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A Next Generation Advanced Traveler Information Precursor System (ATIS 2.0 Precursor System) System Requirements

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16. Abstract

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 System Requirements provide a detailed breakdown of the requirements needed to fulfill the user needs 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. The demonstration system will enable experiments on a traveler intent data archive.

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Chapter 1 – Scope

This chapter provides an overview of the scope of this document as it relates to the ATIS 2.0 Precursor System and includes the following subsections:

- Background
- Terminology
- Identification
- Document Overview
- Intended Audience

1.1 Background

The ATIS 2.0 Precursor System is being designed to combine traveler information service data and system state data to enhance the ability of transportation system managers to impact traveler mobility. At the highest level, the ATIS 2.0 Precursor System seeks to create and test the mechanisms of collecting disaggregate data from multiple sources, including data that provides traveler intent, and combine them in new and innovative ways that allow system managers to make decisions and apply system responses (actions). The objectives of this project are three-fold:

- Identify the potential of disaggregate behavioral data, when captured and properly processed, to support both the provision of enhanced traveler information services and improved transportation system management.
- Create and demonstrate an ATIS 2.0 Precursor System with mutually beneficial relationships among information service users, information service providers and system managers.
- Establish research products (data, algorithm, code and reports) that can serve to further deployment of additional public-private partnerships leveraging the power of disaggregate traveler behavioral data in operational practice.

The process of designing the ATIS 2.0 Precursor System began with the development of Task 5.2 – the Field Test Concept Summary. Task 5.2 served three main purposes:

1. It established test hypotheses and measures of effectiveness for the project
2. It developed an experimental design concept to test the hypotheses
3. It listed anticipated risks to the system implementation and mitigation strategies for the risks

By laying out these steps, the Field Test Concept Summary created a foundation for the Concept of Operations and System Requirements, which are used to define the functionality of the ATIS 2.0 Precursor System. Note that due to current limitations where the intent data cannot be obtained in real-time, the proposed demonstration will produce experiments on an intent data archive.

In order for ATIS 2.0 to accurately and efficiently predict traffic congestion given various forms of data, there is a need to delineate specific operations and the corresponding requirements that the system will meet. These procedures are recapitulated in the Concept of Operations (ConOps) and the System Requirements (SyRS) documents. The documents are intended to identify and explore synergistic

public-private sector arrangements that as a natural outcome improves end user experience, enhances service provision, and improves system management.

The purpose of the Task 5.8SyRS document is to provide a detailed breakdown of the requirements needed to fulfill the user needs of the project. Previously, in the Task 5.5 ConOps specific scenarios were outlined that served to illuminate the origin and purpose of each user need and they will ultimately be incorporated into the final testing and hypotheses of the ATIS 2.0 Precursor System. In the ConOps, it was also ensured that each user need fully encapsulated the hypotheses that were developed in the Task 5.2 Field Test Concept Summary. Additionally, scenarios in the ConOps were developed so that they complement the experimental design developed in the field test concept summary.

The user needs and a brief description from the ConOps are below:

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.

The user needs #2 and #3 are related, but differ in how they will be addressed by the system. The quality of alerts related to accuracy and timeliness (user need #2) will be monitored to provide an operator with likelihood of the predicted alert condition to actually occur in order to aid the operator in the selection between two or more operational responses (using the ATMS). 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.

The user need #3 takes this a step further and provides a feedback mechanism for the adjustment of alert thresholds or alert confidence parameters over time based on the alert quality (measured with the ATIS 2.0 Precursor System) and operational response effectiveness (measured with the ATMS).

Accuracy and timeliness are further discussed in the ConOps section 7.2.

The ultimate goal of the SyRS is to communicate the functional, system interface, performance, security, data, and reliability requirements associated with the development of the ATIS 2.0 Precursor System. It is important to note that this document was designed with the assumption that the reader has a general understanding of the project and is sufficiently acquainted with the systems engineering process.

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.

The following document will be structured in a format that will initially give an overview of the existing information regarding referenced literature that provided a background for ATIS 2.0. The document will proceed to then give a general overview of the final deliverable product which will include a description of its function and the system constraints and assumptions. After this, the document provides a systematic breakdown of the functional, system interface, performance, security, data, and reliability requirements. This listing will be formatted in tabular order so that they can be easily interpreted and followed. The last section of the document will reference each system requirement back to the user needs. This section will be structured as a traceability matrix intended to ensure that the user needs, which were originally developed in the ConOps, were met after completing all of the listed requirements.

