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**Federal Transit
Administration**

TRANSIT OPERATIONS
DECISION SUPPORT SYSTEM (TODSS)
CORE REQUIREMENTS
EVALUATION AND UPDATE
RECOMMENDATIONS

T⦿DSS

October 2009

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13. ABSTRACT (Maximum 200 words)

Transit Operations Decision Support Systems (TODSS) are systems designed to support dispatchers and others in real-time operations management in response to incidents, special events, and other changing conditions in order to improve operating speeds, reduce passenger wait times, and restore service when disruptions occur. In 2003, as part of a joint Federal Transit Administration and Intelligent Transportation Systems Joint Program Office effort, the transit industry developed core functional requirements for service disruption identification and provision of restoration options for TODSS. In 2006, Pace Suburban Bus was selected to lead a demonstration project to develop and evaluate a prototype TODSS and to validate the TODSS core functional requirements. This report documents the evaluation of the TODSS demonstration project with respect to the core requirements and impacts of TODSS, and includes recommended changes and lessons learned for the transit industry to better understand the TODSS core requirements for future implementations.

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TRANSIT OPERATIONS DECISION SUPPORT SYSTEM (TODSS)
CORE REQUIREMENTS EVALUATION AND UPDATE RECOMMENDATIONS
FINAL REPORT

October 2009

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T A B L E S

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GLOSSARY OF ACRONYMS

APTA	American Public Transportation Association
AVL	Automatic Vehicle Location
APC	Automatic Passenger Counting
CAD	Computer Aided Dispatch
CASR	Computer Aided Service Restoration
GCM	Gary-Chicago-Milwaukee Corridor
GIS	Geographic Information System
GUI	Graphical User Interface
IBS	Intelligent Bus System
ICM	Integrated Corridor Management
IDS	Intelligent Decision Support
IV&V	Independent Verification and Validation
MDT	Mobile Display Terminal
PRTT	Priority Request to Talk
RegEx	Regular Expression
RNC	Radio Network Controller
RSS	Really Simple Syndication
RTA	Regional Transportation Authority of Northeastern Illinois
RTT	Request to Talk
SAE	Society of Automobile Engineers
SNMP	Simple Network Management Protocol
SQL	Structured Query Language
TCIP	Transit Communications Interface Profiles
TCP/IP	Transmission Control Protocol/Internet Protocol
TM	TransitMaster™
TODSS	Transit Operations Decision Support System
WA	Work Assignment
XML	Extensible Markup Language

Introduction

This technical memorandum summarizes the TODSS Core Requirements evaluation resulting from the prototype development and implementation of a Transit Operations Decision Support System (TODSS). The project evaluation focuses on a review of the core TODSS requirements based on Pace's experience implementing and operating the TODSS prototype. It is intended that Pace's feedback will assist others considering implementing a TODSS as part of an agency's CAD/AVL system.

The TODSS prototype was installed in March of 2009 with an operational test period lasting through May 15, 2009. During this period the system was tested and accepted. The TODSS configuration was gradually improved and expanded during the operational test as users gained experience and the system passed initial testing. The experiences of the Pace stakeholders are included in the evaluation summary to demonstrate the ease of incorporating TODSS into existing operations, TODSS' practicality, and the usefulness to the agency.

At the conclusion of the operational test period data was gathered in an attempt to measure the outcome of the TODSS prototype. Similar data was gathered for the same period of time from the previous year and used as baseline data for the evaluation analysis. A dispatcher survey was administered and user interviews were conducted. An independent consultant from Booz Allen Hamilton was brought in to perform a high-level independent verification and validation (IV&V) of the TODSS deployment. The IV&V consisted of a review of TODSS requirements, an analysis of data for pre- and post-TODSS deployment, and interviews with key TODSS points-of-contact to determine how well requirements and Pace needs were being met.

These findings as well as a discussion of the issues encountered and recommended next steps are included in this self-evaluation. The findings and recommendations contained in this report are from the Pace team and are for the USDOT's consideration.

The report organization for the remainder of the document includes the following sections:

- Core Functional Requirements Review - An overview of how the core requirements were addressed in the TODSS prototype development
- Evaluation Results – A summary of the stakeholders perceptions and a technical analysis of the TODSS operational test
- Prototype Experience – A discussion of the lessons learned, issues encountered, and benefits
- Summary of Recommendations – Recommendations and next steps for Pace's TODSS implementation and a proposed roadmap for future TODSS core requirements

Core Functional Requirements Review

This section reviews chapter 5 "Core TODSS Requirements" of *Transit Operations Decision Support Systems (TODSS): Core Functional Requirements For Identification Of Service Disruptions And Provision Of Service Restoration Options 1.0* (Mitretek Systems for the FTA and USDOT ITS JPO; May 3, 2003). Comments, observations, and recommendations related to the requirements are based on the experience gained during the operational test of the prototype TODSS and are intended to serve as a guide for future TODSS development and use. The core requirements are broken down into four sections:

- Sources of Information
- Service Disruptions
- Service Restorations
- General System Requirements

The core TODSS requirement outlined in this section are provided in tabular forms. In each table, the first column is the TODSS requirement with recommended changes added in italics after the requirement. The second column indicates whether the requirement was met by the existing IBS, a new feature in the IBS upgrade, or new TODSS development. The third column provides an overview of the requirement implementation in the prototype TODSS.

Sources Of Information Requirements

"Sources of information included in the Core TODSS are the data sources produced, controlled and owned by the operating agency, plus the notification and manual input of information from non-automatic or external data sources through the dispatch console. Note, that these include both "dynamic" real time information from system monitors (e.g. AVL, APC, vehicle & equipment status, alarms, etc.) as well as information from other "static" internal agency databases (e.g. GIS, schedule, vehicle/block, driver run, driver availability, and historical performance and ridership data, etc.)." This definition from the core requirements has held up over time and is a guide to understanding where the TODSS prototype receives the data necessary for the real-time transit communications dispatch function.

This section serves as a guide to an agency as they develop their local concept of operations and local requirements. When an agency includes TODSS requirements in a CAD/AVL RFP, this section provides a reference for verification that the CAD/AVL functional specifications include these TODSS supporting requirements. A TODSS needs a CAD/AVL system infrastructure that meets these requirements in order to be effective as a decision support system.

The following table is from Table 5-1 of *Transit Operations Decision Support Systems (TODSS): Core Functional Requirements For Identification Of Service Disruptions And Provision Of Service Restoration Options 1.0.* After working with this table in the course of the TODSS project, it is recommended that the "TODSS System Parameters" section

be removed from this table. They are an important concept but tend to confuse users when trying to think of the primary sources of data for TODSS. TODSS system parameters are covered in the following sections and removal from this table will not result in a change to the core requirements.

The Status field in the following tables may include one of the following values:
- "Existing" meaning it is an existing IBS feature
- "New" meaning the requirement needs to be implemented as part of the TODSS prototype development
- "Not Included" meaning the core requirement is not part of the local TODSS requirements
- "N/A" meaning not applicable due to the inability to meet the requirement in the prototype development

Table 1 - Sources of Information For TODSS

Sources of Information	Status	Comments/Changes
TODSS System Parameters		System parameters are used to test against primary sources of information. Inclusion with sources of information is confusing. It is recommended that the TODSS system parameters be removed from table 5.1.
Detection Thresholds	New	
Response Thresholds	New	
Prioritization Rules	New	
Response Rules	New	
Transit Agency Static Information		
GIS Data (Street, Route, Stop, Time Point)	Existing	Pace uses their internal GIS department as the source for their map layer data and the IBS survey tool for GPS field surveys.
Transit Schedule	Existing	Giro Hastus is the source for route and schedule data.
Vehicle/Block Data	Existing	Giro Hastus and internal Pace legacy systems are the source of vehicle and block data.
Driver/Run Data	Existing	Giro Hastus and

