Analysis, Modeling, and Simulation (AMS) Testbed Development and Evaluation to Support Dynamic Mobility Applications (DMA) and Active Transportation and Demand Management (ATDM) Programs

AMS Testbed Selection Report

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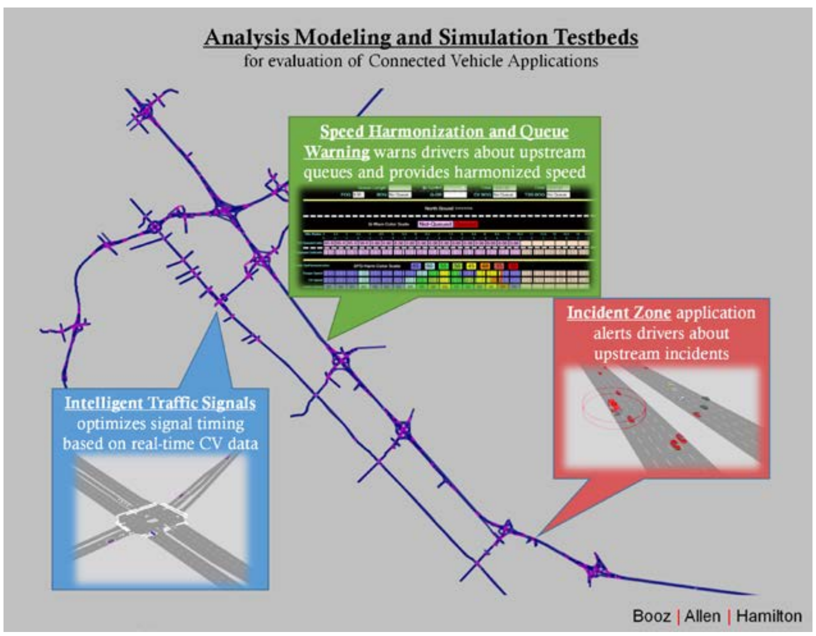

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16. Abstract

The primary objective of this project is to develop multiple simulation Testbeds/transportation models to evaluate the impacts of DMA connected vehicle applications and the active and dynamic transportation management (ATDM) strategies. The outputs (modeling results) from this project will help USDOT prioritize their investment decisions for DMA and ATDM programs.

The primary purpose of this report is to document the AMS Testbed selection process. Four AMS Testbeds were selected to form a diversified portfolio to conduct a detailed evaluation of DMA and ATDM concepts. Additionally, based on stakeholder feedback, two high-priority Testbeds were also added to the portfolio. The six testbeds are – (1) San Mateo (CA), (2) Phoenix (AZ), (3) Dallas (TX), (4) Pasadena (CA), (5) Chicago (IL), and (6) San Diego (CA).

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Preface/Acknowledgments

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Executive Summary

The United States Department of Transportation (USDOT) initiated the Active Transportation and Demand Management (ATDM) and the Dynamic Mobility Applications (DMA) programs to achieve transformative mobility, safety, and environmental benefits through enhanced, performance-driven operational practices in surface transportation systems management. In order to explore a potential transformation in the transportation system's performance, both programs require an Analysis, Modeling, and Simulation (AMS) capability. AMS tools and methodologies offer a cost-effective approach to address complex questions on optimization of long-range investments, short-term operational practices, and overall system performance. Capable, reliable AMS Testbeds provide valuable mechanisms to address this shared need by providing a laboratory to refine and integrate research concepts in virtual computer-based simulation environments prior to field deployments. A joint DMA/ATDM AMS Testbed can make significant contributions in identifying the benefits of more effective and active systems management resulting from integrating transformative applications enabled by new data from wirelessly connected vehicles, travelers, and infrastructure.

The primary purpose of this report is to document the AMS Testbed selection process, and to recommend Testbeds for analysis plan development. The objective of the AMS Testbed selection task is to select multiple (targeting between three and five, with an absolute minimum of two) U.S. based AMS Testbed sites for evaluating the DMA and ATDM concepts. The AMS Testbeds will be virtual computer-based environments in a laboratory setting to facilitate detailed modeling/analysis. The Testbeds will not be directly connected to the systems, algorithms, or TMC operators. However, the AMS Testbed will be as close to real-world as possible by modeling an actual metropolitan region's transportation system and transportation demand (e.g., persons, vehicles, transit) and developed by building off existing and previous AMS capabilities and modeling efforts

The foundational work conducted for the DMA and ATDM programs revealed a number of technical risks associated with the development of an AMS Testbed to facilitate detailed evaluation of the DMA and ATDM concepts. Therefore, instead of selecting one Testbed, it is desirable to identify a portfolio of AMS Testbeds to mitigate the risks of a single Testbed approach, and avoid a single point of failure for the estimation of integrated impacts of implementing DMA bundles and ATDM strategies.

While the AMS team understands that more Testbeds provide more benefits to the overall program, it is imperative that the AMS team limit the number of Testbeds chosen due to schedule and resource limitations. While identifying the Testbed portfolio, it is important to ensure that a diverse portfolio is created to enable testing DMA applications and ATDM strategies to support AMS activities and collectively meet the maximum number of AMS requirements with minimal risks.

At the conclusion of the AMS Testbed selection process, AMS Testbed project team selected **six (6)** AMS Testbeds to form a diversified portfolio to evaluate the impact of DMA and ATDM concepts. It should be noted that the AMS Testbeds selected are not to be considered superior to the AMS Testbeds which were not selected as an outcome of the screening process. Rather, the portfolio of Testbeds selected collectively meets the project needs and provides the diversity needed among the Testbeds to mitigate project risks.

While the AMS Testbed Team believes that the recommended Testbeds possess the capabilities to test DMA Applications and ATDM strategies within an AMS Testbed, it may be necessary to re-evaluate the Testbeds after the analysis plans are developed. If the analysis plan for any recommended Testbed reveals large gaps which may impact the success of the AMS Testbed activities, it behooves the AMS Testbed team to develop an analysis plan for another Testbed and evaluate gaps. Therefore, the AMS Testbed Team plans to reserve additional Testbeds for further consideration after the analysis plan development phase.

The AMS Testbed Team performed gap analysis using the six recommended Testbeds. This analysis revealed that most of the detailed requirements can be met with one or more of the six recommended Testbeds. This indicates that the selected Testbeds are well suited to conduct AMS activities. Based on the detailed screening process, the AMS Testbed team recommends that the following six Testbeds be chosen for analysis plan development.

- San Mateo, CA (US-101) as a tactical facility scale Testbed
- Pasadena, CA as a tactical city scale Testbed
- ICM Dallas, TX as a strategic corridor scale Testbed
- Phoenix, AZ as a strategic regional Testbed
- Chicago, IL as a weather-related strategy regional Testbed
- ICM San Diego as a strategic corridor scale Testbed with online prediction.

In addition, it is recommended that **SHRP 2 Sacramento, and Northern Virginia** Testbeds be considered as reserve Testbeds that can be used for further consideration, if the analysis plans developed using the above six Testbeds reveal any major gaps.

Chapter 1. Introduction

1.1 Background

The United States Department of Transportation (USDOT) initiated the Active Transportation and Demand Management (ATDM) and the Dynamic Mobility Applications (DMA) programs to achieve transformative mobility, safety, and environmental benefits through enhanced, performance-driven operational practices in surface transportation systems management. In order to investigate the potential transformation in transportation systems' performance, both programs require an Analysis, Modeling, and Simulation (AMS) capability. AMS tools and methodologies offer cost-effective approaches to address complex questions on optimization of long-range investments, short-term operational practices, and overall system performance. Capable, reliable AMS Testbeds provide a valuable mechanism to address this shared need by providing a laboratory for the refinement and integration of research concepts in a virtual computer-based simulation environment prior to field deployment. A joint DMA-ATDM AMS Testbed can make significant contributions in identifying the benefits of more effective, and active systems management resulting from integrating transformative applications enabled by new data from wirelessly connected vehicles, travelers, and infrastructure.

The objectives of this project are to—

1. Develop and calibrate multiple AMS Testbeds.
2. Evaluate the system wide impacts of individual and logical combinations of DMA bundles, and identify conflicts and synergies in order to maximize benefits.
3. Evaluate the system wide impacts of individual and logical combinations of ATDM strategies, and identify conflicts and synergies in order to maximize benefits.
4. Evaluate the impacts of the DMA bundles and ATDM strategies when prediction and active management are coupled with data capture and communications technologies that can systematically capture the motion and state of mobile entities, and enable active exchange of data with and between vehicles, travelers, roadside infrastructure, and system operators.

The AMS Testbed Team envisions three distinct phases within the project. In Phase I (Tasks 3, 4, and 5), the Testbed will be identified based on the detailed requirements and Testbed selection will be finalized after the development of detailed Testbed specific analysis plans. In Phase II (Task 6), a detailed evaluation plan be developed; in Phase III (Tasks 7, 8, 9, 10, and 13), the modeling activity will be conducted.

The purpose of this Task 4 report is to document the AMS Testbed selection process. The selected AMS Testbeds will be implemented in a laboratory setting that mimics traffic operations and decisions made by Traffic Management Centers (TMC) by utilizing historical and newly collected Testbed data, state-of-the-art modeling technologies, and deployment of combinations of DMA bundle applications and ATDM strategies to create a variety of operational scenarios. Performance measures generated by AMS Testbeds will be evaluated to determine the efficiencies of the DMA bundles and ATDM strategies when implemented individually or as a combination.

The foundational work conducted for the DMA and ATDM programs revealed a number of technical risks associated with the development of an AMS Testbed to facilitate detailed evaluation of the DMA and ATDM concepts. Therefore, instead of selecting one Testbed, it is desirable to identify a portfolio of AMS Testbeds to mitigate the risks of a single Testbed approach, and avoid a single point of failure for the estimation of integrated impacts of implementing DMA bundles and ATDM strategies.

While the AMS team understands that more Testbeds provide more benefits to the overall program, it is imperative that the AMS team limit the number of Testbeds chosen due to schedule and resource limitations. While identifying the Testbed portfolio, it is important to ensure that a diverse portfolio is created to enable testing DMA applications and ATDM strategies to support AMS activities and collectively meet the maximum number of AMS requirements with minimal risks.

1.2 Report Organization

The purpose of this report is to document the AMS Testbed selection process. This document is organized into four chapters:

- **Chapter 1** of this report provides project background information, the purpose of this report, definitions and terms, and applicable and referenced documents.
- **Chapter 2** describes the overall process used to evaluate and select Testbeds to support AMS activities for DMA and ATDM programs.
- **Chapter 3** details Phase I Testbed evaluation. It presents the screening criteria, provides an assessment of candidate Testbeds based on the screening criteria, presents a description of the Testbeds evaluated in Phase II, and makes final recommendations for detailed Phase II evaluation.
- **Chapter 4** details the Phase ll analysis of Testbeds based on a detailed, requirements-level analysis.
- **Chapter 5** presents final conclusions, recommendations, and next steps.

1.3 Definitions and Key Terms

Active Transportation and Demand Management — ATDM is the dynamic management, control, and influence of travel demand and traffic flow on transportation facilities. Under an ATDM approach, the transportation system is continuously monitored, and through the use of available tools and assets, traffic flow is managed and traveler behavior influenced in real time to achieve operational objectives.

Analysis, Modeling, and Simulation (AMS) — A tool or a group of tools used for conducting analysis, modeling, and simulation for evaluating alternatives. The AMS process replicates the entire chain, which represents a series of decisions that affect transportation demand and utilization of the network. It also represents the points at which actions may influence travel activities.

AMS Testbed— An AMS Testbed as envisioned here refers to a set of computer models that can replicate the effects of public agencies and the private sector in a region implementing concepts, bundles, and strategies associated with the DMA and ATDM Programs. The AMS Testbed will be implemented in a laboratory setting in that the modeling conducted will not be directly connected to the systems, algorithms, or TMC operators that make real-time traffic management decisions. These decisions will, however, be emulated by the AMS Testbed. A Real-World Testbed is, however, directly connected to the systems, algorithms, or TMC operators that make real-time traffic management decisions.

Dedicated Short Range Communications (DSRC)— A short-to-medium-range one-way or two-way wireless protocol. In October 1999, the United States Federal Communications Commission (FCC) allocated 75MHz of spectrum in the 5.9GHz band to be used by Intelligent Transportation Systems.

Dynamic Mobility Applications— The DMA program seeks to identify, develop, and deploy applications that leverage the full potential of connected vehicles, travelers, and infrastructure to enhance current operational practices and transform future surface transportation systems management. Six high-priority DMA bundles have been identified to potentially improve the nature, accuracy, precision, and/or speed of dynamic decision-making by system managers and system users. They are Enable Advanced Traveler Information System (EnableATIS), Freight Advanced Traveler Information System (FRATIS), Integrated Dynamic Transit Operations (IDTO), Intelligent Network Flow Optimization (INFLO), Multi-Modal Intelligent Traffic Signal System (MMITSS), and Response, Emergency Staging and Communications, Uniform Management and Evacuation (R.E.S.C.U.M.E.).

On-Board Equipment (OBE)— A DSRC in-vehicle safety device that generates vehicle-to-vehicle (V2V) safety messages and receives and processes V2V and vehicle-to-infrastructure (V2I) messages via its DSRC communication links.

Roadside Equipment (RSE)— A DSRC device that has one or more 5.9 GHz DSRC radio sets, with each set capable of simultaneously supporting two DSRC radio channels for V2I message transmission. One channel on each radio set will be used for the transmission of low latency time-critical safety messages, and the second channel will be used for transmission of other messages such as communication for security credentials and security management.

1.4 Referenced Documents

The documents referenced for the development of AMS Testbed selection criteria are listed below:

1. AMS Testbed Requirements for DMA and ATDM Programs, Final Report, USDOT, November 2013.
2. AMS Framework for DMA and ATDM Programs, Final Report, USDOT, May 2, 2013.
3. AMS Preliminary Evaluation Plan for DMA Program, Final Report, USDOT, November 2013.
4. AMS Preliminary Evaluation Plan for ATDM Program, Final Report, USDOT, November 2013
5. Active Transportation and Demand Management Foundational Research, Analysis Plan, Final Report, USDOT, June 27, 2013.
6. Potential AMS Testbed Candidates Initial Screening, Final Report, USDOT, November 2013.

1.5 Previous Research

The AMS Testbed project builds on the (1) “AMS Testbed Planning to Support DMA and ATDM Programs” *(henceforth, referred to as “AMS Testbed Planning Study” in this report)* led by Noblis and the (2) ATDM Foundational Research project led by Booz Allen Hamilton.

As a part of the AMS Testbed Planning Study,

- A high-level AMS framework for the AMS Testbed was developed based on high-level functional requirements [2]. The framework consists of system modules which represent an abstract version of the overall transportation system. This framework serves to highlight both the hypotheses posited by the DMA and ATDM programs, and is to be used to evaluate AMS Testbed alternatives.

- The AMS Preliminary Evaluation Plan for the DMA Program [3] and for the ATDM Program [4] identified a group of key research questions that correspond to the set of DMA Program hypotheses and a set of research questions for ATDM strategies [5]. USDOT envisions these questions to be addressed and these hypotheses to be tested through AMS Testbed development and evaluation activities.
- A list of nine potential candidate AMS Testbeds were identified [6] based on a set of Testbed evaluation criteria.

