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A Next Generation Advanced Traveler Information Precursor System (ATIS 2.0 Precursor System) Concept of Operations

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16. Abstract

Advanced Traveler Information Systems (ATIS) have experienced significant growth since its initial inception in the 1990s. Technologies have continued to evolve at a rapid pace, enabling the integration of advanced solutions for traveler information purposes.

As a result of the rapid evolution of technologies and tools available, the Federal Highway Administration (FHWA) has initiated new technical initiatives to investigate, plan, develop, design and implement 'Next Generation' or ATIS 2.0 solutions. This includes the investigation and design of new systems suitable for the collection and aggregation of traveler intent data for the use by system managers.

This Concept of Operations (ConOps) provides an operational overview of the ATIS 2.0 Precursor System to be demonstrated in conjunction with TranStar in Houston. The new ATIS 2.0 Precursor System will advance the state-of-the-practice for ATIS by incorporating traveler intent data in order to provide congestion prediction systems for use by system managers.

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Executive Summary

Advanced Traveler Information Systems (ATIS) have experienced significant growth since their initial inception in the 1990s. Technologies have continued to evolve at a rapid pace, enabling the integration of advanced solutions for traveler information purposes.

As a result of the rapid evolution of technologies and tools available, the Federal Highway Administration (FHWA) has initiated new technical initiatives to investigate, plan, develop, design and implement 'Next Generation' or ATIS 2.0 solutions. This includes the investigation and design of new systems suitable for the collection and aggregation of traveler intent data for the use by system managers.

This project seeks to create and test the mechanisms of collecting disaggregate data from multiple sources, including data that provides traveler intent, and combining them in new and innovative ways that allow system managers to make decisions and apply system responses.

The Next Generation Advanced Traveler Information Precursor System (ATIS 2.0 Precursor System) effort is intended to identify and explore synergistic public-private sector arrangements that as a natural outcome improves end-user experience, enhanced service provision, and improved system management. In this context, the ATIS 2.0 Precursor System is defined as the next generation in advanced traveler information systems, which will identify, collect, cleanse and fuse disaggregate data from varying data sources, including traveler intent sources, to generate information for system managers for enhanced decision-making and operations management. This is called a "Precursor System" because information is used by system managers and is not yet fed directly back to the travelers.

This Concept of Operations (ConOps) provides an operational overview of the ATIS 2.0 Precursor System to be demonstrated in conjunction with TranStar in Houston. The proposed ATIS 2.0 Precursor System will advance the state-of-the-practice for ATIS by incorporating traveler intent data to provide congestion prediction systems for use by system managers.

Chapter 1 Purpose of Document

A key component of the Systems Engineering process is the preparation of a Concept of Operations (ConOps). The ConOps provides a mechanism for project stakeholders to reach a shared understanding and an operational consensus of how the new system will be operated and maintained for the life-cycle of the new system. The ConOps provides a critical step in the system planning process, providing a foundation for the development of project (system) requirements that fulfill the users' needs.

This ConOps provides an operational overview for the ATIS 2.0 Precursor System to be demonstrated in conjunction with TranStar in Houston. The proposed operational framework for the ATIS 2.0 Precursor System is based on user needs as derived from prior project deliverables—including the Use Case Report, Data Transformation Approach, and Test Concept Summary. This ConOps will provide the user needs and operational scenarios for the new ATIS 2.0 Precursor System, which will be used to prepare the System Requirements document.

Chapter 2 Scope of Project

The ATIS 2.0 Precursor System will identify, collect, cleanse and fuse disaggregate data from varying data sources, including traveler intent sources, to generate information for system managers for enhanced decision-making and operations management. Figure 2-1 below illustrates the data flows between all of the elements of a general ATIS 2.0 concept. .

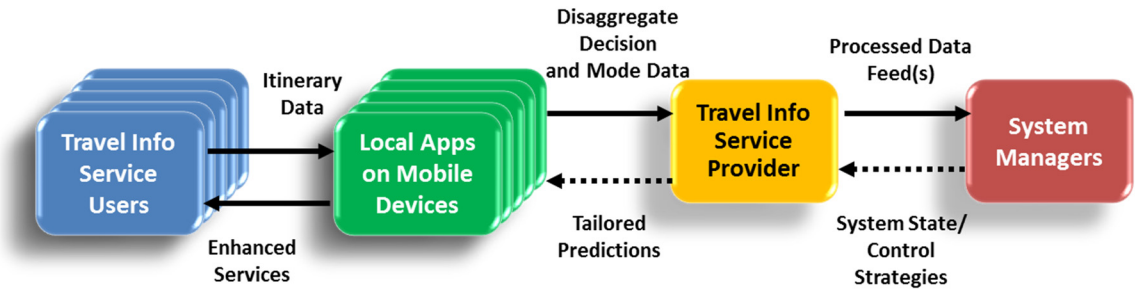

Figure 2-1. ATIS 2.0 Concept Elements and Data Flows

2.1 Project Description

The ATIS 2.0 concept is defined in the previous graphic, with primary informational flows depicted with solid lines. In the ATIS 2.0 Precursor System context, applications (or apps) on mobile devices (green box) provide enhanced services, such as shortest path and travel times, to traveler information service users (blue box), who provide data feeds that include disaggregate itinerary (such as origin and destination points), decision, and mode data. This disaggregate information is fed to traveler information service providers, such as INRIX (yellow box), who feed it to system managers (red box), such as TranStar, who can process the data into aggregate information, such as congestion alerts. This is called a “Precursor System” because information is not yet fed back through the traveler information service providers to the travelers’ mobile apps. The dashed lines represent functionality and system information flows to be implemented under future system development (not a component of this project).

2.2 Project Purpose

The ATIS 2.0 Precursor System project will demonstrate a functional framework that will ingest and process traveler intent data, then utilize algorithms and tools to produce predictive system output, which can be used to improve the operational response of traffic management systems. As a demonstration project, it will both evaluate the effectiveness of traveler intent data in making impactful

predictions for system managers, and also provide a framework for the ATIS 2.0 concept to be implemented with other agencies.

To evaluate the effectiveness of the ATIS 2.0 Precursor System the project will compare congestion predictions using traveler intent data (what is herein referred to as ATIS 2.0 data) against predictions using ATIS 1.0 data (which is herein considered to include historical system state data such as speed and volume). ATIS 1.0 data are generally sourced from point detection or probe vehicles, representing traffic conditions at the time of detection, and are generally characterized as having limited prediction capability.