Sources of Information	Status	Comments/Changes
		internal Pace legacy systems are the source for driver and run data.
Historical Passenger Data (ons/offs/transfers)	Existing	The IBS Data Mart contains historical APC data that is exported to the enterprise Oracle data warehouse.
Historical System Performance	Existing	The IBS Data Mart contains historical system and system performance data.
Transit Agency Dynamic Information		
Operator Availability	Existing	Partial information is available through IBS but Pace internal legacy systems maintain the latest data and are not fully integrated with IBS.
Vehicle Availability (Extra board)	Existing	Partial information is available through IBS but Pace internal systems maintain the latest data and are not fully integrated with IBS.
Time Stamped Location: Flagged rev. vehicle	Existing	IBS provided data
Time Stamped Location: Other rev, vehicles	Existing	IBS provided data
Time Stamped Location: Potential responders	Existing	IBS provided data
Operator Initiated Data Messages	Existing	The structure of this information was re-defined to improve automation as part of the TODSS implementation.
Voice Messages (Operator, Supervisor)	Existing	IBS provided information
Silent Alarm/Security	Existing	IBS provided information (suggest use of the phrase "Emergency Alarm" consistent with the ITS National Architecture)
Automatic Passenger Count	Existing	Irma and Red Pines

Sources of Information	Status	Comments/Changes
		APC systems are integrated with IBS on about 30% of the Pace fleet.
Vehicle & Equipment Status	Existing	IBS includes equipment health messages and a small set of discrete inputs to report on vehicle status.
Dispatch Console	Existing	IBS consoles are installed at nine divisional dispatch centers.
Other Sources (Desirable but not part of core TODSS)		
Traffic volumes & speeds	New	Data for interstate highways, toll roads, and some state roads are accessed through RSS feeds and web links through TODSS
Traffic signal phase and status	Not Included	This data source was not included in the Pace local requirements at the time the project started.
Network Status (Accidents, work zones, road closures, direction)	New	RTA and the GCM web links are used through TODSS to access this source data.
Highway/Rail Intersection status	Existing	Source data is provided manually by Operator initiated data messages.
ROW weather surface conditions	Not Available	Weather conditions are available through RSS feeds within TODSS but a good source for surface conditions is not yet available.
Other mode schedules and status	New	Web links to GoRoo provided by RTA through TODSS have schedule data for all transportation modes in the region.

Sources of Information	Status	Comments/Changes
Special event data (schedules, demand)	Not integrated through TODSS	These sources on information are available but there is limited integration within IBS/TODSS. This is an area for further requirements definition and design in the future.

The sources of information requirements integrated in the prototype TODSS are summarized in the following table. The table includes the original requirement, identifies whether the requirement was in the original IBS or needed to be developed, and how the requirement was implemented in the TODSS prototype. Recommended changes to the requirements are in italics.

Table 2 - Sources of Information Requirements

Requirement	Status	Comments/Changes
SI 1 Core TODSS shall have the ability to interface with the core TODSS sources of information highlighted in Table 5-1	Existing and New	See table above
SI 2 [Desired but not required] Core TODSS should have the ability to interface with the non-core TODSS source on information also shown in Table 5-1	New	The architecture of the TODSS supports this requirement by using XML, RSS, RegEx, and other internet standards and anticipates the use of TCIP.
SI 3 Core TODSS shall have the capability to obtain information from each source of information on a periodic basis to obtain up-to-date information on the transit system status and performance (How the information is obtained may vary based upon the design and architecture of the TODSS system. Examples include periodic polling by the dispatch center, requests to send data from field devices, or periodic data transmissions from field devices (without the request)).	New	IBS is a polling system for vehicle location and exception based for other vehicle messages. TODSS is the event processor and instead of passing data directly to the user interface as in the previous version of IBS, TODSS now processes all incoming sources of data to determine whether the data messages are a potential service disruption.
SI 3.1 Core TODSS shall have the capability to obtain information from each of the "Transit Agency Static	Existing	IBS provides geographic survey, route management, and schedule planning tools to access and merge

Requirement	Status	Comments/Changes
Information" sources shown in Table 5-1 based upon its update cycle, or when dispatch personnel have been notified that a change has occurred (e.g. daily, weekly, monthly, yearly)		static route and schedule data from Giro Hastus and other systems to create daily schedules. The periodic data updates to operate IBS in the long-term require access to these types of data initialization tools.
SI 3.2 Core TODSS shall have the capability to obtain information from each of the "Transit Agency Dynamic Information" sources shown in Table 5-1 on a periodic basis to provide up-to-date information on the transit system status and performance and meet the Core TODSS Identification and Notification of Service Disruption (SD.x.x in Section 5.2) and Provision of Service Restoration Options (SR.x.x in Section 5.3) requirements (Note that the polling frequency will vary depending on the radio system and AVL design. First, the feasible polling rate is dependent on the radio system. Dedicated private mobile radio systems can poll vehicles as fast as every 100ms. Trunked radio systems share bandwidth and the feasible polling rate depends on the amount of information being sent and the size of the fleet. Second, the polling rate needed depends on whether the TODSS analysis is centralized within the computers at the dispatch center, or distributed/event driven where the threshold analysis is performed on each vehicle.)	Existing	IBS is a centralized system with "smart buses" and TODSS shares in that design. Pace has three radio towers with three data channels to service over 600 peak fixed route vehicles. Data polling rates that report vehicle location are every two minutes. The system was designed so that contention slots are always available for other dynamic alarms and messages to be sent as they occur. All dynamic data is coming back in real-time unless there is a gap in data communications. When the data communications are disrupted the data is stored onboard the vehicle and uploaded when returning to the garage through a wireless LAN.
SI 3.3 [Desired but not required] Core TODSS should have the ability to obtain information from each of the non-core TODSS sources on information also shown in Table 5-1 to obtain and display up-to-date information on the transportation system status and performance and assist in meeting the Core TODSS Identification and Notification of Service Disruption	New	TODSS integrates the internet into the user interface by providing automated website links and subscriptions to RSS feeds to receive non-core TODSS sources of information including traffic, weather, and other system's schedules. This development approach is consistent with other existing internet based real-time

Requirement	Status	Comments/Changes
(SD.x.x in Section 5.2) and Provision of Service Restoration Options (SR.x.x in Section 5.3) requirements		transit information systems.
SI 3.4 Core TODSS shall have the ability to regulate the frequency of information updates (e.g. polling or event triggered reporting) in response to an event notification, service restoration action, or system status notification. *(Suggest that the word "updates" be deleted and replaced, because it has several meanings within the TODSS environment, with "reporting".)*	N/A	IBS is designed around a fixed two-minute polling cycle for vehicle location and provides contention slots for other data messages as they occur. The location polling cycle is to a shorter period when a vehicle is reporting an Emergency Alarm state. Due to the cost, changes and a re-design to the underlying communications architecture were not made in the prototype. The two -minute polling rate at Pace is not frequent enough to accurately support real-time traveler information systems. If radio infrastructure supported polling rates between 20 and 40 seconds then this requirement is not as important. However, with long polling rates this requirement may help with the associated data latency problems.
SI 3.5 Core TODSS shall have the ability to regulate the frequency of updates based upon the priority of the event or action being monitored and the data network's capacity to transmit and receive information. *(Suggest substituting "frequency of data reporting" instead of "frequency of updates". The updating process in TODSS is independent of the data reporting from the communications system. The term "updating" in TODSS is the concept of priority updating of an event that has been previously evaluated and generated as a TODSS incident based on changing conditions.*	New	The IBS contention slots are assigned to serve all messages as they occur (other than location messages) and the system is designed to meet Pace operational needs. Therefore, the frequency of data reporting did not need to be regulated. The exception is the vehicle location messages. See SI 3.4. In the TODSS prototype, an updating rule is a rule that acts upon an incident that has already been generated. Updating rules can

Requirement	Status	Comments/Changes
Separation of data communications issues from TODSS requirements should be considered in the future. This requirement may be better suited in the Service Disruptions section.)		be created for any incident and are continuously evaluated by the TODSS event-processing engine. Priorities of incidents can be lowered or raised by the updating rule as configured by the system administrator within the TODSS incident configuration tool or Intelligent Decision Support (IDS).
SI 4 Core TODSS shall have the capability to selectively request information by type (e.g. revenue vehicle location, automatic passenger count) or specific source (e.g. vehicle, field sensor, or dynamic data base) to obtain current status information	New	The TODSS IDS provides many event types, each with numerous parameters and numerous threshold values, to evaluate the real-time status on an event-by-event basis using all available sources of information.
SI 5 Core TODSS shall have the capability to receive and process event notification and other data from each dynamic source of information shown in Table 5-1 within the time between its periodic updates (see requirement SI 3.2)	New	The TODSS event-processing service is operating in real-time on all messages as they are received and no processing problems were experienced with a peak load of over 600 vehicles. The only time a limitation is imposed within the prototype TODSS is the time a query has to complete in order to provide historical data as a source of information in real-time.
SI 6 Core TODSS shall have the capability to accept overrides and modifications to threshold status for each source of information shown in Table 5-1. *(This requirement needs to be more specific and indicate if this refers to automated modifications, real-time user modifications, or near real-time modifications to system configuration. It is too ambiguous as written.)*	New	Pace decided that uniformity of dispatcher action was a goal to be achieved through the local requirement and decided that dispatchers could not modify or override threshold values set to evaluate information sources. The system design allows only the TODSS administrator to make changes to existing threshold values based upon operating conditions and activate them in real-time. In addition, updating rules were designed to decide when to override and modify previous threshold values.
SI 6.1 Core TODSS shall have the	Re-	Password control, user group