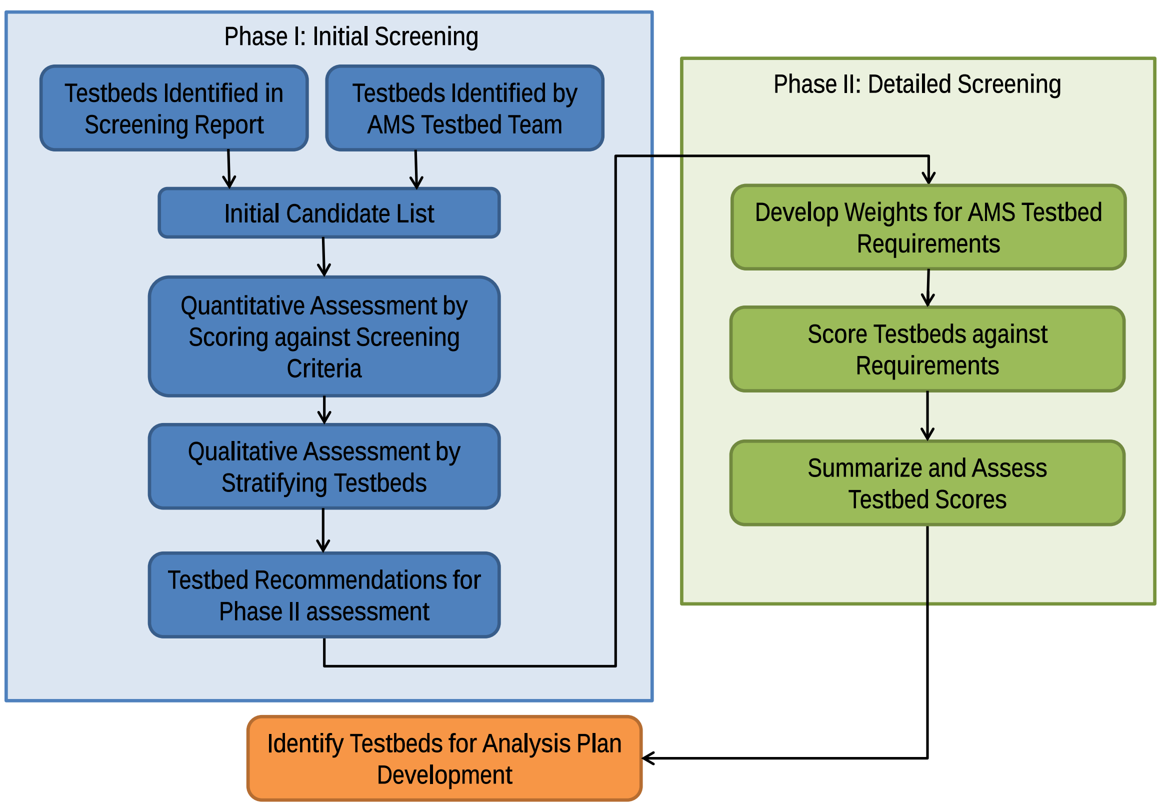
Chapter 2. Testbed Selection Process Overview

This chapter describes the overall process used to evaluate and select Testbeds to support AMS activities for DMA and ATDM programs. The objective is to evaluate the suitability of the Testbeds to support the DMA-ATDM concept evaluation.

USDOT's recently completed "AMS Testbed Planning" effort identified a set of functional requirements that need to be collectively met by the AMS Testbeds. This effort and the AMS foundational work conducted by USDOT for the DMA and ATDM program revealed high levels of technical risk in meeting all DMA and ATDM AMS Testbed modeling requirements, particularly by a single Testbed. In order to mitigate the technical risks, instead of selecting a single Testbed, it is desirable to identify a portfolio of AMS Testbeds and avoid a single point of failure for the estimation of integrated impacts of implementing DMA bundles and ATDM strategies.

The Testbed Selection process helps identify a portfolio of Testbeds which provides diversity in technical approaches and geographic scope of analysis. Exhibit 1 presents the overall approach to identifying and selecting the portfolio of Testbeds.

Exhibit 1: Testbed Selection Process [Source: Booz Allen Hamilton]



As shown in Exhibit 1, the selection process was conducted in two phases. Phase I evaluation process includes the following steps.

- **Step 1:** Identify the candidate AMS Testbeds
- **Step 2:** Perform a quantitative assessment of the candidate Testbeds by scoring the Testbeds against how well they meet the screening criteria developed by the Testbed team
- **Step 3:** Conduct a qualitative assessment of Testbeds by stratifying the Testbeds using key characteristics
- **Step 4:** Use the findings from quantitative and qualitative assessments to recommend candidate list for Phase II evaluation.

It is to be noted that the Phase I screening was conducted to down-select the candidate Testbeds and eliminate Testbeds that do not adequately meet the project needs prior to subjecting the Testbeds to detailed evaluation in Phase II. The Phase II evaluation process includes the following steps.

- **Step 1:** Develop weights to indicate the relative importance of AMS Testbed requirements developed in Task 3.
- **Step 2:** Rate candidate Testbeds (identified in step 1 above) against each requirement to determine the overall suitability of the Testbed to be used for AMS activities to support DMA and ATDM programs. Multiply the requirement weight generated in Step 1 with the Testbed rating for the requirement to generate the score for each Testbed.
- **Step 3:** Conduct an assessment of Testbeds scores to identify final list of Testbeds and recommend to USDOT.

The final output of this phase was a recommendation of a portfolio of Testbeds for analysis plan development. The sections below describe the Testbed selection process in detail.

Chapter 3. Phase I: Testbed Selection

As described earlier, Phase I evaluation includes the following steps:

- **Step 1:** Identify the candidate AMS Testbeds
- **Step 2:** Perform a quantitative assessment of the candidate Testbeds by scoring the Testbeds against how well they meet the screening criteria developed by the Testbed team
- **Step 3:** Conduct a qualitative assessment of Testbeds by stratifying the Testbeds using key characteristics
- **Step 4:** Use the findings from quantitative and qualitative assessments to recommend candidate list for Phase II evaluation.

Prior to subjecting the Testbeds to a more detailed evaluation in Phase II, this process was conducted to select candidate Testbeds and eliminate Testbeds which do not adequately meet the project needs.. This section presents a detailed overview of the Phase I Testbed selection process and the results.

3.1 Identifying Candidate Testbeds

The Testbed Planning effort conducted by USDOT, identified a preliminary list of candidate Testbeds (sites) and selected from that list the best sites. This initial screening research [6] considered a total of 21 Testbed candidates before narrowing them down to nine Testbeds. The evaluation criteria used for initial screening of potential AMS Testbed candidates are listed below:

1. **Geographic Scope-**
   The Testbed location shall be capable of generating data for sufficient geographic scope to represent the impacts of the DMA and ATDM applications and strategies. The location shall be of sufficient complexity to include multiple facilities (e.g., freeways, arterials, parking facilities, intermodal terminals) and offer feasible options for route diversions.
2. **Temporal Scope-**
   The Testbed location shall be capable of generating data of sufficient temporal scale, such as congestion buildup and dissipation, completion of freight and transit trips, incident clearance, and changes in trip departure times or tour-making, to represent the impacts of the DMA and ATDM applications and strategies.
3. **Temporal Resolution-**
   The Testbed location shall be capable of generating data of sufficient temporal resolution, such as generating sufficient data to model the location using a microscopic model or a communications model, or to model and represent the impacts of DMA and ATDM applications and strategies.
4. **Multi-Modal-**
   The Testbed location shall include multiple modes to represent impacts of mode shifts and/or transit operations, High Occupancy Vehicle (HOV) lane operations, etc.

5. **Level of Congestion-**
   The Testbed location shall have significant congestion that necessitates finding solutions achievable through DMA and ATDM applications and strategies.
6. **Multi-Source-**
   The Testbed location should be capable of generating data needed for AMS from multiple sources, including data from existing in-roadway sensors and over-roadway sensors, data from wireless communications (such as DSRC, cell phones, Bluetooth, Wi-Fi), travel demand data, data on traveler behaviors/choices, transit-specific data, freight-specific data, and road-weather data. The Testbed location shall also have archives of quality data for calibration, preferably for each component of the AMS Testbed Framework.
7. **Calibrated AMS Models-**
   The Testbed location shall have corresponding AMS and/or communications models that are available for use by others and are well calibrated using data within the last 10 years.
8. **Ease of Adaptability-**
   The Testbed location shall be capable of allowing AMS tools and communications models to be developed or enhanced for accommodation of DMA applications and ATDM strategies and shall not be constrained by schedules of other efforts.
9. **Existing Deployments and/or Research-**

   The Testbed location should have ATDM strategies in operation and/or research and testing of DMA applications planned or in place.

Upon applying the above screening criteria, the following Testbeds were identified as the candidate AMS Testbeds to support DMA and ATDM evaluation.

1. Integrated Corridor Management (ICM) San Diego, CA (ICM San Diego)
2. ICM Dallas, TX (ICM Dallas)
3. Test Data Set Pasadena, CA (Pasadena)
4. Connected Vehicle (CV) Testbed Anthem, AZ (Anthem)
5. CV Testbed Palo Alto, CA (Palo Alto)
6. Strategic Highway Research Program 2 (SHRP2) C10 Sacramento, CA (SHRP2 Sacramento)
7. Weather-Chicago, IL (Chicago)
8. CV Testbed Novi, MI (Novi)
9. SHRP2 C10 Jacksonville, FL (SHRP2 Jacksonville)

The AMS Testbed Team performed a thorough investigation of additional Testbeds not previously considered, and this investigation revealed that some of existing Testbeds were not fully developed when the initial screening process was conducted. These Testbeds, however are suitable candidates to be considered for AMS Testbed development, and therefore expanded this initial list. It is to be noted that the AMS Testbed Team familiarity with these Testbeds is high. As a result the team is very familiar with the risks and can plan to mitigate the risks. The following lists the additional 5 Testbeds to be considered:

1. Phoenix, AZ (Phoenix)
2. Multimodal Adaptive Control Testbeds (Tucson, AZ; Clearwater, FL) (Tucson and Clearwater)
3. Columbus, Ohio (Columbus)
4. Northern Virginia Testbed (Northern Virginia)
5. San Mateo, CA Testbed (US-101)

3.1.1 Final Candidate Testbed List

The final list of candidate Testbeds considered for further evaluation **included** the nine Testbeds identified by USDOT during the Initial screening along with the five Testbeds that the project team identified. These fourteen Testbeds were assessed based on the preliminary criteria developed for scoring the Testbeds. This section provides a briefing of these criteria as well as the scores obtained by the Testbeds. The complete list of candidate Testbeds is listed below.

- Integrated Corridor Management (ICM) San Diego, CA (ICM San Diego)
- ICM Dallas, TX (ICM Dallas)
- Test Data Set Pasadena, CA (Pasadena)
- Connected Vehicle (CV) Testbed Anthem, AZ (Anthem)
- CV Testbed Palo Alto, CA (Palo Alto)
- Strategic Highway Research Program 2 (SHRP2) C10 Sacramento, CA (SHRP2 Sacramento)
- Weather-Chicago, IL (Chicago)
- CV Testbed Novi, MI (Novi)
- SHRP2 C10 Jacksonville, FL (SHRP2 Jacksonville)
- Phoenix, AZ (Phoenix)
- Multimodal Adaptive Control Testbeds (Tucson, AZ; Clearwater, FL) (Tucson and Clearwater)
- Columbus, Ohio (Columbus)
- Northern Virginia Testbed (Northern Virginia)
- US-101, CA Testbed (US-101)

Exhibit 2 presents the candidate Testbed description and characteristics overview.

Exhibit 2: Summary description of Candidate Testbeds

ID	Name	State	Climate Region	Model Type	Coverage	Demand	Route Assignment/Network	Comm. Model
1	SHRP2 Sacramento	CA	West	Strategic	Region	ABM	DTA/Meso	No
2	SHRP2 Jacksonville	FL	SE	Strategic	Region	ABM	DTA/Meso	No
3	Chicago	IL	Central	Strategic	Region	4-Step	DTA/Meso	No
4	Phoenix	AZ	SW	Strategic	Region	ABM	DTA/Micro	No
5	Anthem	AZ	SW	Tactical	Arterial	No	No/Micro	Yes
6	Palo Alto	CA	West	Tactical	Arterial	No	No/Micro	Yes
7	Novi	MI	Central	Tactical	County	No	No/Micro	Yes
8	US-101	CA	West	Tactical	Freeway	No	No/Micro	Yes
9a	Tucson	AZ	SW	Tactical	Arterial	No	No/Micro	No

ID	Name	State	Climate Region	Model Type	Coverage	Deman d	Route Assignmen t/Network	Comm. Model
9b	Clearwater	FL	SE	Tactical	Arterial	No	No/Micro	No
10	ICM San Diego	CA	West	Strategic	Corridor	4-Step	DTA/Micro	No
11	ICM Dallas	TX	South	Strategic	Corridor	4-Step	DTA/Meso	No
12	Pasadena	CA	West	Strategic	City	4-Step	DTA/Micro	No
13	Columbus	OH	Central	Strategic	Region	ABM	DTA/Micro	No
14	Northern Virginia	VA	SE	Strategic	Region	4-Step	DTA/Micro	No

Legend

1. Climate Region – See Exhibit 6 for a map of the nine Climate Regions in the Continental United States
2. Model Type
   a. Strategic = Model focuses on travel behavior (pre-trip, en-route or both)
   b. Tactical = Model focuses on accurately modeling individual vehicle/driving behavior
3. Coverage – Geographic scope of model zones and network
4. Demand Model Type
   a. No = Model does not compute demand changes due to congestion
   b. ABM = Activity- or tour-based model
   c. 4-Step = Conventional four-step model (trip generation, distribution, mode, route)
5. Assignment Method
   a. No = Model does not shift traffic to alternate routes
   b. SUE = Static user equilibrium
   c. DTA = Dynamic traffic assignment
6. Network Modeling Method
   a. Meso = Mesoscopic simulation (packets of vehicles)
   b. Micro = Microscopic simulation (individual vehicles)
7. Abbreviations:
   a. ASC = Adaptive Signal Control
   b. RDE = Research Data Exchange
   c. ICM = Integrated Corridor Management

CV = Connected Vehicle

3.2 Quantitative assessment of Candidate Testbeds

The 14 Testbeds identified as candidate Testbeds for conducting AMS activities have unique characteristics and strengths which make them viable Testbeds for the project. However, several Testbed-specific characteristics affect Testbed implementation and consequently impact implementation cost, schedule and risks. These Testbed-specific factors listed below need to be carefully evaluated as a part of the Testbed selection process in order to select the Testbeds and create a portfolio of Testbeds that meets the project objectives.

- **Testbed Travel Demand Model Characteristics -** AMS Testbeds need to replicate real-world transportation systems and travel behavior well in order to test DMA and ATDM concepts within an AMS framework. The Testbeds need to contain a transportation network that includes multiple types of facilities in order to test route choice. Testbeds also need to include a demand model to test trip-making behavior and a simulation model to test driving behavior. It is to be noted that the effects of future technologies such as connected vehicle technologies cannot yet be accurately captured by existing demand models since data to validate the demand models does not exist. The analysis plan to be developed (in Task 5 of this project) will have a more detailed discussion on how the short-term and long-term demand impact related to connected vehicle technology will be considered in the analysis.

- **Testbed Data Availability -** To evaluate the benefits of DMA and ATDM concepts, AMS Testbeds need to be validated and calibrated using historical, near-real-time, and real-time data. The data not only has to represent a Testbeds geographic and temporal scope and other characteristics as indicated in the previous section, but it also must represent V2V and V2I communication data flows. The types of available data are important factors in Testbed implementation.
- **Testbed Adaptability -** AMS Testbeds need to be extended to represent prediction and active management for ATDM strategies and communications systems for DMA bundles. This may involve the development of additional algorithms to test ATDM and DMA hypotheses. The adaptability of AMS Testbeds depends on the ease of enhancing modeling tools and the ease of adding additional model functions. Open-source, Application Programming Interface (API)-extensible, and/or well-documented software and models are examples of adaptable or extendable Testbed models. An AMS Testbeds ability to be adaptable or extendable offers more tolerances for implementation, shortens the implementation schedule, and reduces risks and cost.
- **Testbed Team's Familiarity -** The AMS Testbed Team is responsible for the development of the Testbed and evaluation of DMA bundles and ATDM strategies. Familiarity with the candidate Testbeds data and modeling tools significantly reduces the resources required for model enhancements, analysis and interpretation, and evaluation of DMA applications and ATDM strategies. This familiarity will ensure that resources are allocated for critical implementation tasks, and are not consumed during the process of developing an understanding of the AMS Testbed data and components.
- **Computational Efficiency and Testbed-Specific Risks -** The AMS Testbeds are envisioned to be able to utilize state-of-the-art computing techniques and to use computing resources effectively (i.e., to use techniques such as parallel processing). This ability will decrease model run times and ensure that resources are used for critical implementation and analysis tasks. It is also critical to ensure that the underlying AMS Testbed software is supported in the future and that the Testbeds do not use obsolete or soon-to-be defunct tools.

The initial screening conducted during the *Testbed Planning Study* used the criteria listed in Section 3.1. The criterion was used to do a qualitative assessment and support down selecting the Testbeds to address AMS Testbed needs at a high-level. The following criteria were developed based on the initial screening criteria, and supplementing them in order to further evaluate the Testbeds to meet the project needs. Criteria #1 through #5 below intrinsically capture the initial screening criteria while criteria #6 through #8 are additional criteria developed by the AMS Testbed team to supplement the initial screening criteria. Together, these criteria are envisioned to help select the best AMS Testbeds for development. The following lists and describes the criteria.