1.2 Terminology

The meanings of the auxiliary verbs used in this document are defined as follows:

- Shall Compliance with a requirement, specification or a test is mandatory
- Should Compliance with a requirement, specification, or a test is recommended
- May Expresses a permissible way to achieve compliance

1.3 Identification

This document is one of the deliverables for Task 5 of the ATIS project, which is being conducted by the Battelle Team of the Battelle Memorial Institute, TTI, Atkins, and INRIX for the Federal Highway Administration (FHWA) under Contract Number DTFH61-12-D-00046 / T-5010. This document is the deliverable System Requirements Specification (SyRS). This document defines the functional, system interface, performance, security, data, and reliability requirements associated with this demonstration system, which are addressing the needs determined within the final Concept of Operations (ConOps, Task 5.5).

1.4 Document Overview

The purpose of this document is to further elaborate on the concepts and scenarios described in the re-opened and modified Concept of Operations (ConOps) report. This will be accomplished by describing how the system is to operate in terms of detailed requirement statements.

The remainder of this document consists of the following sections and content:

- Chapter 2 (Applicable Documents) describes any external documentation referenced throughout this document.
- Chapter 3 (System Requirements) includes:
  - an overview of the system of interest
  - the system constraints and assumptions
  - the detailed systems requirements
  - the User Needs to Requirements Traceability Matrix
- Appendix A includes the list of abbreviations and acronyms

1.5 Intended Audience

The primary audience for this document is U.S. DOT staff and other identified stakeholders who are interested in understanding the impact of traveler intent data on system state prediction. Additional audiences include the system developers, engineers, and any others who will assist in the development of the ATIS 2.0 Precursor System.

Chapter 2 – Applicable Documents

This research is sponsored by the U.S. Department of Transportation as part of on-going research related to the Dynamic Mobility Applications program. As such, there are a number of reports, presentations, and documents on the various aspects of the EnableATIS program available from the U.S. DOT[1]. The materials in these documents were consulted over the course of this project and are incorporated in this document as applicable.

2.1 Project-Related Documents

The ATIS 2.0 Precursor System SyRS 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)
10. Concept of Operations – Final (Task 5.5)

2.2 Order of Precedence

In the event of a conflict between the text of this document and the references cited herein, the inconsistencies should be brought to the attention of the project manager. Nothing in this document, however, supersedes applicable laws and regulations.

[1] U.S. DOT ITS JPO DMA web site: http://www.its.dot.gov/pilots/pilots_mobility.htm
[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 3 – System Requirements

This chapter sets forth the system requirements of the ATIS 2.0 Precursor System in the following subsections:

- System Description
- System Constraints and Assumptions
- ATIS 2.0 Precursor System Requirements
- Needs-to-Requirements Traceability Matrix

3.1 System Description

The demonstration system that will be tested for the ATIS 2.0 Precursor System Project centers on providing system managers with advance notice of congestion alerts that will improve the ability of the system manager to proactively manage the system. This is accomplished though the processing and transformation of ATIS 2.0 intent data (which is a natural by-product of the interaction between travelers and trip planning services) and other ATIS 1.0 system state data (such as aggregated historical volume/speed data, and real-time data).

The system will be tested to understand the tradeoff between alert prediction timeliness and accuracy. The system will also be tested to understand the tradeoffs between alert predictions using ATIS 2.0 intent data and using ATIS 1.0 system state data.

A logical “system of interest” diagram of the demonstration system is shown in Figure 3-1. The portion of the system being built for the ATIS 2.0 Precursor System Project is contained in the dashed box in the figure. The remainder of the figure is included to provide context for the environment in which the system will be inserted. The system requirements developed later in this document will focus on the data flows into, data flows out of, and objects/functionalities within the dashed box.