Requirement	Status	Comments/Changes
capability to provide access control to overrides and modifications to threshold status for each source of information shown in Table 5-1 as provided for in Core TODSS Requirement GS 12.	designed for TODSS	assignments, and setting group permissions to access the various TODSS IDS functions are included as part of the IDS. It was quickly determined that configuration control of the TODSS rule base would be difficult with too many users making changes to the TODSS setup and this group is tightly controlled.
SI 7 Core TODSS shall have the capability to combine and relate the sources of information shown in Table 5-1 as necessary to meet the Core TODSS Identification and Notification of Service Disruption (SD.x.x in Section 5.2) and Provision of Service Restoration Options (SR.x.x in Section 5.3) requirements	New	IBS, external events, and dispatcher initiated manual events are all supported as sources of information to evaluate in the TODSS event-processing engine to identify service disruptions. Restoration options are applied to each incident as it is created.
SI 8 Core TODSS design shall provide for modular implementation and incorporation of each Core source of information shown in Table 5-1. *(This requirement needs to be rewritten. An explanation of what a modular design means is needed. It is recommended that the requirement be changed to "...modular design that permits the addition of information sources as they become available in a local implementation of each Core source of information shown in Table 5-1.")*	New	The intention of this requirement is admirable but is not specific enough to know the intent of the requirement. Ideally, a TODSS could be used with multiple vendor systems, but this will require more experience with these types of systems before being realistic. The TODSS prototype was designed to be able to include or add any of the information sources as they become available.
SI 8.1 Core TODSS shall have the ability to operate if one or more of the Core sources of information shown in Table 5-1 are not part of a specific system installation and provide reduced functionality based upon the information sources that have been implemented (see Table 5-2and Table 5-3)	New	The TODSS is designed to operate on any subset of the core sources of information. The design includes all existing ITS systems that transit agencies are integrating into "Smart Bus" and CAD/AVL systems. The IDS permits the use of new sources of information as they are added to the system. In the course of developing the prototype, it was demonstrated that a new sources of information (canned query) can and was

Requirement	Status	Comments/Changes
		introduced.
SI 8.2 Core TODSS shall have the ability to operate if one or more of the Core sources of information shown in Table 5-1 ceases to function and provide reduced functionality based upon the information sources that continue to function (see Table 5-2and Table 5-3)	New	Event processing continues on any and all available information sources. The loss of any source of information does not stop the TODSS event-processing engine.
SI.8.2.1. Core TODSS shall notify dispatchers when a source of information ceases to function on its status and the functions it impacts *(Recommend adding TODSS administrators and/or IT personnel to this requirement.)*	New	A robust set of equipment and system health messages are available for TODSS event processing to provide incident notification to dispatchers. Pace has determined that the TODSS administrator should be included in these types of notifications. The administrator has control setting up and configuring who and what messages are triggered.

Identification And Prioritization Of Service Disruptions

"A service disruption is an event where service provision falls outside agency service standards and policies and requires a service restoration strategy decision in response." This definition from the TODSS Core Requirements is what is referred to as an *incident* in the TODSS prototype. Incidents are the output of the TODSS event processing and are what show up in the TODSS user interface.

The identification and prioritization of service disruptions are implemented via the real-time central TODSS engine as a service running on the IBS application server. TODSS is administered by the Intelligent Decision Support (IDS) administration application. IDS provides a series of tab views for administering the various functions within the TODSS. The IDS is used to manage all aspects of the TODSS including the identification of operational scenarios based on local Pace rules, creating prioritized incidents, and providing suggested service restoration actions.

This section provides a summary of how the service disruption requirements were implemented in the prototype TODSS. The following table includes the original service disruption requirement, identifies whether the requirement was in the original IBS or needed to be developed for TODSS, and how the requirement was implemented. Recommended changes to the requirements are in italics.

Table 3 - Identification and Notification of Service Disruptions Requirements

Requirement	Status	Comments/Changes
SD 1 Core TODSS shall have the ability to identify the operational scenario and apply the appropriate system parameters and response rules base at any point in time that they are operating.	New	The IDS Incident tab is used to define the properties of an operational scenario. The Rules tab is used to define the incident trigger and set the incident priority. Rules are built by selecting parameters specific to an event type and assigning values that meet the conditions of the operational scenario.
SD 1.1 [Desired but not required] The operational scenario should be identified based upon the sources of information shown in Table 5-2 and additional internal system variables (e.g. time of day, type of day) *(Recommendation is that this becomes a requirement. The power of TODSS was demonstrated when combining sources of information and internal system variables.)*	New	The operational scenarios are identified using all available sources of data and many internal system variables. A system variable is a parameter with values set (e.g. IsRevenue Service = true). Many new variables were created specifically for TODSS including route type and operator type.
SD 1.2 Core TODSS shall also provide	New	Dispatch Events were created for

Requirement	Status	Comments/Changes
the ability for dispatch to directly set the operational scenario		dispatchers to originate an operational scenario (incident). Three kinds of dispatch events are available: a pre-defined incident list corresponding to known external events, events corresponding to dispatcher canned messages, and events corresponding to vehicle canned messages.
SD 1.3 System parameters for each operational scenario shall include: service disruption and other thresholds; prioritization criteria; and a response rules base. *(Recommend changing to "Properties for each operational scenario shall include: service disruption parameters and thresholds; prioritization ....")*	New	Any operational scenario (incident) can be identified using parameters related to an event with each parameter having a series of thresholds to be tested. The operational scenario is assigned a priority value for placement in the TODSS queue. The definition of an incident includes assigning action plans, research lists, and other incident properties. The collection of all defined incidents can be saved as an XML file and constitutes a rules base for sharing or later use.
SD 1.4 Core TODSS shall have the ability to accept updates to the service baseline as required to identify service disruptions within the appropriate operational scenario. *(Recommend SD 1.4 and sub-sections 1.4.1, 1.4.2 be removed to a supporting CAD/AVL requirements section. SD 1.4 should be replaced with "Operational scenario parameters and thresholds shall be provided to recognize any planned or modified service changes. The level of sophistication of service modifications within the CAD/AVL shall be supported within TODSS by making available the appropriate parameters and thresholds to make intelligent decisions in identifying real service disruptions.")*	Existing	
SD.1.4.1. Core TODSS shall provide for entry of service changes due to release of a published schedule, or operator signup	Existing	This is a specific CAD/AVL functional requirement provided for by the IBS TMRoute Manager

Requirement	Status	Comments/Changes
		and TMPlanner applications.
SD.1.4.2. Core TODSS shall provide for daily entry of planned service modifications (e.g. schedule, trips, route, vehicle type, etc.) prior to pullout.	Existing	This functional requirement is provided to the dispatcher through the IBS Service Adjustment tool including cancel trip(s), offset service on a trip(s), insert service on a trip(s), and short turn a trip. Service waivers are set to adjust schedule adherence reporting properties. Vehicle and operator assignments are dynamic and can be changed in real-time. Service types are defined (e.g. school service, holiday, weekday, Sunday, special event) and multiple services can be assigned to occur simultaneously through the TMPlanner application.
SD 1.4.3. [Desired but not required] Core TODSS should provide the ability to incorporate historic service performance and ridership levels into the service baseline. *(Recommend changing to SD 1.4.1)*	New	A Canned Query can be defined in IDS to count the occurrences of a particular operational scenario. The query continues to run on a periodic basis and the count is updated. An incident can be created using the count from the Canned Query as a parameter corresponding to the number of times an operational scenario occurred during the time frame being monitored. For purposes of the operational test the historical service performance is limited to 24 hours.
SD.1.4.4. [Desired but not required] Core TODSS should provide the ability to adjust service baseline due to service restoration actions taken during real-time operations (e.g. the exchange of two trip schedules when a vehicle passes another on a route in response to "bunching".) *(Recommend changing to SD 1.4.2)*	Existing with new features	When service adjustments are placed or waivers applied the IBS system tracks these changes and makes the information known throughout the system. What is new is TODSS' ability to recognize service adjustments and include them as a condition in determining future incidents.
SD 2 Core TODSS shall have the ability to identify each service disruption type	Protected Transfers	The TODSS prototype followed this table with the following

Requirement	Status	Comments/Changes
shown in Table 5-2 using the Core TODSS sources of information also shown in Table 5-2. *(Table 5-2 serves as a good model for identifying service disruptions. The introduction to the table should qualify that there are many other service disruptions encountered and those provided in the table serve as a guide to mapping inputs to disruptions Also, Connection Protection does not serve as a good disruption category. It should be renamed to Passenger Transfers with line items for Connection Protection (a connection that includes a spatial element), Protected Transfer (a known transfer to be actively managed), and Coordinated Transfers (route intersection where transfers are determined by the system upon request). A new transit input, Passenger Request, should be included.)*	New Feature for IBS with Existing coordin-ated transfer	exception that should be reflected in future versions of the table: Mechanical Breakdown and Mechanical Malfunction should have an x in the Drive Initiated Message box.