Criterion #1: *Does the Testbed location have sufficient* ***complexity****, include multiple facilities (e.g., freeways, arterials, parking facilities, and intermodal terminals), and offer feasible options for route diversions?*

***Criterion #2:** Does the **demand model** accurately represent travelers' trip-making choices prior to trip start in response to travel experiences?*

***Criterion #3:** Does the **mesoscopic/microscopic model** accurately represent tactical driving behavior and vehicle trajectories?*

***Criterion #4:** Does the candidate Testbed contain **archived real-time data** that can be used for validation and calibration? If data is not readily available, can additional data be easily collected?*

***Criterion #5:** Can **new algorithms** be easily developed and the existing tools interfaced with the new AMS components to be built?*

***Criterion #6:** What is the AMS Testbed Team's overall **familiarity** with the candidate Testbeds location, available data, models, and modeling tools? What are the impacts (schedule, risk, resources) of the lack of familiarity with the candidate Testbed?*

***Criterion #7:** Are the candidate Testbeds **computationally efficient** and capable of testing multiple scenarios quickly?*

***Criterion #8:** Are there any **other risks** associated with the candidate Testbeds, such as obsolete software, lack of access to models or tools, or possible lack of support for any of the tools used by the Testbed?*

Using the criteria listed above, an initial screening was conducted to down select Testbeds and eliminate any Testbeds with potential limitations in supporting AMS activities for DMA and ATDM programs. Each candidate Testbed was rated using the following four-scale (0-3) rating:

Scale Rating	Rating Definition
0. Does not meet	Testbed does not meet the criteria, and cannot be adapted to meet the criteria
1. Low	Testbed partially meets the criteria, and requires significant resources to be adapted to meet the criteria.
2. Medium	Testbed partially meets the criteria, and can be easily adapted to meet the criteria.
3. High	Testbed adequately meets the criteria, and requires minimal amount of resources to be adapted to meet the criteria

The original Testbed developers were contacted in most cases to score the Testbed against the eight criteria listed above. When the Testbed developer was not available, the AMS Testbed team scored the Testbeds using publicly available data. The preliminary scores were presented to USDOT and the feedback received was used to update or modify the scores in some cases. Stakeholder inputs were used to review and update the scores. Upon generating the scores, a stakeholder engagement meeting that included USDOT representatives and the project team was conducted to review the Testbed details. Exhibit 3 below shows the scores for the Testbeds.

Exhibit 3: Potential Testbeds' Ratings for the Eight Criteria

	Testbed / Criteria	1	2	3	4	5	6	7	8	Total
1	SHRP2 Sacramento	3	2	3	2	2	2	2	1	**17**
2	SHRP2 Jacksonville	1	3	3	2	2	3	2	2	**18**
3	Chicago	3	3	3	2	2	1	2	1	**17**
4	Phoenix	3	3	3	2	3	3	2	2	**21**
5	Anthem	1	0	3	2	2	1	3	1	**13**
6	Palo Alto	1	0	3	2	3	3	3	3	**18**
7	Novi	2	1	3	2	2	1	3	2	**16**
8	US-101	2	0	3	3	2	3	3	3	**19**
9a	Tucson	1	0	3	2	2	3	3	2	**16**
9b	Clearwater	1	0	3	2	2	3	3	2	**16**
10	ICM San Diego	3	1	3	3	2	1	3	2	**18**
11	ICM Dallas	3	1	3	3	2	3	3	2	**20**
12	Pasadena	2	2	3	3	3	3	2	2	**20**
13	Columbus	1	2	3	2	2	3	1	1	**15**
14	Northern Virginia	3	1	3	3	3	1	2	1	**17**

3.3 Qualitative assessment of the Candidate Testbeds

As part of Phase I, in addition to evaluating the Testbeds using the numerical scores assigned, a stratification of the Testbeds was also conducted to ensure that diversity in the Testbeds is achieved across the following key considerations

- Technical approach
- Geographic scope of analysis
- Climate type mix
- Metropolitan area size

Section below presents the stratification of Testbeds across the four considerations listed above.

3.3.1 Technical Approach

Each Testbed type has its strengths and weaknesses in performing ATDM and DMA analysis. Therefore, <u>it is highly desirable that our final set of Testbeds include one or more representatives from each of the model types</u>.

1. Strategic Models
2. Tactical Models
3. Multi-resolution Models
4. Communication/Management Latency Models

Strategic Models are ones that focus on predicting individual travelers' activity or trip decisionmaking process and how travelers will react to selection of mode, destination, and time-of-day choices (pre-trip and/or en-route travel information)

- These are typically **four-step** or **activity/tour based models** (ABM) covering a geographic area large enough to encompass all of the choices available to the traveler (trip generation, time-of-day choice, destination choice, mode choice, route choice).
- Activity or tour-based models are the preferred subtype for modeling ATDM because they predict the effects of congestion on trip generation and time-of-day choice as well as the other choices. In addition, they also model the individual traveler trip start/end times. Four-step models are limited to predicting individual traveler behavior changes and the effects of congestion on destination choice (in a somewhat limited manner), mode choice, and route choice.
- Most Strategic Models generally do not devote many resources to accurately modeling highway and street-specific operations (signal operations, speeds, queues, etc.). Highway and street (facility) operations are modeled at the macroscopic level using simplified volume-delay functions. However, the advanced strategic models combine a demand model with meso/micro DTA tools.

Tactical Models focus on accurately modeling individual vehicle behavior within the facility (speeds and queues at small time scales). These typically focus on small corridors or sub-regions and are generally limited in their ability to model demand changes, due to the limited information regarding off-facility conditions included in the tactical model.

There are three types of tactical models: **Macroscopic**, **Mesoscopic**, and **Microscopic**. Mesoscopic and Microscopic are of most interest for modeling DMA and ATDM strategies.

- **Mesoscopic** models generally model bunches of vehicles, employing a mix of microscopic and macroscopic speed-flow relationships. They are designed to model small-to-medium systems of highways and streets and can model route choice and some limited time-of-day effects of congestion.
- **Microscopic** models model individual vehicles at small time scales (1 second or less). They may include some limited route choice capabilities, enabling them to model multiple facilities in a corridor or a network.

Among tactical models, the microscopic model subtype will be generally preferred for DMA and ATDM analysis because of its ability to model individual vehicle behavior at a fine time resolution. Route choice and time-of-day choice (the comparative strength of mesoscopic models over microscopic models) can generally be better modeled by the strategic models because of their access to a richer data set for predicting demand and demand changes.

Multi-resolution Models accurately represent traveler's trip making choices prior to trip start as well as individual driver and pedestrian movements and interactions between them. Simple experimental efficiency suggests that one will not want to answer all DMA and ATDM questions and hypotheses at the start by using the most computationally complex tool available, the multi-resolution models.

Communications/Management Latency models aims to accurately represent communications between vehicles, devices, and the infrastructure, as well as system managers' decision making.

Fundamental hypotheses and questions as to which DMA and ATDM strategies should even be evaluated and at what levels they achieve their optimal effectiveness can best be answered using the simpler microscopic tactical models (to estimate the effects of the strategies on facility travel time and reliability for a given demand level) and strategic models (to estimate the demand effects of changes in facility travel time and reliability). Exhibit 4 below stratifies the 14 candidate Testbeds according to their overall modeling approach (tactical or strategic/multi-resolution), their demand model type (none, four-step, and activity based), and their network resolution type (mesoscopic and microscopic). As can be seen, there are several redundancies in coverage among the Testbeds. It should be noted that none of the Testbeds are of Communications/Management Latency focus type..

Exhibit 4: Stratification of Testbeds by Model Technical Approach

Demand Model	Network Type	Overall Model Approach	
		Tactical	**Strategic/Multi-resolution**
No Demand Model	Micro Network	5. Anthem 6. Palo Alto 7. Novi 8. US-101 9a. Tucson 9b. Clearwater	Strategic/Multi-resolution Models, by definition, must include a demand model.
4-Step Demand Model	Meso	Tactical Models, by definition, mostly exclude demand effects	11. ICM Dallas
	Micro		10. ICM San Diego 12. Pasadena 14. Northern Virginia
ABM Demand Model	Meso		1. SHRP2 Sacramento 3. Chicago 4. Phoenix
	Micro		2. SHRP2 Jacksonville 13. Columbus

3.3.2 Geographic Coverage for the Testbeds

The candidate Testbeds range in geographic coverage from individual facilities to corridors to whole metropolitan regions. Individual facility models consist of one main roadway with ramps or feeders. These models are typically used to analyze and optimize the main roadway, and route diversion is not an option. Corridor-level models consist of parallel roadways with streets connecting them and feeders for each parallel roadway. These models are typically used to analyze and optimize the corridor. These models typically use route diversion to optimize traffic. Metropolitan region models consist of all the major roadways in the region and are typically used to analyze demand and supply, whereas the individual facility-based and corridor-based models are not capable of analyzing demand in depth. For the DMA/ATDM evaluation it will be best to have available a range of geographic levels for analysis. A facility-level Testbed can answer questions about the mix and levels of strategies that achieve optimal cost-effectiveness for a fixed demand level on the facility. A corridor level-Testbed can address strategies that integrate two or more facilities. Finally, a regional-level Testbed can identify the system effects of system-level investments in DMA and ATDM, as well as the effects of investments in selected corridors and specific facilities.

Exhibit 5 below stratifies the Testbeds by overall model approach and geographic coverage. The list includes four candidate tactical Testbeds for modeling arterials, one tactical Testbed for modeling freeway ATDM and DMA strategies. Two Testbeds are suitable for evaluating corridors. Finally, seven candidate Testbeds are designed to evaluate performance effects at the citywide or regional level.

Exhibit 5: Stratification of Testbeds by Coverage Area and Model Typology

		Overall Model Approach	
Coverage	**Facility Type**	**Tactical**	**Strategic**
Single Facility	Arterial	5. Anthem 6. Palo Alto 9a. Tucson 9b. Clearwater	*Strategic by definition, must include multiple facilities.*
	Freeway	8. US-101	
Corridor			11. ICM Dallas 10. ICM San Diego
City/County		7. Novi	12. Pasadena
Region		*Infeasible at this time*	1. SHRP2 Sacramento 2. SHRP2 Jacksonville 3. Chicago 4. Phoenix 13. Columbus 14. Northern Virginia

3.3.3 Climate Types for the Testbed region

For evaluation of weather-related DMA and ATDM strategies, it is desirable to have a set of Testbeds that cover a range of climate zones for the United States. The National Climatic Data Center has identified nine climatically consistent regions within the contiguous United States (Karl and Koss[1], 1984).

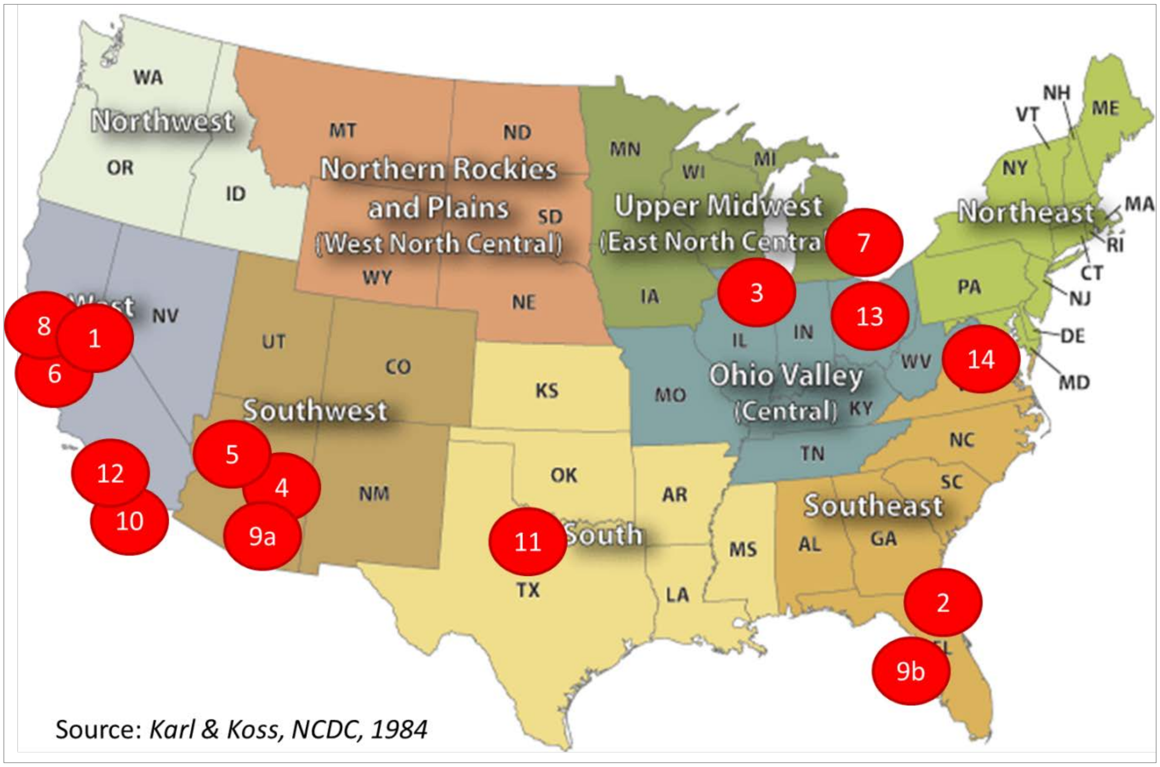
Exhibit 6 shows the stratification of the 14 candidate Testbed sites by U.S. Climate Region. Five of the sites are located in the West Climate Region. Three are located in the Southwest Climate Region. One is located in the South (Texas) Climate Region. Three are located in the Southeast Climate Region. Three are located in the Central (Ohio) Climate Region.

Eight of the sites (1, 4, 5, 6, 8, 9a, 10, 12) are located in comparatively dry and warm climates (West and Southwest Climate Zones, Arizona and California). Three sites (2, 9b, 14) are located in moderate to heavy rain climates (Southeast) with occasional snow. Three sites (3, 7, and 13) are located in moderate snow climates.

[1] Thomas R. Karl and Walter James Koss, 1984: "Regional and National Monthly, Seasonal, and Annual Temperature Weighted by Area, 1895-1983." Historical Climatology Series 4-3, National Climatic Data Center, Asheville, NC, 38 pp.). http://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php

The Northern Climates of the Continental United States (Northwest, Northern Rockies, Upper Midwest, and the Northeast) are not represented in the candidate sites.

Exhibit 6: Stratification of Testbeds by Climate Region [Source: Karl & Koss, NCDC, 1984]



3.3.4 Metropolitan Area Size of the Testbed region

It is desirable that the final selected test sites be representative of a reasonable range of metropolitan area conditions. Drivers in larger metropolitan areas will be more accustomed to regularly encountering recurring or nonrecurring congestion and using various methods (511.Org, etc.) for avoiding severe congestion. In addition, these areas typically provide better transit service than their counterparts. This enables the AMS Testbed Team to test ATDM strategies that present alternate mode options to travelers. In larger metropolitan areas, congestion will tend to be more ubiquitous and bidirectional.

Exhibit 7 ranks the Testbed sites by the population of the metropolitan areas in which they are located. Seven of the sites are located in metropolitan areas with population in excess of 5 million. Two of the sites, Tucson and SHRP2 Jacksonville, are located in metropolitan areas of under 2 million populations.

Exhibit 7: Ranking of Testbeds by Metropolitan Area Population

Site	Name	State	Population (in millions)
12	Pasadena	CA	18.2
3	Chicago	IL	9.9
14	Northern Virginia	VA	9.3
6	Palo Alto	CA	8.4

Site	Name	State	Population (in millions)
8	US-101	CA	8.4
11	ICM Dallas	TX	7.1
7	Novi	MI	5.3
4	Phoenix	AZ	4.3
5	Anthem	AZ	4.3
10	ICM San Diego	CA	3.2
9b	Clearwater	FL	2.8
1	SHRP2 Sacramento	CA	2.5
13	Columbus	OH	2.3
2	SHRP2 Jacksonville	FL	1.5
9a	Tucson	AZ	1.0

3.4 Recommendations for Phase II Evaluation

As specified before, it is recommended that final portfolio include Testbeds of different geographic scope, complexity, technical implementation, climate types among other considerations. Exhibit 8 below shows the summary of the key Testbed characteristics along with the numerical scores assigned based on how well they meet the 8 criteria. Exhibit 8 below groups the Testbeds into logical categories.