2.3 Project Stakeholders

To fulfill the project purpose, the ATIS 2.0 Precursor System will be demonstrated by the FHWA project team in conjunction with Houston TranStar. Additional stakeholders, including other transportation management agencies, are being solicited for input to the ConOps as a framework for future adopters of ATIS 2.0 Precursor Systems. The Federal Highway Administration (FHWA) project team, TranStar, and other stakeholders are described further in Chapter 6.

Chapter 3 Referenced Documents

The development of the ConOps builds on previous task work and output generated in prior tasks of the project, as a result, several key documents have been referenced in the preparation of this ConOps document.

3.1 ConOps Guidance Document

The ConOps for the ATIS 2.0 Precursor System was developed and prepared in accordance with FHWA's Systems Engineering Guidebook for ITS, Section 8.4.5[1]. The Guidebook, which follows systems engineering industry standards, including IEEE 1362 and ANSI/AIAA G-043-1992, was specifically developed for transportation professionals' use in developing transportation solutions in accordance with Federal Rule 23 CFR 940.

3.2 Project-Related Documents

The ATIS 2.0 Precursor System ConOps is prepared with documentation and task work developed as a component of research under previous projects and previous task work under this project. This includes, but is not limited to:

Previous FHWA EnableATIS Dynamic Mobility Application (DMA) Projects:

1. Vision and Operational Concept for Enabling Advanced Traveler Information Services Operational Concept, FHWA-JPO-12-052, May 13, 2012[2]
2. Vision and Operational Concept for Enabling Advanced Traveler Information Services Market Readiness Assessment, FHWA-JPO-12-053, May 22, 2012[3]
3. EnableATIS Strategy Assessment, FHWA-JPO-14-113, February 2014[4]

Current ATIS 2.0 Precursor System Project:

4. Stakeholder Registry and Engagement Plan (Task 2.1)
5. Use Cases for Disaggregate Traveler Data Supporting System Management – Final (Task 2.4)
6. Disaggregate User Data Capture Approach and Testing Plan – Final (Task 3.2)
7. Disaggregate User Data Capture Approach – Final (Task 3.5)
8. Revised User Data Cleansing and Transformation Approach – Final (Task 4.6)
9. Field Test Concept Summary – Final (Task 5.2)

[1] http://www.fhwa.dot.gov/cadiv/segb/views/document/sections/section8/8_4_5.cfm
[2] http://ntl.bts.gov/lib/45000/45900/45929/Final_Package_FHWA-JPO-12-052_508.pdf
[3] http://ntl.bts.gov/lib/45000/45500/45560/FHWA-JPO-12-053.pdf
[4] http://ntl.bts.gov/lib/52000/52600/52622/FHWA-JPO-14-113-v1.pdf

Chapter 4 Background

Chapter 4 provides a project "background" for the ATIS 2.0 Precursor System. The background, in a systems engineering and ConOps context, establishes a baseline of existing conditions for the project, the current system with its limitations, and the proposed changes for an improved system.

4.1 Existing Conditions

The demonstration of the ATIS 2.0 Precursor System project will be installed along-side the existing TranStar system in Houston, Texas. TranStar is the Traffic Management Center for the Houston, TX area. TranStar is a regional partnership of operational entities from multiple jurisdictions and agencies, including:

- City of Houston
- Harris County
- Metropolitan Transit Authority of Harris County (METRO)
- Texas Department of Transportation

In 2015, TranStar reduced total vehicle hours for the region by more than 20.7 million, for a fiscal benefit of approximately $460 million for the calendar year. TranStar's transportation management activities reduced travel times and fuel consumption by 38 million gallons in 2015. TranStar incident management includes incident response, clearance, and motorist assistance. In 2015 there were 47,933 incidents entered into the Regional Incident Management System (RIMS)—incidents types include crashes and congestion, among others. The average incident cleared in 33 minutes and the number of average daily incident hours was 72.[5]

4.2 Current System

The TranStar system currently utilizes a wide array of technologies and tools to operate and manage transportation systems in the Houston, Texas region. The following subsections describe the current data collection, congestion alarms and notifications, operational responses, and limitations.

4.2.1 Current Data Collection

The TranStar Advanced Transportation Management System (ATMS) currently utilizes radar detectors and Automated Vehicle Identification (AVI) sensors for traffic flow analysis. The radar detectors continuously detect vehicle counts and speeds at various (spot) locations throughout the network and are capable of reporting aggregated values at intervals at least as small as one minute.

The other primary means of detecting the system state is through AVI detectors. This system reads identifying characteristics of vehicles as they pass AVI detectors along freeways in the area. As a vehicle drives along a corridor and passes sequential pairs of AVI detectors, its travel time is

[5] Houston TranStar 2015 Annual Report: https://www.houstontranstar.org/about_transtar/docs/Annual_2015_TranStar.pdf

calculated. The average speed of the vehicle can be calculated with knowledge of the distance between detectors and vehicle travel time. The system aggregates vehicle speeds and reports aggregated speed values in one-minute intervals.

4.2.2 Congestion Alarms and Notifications

While radar and AVI data are used to monitor conditions along freeways in the Houston area, alarms are used to help system managers identify locations where problems are occurring, and when traffic management solutions should be implemented. The TranStar system uses AVI-based speed output to determine when an alarm for a particular freeway segment should be issued. Every speed output is compared against a threshold value to determine when an alarm should be issued. Threshold values are calculated using the 2.5 percentile of all speed values over the last 90 days grouped by day of week and time of day, or 40 mph, whichever is greater. This maximum threshold value is generally applicable during off-peak hours, especially between the end of the evening peak and before the morning peak.

When an alarm is issued, it is displayed on a situational display map. ATMS congestion alarms (http://traffic.houstontranstar.org/layers/layers_alarms.aspx) currently occur after congestion has formed (using aggregated AVI probe data). System managers notice these alarms and can implement a system management strategy to mitigate the issue.