Pace local requirements did not include connection protection and the IBS does not support automated connection protection for vehicles not sharing a timepoint. The Protected Transfer operational scenario was automated through TODSS as well as coordinated transfers through Passenger Requested and Driver Initiated Data Message inputs. |
SD 3 Thresholds defined within Core TODSS thresholds shall be parameterized based upon the operational scenario, the Core sources of information shown in Table 5-2, and the Service Baseline	New	Events whether from vehicles, routes, workpieces, CAD/AVL system, dispatchers, external events, or databases sources are packaged into a number of event types. Each event type includes a set of parameters that exposes the associated data to the rules engine to trigger an incident or operational scenario.
SD 3.1 Core TODSS shall provide the ability to calculate thresholds using arithmetic, logical, and Boolean operators	New	Parameters are built into complex rules using AND/OR operators through a graphical user interface and can apply tests of equality, greater than, and less than on the parameter values (thresholds).
SD 4 Core TODSS shall have the ability to define multiple thresholds for action for each type of service disruption defined in Table 5-2, or other event called for within the agency operational scenarios.	New	Any service disruption can be tested simultaneously by multiple rules each using unique parameters and values on that service disruption. As an example, the emergency alarm incident has six associated rules as part of the evaluation process.

Requirement	Status	Comments/Changes
SD 4.1 Core TODSS shall have the ability to set service disruption thresholds for each event (Table 5-2, or other as defined in operational scenario).	New	Thresholds, or the values of variables used in evaluating a parameter, are available for all events processed by the TODSS engine.
SD 4.2 [Desired but not required] Core TODSS should also have the ability to set additional thresholds for each event. These should include: type of notification by contact (visual, audio, alarms), increased data collection, warnings of potential disruptions, or report generation. *(This requirement would make more sense if the word "properties" replaced the word "threshold". Thresholds imply some sort of test being applied whereas properties imply other associated behaviors. A threshold is simply a value of a variable that triggers an action according to the definition provided in Core Functional Requirements.)*	New	Additional properties assigned to a triggering rule are set on the Rules tab including sound and color, TODSS priority, life span of the incident, a delay time on the trigger, and suppression time on further occurrences of the incident. The Incident tab assigns a default incident report form, a default incident report type, a double click action, view filters, ownership filters, a research list, and incident deletion properties.
SD 5 Core TODSS shall trace the impacts of an event/disruption across the network to other fixed route service within the system	New	The research list provided with each incident is intended to guide a dispatcher by providing links that automatically setting up pertinent CAD/AVL tools to provide data to better understand the context of the incident and its' relationship to the transit network. Future algorithm development could work on providing automated aggregation of related data through an extended set of variables to identify the details of the data surrounding an incident.
SD 6 Core TODSS shall provide the ability to monitor a service disruption or event and the impacts of service restoration strategies applied in response	New	The CAD/AVL tools accessible by the research list and action plan(s) links are available throughout the life of the incident.
SD 6.1 Core TODSS shall provide the capability to set thresholds for event tracking	New	The Service Performance tab provides the ability to set values (thresholds) for route level summary statistics that includes headway, schedule adherence, and

Requirement	Status	Comments/Changes
		load monitoring displays.
SD 6.2 Core TODSS shall provide the capability to toggle event tracking at any point in time	New	The IDS Rules tab provides an enable/disable setting that can be set and activated in the real-time system. This will stop or start the triggering rule and the associated incident.
SD 6.3 Event tracking shall consist of monitoring the service associated with the service disruption and all service affected by the disruption identified in meeting functional requirement SD 4. *(Recommend this requirement be moved to 6.1 since it provides an explanation of the term "event tracking" that would be helpful for understanding the other requirements in SD 6)*	New	The research list is comprised of a series of action items. An action item is a link to an available CAD/AVL tool with parameters and variables that the system administrator sets up to provide the appropriate setup automatically within the CAD/AVL tool. There is no limit to the number of action items that can be assigned to a research list. Pace attempted to design research lists to be reused for similar operational scenarios as a means to simplify setup and configuration management. Future enhancements that Pace has identified would be parameters and variables that drilled down to greater detail within the data within the CAD/AVL tools. For example, a link to the vehicle tab to look for vehicles rerunning to the garage would expose the field "Final Timepoint" as a variable to assist with setting up a bus bridge.
SD 6.4 Core TODSS shall have the ability to set additional thresholds for determining the end of the event and conclusion of tracking.	New	There are two methods available to the system administrator for setting properties to conclude an incident: Auto delete on completion of all action items or owner can delete at any time.
SD.6.4.1. Core TODSS shall include the ability to evaluate hysteresis (noise and fluctuation around each threshold) and filter for false notification of already identified service disruptions and events.	New	A rule can create only one incident at a time from a given source of information. Updating rules can be set to address changing conditions surrounding an incident. The suppression property suppresses alarms that continue to be sent

Requirement	Status	Comments/Changes
		such as a maintenance alarm. The delay property requires an incident to occur for a period of time prior to being triggered. Canned queries can test for a number of occurrences before incident is triggered.
SD.6.4.2. Core TODSS shall provide notification to the dispatch center and others as called for in the response rules base when an end of event threshold is triggered. *(Recommend that the requirement be used sparingly if at all and follow the principle that dispatchers shall make all final decisions. The external communications should be left to dispatcher discretion and not automated based on end-of-life of an event.)*	Modified implement ation using existing features	The project team agreed that this requirement did not fit in with the goal of minimizing the clutter and number of messages coming into the TODSS queue and recommended not to include it in the design. If a notification is required prior to an incident removal from the TODSS queue, it is included as an action item in an action plan. The flow of the life of an incident is as follows: An incident displays a lock to all other TODSS users when a dispatcher selects an incident from the TODSS queue and starts working on it. The lock on the incident can be removed or re-assigned at any time. Action Plan links to email, incident reports, or dispatch chat can be set if an end-of-incident notification is required. When an incident is completed it is removed from queue.
SD.6.4.3. [Desired but not required] Core TODSS should provide for additional notification to check conditions by other means (e.g. consult operator, supervisor) where the end of the event cannot be determined using available inputs	New use of existing features	The system administrator will add action items in the action plans and/or research list to assist the dispatcher in addressing and completing Pace procedures related to an incident.
SD.6.4.4. Core TODSS shall provide the ability to continue to track the impacts of service disruptions or events for a specified time period after they are over	New	An incident has the property "Life span (minutes)" that determines how long an incident stays in the TODSS queue. The TODSS administrator sets this parameter based on operating procedures. The incident stays in the queue until the time expires. The audit