Exhibit 8: Candidate Testbeds – Summary Details

Geographic	Candidates	Phase I Rating	Model	Climate	Pop (mil)
1. Tactical Single Facility – Arterial	5. Anthem	13	Micro	West	4.3
	6. Palo Alto	18	Micro	West	8.4
	7. Novi	16	Micro	Central	5.3
	9a. Tucson	16	Micro	SW	1.0
	9b. Clearwater	16	Micro	SE	2.8
2. Tactical Single Facility – Freeway	8. US-101	19	Micro	West	8.4
3. Strategic/Multi-resolution – Corridor	10. ICM San Diego	18	4-Step	West	3.2
	11. ICM Dallas	20	4-Step	South	7.1
4. Strategic/Multi-resolution: Region	1. SHRP2 Sacramento	17	ABM	West	2.5
	2. SHRP2 Jacksonville	18	ABM	SE	1.5
	3. Chicago	17	ABM	Central	9.9
	4. Phoenix	21	ABM	SW	4.3
	12. Pasadena	20	4-Step	West	18.2
	13. Columbus	15	ABM	Central	2.3
	14. Northern Virginia	17	4-Step	SE	9.3

The final recommendations for Phase II evaluation was made based both the quantitative and qualitative assessments described above. The AMS Testbed Team reviewed the Testbeds with the lowest ratings in order to ensure that the AMS Testbed Team understands each of these Testbeds' capabilities well. The findings from this analysis are presented below.

- The **Anthem Testbed** received particularly low ratings for its lack of demand model capabilities and limited geographic scope (six signalized intersections on one arterial street). Anthem was dropped from further consideration because it ranked the lowest among the five candidates in Phase I. However, this Testbed's using VISSIM Application Programming Interface (API) based communication modeling features be used for other Testbeds with a moderate level of effort.
- The **Novi Testbed** received low ratings for its lack of a demand model. Further this model hasn't been used for the past several years. The risks associated with gaining access to the model and learn the model and write custom code to extend the models in order to model ATDM strategies is high. The project team will review the communication capabilities of this Testbed and adopt those to the final Testbeds as applicable.
- The **Tucson and Clearwater Testbeds** received low ratings for their lack of a good demand model and lack of sufficient complexity (small regions without a lot of congestion).
- The **SHRP2 Sacramento Testbed** rated well but we were unable to obtain enough information about the calibration and validation status of this Testbed in order to consider it for Phase II evaluation. The lack of information also prevented us from performing a thorough qualitative assessment of this Testbed. .
- The **SHRP2 Jacksonville Testbed** also rated well, but the developers informed the team that that the demand model cannot easily be modified. In addition, it is to be noted that the Jacksonville Testbed region is a relatively small metropolitan area of 1.5 million and the Testbed does not include a transit network. The Testbed team believes this Testbed lacks the network complexity to test a variety of DMA and ATDM strategies and recommended that this Testbed is not considered for further evaluation.
- The **Columbus Testbed** received low ratings for its demand model capabilities (which require further work), poor computational efficiency for testing multiple scenarios (employs a cumbersome software interface), risks associated with the development of custom code modifications, and the need for additional calibration and validation of the demand model.
- The **Northern Virginia Testbed** rated well, but it is still in the preliminary development phase, and was therefore not being considered for Phase II evaluation.

Initial screening and analysis indicated that it is beneficial to expand the **US-101** Freeway Arterial Testbed to include the Palo Alto Arterial Testbed instead of separate arterial (El Camino Real) and freeway (US-101) tactical Testbeds.

There are two candidate strategic corridor models available (**ICM Dallas** and **ICM San Diego**) and both have strong capabilities to serve as a Testbed. Hence it is recommended that both the Testbeds be evaluated in Phase II. It is to be noted that these two Testbeds were rated identically for all criteria expect Criterion #6 (team familiarity).

There are two activity-based model and two four-step model Testbed candidates for the strategic regional model Testbed. Among the two ABM candidates, **Phoenix** was the top rated Testbed in Phase I. The Columbus Testbed did not rate well in Phase I. It is therefore recommended that the AMS Testbed Team evaluate the Phoenix Testbed in Phase II. Among the four-step model based

Testbeds, **Pasadena** scored the highest, and it is recommended that this Testbed be evaluated in Phase ll. The **Chicago** Testbed has unique weather elements considered and it is recommended that this Testbed also be evaluated in Phase II.

The final recommendations for Phase II evaluation are shown in Exhibit 9 below.

Exhibit 9: Candidate Testbeds for Phase II evaluation

AMS Analysis Need	Candidates	Phase I Rating	Model	Climate	Pop (mil)	Recommendation
Tactical Single Facility – Freeway/Arterial	5. Anthem	13	Micro	West	4.3	STOP Consideration
	6. Palo Alto	18	Micro	West	8.4	STOP Consideration
	7. Novi	16	Micro	Central	5.3	STOP Consideration
	9a. Tucson	16	Micro	SW	1.0	STOP Consideration
	9b. Clearwater	16	Micro	SE	2.8	STOP Consideration
	8. US-101 + El Camino Real	19	Micro	West	8.4	Evaluate Further
Strategic /Multi-resolution Corridor	10. ICM San Diego	17	4-Step	West	3.2	Evaluate Further
	11. ICM Dallas	18	4-Step	South	7.1	Evaluate Further
Strategic /Multi-resolution Region	1. SHRP2 Sacramento	17	ABM	West	2.5	STOP Consideration
	2. SHRP2 Jacksonville	18	ABM	SE	1.5	STOP Consideration
	3. Chicago	20	ABM	Central	9.9	Evaluate Further
	4. Phoenix	21	ABM	SW	4.3	Evaluate Further
	12. Pasadena	20	4-Step	West	18.2	Evaluate Further
	13. Columbus	15	ABM	Central	2.3	STOP Consideration
	14. Northern Virginia	17	4-Step	SE	9.3	STOP Consideration

The section below provides a description of the six Testbeds selected for Phase II evaluation.

3.5 Description of Testbeds selected for Phase II Evaluation

Based on Phase I analysis, the following Testbeds were selected for rating against each detailed requirement:

- US-101 (Tactical Facility-based)
- Pasadena (Tactical City)
- ICM Dallas (Strategic /Multi-resolution Corridor)
- ICM San Diego (Strategic /Multi-resolution Corridor)
- Phoenix (Strategic /Multi-resolution Region)
- Chicago (Strategic /Multi-resolution Region)

The following section presents, for each Testbed, an overview, the modeling tools currently in use, its calibration and validation status, the availability of real-time data and algorithms for implementation, any system manager and connected vehicle modeling currently in use or how well suited the Testbed is for AMS activities, its primary strengths, and any risks involved in choosing the Testbed.

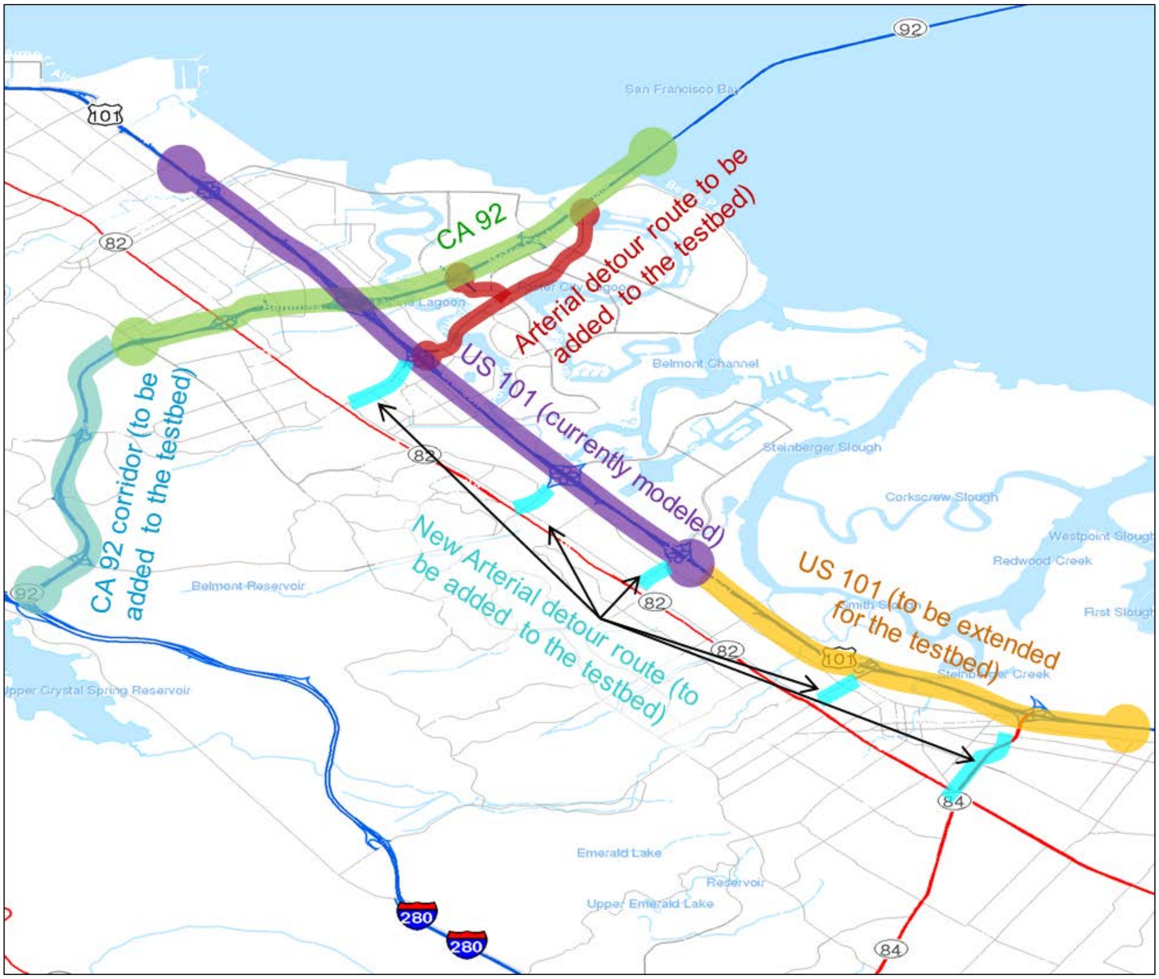
3.5.1 US-101 Testbed, California

3.5.1.1 Overview

The US-101 Testbed includes US-101 (8.1 miles, seven interchanges) from Woodside Road/SR-84 interchange to 3rd Avenue and SR-92 (3.2 miles, five interchanges) from I-280 to Foster City Boulevard to Alameda De Las Pulgas. The 5-hour PM model (2:30 p.m. to 7:30 p.m.) has a key bottleneck on the northbound US-101 at the Hillsdale Boulevard interchange (just south of the US-101 and SR-92 interchange). The on-ramps along the US-101 corridor are metered. Due to congestion on the northbound US-101 at the Hillsdale Boulevard interchange, a possible detour exists. A vehicle could exit the freeway at the Hillsdale Boulevard interchange and enter on the freeway either to the Edgewater Boulevard interchange (short bypass) or the Foster City Boulevard interchange (long bypass). Average annual daily traffic on US-101 at the north of the SR-84 interchange was about 207,000 in 2012 (Source: Caltrans Traffic Volumes).

El Camino Real arterial facilities are to be added to the existing freeway network to support both freeway and arterial applications/strategy modeling. Exhibit 10 shows the existing network detail and the envisioned network detail for this Testbed.

Exhibit 10: US-101 Testbed Network Detail [Source: Kittelson]



This model is not directly linked to a demand model and therefore cannot explicitly consider route choice, mode choice, etc. Diversion curves can be used if needed to quantify impacts. This Testbed is therefore limited in scope to explicitly modeling regional impacts of ATDM concepts or DMA applications.

3.5.1.2 Modeling Tools

This Testbed uses a VISSIM microsimulation model for a freeway facility. The El Camino Real Arterial network will be added as well.

3.5.1.3 Calibration/Validation Status

The current VISSIM model was calibrated and validated based on observed traffic conditions including volumes, travel time, bottleneck location, and duration of congestion. The Metropolitan Transportation Commission approved the calibrated and validated VISSIM model for the study. If the model is converted to use dynamic routing instead of static routing, the current model will need to be recalibrated. Since the existing model is calibrated, the recalibration effort is not expected to require significant resources. In addition, up-to-date field data (counts and travel time) is readily available for additional calibration/validation as needed.

3.5.1.4 Real-Time Data

There are Performance Management System (PeMS) stations along the US-101 corridor. The historical volume inventory (flow data) could be aggregated in 5-minute intervals. PeMS can display the real-time traffic speed data; investigation is required into whether such online real-time speed data can be used for the simulation model.

3.5.1.5 Algorithms

As part of the INFLO Impact Assessment (IA) efforts, INFLO algorithms will be incorporated into this model in the near future. It is recommended that the AMS Testbed leverage these additions to the model.

3.5.1.6 System Manager, Connected Vehicles, and Communications

Connected vehicle communications will also be added to the model as part of the INFLO IA effort.

3.5.1.7 Primary Strength

The US-101 Testbed provides a detailed microsimulation model for a congested freeway facility that can provide detailed operational assessments for DMA and ATDM programs. A significant number of resources have been invested to ensure that the model is well calibrated and validated. The fact that this Testbed is currently being used for INFLO bundle impact assessment work makes it a strong candidate.

3.5.1.8 Risks

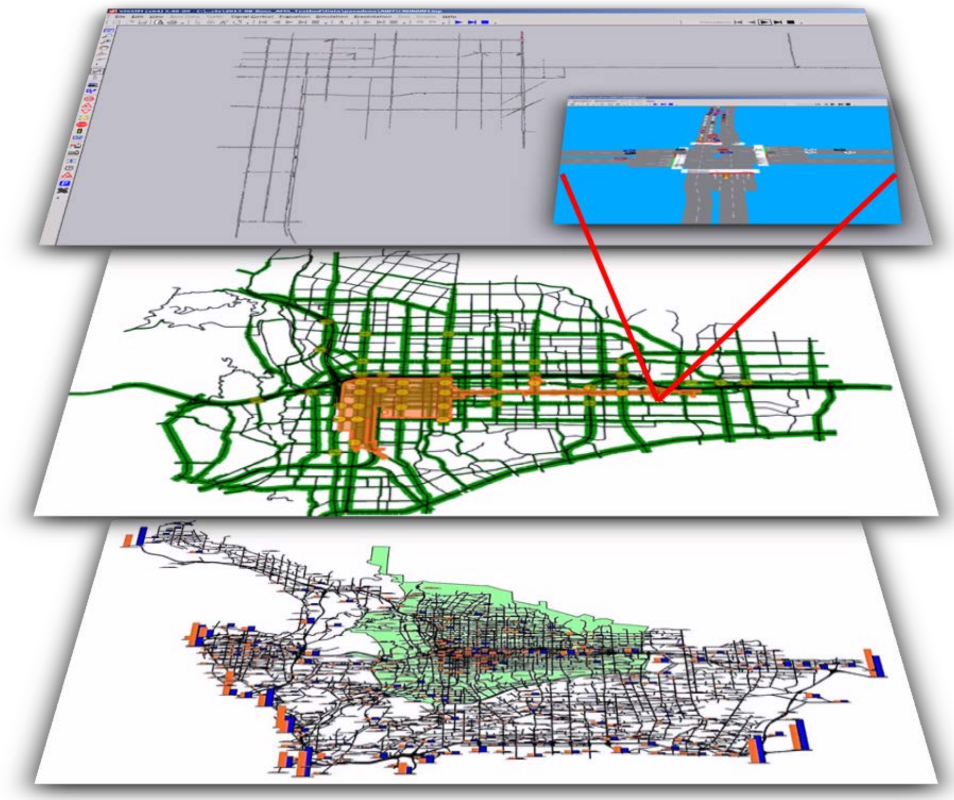
In its current state, this Testbed only allows for operational assessments. It is not currently set up with a demand or routing model to evaluate the behavioral effects of DMA/ATDM strategies. However, it is possible to link this model up with the DTA model for this region. This is a low-risk Testbed that can be used to test scenarios quickly, specifically for freeway and arterial-based DMA applications. In addition, this Testbed offers the ability to build on the INFLO IA work.