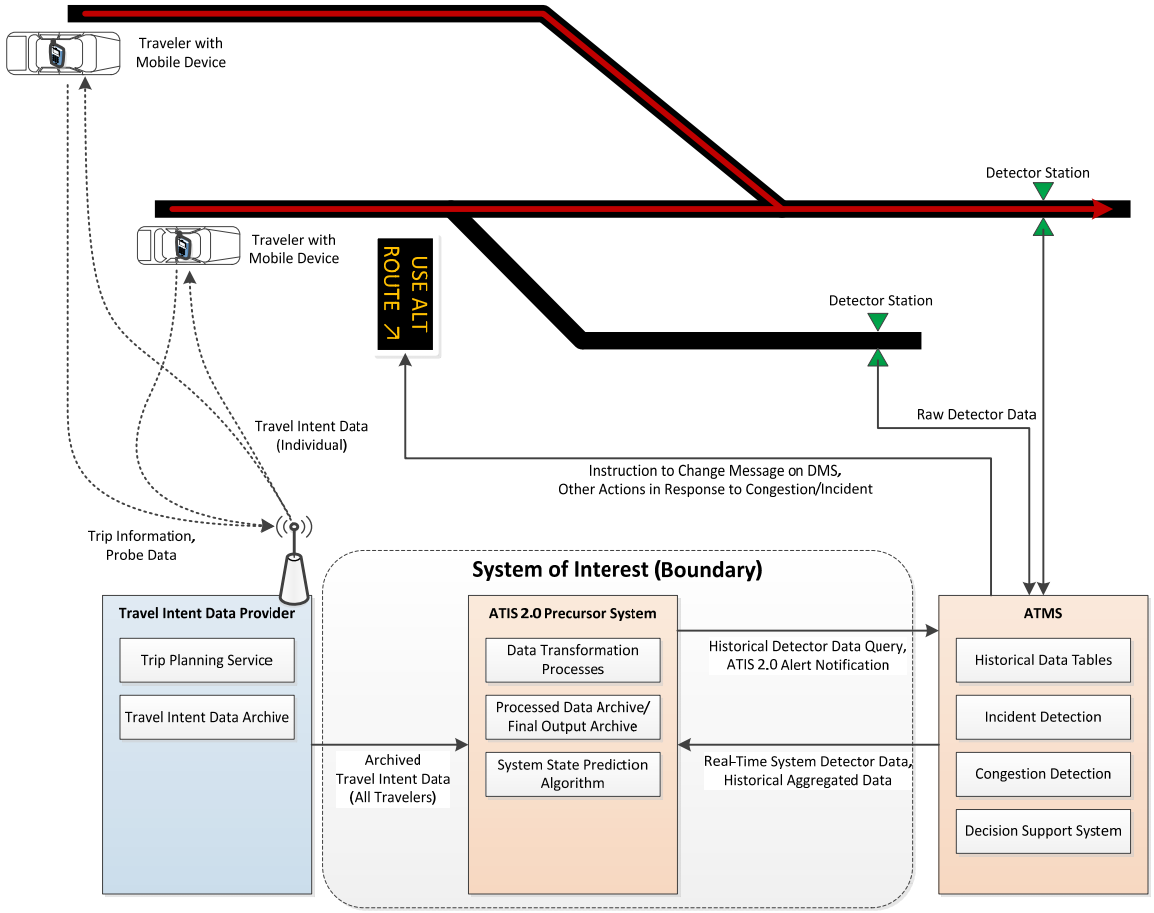

Figure 3-1. ATIS 2.0 Precursor System "System of Interest" Diagram

Travel Intent Data Providers (bottom left, Figure 3-1) provide travel planning services to drivers. It collects probe data from vehicle to assess the system state and collects trip information submitted by drivers. When the traveler provides trip information, the trip planning service is able to utilize the system state information to provide the traveler with a series of optimal routes (a.k.a. intent data) to get to the destination specified in the traveler-supplied trip information. The travel intent data provider archives intent data that it returns to travelers. The travel intent data provider archives intent data that it returns to travelers. Travel intent data is sent directly in real-time to travelers, and is added to a travel intent data archive. This archive can be accessed to provide inputs to the ATIS 2.0 Precursor System.

