistical confidence. Nevertheless, where arterials are being used for major regional movements, we believe that, at a minimum, performance reporting of key arterial travel times is necessary.

While the Highway Capacity Manual provides guidance concerning the arterial travel times that should be met at specific levels of service, in practice few agencies actively monitor and report on these standards.