3.5.2 Pasadena

3.5.2.1 Overview

The Pasadena Testbed is a multi-resolution model that covers the City of Pasadena and its surrounding freeways. It contains both urban and freeway roadway facilities. While the current model does not include transit, light rail, or bus transit systems, this infrastructure exists within the study area and could be added to the Testbed if needed. The model was originally built for 24 hours each day and 3 different day types, but the existing model was calibrated to a.m. (3 hours) and p.m. (4 hours) peak periods only. A real-time predictive model variation of the Dynamic User Equilibrium (DUE) model was also developed for this Testbed. A unique aspect of this Testbed is that it has an AirSage-sourced cell phone sighting dataset, providing insight into network-wide mobility patterns in the area hour by hour, and multiple daily patterns including weekdays, weekends and holidays, and game/event days. Exhibit 11 presents the multi-resolution modeling abilities of this Testbed. However, this Testbed is envisioned to be predominantly used to test tactical strategies.

Exhibit 11: Pasadena Multi-Resolution Modeling Detail [Source: HB America]



3.5.2.2 Modeling Tools

The Pasadena Testbed uses the following software tools: TransCAD, PTV Visum and PTV Optima. While a microsimulation model does not exist, the Visum model contains the network details necessary to create a VISSIM microsimulation model.

3.5.2.3 Calibration/Validation Status

TTS is currently under contract to the City of Pasadena to recalibrate and refine the DUE model. Given that the city is supportive and interested in hosting an AMS Testbed site, all of the models will be readily available for this project.

3.5.2.4 Real-Time Data

Real-time traffic volume and speed data are available for the surrounding freeway facilities from Caltrans' PeMS system. In addition, the City of Pasadena recently completed an extensive traffic count project to collect detailed volume data for key city intersections. Furthermore, the Los Angeles County Information Exchange Network has, since February 2012, developed Pasadena online arterial control and traffic monitoring systems, enabling real-time data polling from a centralized data hub.

3.5.2.5 Algorithms

A potential VISSIM microscopic model and the PTV Optima-based real-time simulation model provide well defined interfaces for additional algorithms.

3.5.2.6 System Manager, Connected Vehicles and Communications

Once a VISSIM model is created, these additional components can be added.

3.5.2.7 Primary Strength

The primary strengths of this Testbed include—

- Diverse network including freeways and urban streets
- Macroscopic, DUE, and real-time simulation model with a user-definable subarea microscopic model
- Ongoing AMS (DTA and microsimulation) project work with the City of Pasadena
- A comprehensive archived operational data environment and a wealth of data sources including PeMS
- Macro/micro tool sets both have API function library, with large body of literature on research and development
- Online predictive modeling/simulation system available for restart
- 24x7 cell phone mobility-derived regional OD tables
- Part of proposed Caltrans ICM deployment corridor

3.5.2.8 Risks

There are no known risks associated with selecting Pasadena as a candidate Testbed. Risks associated with developing the Testbed to meet the project objectives will be detailed in the Analysis Plan.

3.5.3 ICM Dallas

3.5.3.1 Overview

The US-75 corridor is one of the main commuting corridors within the Dallas metropolitan area that connects Dallas' northern suburbs to the city center. The corridor consists of the US-75 freeway, which includes a one-lane HOV facility along its northern section, a parallel light rail line (the Red Line), and an arterial network that extends over multiple cities (Dallas, Richardson, and Plano).

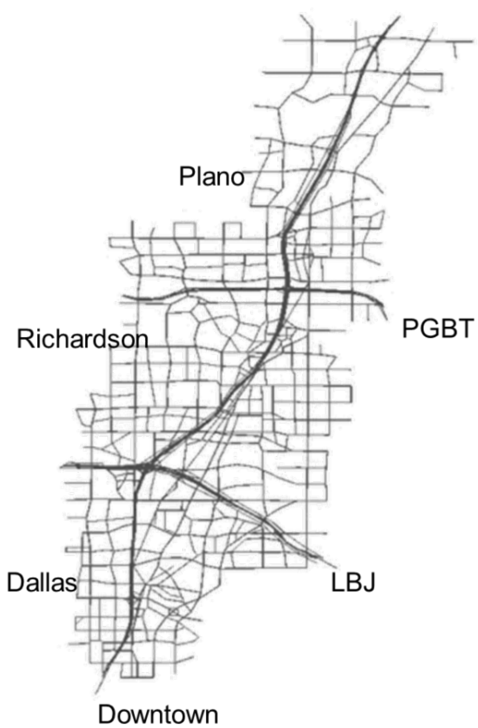
The Testbed was developed by extracting a subarea from the TransCAD-based Dallas-Fort Worth regional travel demand forecasting model. The subarea network consists of about 3,000 highway links and 1,300 nodes with 365 signalized intersections and 90 traffic analysis zones. The base day demand is about 1.8 million travelers who use about 1.5 million vehicles. A Dell server with two quad core 3.4 GHz processors and 32 GB of RAM is used to run the network. The run time for the 24-hour simulation is about 1.5 hours.

The model has been used as an offline tool to evaluate the effectiveness of different ICM strategies that integrate the operations management of freeway, transit, and arterial subsystems. The model has also been used to develop a real-time simulation platform for the US-75 corridor network. The platform provides real-time traffic network state estimation and short-term prediction as part of the decision support capabilities developed for the DalTrans traffic management center. The output of the model can be integrated with any microscopic simulation model to provide more detailed simulation. All input and output data are produced in a XML format to facilitate cross-modeling integration and the multi-resolution modeling framework.

The model approach considers intermodal transportation networks consisting of different travel modes such as private cars, buses, metro/subway, and high occupancy vehicles. It implements a multi-objective assignment procedure in which travelers choose their modes and routes based on a range of choice criteria (e.g., travel time, operation cost, and tolls). The model assumes a stochastically diverse set of travelers in terms of underlying preferences (i.e., relevant choice criteria and associated trade-off rules), as well as in terms of access and response to the supplied information.

The vehicular simulation component is a time-based simulation that moves individual vehicles along links according to local speeds. It adopts a mesoscopic simulation logic in which the average speed of each lane is updated based on the current density. The model allows representation of complete transit networks, with both exclusive and shared infrastructure. This flexibility is allowed by its integrated multidimensional network representation. A set of bus/rail lines is defined in terms of the constituent routes, for which the average headway, stop locations, and vehicle capacities are specified. The model tracks the tempo-spatial loading pattern of all transit vehicles and the time-varying occupancy of all park-and-ride facilities. Exhibit 12 presents the modeling region and the network detail.

Exhibit 12: ICM Dallas Network Detail [Source: Southern Methodist University]



3.5.3.2 Modeling Tools

The model uses Dynamic Intermodal Routing Environment for Control and Telematics (DIRECT), a DTA meso-simulation-based model with a 6-second resolution. The tool is primarily intended for operational planning applications (i.e., strategic to tactical). The model is designed to capture the dynamic interactions between mode choice and traffic assignment as well as the resulting evolution of network conditions while considering different advanced traffic network management and traveler information provision strategies.

3.5.3.3 Calibration/Validation Status

As part of the Dallas ICM project, considerable effort was devoted to calibrating the DIRECT model to ensure that the model is capable of replicating the network conditions for different operation scenarios.

The time-dependent OD demand table and the flow propagation models for the different roadway types were adjusted to represent a typical day. The goal was to replicate time-varying link vehicle counts, travel time runs along main routes, and freeway bottleneck patterns.

These efforts ensured that the model captures the flow patterns along the freeway. For most links, the difference in the estimated and measured hourly traffic volumes in the peak periods was less than 20 percent. Higher percentage differences are usually observed in hours with low volumes. The estimated and measured travel times for the US-75 freeway for every hour during the morning and evening peak periods are recorded. The maximum difference between the estimated and measured travel time in any of the recorded hours is within 12 percent.

3.5.3.4 Real-Time Data

Real-time speed, volume, and density data is available at 5-minute resolution through the DalTrans data system. For the US-75 corridor network, about 87 detectors were mapped with their corresponding freeway links in the modeled network. Capabilities to compare between the model's estimates and the corresponding observed real-world data have also been developed for the purpose of offline calibration as well as online consistency checking for real-time simulation.

3.5.3.5 Algorithms

The new model was developed by researchers at Southern Methodist University (SMU). The AMS Testbed Team at SMU has complete access to the source code of the model. The model was developed in Java using an objected-oriented design that represents the static and dynamic elements of the urban transportation network. Source code for any new algorithms that are not currently available can be easily added or interfaced with the existing code.

3.5.3.6 System Manager, Connected Vehicles, and Communications

System Manager: DIRECT's real-time framework is capable of simulating the daily operations of a typical traffic management center. This framework is capable of—

- Estimating current network conditions
- Providing short-term prediction of congestion dynamics during recurrent and non-recurrent congestion situations
- Applying appropriate expert rules to determine the most effective response plans
- Evaluating the effectiveness of these plans before implementation.

The framework emulates the deployment of the plan in a virtual simulation environment and records a wide range of measures of performance at the facility, subarea, and network levels for any simulated horizon. A rolling horizon approach is used to generate the measures of performance (i.e., at any point in time, the Measures of Effectiveness (MOEs) are produced for the past 30 minutes).

Connected Vehicles and Communications: As detailed above, DIRECT adopts a mesoscopic simulation logic and updates vehicle locations every 6 seconds. With limited development work, the model framework could generate vehicle-to-vehicle adjacency data and could be updated to enable information sharing based on proximity at the 6-second resolution. If the start and end of each simulation interval is assumed as a boundary condition, high-resolution simulation logic could be incorporated to represent the communication layer among vehicles using a smaller time-step (e.g., 0.1 to 0.5 seconds).

3.5.3.7 Primary Strength

The primary strengths of this Testbed include—

- The US-75 corridor Testbed is based on real-world application (Dallas-ICM demonstration project)
- Significant offline calibration and validation efforts have been conducted for the simulation platform
- Real-time data is available and well archived in the DalTrans and SmartNet system, which is used by the ICM project
- A real-time simulation platform has been developed and is integrated as part of a decision support system for the corridor. The system, which is currently in production, provides real-time traffic network state estimation and prediction capabilities for evaluating recommended response plans. The developed online simulation capabilities can easily be extended to develop the proposed virtual simulation environment to study the ATDM/System Manager AMS activities.
- Access to the source code facilitates any required modifications in the developed algorithms to better fit the DMA/ATDM modeling activities. In addition, the XML input/output structure facilitates the multi-resolution and cross-modeling approach intended for this study.

3.5.3.8 Risks

There are no known risks associated with selecting ICM Dallas as a candidate Testbed. Risks associated with developing the Testbedsto meet the project objectives will be detailed in the Analysis Plan.

3.5.4 ICM San Diego

3.5.4.1 Overview

In 2010, the I-15 corridor in the San Diego region was selected as one of two pilot sites in the nation to develop, implement, and operate an ICM system. The ICM system will allow individual transportation systems to be operated and managed as a unified corridor network. The cutting-edge technology will identify and determine how freeway, arterial, and transit networks can be managed together to improve mobility and maximize system efficiency.

The project covers a 20-mile section of I-15 from just north of SR-52 in the City of San Diego to SR-78 in the City of Escondido, including the state-of-the-art I-15 Express Lanes and major arterial routes on either side of I-15 within several miles of the freeway. The network extends from the SR-163 and I-15 intersection/merge in the south and to the El Norte Parkway (just north of SR-78) interchange north of San Diego. It includes all roads except local access roads within a 4-mile envelope east and west of the freeway. The model includes all the signals, ramp metering configurations, dynamic tolling, and configuration for the managed lanes, in addition to real-time bus locations and all bus routes/stops within the network area.

The overall vision of the I-15 ICM project is to apply predictive algorithms and real-time modeling tools to forecast traffic across multiple networks and recommend actions to manage anticipated congestion. For example, the ICM system will coordinate the use of freeway ramp meters and arterial traffic signals to improve day-to-day conditions or route traffic around major incidents. The hypothesis is that the ICM will reduce delays and improve travel reliability. The trip model is a 24-hour demand model, and runs 1-hour simulations with about 100,000 trips in the peak hour in less than 5 minutes.

The San Diego ICM project team is led by San Diego Association of Governments (SANDAG) and includes partnerships with USDOT, Caltrans, Metropolitan Transit System, North County Transit District, and the cities of Escondido, Poway, and San Diego. The ICM system has been online since early 2013 and will be operational through the end of 2014. Exhibit 13 presents a snapshot of the ITS Infrastructure used by ICM San Diego to proactively manage traffic.

Exhibit 13: ICM San Diego ITS Infrastructure [Source: San Diego Association of Governments]

3.5.4.2 Modeling Tools

SANDAG is transitioning from its existing 4-step transportation model to a more advanced, activity-based model. A TransModeler-based simulation model was used for the initial AMS effort in Phase II of the ICM initiative. This model has not been maintained because of the transition to an Aimsun model. Currently, Aimsun Online is used for network assignment (100,000 trips during the peak hour).

3.5.4.3 Calibration/Validation Status

The Aimsun model is continually being updated as new data is obtained from the ICM. These updates could be easily transferred to the current offline model.

3.5.4.4 Real-Time Data

Aimsun Online uses live data feeds and simulations to dynamically forecast traffic conditions based on the current state of the network and to help operators evaluate incident response or congestion management strategies.

3.5.4.5 Algorithms

A number of ICM strategies, including en-route and pre-trip traveler information, Responsive Traffic Light Synchronization, coordinated ramp metering, increased HOV occupancy requirements, and bus priority on arterials were deployed to manage multiple modes proactively through and along the corridor. Strategies to empower the motorist and aid their decision-making include both pre-trip and en-route traveler information.

On-road activities involve everything from freeway coordinated adaptive ramp metering and signal coordination on arterials with freeway ramp metering to regional arterial management.

Further operational strategies include real-time multimodal decision support, network traffic prediction, online microsimulation analysis, and real-time response strategy assessment.

3.5.4.6 System Manager, Connected Vehicles, and Communications

All corridor operations will be coordinated through the Integrated Corridor Management System, in which corridor networks and agencies will share data and information and make changes for the benefit of the corridor's operations. For example, operations personnel will adjust traffic signals and ramp meters to direct travelers to High-Occupancy Toll lanes, bus rapid transit, and other operations tools as needed. The Decision Support System (DSS) will forecast corridor performance problems and recommend response plans to allow for proactive action.

Predictions and recommendations will be generated in 15-, 30-, and 60-minute horizons based on real-time and historical performance data. As a result, systems managers will be able to carry out a coordinated response, including synchronizing freeway ramp meters with traffic signals and providing advanced traveler information via electronic message signs or the 511 service. The public will receive information about different travel options and modes to avoid gridlock, instead of simply defaulting to using arterial routes based on past experience and knowledge of typical arterial travel times.

3.5.4.7 Primary Strength

The I-15 ICM project will—

- Capitalize on existing ITS investments that have been implemented for freeway, transit, and signal management systems to measure and manage corridor performance
- Enhance ramp metering to include analysis of overall freeway throughput and integration with traffic signals to better manage traffic entering and exiting the freeway
- Improve data collection for transit, highways, and arterials to monitor corridor performance, enhance traveler information, and support incident management
- Deliver a first-of-its-kind DSS capable of forecasting real-time traffic and making system recommendations to avoid and minimize congestion impacts
- Adopt proactive multimodal operational strategies and agreements that prioritize overall corridor performance.

3.5.4.8 Risks

The AMS Testbed Team has worked with the tools used in the Testbed; however, the time it would take to gain familiarity with the Testbed is a risk. This risk would be mitigated by adding developers familiar with the tool to the AMS Testbed Team. The AMS Testbed Team has contacted the developers and they have informed the team that they would assist in the Testbed development if needed. Therefore, the risk of choosing this Testbed is low.