INRIX is the travel intent data provider that has been designated for this project. The Disaggregate User Data Capture Approach (final deliverable from Task 3) indicates that INRIX is capable of capturing and archiving intent data that contains attributes required by the ATIS 2.0 Precursor System. One current limitation is that the INRIX intent data archive does not provide a real-time feed, therefore the ATIS 2.0 Precursor System cannot run in real time. This means that the system will use archived intent data over a long period of time (six months) to simulate the receipt of intent data in real time for system development and testing purposes. The use of the archive in this demonstration will still enable the project to test the effectiveness of the intent data in predicting congestion alerts. A successful test will provide the framework for future ATIS 2.0 Precursor System adopters to deploy this in a real-time system. This limitation is listed in Chapter 3.2 – System Constraints and Assumptions.

The system also contains static data items that are used during the transformation process. Static data includes information such as bonding box coordinates, screenline locations, linear regression coefficients, and the relationship between speed and flow at each site/direction. The final output of the transformation process is an advance alert notification that can be used by system managers for traffic management purposes. The User Data Cleansing and Transformation Approach (final deliverable for Task 4) indicates that the transformation processes listed and described above are capable of providing this output in a reasonable amount of time.

Existing Advanced Traffic Management Systems (ATMS) (bottom right, Figure 3-1) use real-time data from roadway sensors, cameras, and detectors to improve mobility and safety of road users. They accomplish this by passing sensor data through incident and congestion detection algorithms. ATMS platforms can be expanded to read and process alternate forms of data and execute new algorithms as needs warrant. If congestion is detected/predicted, a system manager can rely on experience to determine which traffic management solution to implement. In more advanced ATMSs, a decision support system (DSS) is used to determine the most optimal solution given the conditions represented in the sensor data. Actions in response to congestion can include, but are not limited to displaying a message on a Dynamic Message Sign (DMS), changes to variable speed limit (VSL) signs, changes to traffic signal timing, changes to ramp meter, sending a notification to other agencies, sending a notification within the department, and/or sending a notification to emergency responders.

The ATIS 2.0 Precursor System is anticipated to be deployed in the Houston, TX area. The Texas Department of Transportation (TxDOT) maintains a traffic management center (TMC) in the Houston area named TranStar. TranStar has radar detectors which collect volume and speed information from roadways and automated vehicle identification (AVI) detectors that determine a vehicle's travel time from one AVI detector to the next. Both radar data and AVI detector data are aggregated and stored in an archive kept by TranStar. The TranStar system uses real-time AVI data to determine when an alert should be issued. Alerts occur when the AVI-based speed falls below a threshold value – for each AVI segment, this threshold is the 2.5 percentile of all speeds for a given location, direction, day of week, and time of day over the last 90 days. These alarms are overlaid onto a map of the Houston area that also shows freeway speeds. The system manager observes these alarms, and uses best judgement to determine which traffic management strategy can be implemented to handle the situation at hand. Traffic management strategies used by TranStar in the Houston area include but are not limited to posting messages to DMS.

Data exchanges between the entities include:

1. Travel Intent Data Provider → ATIS 2.0 Precursor System – Travel Intent Data flows between the travel intent data provider and the ATIS 2.0 Precursor System. Described earlier, traveler intent data is a natural by-product of trip planning user-service interactions. The trip planning service generates route information, which is sent to the driver (who requested the information) and to the ATIS 2.0 Precursor System. Intent data contains route information including, but not limited to the time of the response, one or more routes (travel time, route coordinates), and information about incidents along the route. The ATIS 2.0 Precursor System uses travel intent data to generate an intent-related variable for the ATIS 2.0 prediction model.

2. Existing ATMS → ATIS 2.0 Precursor System – Historical Aggregated Data and Real-Time System State Data are sent from the ATMS to the ATIS 2.0 Precursor System. Historical aggregated data, which are archived by the ATMS are used by the ATIS 2.0 Precursor System for predicting future conditions. Real-time data are paired with predictions so that the accuracy of the model can be assessed offline.

ATIS 2.0 Precursor System → Existing ATMS – A DSS Trigger is sent from the ATIS 2.0 Precursor System to the Existing ATMS. The trigger is an indication that traffic congestion has increased beyond a set threshold (based on evaluation of historical measurements) and are used to prompt a response from the system manager or DSS.