Requirement	Status	Comments/Changes
		history will indicate if an incident expired due to time, was completion status, or deletion details.
SD 7 Core TODSS shall provide the ability to prioritize all service disruptions and notifications/actions triggered by defined thresholds in order to determine their importance/severity and order in event queues *(Recommend that SD 7.1 and 7.2 be removed. Recommend adding, "Priorities shall be assigned as part of the TODSS service disruption event processing based on the operational scenario requirements and associated parameters and values.)*	New	The priority of the incident is set by the system administrator when configuring the operational scenario. The priority of an incident is an integer value from 0 to 100. Priority 0 never reaches the TODSS queue but is processed and tracked by the TODSS engine.
SD 7.1 Potential parameters for each priority calculation shall include Table 5-2 sources of information; Service characteristics (route, run, block); Threshold value (high, low); Latency (when was the threshold triggered); Geographic location (system, corridor, sub-area); Available resources; Dispatch supervisor; and the Operational scenario context (time of day, type of day, special event, overall system status). *(See SD 7 - Recommend this requirement be removed.)*	N/A	The TODSS administer selects all the parameters and sets the values used to trigger generating or updating rules. The TODSS Administrator then assigns the priority based upon the rule. Priority is not automatically set but left to the discretion on the TODSS administrator based upon the underlying operational processes and procedures.
SD 7.2 Core TODSS shall provide the ability to calculate priority levels using arithmetic, logical, and Boolean operators. *(See SD 7 - Recommend this requirement be removed.)*	N/A	Calculations are used to create the triggering rules and a priority is assigned to the operational scenario.
SD 8 Core TODSS shall provide the ability to display a summary of current and historic system status upon request	New IBS feature	The Service Performance tab provides a graphical summarization of current system status.
SD 8.1 The system status summary shall have the capability to summarize the amount (percentage) service by threshold value for each type of service disruption shown in Table 5-2. *(Recommend changing to "The system status summary shall have the capability to summarize*	New IBS feature	Route performance summarization of adherence, headway, layover, and load are configurable by setting desired percentage variables, averages, or counts. Other service disruptions in table 5-2 are not represented in the

Requirement	Status	Comments/Changes
the service by user-definable statistics including percentage values for route schedule, adherence, and load. The system status summary shall provide counts and other summary statistics as appropriate for the other service disruptions shown in Table 5-2.)"		Service Performance tab. There was uncertainty on how to provide percentage thresholds of the other service disruptions. Future improvements would include providing statistics (e.g. counts) of the other service disruptions that TODSS is currently monitoring.
SD 8.2 [Desired but not required] The system status summary should have the capability to summarize the amount (percentage) of service by threshold value for additional thresholds and performance measures defined by the transit agency. *(Recommended change: "The system status summary shall have the capability to summarize multiple performance measures using different threshold values as defined by the transit agency.)*	New IBS feature	Multiple views of the Service Performance tab using different sets of measures and thresholds can be displayed as tiled views or separate windows. View settings can be saved (and shared with other users) to be loaded when needed.
SD 8.3 [Desired but not required] The system status summary should allow system performance to be broken out by Type of service disruption or threshold, Type of service (e.g. local, limited, express, commuter. BRT), Geographic location (e.g. system wide, corridor, sub area, facility assignment, or other criteria as defined by the transit agency	New	A route type property was developed for testing types of service. The Service Performance windows can sort and filter based on Pace defined route types (e.g. arterial, feeder, and circulator). Work Assignment roles also break out the summary status into only those assigned garages, routes, vehicles, or geographic regions assigned to dispatchers within that role.
SD 8.4 [Desired but not required] The system status summary should allow the playback, or display, of performance and trends for the time preceding the request, or of historic performance from previous days, weeks, or months. *(In practice, this is two requirements one for historical performance and one for historical system summarization and should be in separate line items.)*	New IBS feature	The instant playback function provides historical playback of performance and is available as a TODSS action item. The playback function provides either a selected vehicle view or all messages in the time frame selected. This is not summarized data but actual historical performance. The historical display of system status is available through the reporting module of the CAD/AVL but rarely used in a real-time mode of operations.

Requirement	Status	Comments/Changes
SD 9 Core TODSS shall provide the ability to define and select as needed displays and notifications of current system performance and service disruption/event status *(SD 9 sub-sections are primarily CAD/AVL requirements. Public transit CAD/AVL products have matured to the point where this level of detail is no longer needed in TODSS requirements. Subsection 9.1 – 9.3 should be used as guidelines for CAD/AVL requirements.)*	Existing	TODSS action items can provide links and setup to all CAD/AVL tools that are sources of related data to a service disruption.
SD 9.1 Core TODSS shall provide the capability for geographic display on dispatch center, remote terminals, MDTS, and mobile devices of the current location and status of all revenue and non-revenue vehicles logged on to the system	Existing	IBS meets these CAD/AVL requirements with the exception of Mobile Display Terminals (MDT). The older technology of the Pace MDTs does not support map displays.
SD.9.1.1. The scale of the geographic display shall be selectable and vary from displaying the complete system area to focusing on the operations of a single transit center or bus stop	Existing	IBS meets these CAD/AVL requirements.
SD.9.1.2. The geographic display shall be built upon a base map that should include but not be limited to: Background road network; major transportation facilities; and other significant geographic features; Location of bus stops, garages, terminals, turn-around and transfer points; Current baseline service footprints	Existing	IBS meets these CAD/AVL requirements.
SD.9.1.3. The geographic display of service shall include the current position of each vehicle based upon the most recent poll of the system by the GPS / AVL component	Existing	IBS meets these CAD/AVL requirements.
SD.9.1.4. The geographic display shall have the capability to show: vehicle identification by route, run, block and type; and current status of each service disruption shown in Table 5-2 (e.g. schedule adherence, off route status; and alarms).	Existing	IBS meets these CAD/AVL requirements.
SD.9.1.5. [Desired but not required] The	Existing	Predicted adherence is displayed

Requirement	Status	Comments/Changes
geographic display should have the ability to show but not be limited to: predicted status of each service disruption; and service performance (e.g. headway, direction, speed, passenger load, or special passengers)	functions enhanced by the new TODSS interface	in the geographic display and the spatial representation is available to analyze headway spacing. Vehicle properties are revealed by double clicking a vehicle icon with all current status related to a vehicle displayed. An incident in the TODSS queue can be directly displayed to the map through an action item link.
SD.9.1.6. The scale, detail of information, and refresh frequency provided by the TODSS system shall determined by the geographic display characteristics and communications speed and capacity of the output device receiving the information	Existing	IBS meets these CAD/AVL requirements.
SD 9.2 Core TODSS shall provide the capability for tabular display and notification to dispatch center, remote terminals, MDTs, and mobile devices, of current system performance and service disruption/event status	Existing	IBS meets these CAD/AVL requirements
SD.9.2.1. Core TODSS shall provide the capability to display but not be limited to separate tables of: Current status and performance of all revenue vehicles currently logged on the system identified by route, run, block and type; Current status of each service disruption shown in Table 5-2 (e.g. schedule adherence, off route status; and alarms); Predicted status of each service disruption; Emergency alarms	Existing	IBS meets these CAD/AVL requirements except for "Predicted status of each service disruption;" requirement. The prediction engine is currently limited to schedule adherence prediction based on schedule. The other service disruptions can display the current status but not the predicted status. Next steps in TODSS research and development should be to begin to build the simulation and modeling algorithms necessary to expand prediction capabilities. This would include the use of both historical and real-time data in combination to provide predictions related service disruptions other than schedule.
SD.9.2.2. Core TODSS shall provide the	Existing	IBS meets these CAD/AVL

Requirement	Status	Comments/Changes
capability to display tables of prioritized service disruptions and events for both current and estimated/predicted conditions		requirements related to schedule and headway adherence.
SD 9.3 Core TODSS shall provide the capability to produce graphical displays of service and headway performance to dispatch centers, remote terminals, and mobile devices. Examples include time based "race track" displays; vehicle time-space trajectories; and service histograms	Existing	IBS meets these CAD/AVL requirements through "race track" or the Route Ladder tool for adherence, headway, and corridor monitoring. The Route Ladder tool is available to mobile, remote, and central dispatchers.
SD.9.3.1. Core TODSS shall provide the capability to filter the service shown by type of service, route, corridor, and sub-area	Existing	IBS meets these CAD/AVL requirements through individual route selection (up to 10), corridor selection, and based on Work Assignment roles.
SD 10 Core TODSS shall provide the capability to select and control the display of all potential screens and notifications identified in Requirement SD 9. *(SD 10 sub-sections are primarily CAD/AVL requirements. Public transit CAD/AVL products have matured to the point where this level of detail is no longer needed for TODSS requirements. Recommend subsection 10.1 – 10.4 be deleted and SD 10 changed to "Core TODSS shall provide the capability to select and control the display of all potential screens and notifications identified in Requirement SD 9 through filter capabilities, display order, and use of color, and screen size.)*	Existing	IBS meets these CAD/AVL requirements.
SD 10.1 Core TODSS shall provide the capability to apply filters defined by the user for all geographic displays, tables, and graphs. These shall include the ability to filter by: • Service type (e.g. local, limited, express, commuter) • Geographic location (route, corridor, sub-area, bus facility) • Existing service disruptions and events (now occurring) by type (all) Predicted service disruptions and events	Existing and New	IBS meets these CAD/AVL requirements. Service type was created for TODSS and called "Route Type" (within IBS, the term service is related to levels of service to accommodate school service, weekday service, weekend service…).