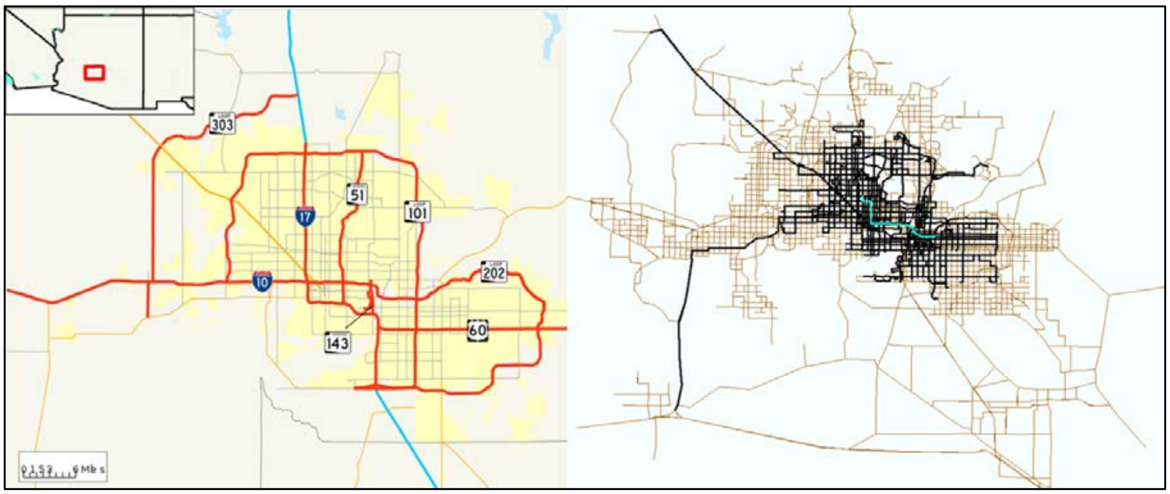
3.5.5 Phoenix

3.5.5.1 Overview

The Phoenix Testbed encompasses the entire Greater Phoenix metropolitan area. The geographic scope covers the entire region, which includes a population of more than 4 million people residing in about 1.5 million households. The latest version of the model corresponds to the base year of 2011, with more than 3,000 zones. The highway network includes more than 30,000 links, 6,000 centroid connectors, and 14,000 nodes. There are 440 centerline miles of freeway, 3,322 centerline miles of arterials, 4,085 centerline miles of other highways, and 140 miles of HOV lanes. Daily travel demand in the region is in the order of 14 million trips with just less than 2 percent undertaken by transit (including local bus, circulators, express bus, and light rail). Premium transit modes incorporate both walk and auto access (park-and-ride and kiss-and-ride).

The modeling approach incorporates an integrated demand-supply model system that is capable of simulating detailed trajectories of vehicles and travelers through the course of an entire day. The modeling approach may therefore be considered to be strategic, tactical, and multi-resolution in nature. The model system, by virtue of incorporating an activity-based microsimulation model, simulates travelers' strategic decisions and choices about activity scheduling, modes, trip chaining, task allocation among household members, and destinations. The incorporation of the dynamic traffic assignment model (which is tightly coupled with the demand model) allows the consideration of tactical decisions as drivers navigate the network. Exhibit 14 presents the network detail for this Testbed (map to the right) with the light rail system highlighted in cyan.

Exhibit 14: Phoenix Network Detail [Source: Arizona State University]



3.5.5.2 Modeling Tools

There are at least four model systems that can be brought to bear for this Testbed. First, there is PopGen, a synthetic population generator, which is capable of synthesizing a population for a region for a variety of socioeconomic and demographic futures. Through a series of location choice and vehicle type choice models, each household and person is synthesized with information about household location choice, work location choice, school location choice, and vehicle fleet composition.

Second, there is OpenAMOS, which is a detailed activity-based microsimulation model system. This model considers household interactions and person time-space prism constraints in simulating activity-travel patterns of individuals through the course of a day. It is a continuous time activity scheduling model and provides detailed information about modes, vehicles, passengers, and destinations for all tours and trips undertaken by a synthetic population.

Third, there is DTALite, a fast and efficient dynamic traffic assignment model that is capable of routing travelers through a network while considering a number of possible criteria in a multi-criteria objective function (travel time, generalized travel cost, fuel consumption, vehicle emissions, or any combination thereof). Through efficient computations, the model is able to route and re-route travelers through the network and output detailed vehicle trajectories. DTALite may be interfaced with VISSIM (or any other traffic microsimulation model) to analyze and simulate vehicular movements in a detailed manner. The traffic microsimulation model would have to be applied to a subarea or corridor to capture the detailed patterns of movements across lanes of traffic, turning movements, and intersection delays.

Fourth, the models described above may be interfaced with RHODES, a real-time traffic signal control system that takes information from sensors and connected vehicles to optimize signal operations with respect to flow and delay criteria. Thus, the integrated model system is capable of reflecting demand adjustments in response to supply attributes, and supply adjustments (real-time traffic control) in response to demand. The model system is also able to accommodate sensitivity to real-time en-route traveler information, thus making it an ideal Testbed for connected vehicle simulation.

3.5.5.3 Calibration/Validation Status

There are readily available versions of OpenAMOS and PopGen for the region. However, they need to be updated to the 3,000-zone system (they are currently calibrated and validated to the 2,000-zone system). Updates should be reasonably straightforward. Previously, the AMS Testbed Team gained vast experience calibrating and validating a multi-resolution integrated demand-supply model system called SimTRAVEL by interfacing OpenAMOS with MALTA/DynusT (developed by the University of Arizona). Thus, the AMS Testbed Team has extensive experience calibrating and validating an integrated model system for the region. For this project, we propose replacing MALTA/DynusT with DTALite, given DTALite's ability to consider multiple criteria for routing travelers through the network and its substantial gains in computational efficiency. Efforts are currently underway to integrate OpenAMOS with DTALite for the Greater Phoenix metropolitan region with a plan to develop an integrated modeling platform capable of simulating the behavioral and network performance impacts of a range of demand- and supply-oriented strategies.

3.5.5.4 Real-Time Data

The Maricopa Association of Governments, in conjunction with the Arizona Department of Transportation and the Maricopa County Department of Transportation, has an extensive traffic data collection enterprise that is one of the best in the country. The traffic data is at a 5-minute resolution for a number of selected locations and at a 15-minute aggregation for other locations. In general, there is extensive sensor data, traffic data, speed data, and other information that can be used to calibrate and validate models at a fine-grained spatial and temporal resolution. Given the rich data collection system in place in the Greater Phoenix metropolitan area, it should be feasible to work with the respective agencies and obtain the data needed for this project without much effort.

3.5.5.5 Algorithms

In general, the tools described incorporate a rich set of analytical algorithms that reflect macro-level, meso-level, and micro-level behaviors of travelers in complex networks. The tools need to be expanded to ensure that they are responsive to the DMA/ATDM strategies of interest in this project. For example, the tools need to be enhanced to reflect traveler response to en-route and real-time traveler information that may be obtained through sources including connected vehicle and vehicle-to-infrastructure systems. Algorithms to address real-time and en-route decision-making are currently being developed and incorporated in the SimTRAVEL framework encompassing both OpenAMOS and DTALite. The AMS Testbed Team anticipates that any additional algorithms that may be needed can be developed and interfaced with the tools.

3.5.5.6 System Manager, Connected Vehicles, and Communications

As detailed earlier, it should indeed be feasible to simulate connected vehicle systems in this Testbed. The tools proposed are flexible and hook directly to a data hub that can efficiently handle large-scale data flows across model systems. The model systems are currently being enhanced with reasonably modest effort to address real-time traveler information impacts and en-route decisionmaking. It should be possible to further enhance the model interfaces to address connected vehicle systems within a reasonable amount of effort and time. In fact, it is likely that the tools for the Greater Phoenix test site are the most amenable to such enhancement given their flexibility, behavioral sensitivity, and continuous-time dynamic adaptive traveler choice paradigm.

3.5.5.7 Primary Strength

This Testbed has a number of unique strengths:

- A rich set of modeling tools those are suited to simulate the full range of possible behavioral responses to a wide array of DMA/ATDM strategies. The modeling tools can simulate the effects of real-time traveler information on en-route decision-making across a number of behavioral choices including activity engagement, intra-household task reallocation, route choice, destination choice, time of day choice, mode choice, and vehicle type choice. It consists of an integrated model system with continuous-time dynamic interaction between the activity-based demand model and the dynamic traffic assignment/simulation model.
- The Greater Phoenix metropolitan region is a large area with all modes of transportation, and presents an ideal sprawled land use context for testing the potential impacts of DMA/ATDM strategies on traveler choices and vehicle travel across space and time dimensions. The model system is flexible enough to accommodate a number of operational strategies.
- The agencies in the region have an extensive traffic and speed data collection program with a vast network of sensors collecting data continuously. This data is extensive and has allowed the agencies to embark on major initiatives involving the development of continuous-time activity-based travel microsimulation models and dynamic traffic assignment models. In addition, an existing TransModeler implementation for a 500-square-mile area of the region could be used to simulate microscopic driver behavior.
- This Testbed is currently being used to evaluate Applications for the Environment: Real-Time Information Synthesis Eco-Traveler Information Application.
- The Testbed has an extensive traffic and speed data collection program with a vast network of sensors collecting data continuously.

3.5.5.8 Risks

There are no known risks associated with selecting Phoenix as a candidate Testbed. Risks associated with developing the Testbed to meet the project objectives will be detailed in the Analysis Plan.

3.5.6 Chicago

3.5.6.1 Overview

The goal is to develop a framework and procedures for implementing and evaluating weather-responsive traffic management strategies. This was accomplished by using Traffic Estimation and Prediction System (TrEPS) methodologies to support the decision making process for addressing the disruptive effect of inclement weather on the traffic system. Tools were developed, calibrated, and tested in Salt Lake City, Utah, New York’s Long Island Expressway Area, and Chicago, Illinois, based on the application of the DYNASMART-X model. This section describes the effort that calibrated weather-specific speed density curves and Weather Adjustment Factors (WAF) for Chicago, Illinois.

The focus for this model was to determine the value of four strategies (advisory Variable Messaging Systems [VMS], mandatory VMS, speed management, and signal control) in response to severe weather conditions such as blizzards and light to moderate snow events. The demand and supply sides of the DYNASMART model are modified to capture the effect of weather on traffic patterns. Analyses indicated that the use of WAF successfully replicated the weather effects on both link speed and flows.

The Chicago network used for the study was extracted from the larger regional network model used by the Chicago Metropolitan Agency for Planning (CMAP), for which the agency developed a full-blown activity-based travel behavior model system. The full regional network model (40,443 links; more than 4 million trips loaded during a.m. peak) was developed, calibrated, and validated using DYNASMART.

This Testbed network used for the weather-related TrEPS application was extracted for the larger regional network. It includes all of downtown Chicago, most of the city of Chicago, and a significant portion of the immediate northern and northwestern suburbs. The location offers sufficient geographic scope and complexity to represent the impacts of the DMA and ATDM applications and strategies. The extracted sub-network has 4,805 links and 1,578 nodes. The network includes freeways, other expressways and highways, ramps, arterials, and city streets.

The Chicago model is calibrated and validated for time-varying Origin-Destination (O-D) demand from 5 a.m. to 11 a.m. The O-D demand is available in 10- or 15-minute time-steps, but individual travel chains have been created for all travelers. Archived data varies in granularity and extent and typical measurements are available for 5-minute intervals.

This temporal granularity of the model is suitable for representing the impacts of DMA and ATDM on traveler choices of mode, departure time, and route. These choices have already been incorporated in another model intended to capture traveler responses to weather events. The flow impacts of Active Demand Management and ATDM may require additional development in conjunction with finer-resolution microscopic models (the time-step for flow propagation is 6 seconds in the meso model used here).

Temporal data in this context refers to the detailed demand (trips by mode) and supply data (highway/transit operations) for entire a.m. and/or p.m. peak periods at finite increments (e.g. 10 or 20 minutes).

The model represents single-occupancy and high-occupancy vehicles; a recent update for CMAP is incorporating all transit modes.

3.5.6.2 Modeling Tools

This Testbed uses DYNASMART-P (offline) and DYNASMART-X (online).

3.5.6.3 Calibration/Validation Status

The level of calibration is moderate. It has been subsequently refined in ongoing work for CMAP.

3.5.6.4 Real-Time Data

The Chicago network was selected based on availability of historical detector data for years 2004 through 2008 at a 5-minute resolution. Further historic weather data from five Automated Surface Observation System stations at 5-minute resolution was available beginning in the year 2000. In addition, Clarus data at 20-minute resolution was also available from December 2008, increasing from one to five stations.

The Testbed location has limited capability to generate multi-source data. For example, data from wireless communications is not available. Historical loop detector data with 5-minute aggregation intervals are used for this model.

3.5.6.5 Algorithms

The AMS model was not developed for specifically testing any of the DMA applications, and does not include any communications modeling. However, the AMS model can be extended to represent ATDM strategies. It has been used in another study to test the effect of information strategies and travel demand management to mitigate the impact of weather-related disruptions. It has also been used in connection with a microsimulation tool to study the impacts of speed harmonization, which is an INFLO strategy. As this is a research product, the ease of adaptability by the developers is high. The ease of adaptability by others depends on their level of familiarity with the methods and implementation.

3.5.6.6 System Manager, Connected Vehicles, and Communications

The level of effort would be comparable to any other similar tool or model. These aspects are more readily implemented in a microscopic environment rather than a mesoscopic one. The developers are evaluating whether the Testbed has the capabilities to emulate system manager decisions or can be enhanced to do so in future. The developers are also evaluating whether the Testbed has the capability to support added communication methods/tools that emulate BSMs, BMMs, and dissemination of traveler information to people.

3.5.6.7 Primary Strength

This Testbed location has sufficient geographic scope and complexity to represent the impacts of the DMA and ATDM applications and strategies. The Testbed models VMS under inclement weather, which is of interest to both DMA and ATDM. The model is fully “weatherized,” meaning it is calibrated with actual local historical data to capture the effects of rain and snow of different intensities and associated visibility levels.

3.5.6.8 Risks

There are no known risks associated with selecting Chicago as a candidate Testbed. Risks associated with developing the Testbed to meet the project objectives will be detailed in the Analysis Plan.

Chapter 4. Phase II: Testbed Scoring

The purpose of this section is to present the process used to evaluate the six Testbeds selected in Phase I using the AMS Testbed requirements, and subsequently recommend Testbeds for the analysis plan development. The Phase II evaluation process includes the following steps.

Step 1: Develop weights that indicate the relative importance of AMS Testbed requirements developed in Task 3.

Step 2: Rate candidate Testbeds (identified in step 1 above) against each requirement to determine the overall suitability of the Testbed to be used for AMS activities to support DMA and ATDM programs. Multiply the weights generated in Step 1 with each Testbed rating for that particular requirement to generate the overall score for each Testbed.

Step 3: Conduct an assessment of Testbeds scores to identify final list of Testbeds and recommend to USDOT.

4.1 Develp AMS Testbed Functional Requirement Weights

AMS Testbed Planning effort [6] presents a set of 103 high-level requirements for an AMS Testbed. These requirements were compiled based on the foundational research already conducted under the ATDM Program and the analytical needs of the DMA bundles. These requirements were identified and grouped into seven categories as follows:

- **System User (SU) requirements**: Functional requirements related to System Users include users who are human, who make a range of strategic and tactical decisions regarding their travel. These decisions may be whether to travel or not, what mode of travel to use, when to take a trip, which route to choose, where to park, and, finally, how a collection of trips (a tour) within a day will meet a variety of obligations and desired outcomes.
- **Connected Vehicles (CV) and Connected Traveler Devices requirements:** Functional requirements related to Connected Vehicles include vehicles equipped with one or more Carry-In or Integrated Devices. Note that a Connected Vehicle may contain Passengers utilizing Mobile Devices.
- **Communications Systems (CS) requirements**: Functional requirements related to communication systems include Traffic Detection Systems, Traffic Control Systems, Broadcast Media, DSRC Roadside Device Networks, and Wide-Area Wireless Networks.
- **Operational Data (OD) Environment requirements:** Functional requirements related to Operational Data Environments include Data Quality Checks and Aggregation, Private Sector Data Services, and Predictive tools.
- **Operational Conditions (OC) requirements:** Functional requirements related to Operational Conditions include System Performance Measures.
- **System Manager (SM) requirements**: Functional requirements related to System Managers include Freeway/Tollway Managers, Arterial System Managers, Road-Weather System Managers, Transit System Managers, Parking System Managers, and Freight System Managers.

- **Data and Information (DI) Flows requirements:** Functional requirements related to Data and Information Flows include Basic Safety Message (BSM), Basic Mobility Message (BMM), and Signal Phase and Timing (SPaT) Message.
- **DMA Applications (AP) and ATDM Strategies requirements:** Functional requirements related to ATDM Strategies and DMA Applications.

As not all requirements are not of same importance to meet the overall DMA and ATDM program needs, it was desirable to assign an importance rating (Low, Medium, High) to each requirement and consequently assign a weight (Low=1, Medium=2, High=3). Importance ratings represent a subjective measure of how critical a requirement is for differentiating among expected alternatives. These ratings were compiled by seeking inputs from a group of experts. It was observed that there was a distinction between experts who typically conduct large-scale regional or corridor analyses and those who most typically conduct detailed tactical analyses. Therefore, to highlight these critical differences in insights, responses were grouped into tactical and strategic application areas. Since the high-level requirements were given a strategic and tactical importance rating as part of Testbed Planning effort, these ratings were used as a starting point.