3.2 System Constraints and Assumptions

The demonstration system will be developed using the following constraints and assumptions:

1. This project originally expected to implement the ATIS 2.0 Precursor System in a live environment, where its ability to affect the system manager's primary impact could be assessed. However, the ability to provide intent data in real time (or near real time) could not be achieved. Because intent data cannot be provided in this fashion, this affects several aspects of the design of the system. Primarily, this will affect the way in which data is received. INRIX, the travel intent data provider for this project, archives its travel intent data records. This archive can be queried to obtain a continuous period of intent data responses. This data can then be used to simulate the receipt of intent data in the ATIS 2.0 Precursor System.
2. Because intent data cannot be received in real time, the system cannot be implemented in real time. However, this allows for a controlled experiment to be conducted using multiple prediction timeliness values. This will be useful for assessing tradeoffs between timeliness, accuracy, and system manager ability to be assessed.
3. The ability of intent data to provide an improvement in the predictive ability of the ATIS 2.0 predictive model is predicated on the ability of the intent data to represent a statistically significant portion of travelers throughout the network. The system may not work as intended if the penetration rate of INRIX users is too low. The sensitivity of predictions to a low intent data penetration rate is discussed in the Field Test Concept Summary (Task 5.2) and will be addressed in the Field Test Experimental Plan (Task 7).
4. The ability of the ATIS 2.0 prediction model to function properly is predicated on consistent usage of the INRIX travel planning application at each location and direction within each time aggregation period (day of week and time of day). High variability in the penetration rate within the aggregation period or systematic changes in usage patterns of the INRIX application will affect results. The sensitivity of predictions to a high variability in the intent data penetration rate is discussed in the Field Test Concept Summary (Task 5.2) and will be addressed in the Field Test Experimental Plan (Task 7).
5. Data gathered from sensors in the Houston area will be used as a ground truth measurement against which outputs from the prediction process are compared against to assess prediction accuracy. This data is also being used to calibrate the system state prediction model. It is important to realize that the radar and AVI sensors in the Houston area have their own limitations in accurately measuring traffic conditions. There is a risk that some sensors may not be accurately calibrated resulting in inaccurate ground truth data which would potentially affect the ability to properly calibrate and/or assess the ATIS 2.0 Precursor System.
6. The system relies on the availability of INRIX trip planning data, which requires INRIX users to have Internet access inside of the test region and to use the INRIX trip planning application. Without Internet access, travelers are not able to access trip planning services resulting in an absence of intent data from trips originating in the affected areas. In general, the system relies on the availability trip planning services throughout the test period.
7. The system relies on the available coverage of TranStar sensor data throughout the test period.

8. It is assumed that travelers are not interacting with the mobile device in an unsafe or unlawful manner while driving.
9. Not all intent data provided may be unique. That is, multiple intent data records may be provided for the same traveler on the same trip.
10. Data gathered from the INRIX system must protect user privacy according to accepted practices of the U.S. DOT and the Battelle Institutional Review Board (IRB). Personally identifiable information (PII) will be removed by the provider (e.g., INRIX) or the system manager before intent data is stored or forwarded.
11. Data gathered from the Houston ATMS and the INRIX system and used in the testing will be exported from the ATIS 2.0 Precursor System and then provided to FHWA for posting to the Research Data Exchange (RDE).

3.3 ATIS 2.0 Precursor System Requirements

Requirements for the ATIS 2.0 Precursor System are organized into four components which define the system. These components include intent data, ATMS State Data, the Prediction Engine, and Prediction Algorithms, as illustrated in Figure 3-2 below. The prediction engine receives both intent data and ATMS state data and uses this data in prediction algorithms, which are used to generate system state prediction outputs that can subsequently be viewed and assessed by system users. An explanation of each component and how the requirements are expected to support each component is provided in the text following Figure 3-2.