Requirement	Status	Comments/Changes
(from propagation and arrival time estimates) by type (all) • Emergency alarms • Service restoration strategy applied (unplanned events where action has been taken)		
SD 10.2 Core TODSS shall provide the capability to set the display order of any screen based upon the service disruption priority or other criteria	Existing	Setting display order is provided for all column headings in each tabular display.
SD 10.3 Core TODSS shall provide the capability for the user to control the colors used to display information on any screen	New	Color is assigned to an operational scenario by the system administrator. Pace created a scheme where color and depth of color correspond to the event types and the numerical priority values.
SD 10.4 Core TODSS shall provide the capability for the user to control the size and display order of any screen on the console	New features in IBS	All windows can be resized, multiple copies of a window can be created, and windows can be undocked from the main application frame and be moved from screen to screen.

Provision of Service Restoration Options

Tables 5-3 and 5-4 from the *Transit Operations Decision Support Systems (TODSS): Core Functional Requirements For Identification Of Service Disruptions And Provision Of Service Restoration Options 1.0* document are good reference material for other agencies to review. Table 5-3 identifies potential strategies and sources of data to use for analysis and aid in implementing the strategies. Table 5-4 identifies service disruptions and the feasibility of applying various restoration strategies to each.

These two tables attempt to fill a gap in the documented theory and practice of transit bus service management in the US. The information provided in these tables was a helpful guide during the local concept of operations, requirements, and design phases of the TODSS project. These tables would serve as a research topic area for further study to begin to collate an accepted industry-wide theory of bus service management that would identify standard practices for agencies to apply in their local concept of operations and requirements. In the future, it should be made clear that when TODSS requirements refer to these tables, that formal local standard operating procedures and processes should supplement these tables when writing local requirements.

The remainder of this section provides a summary of how the service restoration requirements were implemented in the prototype TODSS. The following table includes the original service restoration requirement, identifies whether the requirement was in the original IBS or needed to be developed for TODSS, and how the requirement was implemented at Pace. Recommended changes to the requirements are in italics.

Table 4 - Identification and Recommendation of Service Restoration Strategies Requirements

Requirement	Status	Comments/Changes
SR 1 Core TODSS shall provide service restoration strategy options for action to appropriate dispatch center personnel and others as identified by the rules response base for the applicable operational scenario.	New	The IDS Action Plans tab assigns a grouping of action items into an ordered list. An action item provides automated links, configured by user-defined parameters and values, to any of the numerous CAD/AVL tools (e.g. map, route ladder, schedule tab, vehicle tab, and playback) and other possible actions such as web links and sending emails. When an incident is defined up to three action plans can be assigned. Upon selecting an incident in the TODSS queue, the dispatcher will see a visual cue when more than

Requirement	Status	Comments/Changes
		one action plan is available. The dispatcher chooses the action plan most suited to the existing operational conditions based on the naming conventions. Each action item in an action plan has a checkbox for the dispatcher to check upon completion of the action. Each action item has a comments field for any related information to be included in the audit files. If the dispatcher changes their mind, they can open an alternative action plan at any time. If there are duplicated action items that have been previously checked as completed in the original action plan they will appear in the newly selected action plan.
SR 2 Core TODSS shall have the capability to analyze each type of potential service restoration strategy shown in Table 5-3 using the sources of information also shown in Table 5-3	New	The IDS provides a Research Lists tab that is used to create a collection of ordered action items. Each incident has an assigned research list to assist with analyzing the service disruption throughout the duration of the incident. Research links do not have check boxes and are not required actions. In addition, the Dispatch Documents CAD/AVL tool is an online agency archive of policies, procedures, and service notices. For easy online dispatcher access, an action item can automatically link, with key words, to the specific policy for each operational scenario defined in TODSS.
SR 3 Core TODSS shall have the ability to determine for each service disruption	New	The TODSS administrator includes those action items that

Requirement	Status	Comments/Changes
type shown in Table 5-4 the set of potential service restoration strategies as also identified in Table 5-4.		have been determined to assist the dispatcher in implementing their final decision in accordance with the proper course of action. Dispatchers do not have to follow the action plans and can substitute different actions based on their experience and the unique operational conditions that may be occurring. They are expected to document any deviation from standard policy by adding a brief narrative in the action plan's action item comment field.
SR 4 Core TODSS shall have the ability to accept other non-automated external information sources (operator, supervisors, maintenance vehicles, dispatch centers) to assist in identifying and providing options for potential restoration strategies for a given service disruption or event	New	Action items include the links that guide dispatchers to outside information. External sources of data are included in several action plans and research lists for the operational scenarios that Pace has defined.
SR 5 Core TODSS shall verify the feasibility of all potential restoration strategies based upon the available sources of information	New	Based on Pace's existing policies and procedures the TODSS administrator provides the action item links to the information and restoration actions. The prototype TODSS design and implementation has left the final verification of service restoration feasibility as a dispatcher decision.
SR 5.1 Core TODSS shall provide feasible options	New	The Pace project working group relied on existing written policies and procedures to develop the list of feasible options for each operational scenario. These options were setup and configured by the TODSS administrator in IDS.
SR 5.2 Core TODSS shall include notification that additional information must be obtained to verify feasibility as called for to implement an option (e.g. cumulative operating time of an operator).	New	Action plans include required links to obtain additional information that require the dispatcher to complete and add comments as needed prior to closing an incident. The dispatcher is

Requirement	Status	Comments/Changes
		required to check the action item as completed as a record of acknowledgement.
SR 5.3 [Desired but not required] Feasibility analysis should be carried out using Vehicle availability, Manpower availability, Work rules, and hours of operation, time and distance required to provide the relief	New	The feasibility analysis is completed by TODSS leading dispatchers to pertinent information and the dispatcher, after reviewing the data, determining the feasibility of the action(s). The integration of the Pace operator management system and vehicle maintenance system with IBS is not completed. Pace dispatchers must use the legacy system(s) for same-day changes to data related to operators and vehicles prior to real-time operations. Once they enter the real-time system, IBS tracks availability.
SR 5.4 [Desired but not required] Core TODSS should provide upon request non-feasible options with notification of additional requirements to make them feasible (e.g. insert vehicle with recommendation to call in operators when there are no available operators on duty)	New	Dispatchers have the ability to create a dispatcher event based on an existing incident. This dispatch event would then provide an alternative action plan(s). Dispatch events correspond to the available set of dispatcher and driver canned data messages and a set of manual events pre-configured by the TODSS administrator. However, suggestions and a narrative of the detailed steps of an action to take are available as a Dispatch Document link and not available dynamically to the TODSS engine in this version of the prototype. Note that feasible options as determined by a dispatcher that are not included in the TODSS action plans are always available for use

Requirement	Status	Comments/Changes
		by dispatchers at their discretion. Dispatchers are expected to provide comments to document their changes to the suggested plan.
SR 6 Core TODSS shall have the ability to trace the impacts of all feasible service restoration strategies across the network to other fixed route service within the system.	Existing	If this requirement is referring to CAD/AVL capabilities then the TODSS does have the tools and information available to dispatchers to trace the impact of service restoration strategies to existing service. However, TODSS does not assist with tracing the impacts but only providing direction to the data that underlies the impacts. In the future, it is anticipated that more design and development in modeling and simulation algorithms will be added to TODSS. When there is a better body of work of theory of operations reference material and more experience gained working with TODSS it is anticipated that adding this degree of sophistication to the TODSS will be a natural progression. Modeling and simulation will improve the feasibility analysis by providing the ability to anticipate predict effects of applying a restoration option on the transit network.
SR 7 Core TODSS shall provide the ability to prioritize all feasible service restoration strategies.	New	IDS provides the ability to present up to three action plans per operational scenario. The action plans would relate to different operating factors such as time of day, weather conditions, or special events. IDS also provides the capability to save complete sets of operational scenarios that can be loaded in

Requirement	Status	Comments/Changes
		real-time and replace an existing set. Examples of different TODSS rule sets would include emergency operations, snow operations, or flood operations. Work Assignment roles can be set up to handle different operating conditions with the role chosen by a dispatcher corresponding to the operating conditions experienced in real-time including restoration strategies consistent with the role selected. However, each of these methods used to provide restoration strategies consistent with operating conditions are initiated by either the TODSS administrator or the dispatcher. It is anticipated that future TODSS development would assist in automating or prioritizing actions plans based on system variables, triggering rules, or some other methods that apply existing conditions to an order of preference.
SR 7.1 Potential parameters for each priority calculation shall include but not be limited to: The priority level of the service disruption being addressed; Table 5-3 sources of information; Service characteristics (route, run, block); Latency (when was the threshold triggered); Geographic location (system, corridor, sub-area); Available resources; Dispatch supervisor; and the Operational scenario context (time of day, type of day, special event, overall system status)	N/A	These parameters are used in the triggering rules to narrowly define an incident and minimize the number of restoration options to consider for a particular operational scenario. The restoration strategies are not prioritized in this version of the TODSS prototype. The complexity of adding a second priority system, and actually understanding how to implement it, is better understood now that there is some experience using a TODSS.