The following presents a definition of tactical applications from the *AMS Testbed Requirements for DMA and ATDM Programs* FHWA report [1].

- Tactical applications are applications that focus on influencing decisions and maneuvers made by system users (e.g., drivers) to pre-position or control their vehicles while en route, as well as applications that influence control/advisory decisions generated by System Managers to influence these short-term tactical behaviors/maneuvers. Examples of such applications include, Adaptive Traffic Signal Control, Adaptive Ramp Metering, Queue Warning, Dynamic Speed Limits, Cooperative Adaptive Cruise Control, etc.
- Strategic applications are applications that primarily influence long-term decisions made by travelers in response to traffic conditions and travel experiences, as well as applications that emulate control/advisory decisions made by System Managers to influence these long-term travel choices. Examples of such applications include, Traveler Information, Dynamic Pricing, Dynamic Fare Reduction. Clearly, tactical applications may have impacts on strategic decision-making and vice versa. This distinction should not be confused with long-term (habitual) behavior versus short-term behavior, which is a separate dimension for consideration in representing traveler behavior. Drivers may develop long-term tactical behaviors, e.g., proclivity for lane-changing or routinely choosing a particular lane for travel. Similarly, travelers may make short-term adjustments to strategic behaviors, such as habitual time of departure choice for a routine commute based on current weather conditions.

4.1.1 Assigning Importance Ratings

The AMS Testbed Team reviewed each high-level requirement's importance rating and adjusted them based on additional knowledge and information obtained through discussions between AMS Testbed Team members. This process modified less than 10 percent of both the strategic and tactical importance ratings. Exhibit 15 presents the modified high-level requirements' importance ratings along with the original importance ratings. The highlighted cells indicate the modified importance ratings. For example, the tactical importance for SU-1 was changed from high to low because a tactical Testbed, which is envisioned to contain a corridor or a subarea, will not be able to capture the entire trip. Therefore this requirement by definition is not important for a tactical Testbed.

Exhibit 15: Requirements Importance Adjustments (Sample)

ID	Requirement	Tactical Importance (from Planning Study)	Modified Tactical Importance
SU-1	The AMS Testbed shall emulate and track each Traveler's time-referenced geographic location (position) as he/she plans, executes, and completes a trip within the transportation system.	High	Low
SU-22	The AMS Testbed shall emulate decisionmaking by Public Safety Vehicle Drivers in the absence and presence of mobile devices, carry-in devices, integrated devices, and message signs subject to the nature and accuracy of data available to support the decision.	Low	Medium
SU-23	The AMS Testbed shall emulate adherence by Drivers of light, transit, and freight vehicles with directions when received in presence of emergency response personnel subject to the nature and accuracy of data available to support decisionmaking.	Low	Medium

As a part of the Task 3 of this project *(Develop Detailed AMS Requirements)*, detailed AMS requirements were developed based on the high-level requirements that were developed during *AMS Testbed Planning Study*. In total of 325 requirements were developed. These detailed requirements are used for the scoring and selection process.

Once the high-level requirements' importance ratings were modified, they were propagated to the detailed requirements (i.e., each detailed requirement inherited its parent's importance ratings). These formed the preliminary importance ratings for the detailed requirements. The AMS Testbed Team reviewed each detailed requirement's strategic and tactical importance ratings and adjusted them as needed. This provided the final importance ratings for each detailed requirement. Exhibit 16 presents a snapshot of the detailed requirements' importance ratings. The complete table is provided as an appendix (Appendix -1) to this document.

Exhibit 16: Detailed Requirement Importance Ratings and Weights (Sample)

	---------------Strategic---------------		---------------Tactical---------------	
Requirement	Importance	Weight	Importance	Weight
AP-1-1	High	3	High	3
The AMS Testbed shall emulate the dynamic operation (e.g. open/close, posted speed) of the Shoulder lanes to reflect System Managers real-time decision making based on current and/or predicted network conditions.				
AP-1-2	High	3	High	3
The AMS Testbed shall capture the network performance, lane flows and lane changing behavior on both regular and shoulder lanes on a continuous basis.				
AP-2-1	Low	1	High	3
The AMS Testbed shall distinctly emulate driver behavior (e.g. acceleration rates, deceleration, gap acceptance) on Dynamic Shoulder Lanes				
AP-2-2	Low	1	High	3
The AMS Testbed shall distinctly emulate driver behavior on regular lanes (e.g. acceleration rates, deceleration, gap acceptance)				
AP-3-1	High	3	High	3
The AMS Testbed shall track vehicle types (e.g. transit) and vehicle occupancy (e.g., HOV 2+, HOV 3+) in real-time and emulate restriction of access to Dynamic Shoulder Lanes by vehicle type and/or occupancy in response to real-time change in operations imposed by System Manager.				
AP-4-1	High	3	High	3
The AMS testbed shall emulate Lane Use operations on regular and shoulder lanes that are controlled by System Manager in response to current and/or predicted network conditions.				

4.2 Score Testbeds Against Requirements

After generating the requirements' weights, candidate Testbeds were evaluated against each detailed requirement using the following four-scale (0-3) rating:

Scale Rating	**Rating Definition**
0. Does not meet	Testbed does not meet the requirement, and cannot be adapted to meet the requirement
1. Low	Testbed partially meets the requirement, and requires significant resources to be adapted to meet the requirement.
2. Medium	Testbed partially meets the requirement, and can be easily adapted to meet the requirement.
3. High	Testbed adequately meets the requirement, and requires an insignificant amount of resources to be adapted to meet the requirement

Exhibit 17 presents an example of how Testbeds' rating for each detailed requirement.

Exhibit 17: Testbed Rating (Sample) [Source: Booz Allen Hamilton]

Req Group	Req Group ID	Strategic Testbeds			Tactical Testbeds		
		1	2	3	1	2	3
SU-1	1	2	1	3	2	3	1
	2	3	3	3	1	1	2
	3	1	1	3	3	3	3
	4	2	3	3	1	3	2
	5	1	1	2	2	3	3
	6	3	3	3	1	3	1
CV-1	1	1	2	1	2	1	3
	2	2	2	2	3	1	1
	3	3	1	2	2	3	3
	4	1	3	1	2	3	2
	5	1	1	2	1	3	1
	6	2	2	2	3	3	1

Since the Testbeds were grouped into two modeling approach types, each Testbed needs to be weighted by the appropriate weight (i.e., the Testbeds in the strategic approach type will be weighted with the strategic priority-based weight, and the Testbeds in the tactical approach type will be weighted with the tactical priority-based weight).

Composite scores for each category and for all the requirements were computed by multiplying each requirement weight and score and summing these up for each category and for all the requirements.

$$Composite\ Score\ (category\ m) = \sum \{Requirement\ Weight\ (m,n) \times Requirement\ Score(m,n)\}$$

Where the composite score of requirement category m is the sum of Testbed scores of each requirement n under that category. Testbed score of a requirement is computed by multiplying the weight assigned to that requirement and the score of how the Testbed meets that requirement.

This process provided an objective method to compute an initial score that is based on a logically sound methodology. Exhibit 18 presents an example of how scores and weights are used to compute composite scores for each category. In addition, a total score is also computed. This enabled the use of both composite category scores, and total scores to evaluate Testbeds.

Exhibit 18: Testbed Composite Scores (Sample) [Source: Booz Allen Hamilton]

Req Group	Req ID	Strategic Testbeds			Tactical Testbeds		
		1	2	3	1	2	3
SU-1	1	10	5	15	4	6	2
	2	12	12	12	3	3	6
	3	3	3	9	3	3	3
	4	4	6	6	4	12	8
	5	2	2	4	8	12	12
	6	3	3	3	2	6	2
	Composite Score	5.67	5.17	8.17	4.00	7.00	5.50
CV-1	1	5	10	5	10	5	15
	2	2	2	2	12	4	4
	3	3	1	2	8	12	12
	4	1	3	1	8	12	8
	5	3	3	6	2	6	2
	6	2	2	2	6	6	2
	Composite Score	2.67	3.50	3.00	7.67	7.50	7.17
	Total Score	4.17	4.33	5.58	5.83	7.25	6.33

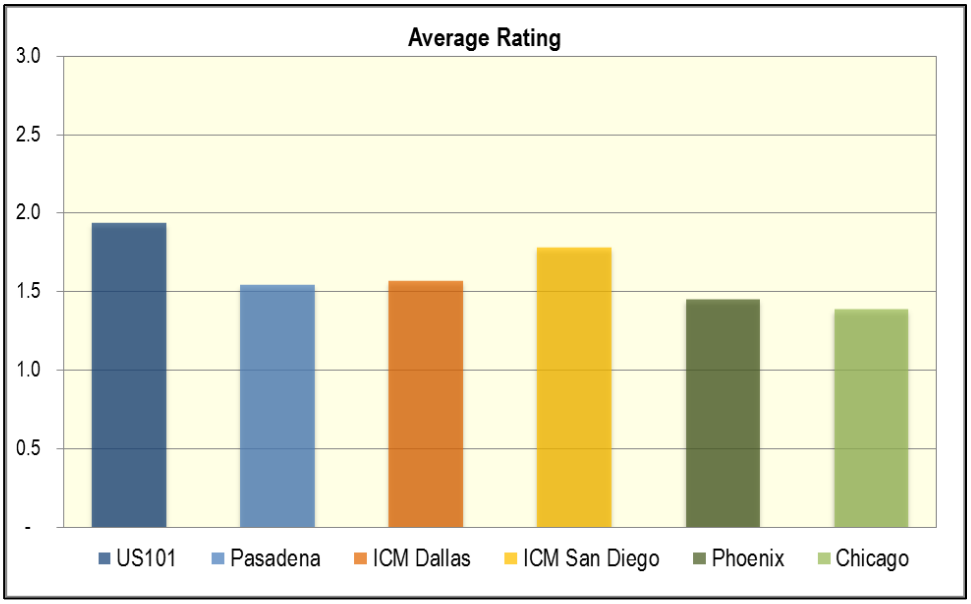
4.3 Assessment of Testbeds

The Testbed scores were evaluated using both the raw scores and the weighted scores across the functional groups. In addition, the number of high importance requirements met by Testbeds was also reviewed. Finally, a gap analysis was conducted to determine the need for adding additional Testbeds to the portfolio. The section below presents the key findings of this assessment.

4.3.1 Assessment of Testbeds raw scores

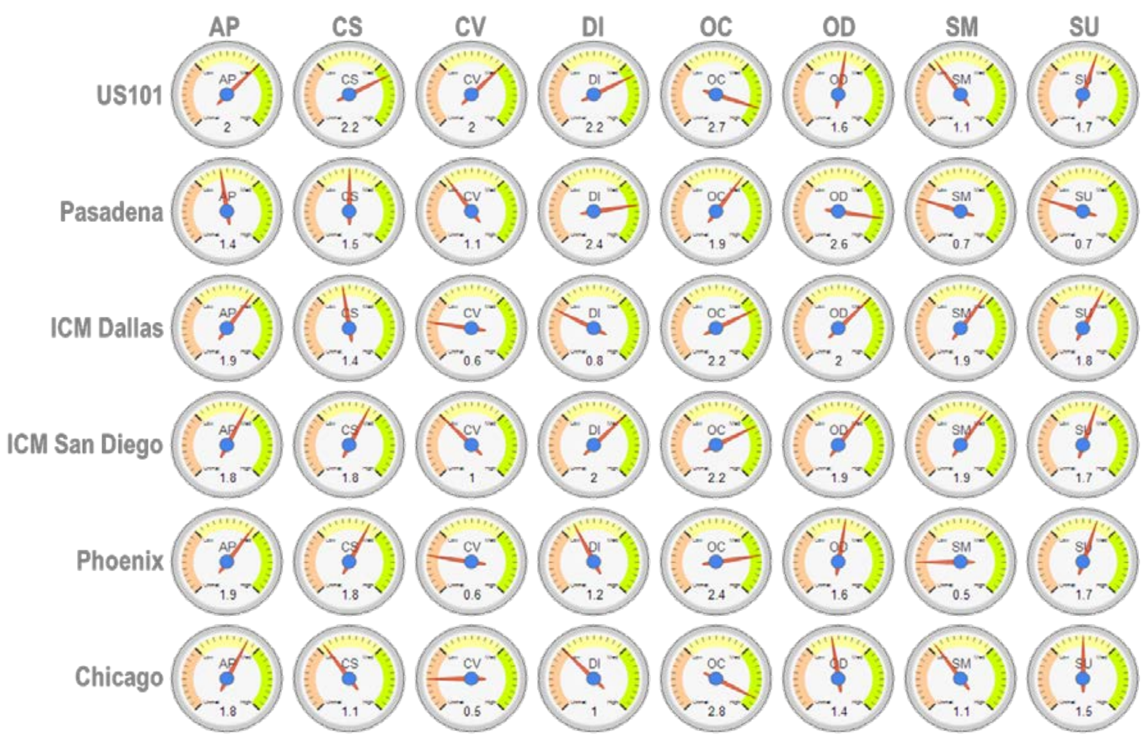
Each Testbed developer was given a detailed requirement listing along with each requirement's weight and asked to evaluate the Testbed against each detailed requirement. As detailed in Section 4.2, the evaluation process asked developers to rate the Testbeds using the following four-point (0–3) rating. Once Testbed developers provided their ratings, the AMS Testbed Team reviewed each rating and modified them if necessary. This modification was necessary because each Testbed developer viewed the requirements differently — and at times — Testbeds with similar capabilities received contrasting ratings for the same requirement. For example, driver behavior ratings were adjusted to ensure consistency across Testbeds. Preliminary analyses revealed that all six Testbeds rated well, and are all good candidates overall. Exhibit 19 presents the average rating for each Testbed across all requirements.

Exhibit 19: Average Testbed Rating [Source: Booz Allen Hamilton]



The AMS Testbed Team also analyzed the ratings for each Testbed by requirement group. Exhibit 20 presents this information as a gauge chart. This chart allows one to compare the rows (Testbeds) and the columns (all requirement groups). The label in the gauge represents the requirement group. This chart shows that US-101 was rated better than Pasadena in the tactical category, while ICM Dallas and ICM San Diego received similar ratings. Phoenix rated better than Chicago in most categories.

Exhibit 20: Average Testbed Ratings by Requirement Group [Source: Booz Allen Hamilton]



Provided below are a few observations from the exhibit presented above:

- All six Testbeds are well suited to test applications
- US-101, Pasadena, and ICM San Diego are well suited to meet data and information flow requirements
- All Testbeds are well suited to conduct operational conditions and operational data testing
- ICM Dallas and ICM San Diego are better suited than other Testbeds to model strategies that pertain to system management
- All Testbeds except Pasadena are well suited to meet system user requirements.

4.3.2 Assessment of Testbeds weighted scores

Once the Testbeds were rated, the next step in the process was to multiply each detailed requirement's weight with the corresponding rating in order to compute the score for each detailed rating. Once these scores were computed, they were summed to create a total score for each Testbed. Exhibit 21 presents the total scores for each Testbed.