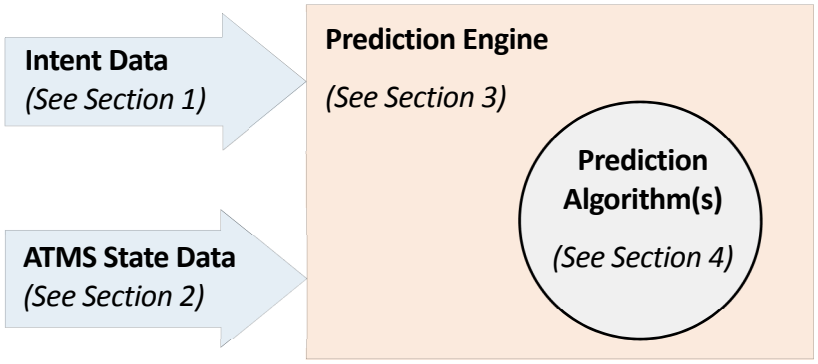

Figure 3-2: System Context Diagram

Requirements sections 1 and 2 contain requirements regarding the system inputs. These are the data streams that the system must obtain for the prediction engine and prediction algorithm. Requirements section 3 is the prediction engine. This is the environment in which all the main software "tasks" live. It must find input data, process the input data, select an algorithm to use, run that algorithm, and show and store results. Finally, requirements section 4 is the generic set of requirements that any given prediction algorithm will utilize by acting on the provided inputs. The requirements for the demonstration system, arranged by component, are defined below in Table 3-1.

Table 3-1: ATIS 2.0 Precursor System Requirements

Req. ID	Requirement Description
1	The system shall be capable of storing traveler intent data.
1.1	The system shall remove all personally identifiable information (PII) before traveler intent data is stored or forwarded.
1.1.1	Any route information contained in the traveler intent data shall have had a system-configurable distance removed from the beginning and end of the route (e.g., the first and last mile removed).
1.2	The system shall store identified traveler intent data types.
1.2.1	The system shall be capable of storing route data contained in the traveler intent data (which is clear of PII).
1.2.2	The system shall be capable of storing travel times contained in the traveler intent data.

Req. ID	Requirement Description
1.3	The system shall store traveler intent data in a manner that enables that data to be provided to the prediction engine based on a user-specified geographic region, start date, end date, and time increment (to emulate a live feed).
1.4	The system shall identify traveler intent data records that are generated on the same trip (that is, duplicate traveler intent data).
1.5	The system shall make all traveler intent data available to the prediction engine.
2	The system shall be capable of storing ATMS state data.
2.1	The system shall store identified ATMS state data types.
2.1.1	The system shall be capable of storing detector data.
2.1.2	The system shall be capable of storing alert data.
2.1.3	The system shall be capable of storing alert threshold data.
2.2	The system shall store ATMS state data in a manner that enables the data to be provided to the prediction engine based on a user-specified geographic region, start date, end date, and time increment (to emulate a live feed).
2.3	The system shall make all available ATMS state data available to the prediction engine.
3	The prediction engine shall allow one or more system state prediction algorithms to execute.
3.1	In the event of more than one available algorithm, the prediction engine shall provide a means for user to select which prediction algorithm will be used.
3.2	The prediction engine shall provide to each prediction algorithm a user-specified geographic region, start date, end date, and time increment information.
3.2.1	The prediction engine shall provide to the prediction algorithms a configurable prediction time increment. For example, every 5 minutes.
3.2.2	The prediction engine shall provide to the prediction algorithms a configurable forecast period. For example, a forecast 15 minutes prior to a target time.
3.3	The prediction engine shall provide to each prediction algorithm all available traveler intent data corresponding to the increments of the prediction timeframe.
3.4	The prediction engine shall provide to each prediction algorithm all available ATMS state data corresponding to the increments of the prediction timeframe.
3.5	The prediction engine shall provide a means for each algorithm to report predicted system state.
3.6	The prediction engine shall provide a means to view predicted system state.
3.6.1	The prediction engine shall provide a means to view alerts.
3.6.2	The prediction engine shall enable algorithms to report confidence of alerts.
3.7	The prediction engine shall provide a means for each algorithm to present information to users.
3.8	The prediction engine shall provide a system log to which each algorithm may write diagnostic or informational messages.
3.8.1	The prediction engine shall make the system log visible to users.
4	The prediction algorithms shall operate independently within the prediction engine.
4.1	The prediction algorithms shall be capable of accepting traveler intent data.