Requirement	Status	Comments/Changes
		Based on the operational experience there is a need for some type of prioritization when multiple action plans are provided. At a minimum, the default action plan displayed on selection of an incident should be based on a priority scheme based on system variables that represent actual operating conditions. It is recommended that this requirement be further developed for future TODSS implementations.
SR 7.2 Core TODSS shall provide the ability to calculate priority levels using arithmetic, logical, and Boolean operators	N/A	See SR 7.1
SR 8 Core TODSS shall have the ability to incorporate transit agency standard operating procedures and rules under each operational scenario into the response rules base	New	This is the essence of the IDS capabilities. The responses are included in the rules base after the operational scenario has been narrowly defined.
SR 8.1 Core TODSS shall have the ability to carry out, or assist in carrying out, additional actions defined by the response rules base for an operational scenario to determine potential restoration strategies for specific service disruptions or events (e.g. the proper response to suspicious packages or activities)	New	Using IDS Pace implemented more than 35 specific operational scenarios for testing in the prototype TODSS. The action plans were designed by Pace to specifically include additional actions beyond any service adjustment. Typically, there are several related activities required as part of existing agency policies and procedures for each operational scenario.
SR 8.2 Once a restoration strategy is chosen Core TODSS shall have the capability to carry out, or assist in carrying out, the follow up communications to notify operators, supervisors, and other transit agency personnel responsible for executing the strategy	New	Other actions including operator data messages, email communications with external entities, email communications with internal management, enterprise incident reporting, text messages to on-street signs, and operator management actions are required steps included in action plans.

Requirement	Status	Comments/Changes
SR 8.3 Once a restoration strategy is chosen Core TODSS shall have the capability to carry out, or assist in carrying out follow up communications to other management centers to provide both notification and request for action (Fire, Police, Public safety, Incident management, and Transportation management)	New	Internet based email action items are provided capable of sending complete incident details to any other agency that accepts email. This was tested successfully with Pace Traveler Services and RTA Customer Service. The prototype TODSS includes the RSS feed protocol for subscribing to external agencies through their web sites. TODSS does not publish RSS feeds to the outside but developing as RSS feed for traveler information and schedule updates would automate actions further and minimize the need to email information.
SR 8.4 Once a restoration strategy is chosen Core TODSS shall have the capability to shift command and control to appropriate locations based upon the response rules base for the applicable operations scenario. This may be to operators, field supervisors, other response personnel on the scene, or other command centers	Existing with new TODSS features	Once an incident is selected, that user owns the incident. Others can view the incident, if they have the proper permissions and rights, but they cannot act on the incident. Ownership of an incident may be transferred to another user so they can act upon it. Mobile dispatch is available to road supervision with complete IBS and TODSS functionality. The TODSS design made the mobile dispatch user interface easier to navigate by improving the methods that windows and tabs can be configured by the user. In particular, this makes map access easier on a one screen portable computer. Pace uses terminal services to provide other user's access to the IBS. Pace would like RTA to accept a remote connection to IBS and eliminate many of the emails going to RTA. Rights and permissions of users can be

Requirement	Status	Comments/Changes
		controlled by the TODSS administrator to safeguard and secure the system.
SR 9 Core TODSS shall have the ability to incorporate "Work Flow" checks and supervisor approval for specific actions (e.g. violation of work rules, using a restoration strategy not on the recommended list) based upon the response rules base for the applicable operational scenario	New	The check boxes required for each action item in an action plan were designed to meet this requirement. The action links provide the required actions. Upon completion of the action item, the dispatcher checks the box with a click of the mouse. The audit history provides information about how the dispatcher handled the action item.

One final correction in this section of the TODSS Core Requirements document is noted (Section 5.3 of *Transit Operations Decision Support Systems (TODSS): Core Functional Requirements For Identification Of Service Disruptions And Provision Of Service Restoration Options 1.0*). The opening paragraph introduces two tables included later in the section. Table 5-3 is incorrectly identified as Table 5-2.

General System Requirements For TODSS

The requirements in this section are not directly related to identifying service disruptions or providing options for service restoration. These requirements serve as a baseline for a modern transit voice and data communications system with CAD/AVL. Transit agencies should be advised in the future that these general system requirements are essential infrastructure to a successful TODSS. These requirements are not intended to be included in the TODSS requirements section of an RFP. However, new or replacement CAD/AVL RFPs should meet these basic requirements. Recommended changes to the requirements are in italics.

Table 5 - General System Requirements

Requirement	Status	Comments/Changes
GS 1 Core TODSS shall provide the capability to select operators, supervisors, maintenance, public safety, and dispatch terminals individually or in groups for one or two way data and voice communications. *(Suggest that a more general requirement for GS 1 be written and delete the subsections.)*	Existing	What is most important in this requirement are not the number of exotic ways to make group calls but rather that fleet calls, route calls, and user defined group calls are supported in the voice and data communications system.
GS 1.1 Core TODSS shall provide the ability to pre-establish call groups by type of service, route, corridor, or other user defined parameters	Existing	See GS 1
GS 1.2 Access to communication channels and requests to transmit and/or receive information (voice and data) shall be controlled by the dispatch center	Existing	Not necessarily true in all cases. In some instances, fixed route may need to participate in an open channel to support on-demand service.
GS 1.3 Core TODSS shall provide the capability for operator to supervisor, or operator to operator data or voice communications based upon dispatch center permission	Existing	This is a good feature but not a requirement for a TODSS.
GS 2 Core TODSS, hardware, software, and protocols shall use applicable ITS standards and interoperability tests that have been officially adopted through rulemaking by the United States Department of Transportation (No ITS standards or interoperability tests have been officially adopted by	Not supported	Internet protocols and standards were used for interoperability in the TODSS prototype including extended XML, Really Simple

Requirement	Status	Comments/Changes
the U.S. DOT as of January 2003) *(Recommend updating the requirement)*		Syndication (RSS), and Regular Expression (RegEx).
GS 3 [Desired but not required] Core TODSS should use ITS standards that have been approved and published by their associated Standards Development Organization (SDO) where it is affordable and practicable to do so. These include but are not limited to the SAE 1708/1587/1455 Vehicle Area Network standards for the vehicle sub-system, and the NTCIP Transit Communications Interface Profiles (TCIP) dialogues published by the American Public Transportation Association (APTA) when they become available *(Recommend updating the requirement; TCIP has been published by APTA)*	Existing	SAE J1708/J1587 /J1455 standards are used in the mobile equipment design. The TCIP standard has been issued during the time of the TODSS prototype development but has not been officially adopted
GS 4 [Desired but not required] To assist agencies in National ITS Architecture Conformity Analysis, Core TODSS software packages should include documentation that maps their functions, and potential interfaces to the current version of National ITS Architecture at the time of any specific implementation	N/A	This is an agency activity required as part of the Systems Engineering Analysis Report.
GS 4.1 [Desired but not required] Where functions and interfaces do not exist within the National ITS Architecture suggested additions should also be included. The Turbo Architecture Tool developed by the Federal Highway Administration's ITS Joint Program Office may be used for this purpose *(Recommend updating the requirement; the ITS Joint Program Office is now a part of the Research and Innovative Technology Administration)*	N/A	See GS 4
GS 5 Core TODSS shall have an open system architecture and provide for interoperability, interconnectivity, portability and scalability across various hardware platforms and networks. *(Scalability is important but not necessarily among hardware platforms and networks. What is most important today is that TODSS works in a TCP/IP network environment, that the CAD/AVL/TODSS data is publicly available, and the CAD/AVL system follows industry interface standards or provides open protocols for integrating ITS systems as they become available.)*	Partially supported	The TODSS, as part of the Continental TransitMaster™ suite of products, is designed to operate on a Microsoft platform in a TCP/IP network environment. It supports both Oracle or Microsoft databases and multiple voice and data communications technologies. The