4.2.3 Operational Responses

Operations responses are pre-determined via the TranStar Standard Operating Procedures (SOPs). Traffic management solutions available to TranStar traffic managers can include:

- Digital Message Signs
  - Guide drivers to alternate routes
  - Suggest use of Transit
- Adjustment of freeway ramp meter timings
- Adjustment of frontage road signal timings
- Removing occupancy restrictions on managed lanes

The ability of the system manager to implement a traffic management solution is based on the issuance of alarms. The impact of the operational response is dependent on the accuracy and timeliness of the data used to generate the alarms.

4.2.4 Limitations

It is important to note that AVI-detector-based travel times, though occurring in real-time, represent slightly outdated conditions at the moment a travel time can be calculated. This is due to the nature of AVI data—by the time the travel time for a vehicle can be calculated (that is, the vehicle passes a second detector along a corridor), conditions along the corridor have changed, rendering the calculation slightly outdated. Within the context of other activities that comprise traffic management, the influence of delay in obtaining AVI data can range from negligible to significant depending on the severity of the delay. As the distance between detectors increases and as travel times increase, so does the amount of time it takes to determine travel time, resulting in data that is increasingly outdated and more likely to negatively influence the ability to use the data to effectively manage the network.

Currently, system managers are limited to a "reactive" operational response. Because operational responses occur after congestion has already occurred, the system manager's operational efforts are

reactive to recurring congestion. Operational responses to recurring congestion could be proactive and better managed (e.g., load balancing) if a better prediction of onset of the congestion can be made.

In addition, the current system makes no use of traveler "intent" data, or archive data, to predict future operational conditions, such as impending congestion.

4.3 Planned Changes

System managers will be given additional predictive system data based on capturing traveler intent, as well as existing intelligent transportation system (ITS) infrastructure data to monitor and predict travel network conditions. Intent data represents the next generation of traveler information data (ATIS 2.0), which will assist system managers with congestion prediction and therefore changing from existing "reactive" responses to "proactive' responses for system management. In an ideal ATIS 2.0 Precursor System, System Managers would be able to proactively minimize the effects of major congestion. It is expected that intent information will allow the ATIS 2.0 Precursor System to provide system managers with a congestion prediction to proactively manage peak hour traffic.

If the current and predicted conditions vary greatly with historic trends, the ATIS 2.0 Precursor System will alert system managers to consider taking proactive actions. From the predictive data system managers will have a better understanding regarding the sources of the increased traffic demand, and be able to provide more effective responses.

Chapter 5 Concept for the ATIS 2.0 Precursor System

The ATIS 2.0 Precursor System will encompass the Peak Hour Traffic Management use case identified in the Task 2 - Use Cases Report. Under this concept, the system managers will be able to manage peak hour traffic proactively to prevent or mitigate highway congestion based on real-time and predicted traffic demand information.

Because the ATIS 2.0 Precursor System is a demonstration project, the system will support an experimental design that shows the primary impacts of the operational ATIS 2.0 Precursor System. The term 'primary impact' is described for this task as the delivery of the transformed data product to system managers who can assess its practical value and immediate impact in enhancing transportation systems management. The main questions that must be answered to assess primary impact include:

- "What is the improvement generated by the transformation of traveler intent data in the ATIS 2.0 Precursor System?" and
- "Can the ATIS 2.0 Precursor System provide the system manager a timelier notification of impending system state conditions or a strategy implementation trigger, allowing the system manager to preemptively execute a demand management strategy?"

Traveler intent data is the by-product of user-service interactions. Travelers input a desired origin and destination into a mobile travel planning application and receive route information for navigating between the origin and destination. This information is captured by the ATIS 2.0 Precursor System and is the input to a process that transforms disaggregate data collected from all travelers using the travel planning service (along with other real-time and historic data sources) into an advanced prediction of traffic congestion (alerts). When these alert predictions are issued, traffic managers may choose to implement any number of management strategies at their disposal. The proposed system will compare the alerts generated from the current system (ground truth data) against the predictive alerts generated from both the ATIS 1.0 and the ATIS 2.0 data as described in the following sections.

5.1 Operational Overview

It is the nature of travel intent data to be representative of demand and is expected to be utilized to predict congestion that is demand-related. Predictive intent data and real-time system state data transformed and evaluated by the ATIS 2.0 Precursor System will alert system mangers to major congestion events resulting from increases in demand. This includes recurring congestion from bottlenecks, or non-recurring congestion from special events. Proactive management will help to prevent or mitigate congestion and thus improve the mobility and safety performance of the highway system. Because of the demand focus of travel intent data, it will not be used to predict traffic impacts that can be attributed to weather or other external factors such as incidents.

5.2 Consideration of Alternative Concepts

In the context of this ConOps (and task order), the current TranStar congestion alerts are considered the "existing system". This includes all supportive subsystems, applications for processing and management of data and information, as well as supporting subsystems for producing and disseminating congestion alerts.

The overarching goal of the project is to enhance the functionality of an ATIS 1.0-based alert system by adding new and innovative data capture and transformation techniques, thereby creating new capabilities for an ATIS 2.0 Precursor System.

ATIS 1.0 data is historical system state data such as speed and volume, and is limited in prediction capabilities. ATIS 1.0 data is generally sourced from point detection or probe vehicles, representing traffic conditions at the time of detection, but loses value for predictions over time.

ATIS 2.0 data will be used to derive prediction functionality from traveler OD data and prediction algorithms, thus providing forecasted conditions for the system manager.

The proposed demonstration project will include two alternatives for an improved predictive congestion alert system:

1. Intent data based prediction (ATIS 2.0);
2. Historic versus current speed/volume data based prediction (ATIS 1.0).

The purpose of the demonstration is to compare these alternatives on archive data to understand the number, effectiveness, and quality of alerts within each alternative.

Chapter 6 User / Stakeholder Operational Descriptions

This chapter describes the project goals and objectives, and how the stakeholders and users are involved with the project.

6.1 Project Goals and Objectives

In a general sense, the following project goals and objectives discussed in this section are considered overarching for most traffic management and traveler information systems, as it relates to traveler information processing and dissemination. This project as a demonstration intends to develop a framework to examine how, and how well, traveler intent data can be used in the context of transportation management.

6.1.1 Goals

The primary goal for the ATIS 2.0 Precursor System project is to develop, design and implement a next-generation traveler information system based on traveler intent data. The resultant output goal will be to provide system managers with advanced, predictive traveler information, more specifically peak-hour congestion information based on traveler intent data.