Req. ID	Requirement Description
4.2	The prediction algorithms shall be capable of accepting ATMS state data.
4.3	The prediction algorithms shall write diagnostic and informational messages to the system log.
4.3.1	The prediction algorithms shall report at a minimum the following items: number of input records, processing time, and number of output records
4.4	The prediction algorithms shall be capable of producing predicted system state outputs.
4.4.1	The prediction algorithms shall be capable of predicting link speeds.
4.4.2	The prediction algorithms shall be capable of predicting congestion alerts.
4.4.2.1	The system shall enable users to alter configurable algorithm-specific parameters. For example, alert threshold.
4.4.3	The prediction algorithm using ATIS 2.0 traveler intent data shall be capable of providing the number of traveler intent data users (i.e., mobile app user penetration).
4.4.4	The prediction algorithm output shall include a value which quantifies the confidence of each prediction's accuracy.
4.5	The prediction algorithms shall use the capabilities provided by the prediction engine to present information to users. For example, link speeds, congestion alerts, and prediction confidence.
4.6	The system shall be capable of storing and exporting output (including link speeds, congestion alerts, and prediction confidence) in a format that facilitates evaluation of each algorithm's performance over time.

Source: Battelle

3.4 Needs-to-Requirements Traceability Matrix

User Needs were developed in the ConOps, and must be supported by requirements listed above. Also, some of the requirements relate to one or more system constraints and assumptions as detailed in section 3.2. The needs-to-requirements traceability matrix is shown in Table 3-2 to indicate that the system requirements meet the user needs and constraints. The same requirement may support one or more user needs and/or constraints. All user needs are fulfilled by the requirements. Some of the constraints (that is, 5, 6, 7, and 8) are assumptions that do not need to be fulfilled by the requirements.

Table 3-2. User Needs-To-Requirements Traceability Matrix

Req. ID	Requirement Description	Needs			Constraints and Assumptions										
		Need #1	Need #2	Need #3	Constraint #1	Constraint #2	Constraint #3	Constraint #4	Constraint #5	Constraint #6	Constraint #7	Constraint #8	Constraint #9	Constraint #10	Constraint #11
1	The system shall be capable of storing traveler intent data.	X	X	X											

Req. ID	Requirement Description	Needs			Constraints and Assumptions										
		Need #1	Need #2	Need #3	Constraint #1	Constraint #2	Constraint #3	Constraint #4	Constraint #5	Constraint #6	Constraint #7	Constraint #8	Constraint #9	Constraint #10	Constraint #11
1.1	The system shall remove all personally identifiable information (PII) before traveler intent data is stored or forwarded.													X	
1.1.1	Any route information contained in the traveler intent data shall have had a system-configurable distance removed from the beginning and end of the route (e.g., the first and last mile removed).													X	
1.2	The system shall store identified traveler intent data types.	X	X	X											
1.2.1	The system shall be capable of storing route data contained in the traveler intent data (which is clear of PII).	X	X	X											
1.2.2	The system shall be capable of storing travel times contained in the traveler intent data.	X	X	X											
1.3	The system shall store traveler intent data in a manner that enables that data to be provided to the prediction engine based on a user-specified geographic region, start date, end date, and time increment (to emulate a live feed).	X	X	X	X										
1.4	The system shall identify traveler intent data records that are generated on the same trip (that is, duplicate traveler intent data).	X	X	X									X		
1.5	The system shall make all traveler intent data available to the prediction engine.	X	X	X											
2	The system shall be capable of storing ATMS state data.	X	X	X											
2.1	The system shall store identified ATMS state data types.	X	X	X											
2.1.1	The system shall be capable of storing detector data.	X	X	X											
2.1.2	The system shall be capable of storing alert data.	X	X	X											
2.1.3	The system shall be capable of storing alert threshold data.	X	X	X											