Exhibit 21: Total Scores [Source: Booz Allen Hamilton]

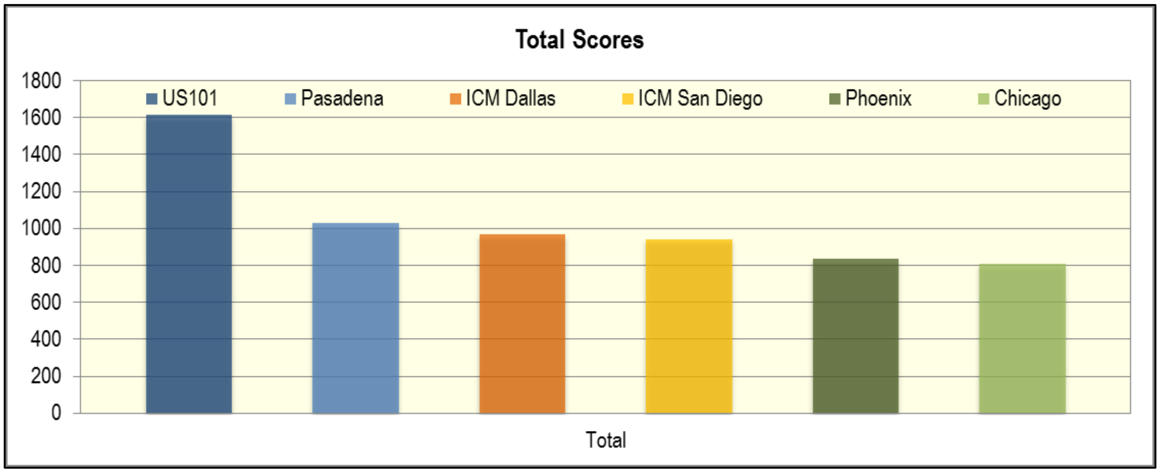
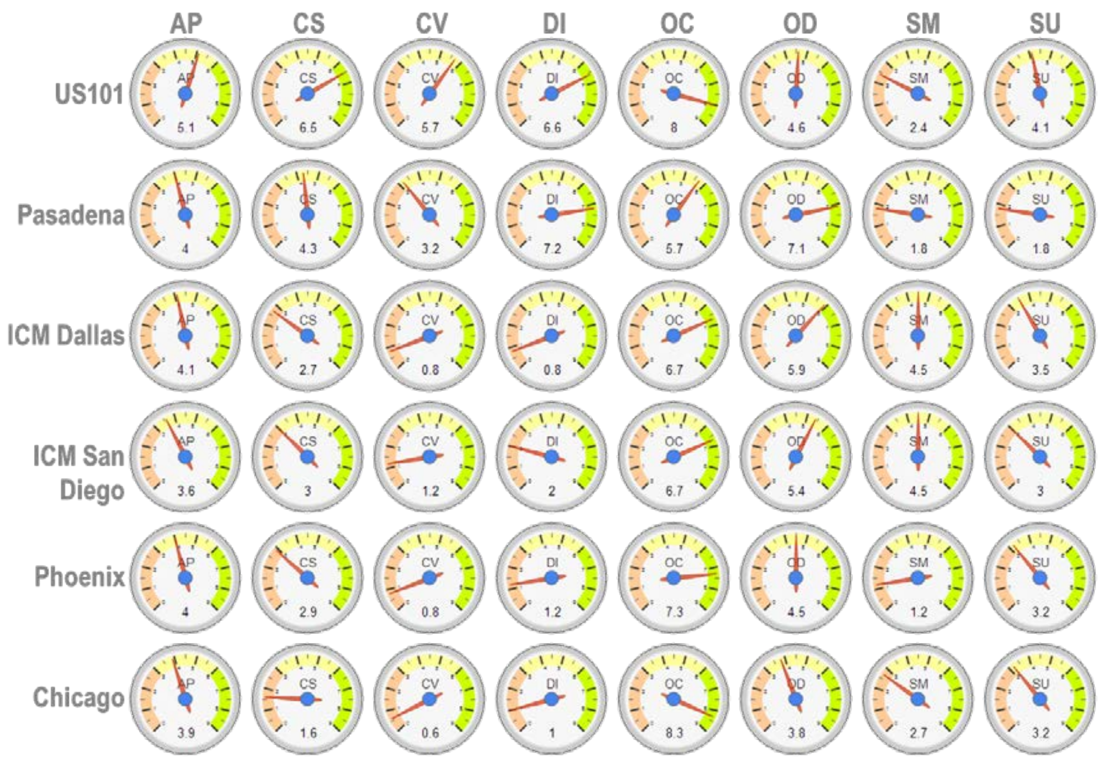


Exhibit 21 clearly shows that all six Testbeds are viable Testbeds to support AMS activities for the DMA and ATDM program. While the total scores provide an indicator of the overall capabilities of the Testbed for ATDM and DMA testing, it is important to understand each Testbeds capabilities for each of the eight requirement categories. Exhibit 22 presents this information. Overall, this follows the total scores' pattern; however, ICM San Diego scored better than ICM Dallas in the CS, CV, and DI categories.

Exhibit 22: Testbed Scores by Requirement Group [Source: Booz Allen Hamilton]



While different Testbeds score well in different groups, collectively they meet the requirements reasonably well. This chart was created to identify gaps and enable the AMS Testbed Team to ensure that the gaps are filled and the Testbeds collectively meet the requirements in each group. This chart does not reveal large gaps. If large gaps had been revealed, the AMS Testbed Team would have considered additional Testbeds from the preliminary list. Although these gauges are presented on a 0–9 scale, it is not possible for all of the scores to achieve the maximum score of 9 because the scores are a product of the requirement importance weight (1–3 scale) and a rating (0–3 scale). If the requirement's importance is low, the maximum possible score for that requirement would only be 3. This gauge chart, however, helps illustrate the relative differences in Testbed capabilities.

4.3.3 High Importance Requirements

While the total scores and composite scores by category provide clear indicators of Testbed capabilities, it is also important to understand the number of high-importance requirements met (rated medium or high) by each Testbed. While 221 requirements were given a high importance rating for the tactical category (US-101 and Pasadena), only 84 requirements were given a high importance rating for the strategic category (ICM Dallas, ICM San Diego, Phoenix, and Chicago). Exhibit 23 presents the number of these high-importance requirements that were met by each Testbed. US-101 meets almost all of the tactical Testbed high-importance requirements, while ICM Dallas meets most of the strategic Testbed high-importance requirements. ICM San Diego also meets a significant portion of the requirements. Therefore, we recommend that these two Testbeds (US-101 and ICM Dallas), at a minimum, be chosen for analysis plan development.

Exhibit 23: Number of High-Importance Requirements met by Testbed [Source: Booz Allen Hamilton]

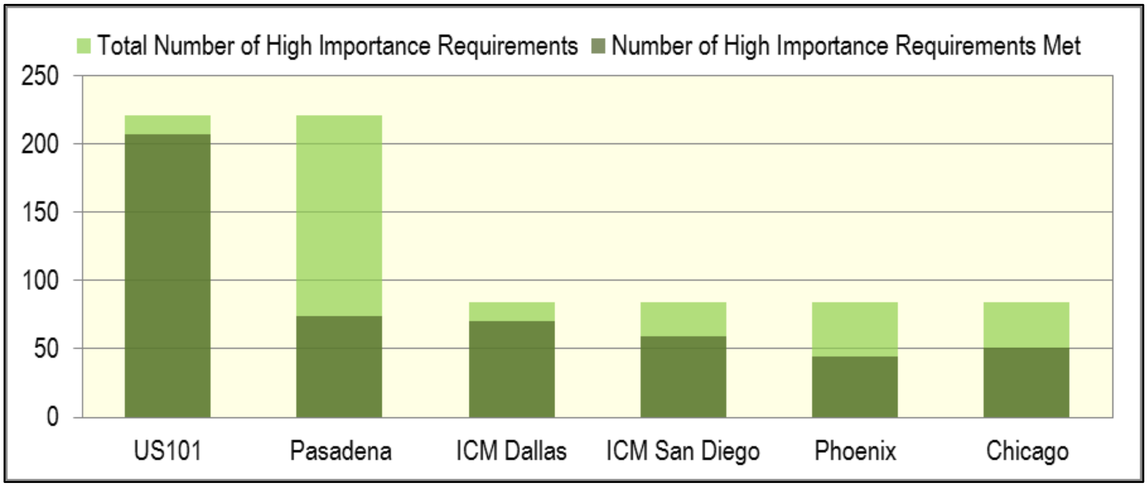
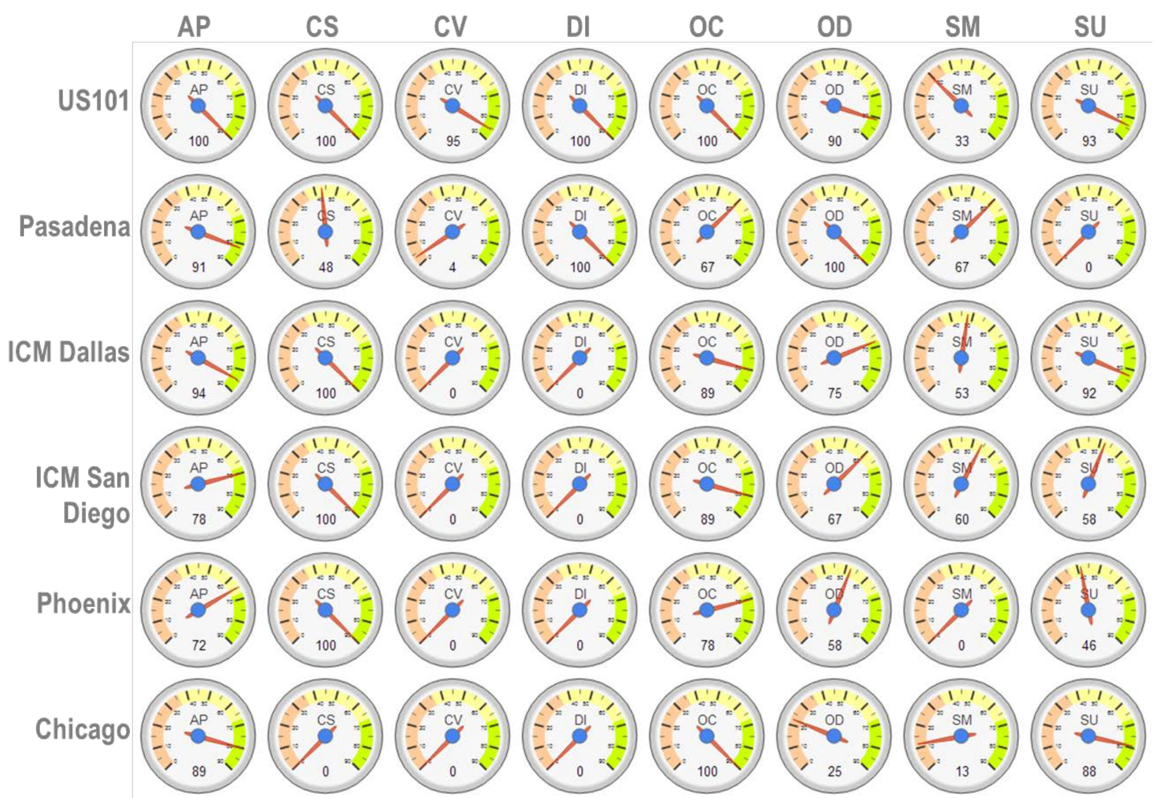


Exhibit 24 presents the percentage of high importance requirements met by each requirement category. This shows the same patterns as the previous charts with a few differences. Chicago meets more high-importance requirements than Phoenix in the AP, OC, and SU categories, but does not meet any of the high importance requirements in the CS category. This is as expected, given the charts presented previously that show no clear winner between these two Testbeds.

Exhibit 24: Percentage of High-Importance Requirements met by Testbed by Requirement Group [Source: Booz Allen Hamilton]



4.3.4 Gap Analysis

The following presents a synopsis of the requirements that cannot be completely captured by the Testbed portfolio in their current state. The AMS Testbed Team recognizes these gaps and, as part of the analysis plan development process, will develop a plan to overcome these challenges.

1. **System User (SU):**
    a. The impact of safety considerations on travelers' decision-making during the pre-trip state.
    b. Non-motorized travelers' and transit riders' decision-making in the presence of mobile devices.
    c. Light vehicle drivers' gap acceptance and speed selections with or without relevant real-time information.
    d. Transit drivers' location along the time when it is in service or out of service.
    e. Truck drivers' decision-making in the presence and the absence of mobile devices, carry-in devices, and integrated devices.
    f. Different users' perceptions and reactions to receiving advisory and regulatory information.
2. **Connected Vehicles (CV) and Connected Traveler Devices:**
    a. The interaction between the transmitting messages via cellular and DSRC.
    b. The limitations of the cellular network coverage area.
    c. The time-referenced geographic location in the different operational status (on, off, not functioning), and power status of the mobile device and the DSRC devices.
3. **Communications Systems (CS):**
    a. The latency of messages via the DSRC roadside network under different locations, communications load, and density of nearby DSRC-capable devices.
    b. The simulation of the dynamic DSRC network capacity in real time.
    c. The ability of traffic control systems to receive, process, and implement control setting changes from system managers, including the latency and reliability of response to system manager direction.
4. **Operational Data (OD) Environment:**
    a. The sensitivity of the different data quality and aggregation levels on the system manager decisionmaking (e.g., changing ramp meter plans, providing speed advisory on dynamic message signs).
    b. The capture of data from mobile devices, carry-in devices, and integrated devices on a continuous basis.
5. **Operational Conditions (OC):**
    a. The ability to calculate transportation network performance including travel times and travel delays on a continuous (second-by-second) basis and dynamically update the system.
6. **System Manager (SM):**
    a. The duration and outcomes of decision-making by freeway system and toll managers are subject to the latency, accuracy, reliability, and nature of operational data environments.
    b. The decision-making of arterial system managers in response to the change of arterial operations (e.g., changes to signal timings, granting signal priority based on vehicle types).

7. **Data and Information (DI) Flows:**
    a. Emulate the transmission and reception of information and data flows between system entities over a specific communications system, whether broadcast or point-to-point in nature, the interval at which the data flow occurs, and the content of the message contained in the data flow.
8. **DMA Applications (AP) and ATDM Strategies:**
    a. The dynamic operation of the network, lane flows, and lane changing behavior on both regular and shoulder lanes on a continuous basis.
    b. The tracking of different vehicle types (e.g., transit) and vehicle occupancy (e.g., HOV) in real time and emulating restriction of access to dynamic shoulder lanes by vehicle type and/or occupancy in response to real-time change in operations imposed by the system manager.
    c. Driver decision-making (e.g., speed reductions) in response to target speed recommendations made by carry-in devices or integrated devices.

4.3.5 Phase II Assessment Summary

A detailed assessment of the six Testbeds revealed that the Testbed portfolio will be able to meet the AMS Testbed project needs. The down-selection process in Phase I ensured that the each Testbed considered in Phase II has unique capabilities which make it a suitable Testbed for conducting the project activities. However, the scoring process also revealed gaps which need to be addressed in in order to ensure that the Testbed is completely capable of meeting the project needs. Chapter 5 presents the final Testbeds recommended for developing AMS Analysis Plans.

Chapter 5. Conclusions and Recommendations

As detailed earlier, the foundational work conducted for the DMA and ATDM programs revealed a number of technical risks associated with developing an AMS Testbed which can facilitate detailed evaluation of the DMA and ATDM concept. Therefore, instead of selecting a single Testbed, it is desirable to identify a portfolio of AMS Testbeds and mitigate the risks posed by a single Testbed approach by conducting the analysis using more than “optimal” number of Testbeds, reduces the resources available to enhance or improve the Testbeds to address the gaps. While any combination of the six Testbeds can likely meet the project needs, it is desirable to not have Testbeds of same characteristics in the final portfolio. Keeping this in mind, the following presents the conclusions derived from the Testbed evaluation process and recommended AMS Testbeds for DMA and ATDM evaluation.

- **San Mateo US-101** is clearly the best suited Testbed for the tactical category. US-101 is a low-risk small corridor; therefore, it is recommended for analysis plan development.
- **Pasadena** is the only tactical Testbed for a region (small city). This Testbed can be used to test route choice along with microsimulation; therefore, it is recommended for analysis plan development.
- Both ICM San Diego and ICM Dallas fall under the strategic corridor Testbed category and these Testbeds are suited to evaluate the dynamic management strategies effectively. As the AMS Testbed Team is more familiar with Dallas Testbed, it is recommended that **ICM Dallas** Testbed be used for analysis plan development. However, **ICM San Diego** is also used for analysis plan development owing to its added value to the project in terms of possibility of corridor-level DMA and ATDM application combinations.
- While Phoenix and Chicago Testbed’s scores are about the same and meet about the same number of high-importance requirements, the **Phoenix** Testbed is better suited than Chicago, as it has a finer-resolution activity-based model. In addition, the AMS Testbed Team is more familiar with the Phoenix Testbed has access to the source code, and can modify it easily.
- **Chicago** Testbed presents possibility to introduce inclement weather conditions and modeling of weather-related ATDM strategies. Therefore, Chicago Testbed is also added to the portfolio.

The AMS Testbed Team believes that while the recommended Testbeds possess the capabilities to test DMA applications and ATDM strategies within an AMS Testbed, it is necessary to reevaluate the Testbeds after the analysis plans are created. If the analysis plan for a Testbed reveals large gaps that may impact the success of the AMS Testbed activities, it behooves the AMS Testbed Team to develop an analysis plan for another Testbed and evaluate gaps. Therefore, the AMS Testbed Team plans to reserve the **SHRP2 Sacramento** and **Northern Virginia** Testbeds for further consideration after the analysis plan development as these two Testbeds have already been evaluated at the requirement level.

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