Subsequently, additional supporting goals have been developed to support the overarching aforementioned project goal. These additional project goals include:

- Successful identification and aggregation of traveler intent data pertinent/relative to the ATIS 2.0 Precursor System
- Appropriate formatting and processing tools and applications for traveler intent data, necessary for actionable output from the ATIS 2.0 Precursor System

6.1.2 Objectives

In direct correlation to the aforementioned project goals, project objectives were derived to support necessary user needs for the project, deemed essential in successfully implementing a traveler intent based transportation management system. These include:

- Monitor transportation networks in real-time and near-real time
- Detect and identify (locate) traffic-flow anomalies
- Provide predictive alerts to allow system managers to better manage transportation networks in response to traffic flow anomalies

As stated previously, the current TranStar ATMS does not integrate traveler intent data or process and utilize traveler intent data to any significant extent. The proposed system will use traveler intent data to predict traffic congestion and generate alerts. Since this is a demonstration system, these new

predictive alerts will be compared against the current alert system to determine the potential benefits to system managers in managing the transportation network.

6.2 Stakeholders

In a systems engineering context, "Project Stakeholders" represent all entities that communicate, operate or interface with the proposed system in any fashion.

For this ATIS 2.0 Precursor System demonstration project, which seeks to understand the ability and benefits of congestion alerts based on predictive intent data, the stakeholder group includes a mix of U.S. DOT researchers and TranStar system managers—who are the eventual users of a deployed ATIS 2.0 Precursor System.

- FHWA ATIS 2.0 Precursor System Project Team:
    - FHWA and research support team including Volpe and Noblis – oversee the project and progress in achieving project goals
    - Contractor research team including Battelle, Atkins, TTI, and INRIX – develop and demonstration the ATIS 2.0 Precursor System
- TranStar Stakeholders
    - TranStar System Operators and Managers – provide input to ATIS 2.0 Precursor System concept, requirements, and data, and assist with assessment of potential impact of system prediction.
- Other Stakeholders
    - State/city transportation operations managers – provide input to ATIS 2.0 Precursor System concept and requirements, and assist with assessment of potential impact of system prediction

6.3 Users

The stakeholders described above will include the "end user" who receives and processes information delivered from the system—that is, the system managers. The system managers operate, monitor and manage the ATIS 2.0 Precursor System, and are ultimately responsible for decisions made based on the output from the system. The system managers will come from two of the stakeholder groups described above. First, the U.S. DOT researches who will be operating the system and determining the expected benefits of the traveler intent data-based congestion prediction. Second, the TranStar system managers who will be the eventual end users and providing input on how well the system operates and how best to eventually integrate the system into the existing TranStar operations.

Chapter 7 Operational Needs

In the systems engineering context, "user needs" establish the initial framework for a proposed project. User needs establish the building blocks for the project by soliciting user input pertinent to individual (unique) system operations.

The development of user needs is a cyclical process, conducted throughout the life-cycle of a project. A set of user needs has been identified to initiate the project development process. This set of user needs may be refined through throughout the project development process.

This chapter describes the overarching user needs from a project perspective. In the first section user needs are addressed. The second section describes some considerations on the user needs as they relate to each of the stakeholders

7.1 User Needs

The ATIS 2.0 Precursor System is being developed to fulfill the user needs. As described in the previous chapter, this demonstration system will fulfill the user needs of stakeholders in two groups—U.S. DOT researchers and TranStar system managers. The user needs are presented at a level such that the needs represent both stakeholder groups. Ultimately, these user needs will determine requirements development and project traceability.

Based on initial stakeholder interviews in Task 2 and preliminary project development in tasks 3 and 4 the following user needs have been identified:

1. A system manager needs advanced notification of transportation network congestion to improve operational response.

   It is not enough for a system manager to get existing data, the system manager will use an advanced warning—that is, predictive alerts based on traveler intent data and system state data—of the onset and duration of a potential network congestion problem in order to proactively select an appropriate operational response.

2. A system manager needs to be able to monitor alert quality.

   Having the advanced alerts is only helpful if the quality of the alert is accurate (reliable) and timely (predictive). The accuracy and timeliness of the alerts are key to the usability of the ATIS 2.0 Precursor System.

3. A system manager needs to be able to establish, monitor, and configure alert thresholds and alert confidence tolerance.

   The alert threshold is the point at which a system manager is prompted to make an operational response. The alert confidence is a parameter provided to the system manager representing the likelihood of the predicted alert condition to actually occur. The alert threshold parameter may be changed over time and even within a particular situation—that is,

depending on changes in operational responses. Long-term changes in traffic trends necessitate the ability of a predictive system to be flexible and adaptable. The alert confidence parameter will be used by the system managers to select the appropriate operational response. System managers will be able to determine and adjust the alert thresholds and optimal prediction period depending on the alert confidence tolerance for a given area or link and the appropriate operational response.

7.2 Stakeholder Considerations for User Needs

As previously noted, the user needs defined for this ATIS 2.0 Precursor System ConOps consider both the U.S. DOT researchers and TranStar system managers as stakeholders. These user needs will fulfill the demonstration of the ATIS 2.0 Precursor System. The results of this demonstration will include analysis and testing to determine the viability and benefits of using traveler intent data for predictive alerts.

The U.S. DOT researchers will develop the new ATIS 2.0 Precursor System, including identification of the relevant intent and system state data, data collection and processing requirements, data and information output, and the performance metrics and procedures for assessing the overall effectiveness of the ATIS 2.0 output. The researchers will conduct assessments through iterative modifications to the processing procedures, such as varying the forecast prediction period and comparing ATIS 2.0 versus ATIS 1.0 inputs. Researchers will also develop measurement tools to assess the accuracy of system output and present the results to TranStar system managers.

The TranStar system managers will assess the viability of the ATIS 2.0 Precursor System as an additional resource for transportation management. Output from the ATIS 2.0 Precursor System will provide TranStar system managers with predictive alerts, which could be used to better manage arterials and freeways in the Houston area. The system managers will review output from the system—that is congestion prediction alerts—and identify whether the accuracy and timeliness of these alerts are suitable for initiating operational responses within the transportation network. The result of this project will then be a framework ConOps and ATIS 2.0 Precursor System that TranStar and other agencies can enhance and deploy for their specific needs.