Req. ID	Requirement Description	Needs			Constraints and Assumptions										
		Need #1	Need #2	Need #3	Constraint #1	Constraint #2	Constraint #3	Constraint #4	Constraint #5	Constraint #6	Constraint #7	Constraint #8	Constraint #9	Constraint #10	Constraint #11
2.2	The system shall store ATMS state data in a manner that enables the data to be provided to the prediction engine based on a user-specified geographic region, start date, end date, and time increment (to emulate a live feed).	X	X	X											
2.3	The system shall make all available ATMS state data available to the prediction engine.	X	X	X											
3	The prediction engine shall allow one or more system state prediction algorithms to execute.	X	X	X											
3.1	In the event of more than one available algorithm, the prediction engine shall provide a means for user to select which prediction algorithm will be used.					X	X	X							
3.2	The prediction engine shall provide to each prediction algorithm a user-specified geographic region, start date, end date, and time increment information.	X	X	X											
3.2.1	The prediction engine shall provide to the prediction algorithms a configurable prediction time increment. For example, every 5 minutes.	X	X	X											
3.2.2	The prediction engine shall provide to the prediction algorithms a configurable forecast period. For example, a forecast 15 minutes prior to a target time.	X	X	X											
3.3	The prediction engine shall provide to each prediction algorithm all available traveler intent data corresponding to the increments of the prediction timeframe.	X	X	X											
3.4	The prediction engine shall provide to each prediction algorithm all available ATMS state data corresponding to the increments of the prediction timeframe.	X	X	X											
3.5	The prediction engine shall provide a means for each algorithm to report predicted system state.	X	X	X											

Req. ID	Requirement Description	Needs			Constraints and Assumptions										
		Need #1	Need #2	Need #3	Constraint #1	Constraint #2	Constraint #3	Constraint #4	Constraint #5	Constraint #6	Constraint #7	Constraint #8	Constraint #9	Constraint #10	Constraint #11
3.6	The prediction engine shall provide a means to view predicted system state.	X	X	X											
3.6.1	The prediction engine shall provide a means to view alerts.	X	X	X											
3.6.2	The prediction engine shall enable algorithms to report confidence of alerts.	X	X	X											
3.7	The prediction engine shall provide a means for each algorithm to present information to users.	X	X	X											
3.8	The prediction engine shall provide a system log to which each algorithm may write diagnostic or informational messages.			X											
3.8.1	The prediction engine shall make the system log visible to users.			X											
4	The prediction algorithms shall operate independently within the prediction engine.	X	X	X											
4.1	The prediction algorithms shall be capable of accepting traveler intent data.	X	X	X											
4.2	The prediction algorithms shall be capable of accepting ATMS state data.	X	X	X											
4.3	The prediction algorithms shall write diagnostic and informational messages to the system log.			X											
4.3.1	The prediction algorithms shall report at a minimum the following items: number of input records, processing time, and number of output records			X											
4.4	The prediction algorithms shall be capable of producing predicted system state outputs.	X	X	X											
4.4.1	The prediction algorithms shall be capable of predicting link speeds.	X	X	X											
4.4.2	The prediction algorithms shall be capable of predicting congestion alerts.	X	X	X											
4.4.2.1	The system shall enable users to alter configurable algorithm-specific parameters. For example, alert threshold.	X	X	X											

Req. ID	Requirement Description	Needs			Constraints and Assumptions										
		Need #1	Need #2	Need #3	Constraint #1	Constraint #2	Constraint #3	Constraint #4	Constraint #5	Constraint #6	Constraint #7	Constraint #8	Constraint #9	Constraint #10	Constraint #11
4.4.3	The prediction algorithm using ATIS 2.0 traveler intent data shall be capable of providing the number of traveler intent data users (i.e., mobile app user penetration).		X	X											
4.4.4	The prediction algorithm output shall include a value which quantifies the confidence of each prediction's accuracy.		X	X											
4.5	The prediction algorithms shall use the capabilities provided by the prediction engine to present information to users. For example, link speeds, congestion alerts, and prediction confidence.	X	X	X											
4.6	The system shall be capable of storing and exporting output (including link speeds, congestion alerts, and prediction confidence) in a format that facilitates evaluation of each algorithm's performance over time.		X	X		X	X	X							X

Source: Battelle

APPENDIX A – List of Acronyms

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
ConOps	Concept of Operations
DMA	Dynamic Mobility Application
DMS	Dynamic Message Signs
DSS	Decision Support System
DOT	Department of Transportation
FHWA	Federal Highway Administration
IRB	Institutional Review Board
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
PII	Personally Identifiable Information
RDE	Research Data Exchange
SyRS	System Requirements Specification
TMC	Traffic Management Center
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
VSL	Variable Speed Limit

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