Stakeholders were engaged to obtain feedback focused on the ATIS 2.0 Precursor concept. The text below provides a summary of the feedback received that will have an impact on the design of an ATIS 2.0 Precursor System:

- The amount of accuracy required for prediction depends on type of action taken that will be taken to address congestion. For instance, changing a signal timing plan requires more confidence as the implication of changing a signal timing plan has notable consequences if the prediction is incorrect. Conversely, posting traveler information does not necessarily require a prediction to be as precise, as the consequences of posting incorrect traveler information are not as adverse.

- There are multiple scales to consider for timeliness. Shorter intervals (5-15 minutes) within urban areas, and 1 hour or more for regional travel (i.e. what is the best route for through traffic to take to get from one side of a metro area to the other?). Additionally, it would be useful for choosing operational responses to predict the end time and duration of the congestion.

- System managers are generally hesitant to implement a traffic management solution based only on a prediction. Solutions are currently implemented only if the event can be observed

and confirmed. Another consideration is the time needed to implement a change, such as change in traffic signal timing or opening a shoulder, and its implications on traffic flow. Stakeholders indicated they would need a prediction with a high confidence level to allow a system manager to take proactive action.

Chapter 8 System Overview

The ATIS 2.0 Precursor System will be developed for the purpose of conducting the research and demonstration associated with this project. The long-term goal is to provide a framework for transportation system managers to build on that provides a method for integrating predictive alerts based on traveler intent data into an existing ATMS. The system evaluation portion of this project (e.g. assessment of prediction accuracy) is conducted outside of the system, and requires the post-processing of system outputs as the basis for assessment—as discussed later in Chapter 12. The following diagram (Figure 8-1) shows the proposed data and information flows for the ATIS 2.0 Precursor System.

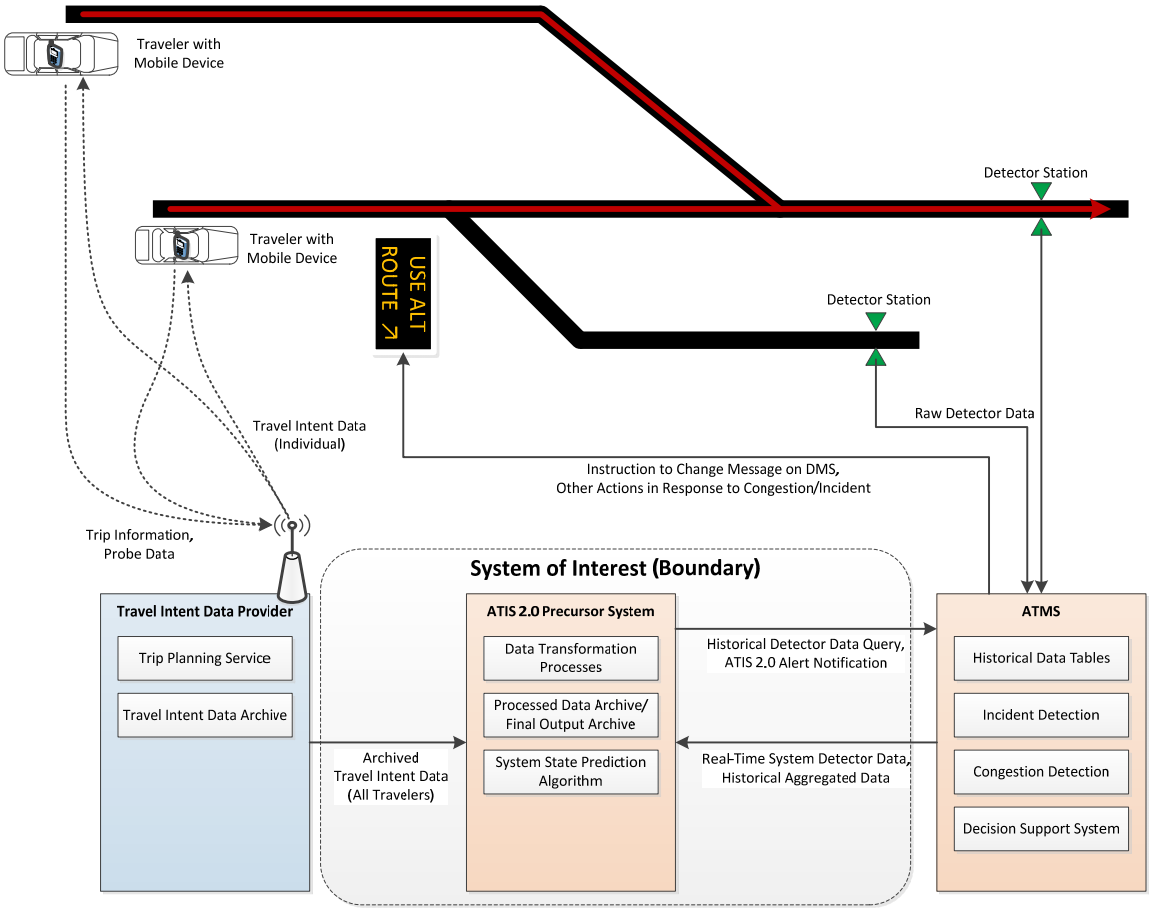

Figure 8-1. ATIS 2.0 Precursor System Diagram

The upper part of the diagram shows the context of the physical environment, which includes elements commonly found in transportation management systems. The elements are connected by information flows to the system of interest, shown in the bottom part of the diagram.

8.1 System Scope

The scope of this next generation ATIS 2.0 Precursor System includes all components to successfully integrate disaggregate traveler behavior data into transportation system management practices.

The system inputs will include system state data from existing TranStar systems and traveler intent data from the INRIX mobile traffic app. The ATIS 2.0 Precursor System processing will be a separate application developed specifically for this demonstration project, which will also serve as a framework for future system adopters. The system outputs will include predictive congestion alerts with varying parameters to assess system effectiveness.

8.2 System Goals and Objectives

The goal of the ATIS 2.0 Precursor System is to provide predictive alert capability using traveler intent data to enable system managers improve traffic management and reduce congestion.

The objectives of this system are three-fold:

- The system shall be capable of aggregating, processing and disseminating actionable information based on traveler intent data.
- The system shall be capable of being monitored and configured as required in the operational environment.
- The system shall be flexible with regards to data types utilized for ingestion and processing.

8.3 System Users

"Users" for this ATIS 2.0 Precursor System ConOps directly reference System Managers that operate and maintain traffic management systems. This ConOps references both U.S. DOT researchers and TranStar system manager stakeholders who will use the demonstration of the ATIS 2.0 Precursor System at TranStar to assess system effectiveness.

The "System Manager" user is defined as the primary decision maker who oversees, operates and manages traffic management and traveler information systems. The System Manager will monitor output from the ATIS 2.0 Precursor System, analyze and assess the information, and determine the benefits related to the current traffic management system.

8.4 System Interfaces

The ATIS 2.0 Precursor System will be used to demonstrate the capabilities of traveler intent data in producing predictive alerts. The system will require two interfaces:

1. An input interface with the transportation management center data archive, so that aggregated historical data can be paired with intent data and input into a system state prediction algorithm.

2. An output interface for the system manager, so that triggers produced by the ATIS 2.0 Precursor System can be evaluated as a potential input to the TranStar operations.

System manager actions based upon alerts from the ATIS 2.0 Precursor System would be handled separately by the ATMS and would take the form of traveler information distribution to drivers. These messages can be sent either:

- Pre-trip via web pages, mobile device, or in-vehicle applications.
- En-route via roadside, mobile device, or connected-vehicle applications.

These actions of the ATMS are outside the boundary of the ATIS 2.0 Precursor System, but are important to consider in the design of the system.

Chapter 9 Operational Environment

This chapter describes the physical operational environment in terms of facilities, equipment, computing hardware, software, personnel, operational procedures and support necessary to operate the demonstration system. As described previously, the ATIS 2.0 Precursor System will operate as a demonstration project to fulfill the needs of the U.S. DOT researchers and TranStar system managers.

9.1 Location

The ATIS 2.0 Precursor System will be demonstrated within the existing Houston TranStar regional operations coverage area. End-users and system managers will be located inside and outside the region—including TranStar and the U.S. DOT research team. Physically, the system will be a location-independent cloud-based software application, which will serve both TranStar, located at the Greater Houston Transportation and Emergency Management Center, and U.S. DOT researchers, located throughout the country. Data collection components (input) will also be located within the region, including field inputs from Houston TranStar ATMS and the INRIX Traffic smartphone application (available on iOS and Android). Information dissemination nodes (output) will include data from the cloud-based application accessible by both users inside and outside the region.

Some additional elements may be located outside of the general region, such as communications networking, third-party data providers, and remote system backup facilities.

9.2 Facilities

Primary facilities for the ATIS 2.0 Precursor System will include, but may not be limited to the U.S. DOT researcher facilities (including TTI, Battelle, Atkins, and/or INRIX), TranStar system manager facilities, communications infrastructure, and field equipment (devices) for data collection and distribution of information. This system is also expected to use third-party facilities for data sourcing, data storage, and system analytics.

Additionally, support facilities including, but not limited to electrical (power) utilities will be required to operate the ATIS 2.0 Precursor System.

9.3 Hardware and Equipment

Hardware and equipment represents capital expenditures required by an agency to implement, operate and maintain the ATIS 2.0 Precursor System. For this demonstration project all hardware and equipment for the new ATIS 2.0 Precursor System will be provide by the U.S. DOT research team under the FHWA contract. The ConOps does not include third-party or contracted hardware and equipment.

9.3.1 Central

Central hardware and equipment shall include, but may not be limited to computers/servers for running the ATIS 2.0 Precursor System application, and for providing backup (storage) for data and information generated by the application. The ATIS 2.0 Precursor server(s) will interface with existing advanced transportation management information servers and information systems located within the same central environment, whether local or virtual.

Central hardware and software shall also consist of support devices such as firewalls, switches, routers, UPS and redundant hardware and equipment necessary to provide a secured, reliable traveler information subsystem. This shall also include networking and communications equipment required to integrate the ATIS 2.0 Precursor System, and its support hardware and equipment.

9.3.2 Remote/Field

The initial demonstration test-bed (contained within this ConOps) will not require remote/field elements and/or integration of remote/field elements. All testing and analysis will be conducted on the intent data provided by INRIX and the system state data provided by TranStar.

9.4 Software

The demonstration system software will consist of primary, existing, support, and third-party applications as described below.

9.4.1 Primary (Core) Application

Central software will primarily consist of the ATIS 2.0 Precursor System application (module), and supporting software (such as data transfer applications) required to integrate and operate the Precursor System application with existing TranStar ATIS and ATMS applications.

9.4.2 Existing Applications

The ATIS 2.0 Precursor System application will integrate and operate within the existing ATIS and ATMS application environment. Future configurations are likely to vary significantly from the demonstration TranStar configuration, however, this shall typically include integrating and operating existing ATIS and ATMS databases—including volume and speed data, and existing ATIS and ATMS applications—including existing congestion alerts.

9.4.3 Support Applications

Supporting software shall include, but is not limited to database and server software to operate and support the ATIS 2.0 Precursor System application within its core environment, as well as firewall and system monitoring applications external to the core application environment. Support application may include the integration of performance monitoring applications, in addition to end-user graphical user interface applications.

9.4.4 Third-Party Applications

The ATIS 2.0 Precursor System application will interface with third-party travel information service providers to obtain intent data and information. A live system would obtain data in real-time or in frequent near-real-time intervals. Based on current functionality of INRIX as the third-party data providers, the system will be implemented in a demonstration environment on archive data, not in a live environment. Each batch of archived data will be obtained from the data provider and the receipt of data for a future live system can be emulated using the archived data. Definition of the applications is beyond the scope of this ConOps, however will be included in the design of the software environment for the ATIS 2.0 Precursor System application.

9.5 Personnel

The U.S. DOT researchers will develop and deploy the ATIS 2.0 Precursor System. The researchers will execute the demonstration deployment, which will assess the ability of the system to fulfill the user needs defined in this ConOps.

Houston TranStar staff currently manage the various functions of the TranStar Traffic Operations Center. Functions include traffic management, incident management, and serving as an emergency operations center. Staff are likely assigned to one or more of these various functions, but the staff that will be involved with the operational environment of the ATIS 2.0 precursor system are the staff that are involved with traffic management activities. These staff would be responsible for acting upon any alerts that are output from a future live ATIS 2.0 Precursor System and will be able to assess the effectiveness of alerts from the demonstration system. Actions to be undertaken by TranStar system managers for the demonstration include observing the issued alerts, determining whether or not to implement a traffic management solution in response to an alert, and determining which operational response would be implemented. The testing portion of the project will require the TranStar system managers to evaluate the alert outputs from various models and to provide feedback on how each model would impact their ability to manage traffic.

9.6 Operational Procedures

All operational procedures shall be reviewed, approved and integrated with existing SOPs currently approved and implemented by the operating agency.

Chapter 10 Support Environment

This chapter describes the planned physical support environment, including facilities, equipment, interfaces, and support agreements for access, operational procedures and any other support from outside agencies.

10.1 Physical Environment

The ATIS 2.0 Precursor System will directly integrate with the existing ATIS and ATMS platform(s). This includes system state information (TranStar) and traveler intent information (INRIX) applications.

The ATIS 2.0 Precursor System module will ingest (input) raw data from the traffic data sources, which includes INRIX as the data third-party data provider and TranStar as the system state (archive) data provider, then cleanse and process the data to generate demand data that can be used in a system state prediction.

Output from the ATIS 2.0 Precursor System will then be disseminated to end-users, including system managers and researchers, to assess its use in managing the transportation network.

10.2 Support Agreements

Support for the demonstration ATIS 2.0 Precursor System will be provided by the U.S. DOT researchers. Agreement on data inputs and output review from the TranStar system managers will be coordinated between TranStar and the U.S. DOT researchers in conjunction with FHWA.

Support from the U.S. DOT researchers will include the demonstration on a six-month set of test data, and follow up analysis to determine system effectiveness as discussed previously.

Ultimately, a future live ATIS 2.0 Precursor System would run autonomously and would likely include a number of support and service agreements. These would include agreements with third-party data providers for the sourcing of specific data and on-call support from third-party data providers for support in operating and maintaining data procured through the support agreements.

Chapter 11 Operational Scenarios

This chapter describes the Operational Scenarios likely to be encountered in the future operational environment. This chapter is divided into three sections detailing a hypothetical (future) deployment scenario, a comparison of demonstration operations versus typical (future) operations, and specific demonstration operational scenarios.

11.1 Hypothetical Deployment Scenario

In the context of a future full deployment of a live ATIS 2.0 Precursor System the following scenario is presented as an example. A city attracts a large number of visitors every summer. Traditionally, its highway system has much higher traffic during peak hours than non-peak hours. The additional demand from non-commuters/visitors worsens the traffic condition during summer peak hours. The ATIS 2.0 Precursor System can use disaggregate traveler intent data (i.e., pre-route planning information) from both commuters and non-commuters to estimate the new traffic demand, and thus alert System Managers before the major congestion events happen. With this predictive information, the System Manager can proactively manage traffic through Dynamic Message Signs (DMS), signal control, ramp metering, or any other proper traffic control strategies.

11.2 Demonstration Operations in the context of Typical Operations

In the ATIS 2.0 Precursor System demonstration, the system managers will assess the impact of the predictive congestion alerts based on a six-month data set. The system managers will make this assessment based on their knowledge of how they currently monitor all transportation networks within the TranStar region and how the predictive alerts would improve this monitoring and response. This will include understanding the current SOPs for system monitoring, and for congestion detection and response.

For each congestion prediction notification (alarm) that is presented, the system manager will use the system monitoring tools to verify alarm accuracy (against the ground truth data archive). For each verified alarm, the system manager will indicate their relative ability to implement a traffic management strategy, and the improvement expected from said operational response.

If a predictive alarm (ATIS 2.0) is determined to be inaccurate, the system managers shall flag the output for further analysis—including the expected impact of any unnecessary operational response.

11.3 Demonstration Operational Scenarios

The operational scenarios reflect operations within the context of the TranStar system and both the U.S. DOT researchers and TranStar system managers. The scenarios detail anticipated operations

with respect to the new ATIS 2.0 Precursor System as it relates to the demonstration with the existing ATMS and the anticipated field tests. This will enable the U.S. DOT researchers and TranStar System Managers to determine the viability and benefits of the system. The field tests will include the assessment of the system to fulfill the user needs by analyzing the congestion alarm prediction and the intent data predictive ability as described below. The demonstration operational scenarios are composed in such a manner that they mimic operations of a future fully deployed system. The difference with this demonstration, is that the system managers will be running multiple scenarios and changing variables (e.g., prediction period) to analyze the system. This type of comparative analysis is important to any newly deployed system, and providing adjustment functions within the system can provide an advantage over systems deployed without flexibility.

11.3.1 Congestion Alarm Prediction

Two congestion alarm prediction scenarios will be examined in the demonstration as follows:

A. The system manager will examine congestion alarm prediction outputs produced from aggregated historic/real-time data (ATIS 1.0) plus intent data (ATIS 2.0) at 0, -5, -10, and -15 minutes (forecast prediction period) compared against the ground truth alarm data. This analysis will record the total and proportional results for each prediction comparison, including true positive, true negative, false positive, and false negative.

B. The system manager will examine congestion alarm prediction outputs produced only from aggregated historic/real-time data (ATIS 1.0) at 0, -5, -10, and -15 minutes (forecast prediction period) compared against the ground truth alarm data. This analysis will record the total and proportional results for each prediction comparison, including true positive, true negative, false positive, and false negative.

In this analysis context the “comparison against ground truth alarm data” here means that if a 5-minute prediction has been made, the system manager will examine the data from 5 minutes later and compare the predicted alarms against any generated alarms that actually happened.

Based on analysis of sample data and input from stakeholders, advance notice of up to 15 minutes would be helpful to system managers. In section 7.2 Stakeholder Considerations for User Needs, it was mentioned that 15 minutes is the logical limit of advance notification for an urban area, based on average trip length. Considering that the average travel time of INRIX users in the Houston area is about 30 minutes and varies by time of day, 15 minutes will be used as the furthest advanced notification for this demonstration in order to obtain a large enough intent data sample size to generate predictions. [The average uncongested travel time is 25 minutes (median 24 minutes) and the average congested travel time is 31 minutes (median 29 minutes).]

11.3.2 Intent Data Predictive Ability

One intent data predictive ability scenario will be examined in the demonstration as follows:

C. The system manager will examine a comparison of ATIS 1.0 and ATIS 2.0 predictions and make a qualitative assessment of improvements against ‘ground truth alarm data’. In this scenario the system managers will indicate their relative ability to implement a traffic management strategy based on the predictive data, and indicate the improvement expected from the proposed operational response—in contrast to the operational response actually conducted.

Chapter 12 Summary of Impacts

This chapter provides a summary of the impacts that are anticipated as a result of the ATIS 2.0 Precursor System demonstration. The primary objective of this project is to assess the impact that can be attributed to the addition of travel intent data. Note that this project does not attempt or expect to create a predictive modeling method better than existing methods. The concept is to utilize an existing modeling method that be easily modified to include intent data to assess whether or not intent data improves model accuracy and the system manager's ability to manage the transportation network. The identified impacts describe the effects of the overall system within the operational environment. The summary below includes tables of the three user needs in the context of impacts and performance metrics.

12.1 User Needs and Impacts

The expected impacts have been mapped to specific user needs, as defined earlier in this ConOps. The impacts specify what improvements are expected and for whom, and limitations associated with the implementation of the new system. Expected impacts are shown below in Table 12-1.

Table 12-1. ATIS 2.0 Precursor System User Needs and Impacts

User Need	Impacts
1. **A system manager needs advanced notification of transportation network congestion to improve operational response.**	• System managers will be privy to more useful, actionable information; predicting conditions before they occur. • System managers will be able to better manage transportation network via predictive alerts.
2. **A system manager needs to be able to monitor alert quality.**	• Monitoring of predictive alerts will allow system managers the ability to gauge accuracies and values of information generated by the system. • System managers will be able to gauge whether the predictive model is providing timely, accurate, actionable information or not.
3. **A system manager needs to be able to establish, monitor, and configure alert confidence thresholds.**	• The ability to implement confidence thresholds will provide system managers the ability to continue to refine the ATIS 2.0 Precursor System. • System managers will be able to gain intelligence regarding the capabilities and limitations associated with the predictions.

12.2 Performance Measures

Formal measures will be developed to assess the performance of the implemented solutions and overall ability and effectiveness to address user needs and project goals and objectives. These measures of effectiveness (MOE) will be applied throughout the entire life-cycle of the project and system, and updated and modified as required to accurately reflect overall system effectiveness. MOEs for the project hypotheses were proposed in Task 5.2 – Field Test Concept Summary. Both an ATIS 1.0 prediction model (does not include travel intent data) and an ATIS 2.0 prediction model (includes travel intent data) will be created. The MOEs of each model will be assessed and compared against each other to determine if the inclusion of intent data provides benefit to the system managers. A summary of the two hypotheses and their associated MOEs are detailed below.

Hypothesis 1: The system manager will be provided a timelier notification of impending system state conditions or a strategy implementation trigger. Despite these predictions being less accurate than ground truth data, the system manager is able to more effectively implement demand management strategies.	**Measures of Effectiveness for Hypothesis 1:**
	• Coefficient of determination (r-squared)
	• Contingency Table – predicted versus observed alerts
	  o correct positive predictions
	  o false positive predictions
	  o false negative predictions
	  o correct negative predictions
	• System Manager ability to act (and affect the system) based on the alert

Hypothesis 2: Intent data allows for statistically significant improvement in the prediction of speed and the prediction of alarms.	**Measures of Effectiveness for Hypothesis 2:**
	• Coefficient of determination (r-squared)
	• Variable significance
	• Mean-Square Error
	  o F-test results (likelihood of model improvement)
	• The penetration rate of participating service users
	  o Penetration Rate Coefficient of Variation

The MOEs will be prepared to assess how well the demonstration system meets its performance objectives. MOEs will track the expected performance and effectiveness of demonstration system. Expected MOEs for the field test are shown below in Table 12-2.

Table 12-2. ATIS 2.0 Precursor System User Needs and MOEs

User Need	Metrics

1. **A system manager needs advanced notification of transportation network congestion to improve operational response.**	• Number of ground truth alarms
	• ATIS 2.0 and ATIS 1.0 alarm prediction accuracy (number and percent) at varying degrees of timeliness (t-0, -5, -10, and -15 minutes):
	  ○ True Positive
	  ○ True Negative
	  ○ False Positive
	  ○ False Negative

2. **A system manager needs to be able to monitor alert quality.**	• Perceived ability of the system manager to mitigate congestion based on ATIS 2.0 and ATIS 1.0 alarm prediction output values at varying degrees of timeliness (t-0, -5, -10, and -15 minutes)

3. **A system manager needs to be able to establish, monitor, and configure alert confidence thresholds.**	• Intent data predictive ability of ATIS 2.0 and ATIS 1.0 alarm prediction output values at varying degrees of timeliness (t-0, -5, -10, and -15 minutes), including:
	  ○ Adjusted r^2
	  ○ Variable Significance
	  ○ Mean squared error (MSE)
	  ○ F-test Significance
	  ○ Penetration average and coefficient of variance
	• Threshold flexibility index (to be derived)

12.3 Anticipated Limitations

Drawbacks and limitations to the ATIS 2.0 Precursor System center on the quality of input, and specifically the quality and quantity of "intent" data available for collection and processing. The systems overall effectiveness relies on this component.

In addition, the system manager will be initially limited in the overall ability to implement effective traffic management measures as a result of information received regarding predictive and intent model output. This is not a direct limitation of the new ATIS 2.0 Precursor System, but a fact of limited proactive operational strategies to manage transportation networks.

Appendices

Appendix A: List of Acronyms

AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
Apps	Applications
ATIS	Advanced Traveler Information System
ATIS 2.0 Precursor System	A Next Generation Advanced Traveler Information Precursor System
ATMS	Advanced Transportation Management System
AVI	Automated Vehicle Identification
CFR	Code of Federal Regulations
ConOps	Concept of Operations
DMA	Dynamic Mobility Application
DMS	Dynamic Message Signs
DSS	Decision Support System
DOT	Department of Transportation
FHWA	Federal Highway Administration
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
METRO	Metropolitan Transit Authority of Harris County
MOEs	Measures of Effectiveness
MSE	Mean Squared Error
OD	Origin-Destination
RIMS	Regional Incident Management System
SOP	Standard Operating Procedure
TTI	Texas A&M Transportation Institute

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