Requirement	Status	Comments/Changes
		system scales from small systems to large systems. The data is available for Pace internal use and non-sensitive data is available for public use. Examples of sensitive data not appropriate for public use include accident investigation details or security related information.
GS 6 Core TODSS shall provide for data access and transfer to external users, applications, and operations centers (e.g. remote terminals, passenger information, maintenance, public safety)	Existing	A real-time data feed is available and being tested with RTA for the GoRoo project. Other applications are using CAD/AVL data including the Pace Oracle data archive system.
GS 7 Core TODSS shall be modular in order to minimize the time and complexity involved in upgrading existing components, incorporating new sources of information and interfaces, or adding new functions and capabilities. *(Too much ambiguous detail in this section. Suggest GS 7 address meeting standard software engineering practices and require a Quality Assurance program. Delete GS 7.1 and GS 7.2.)*	Existing	Pace had one update applied during the operational test period that added new functionality. The system is designed around a group of applications and services tightly coupled to the underlying data.
GS 7.1 System design shall include the separation of hardware interface modules from other software modules	Existing	The IBS has mobile software and central system hardware managed separately from each other.
GS 7.2 Logic and data shall be separated into distinct modules	Existing	The system uses Microsoft Operating System services for logic and Microsoft SQL Server for data.
GS 7.3 Where ever possible all system options and application logic shall be maintained as separate	New	The events and parameters are

Requirement	Status	Comments/Changes
parameter files and not directly coded into the TODSS system. *(This is an important TODSS requirement and should be moved into the Service Disruption and Service Restoration requirements sections. The requirement should strongly state that setting parameters and values are a user defined activity).*		hardcoded within the IDS and available to the TODSS administrator to configure and setup. There are an incredible number of parameters and values available for user configuration. On Pace request, several new parameters and values were added into IDS (such as a test for revenue service). The changes were easily accommodated.
GS 8 Core TODSS shall provide the capability to update the service disruption identification thresholds, disruption and restoration strategy priority weights, and restoration strategy response rules using user supplied inputs and parameter values. *(This is an important TODSS requirement and needs to be moved into Service Disruption and Service Restoration sections.)*	New	This is the essence of the IDS. The available parameters are a function of the IBS capabilities.
GS 9 Core TODSS shall provide for identification and notification of the failure of key components of the system or its core information sources. *(This is an important TODSS requirement and should be moved into the Service Disruption section.)*	New	System Health event parameters for the entire system are available with appropriate value settings that are used to create incidents with view properties set to a system administrator group. This complements the Simple Network Management Protocol (SNMP) tool set and puts the notification in the hands of users and not network administrators.
GS 10 Core TODSS shall provide the capability to monitor and archive an audit trail of all system events, parameters, data communications, screen	New	TODSS provides an audit trail with data going back about five

Requirement	Status	Comments/Changes
displays, notifications and alarms, logons, and actions performed by the system and those interfacing with it (dispatch, supervisors, operators, public safety, maintenance and remote terminals) *(This is an important TODSS requirement and should be moved into the Service Restoration section. The focus of the requirement should be on TODSS and not CAD/AVL data. The audit should be on the displayed service interruptions, dispatcher actions, and all related rules and actions.)*		days within the prototype application. This information is used to evaluate incident configuration prior to making it available to dispatchers in real-time. The audit trail is used to identify outstanding dispatcher performance to be duplicated and under-performing dispatchers in need of management scrutiny. The audit trail provides feedback directly to operations personnel without having to go through the IT department to request custom data sets or custom reports. The data is incident specific and should provide a good window into the historical service disruptions from a service development perspective.
GS 11 [Desired but not required] Core TODSS should provide the capability to replay system conditions and events either from short term on-line storage or longer term archived information. *(This section is too detailed and GS 11.1 and 11.2 should be deleted. GS 11.3 is not a playback function but rather a simulation and modeling tool that should be a separate requirement.)*	Existing	Full playback functionality is provided as part of the IBS. Playback is available as a separate application or is instantly available through the TODSS interface.
GS 11.1 If implemented, replay shall recreate the exact system conditions that occurred over the selected time interval	Existing	Playback provides a complete set of vehicle related data messages that can recreate any time period based on the agencies data

Requirement	Status	Comments/Changes
		retention policies.
GS 11.2 If implemented, replay shall have the capability to recreate all system events parameters, data communications, screen displays, notifications and alarms performed by the system over the selected time interval	Existing	See 11.1
GS 11.3 If implemented replay shall have the capability to use the TODSS and AVL/CAD features to view displays, analyze information, and enter commands that were not used when the original event occurred	Existing (partial)	Entering commands not used during the regular event is not supported but is a good concept and is describing a simulation and modeling tool. The requirement should be in its own section and not be in the replay section. It is suggested to include forward looking simulation as part of the requirement.
GS 12 Core TODSS shall provide multi-level password protected access control through logon and logoff procedures for all terminals, monitors, and data ports. *(This section is too detailed and GS 12.1, 12.2, and 12.3 should be deleted. GS 12 should be in Service Disruption and Service Restoration sections with an express concern of adding TODSS to the CAD/AVL security scheme.)*	Existing with new TODSS features	The Security Manager, included as a function of the IDS, complements the Microsoft Operating System security scheme.
GS 12.1 The ability to read, write, and modify real time displays, system parameters, data inputs, or historical reports shall be determined by rights granted through individual user access profiles	Existing with new TODSS features	New security features related to the IDS were incorporated including security settings for the audit trail, incident configuration, and security modules.
GS 12.2 Default security levels which set the access rights on different types of information may also be used to simplify the management of security access to all TODSS interfaces and displays shall be password protected through logon and logoff procedures	Existing	Security settings are made at the group level with individuals placed into groups. The highest level of security it operative if an individual is included in more than one group.
GS 13 Core TODSS shall also provide the capability to archive information for use in performance	Existing	IBS includes end-of-day procedures to

Requirement	Status	Comments/Changes
monitoring, route and schedule planning, and subsequent operational analyses		extract, transform, and load data into a data mart. The data mart is used as a source for the IBS reporting system.

TODSS Evaluation Results

TODSS was implemented at all nine Pace dispatching locations and managed at Pace headquarters. All dispatchers and supervisors that perform the communications dispatcher role received training that highlighted the IBS updates and basic use of the TODSS interface prior to the go-live date. The primary goal of TODSS was to remove the "clutter" or those incidents not required to be acted on in alignment with Pace's current operating procedures. Pace management was also looking to increase the uniformity of the dispatch function between the nine divisions.

Although TODSS was implemented system-wide, three divisions were targeted to be included in the evaluation process of the TODSS prototype implementation. The first selected division was South that serves the South Cook County and DuPage County suburbs. This division operates 24/7 and covers all after hours communications for all Pace divisions. The second selected division is North Shore that serves Evanston and the northern suburbs where the service focus is commuter runs. The third selected division was Heritage serving the Joliet area with service relying on pulse points and coordinated transfers.

With the assistance of a TODSS working group drawn from the three targeted divisions, IBS data messages were identified from the old system that were deleted without action, ignored, or expired due to inaction. These data messages were excluded as service disruptions within the TODSS. The TODSS working group was involved in developing the local concept of operations and was involved in defining the initial set of TODSS incidents. Headquarters personnel were the TODSS administrators responsible for all TODSS configuration and setup.

The first part of the project evaluation is focused on primary stakeholder perceptions. Activities for this phase included:
- To gauge dispatcher performance, interviews were conducted with key dispatchers once the TODSS operational period was over.
- A survey was repeated with active dispatchers to identify any changes in dispatcher attitudes.
- Interviews with senior management were conducted to understand their perspective on the changes resulting from the TODSS prototype.

The second part of the evaluation focused on the technical aspects of the TODSS. Baseline data from a sixty day period 12 months prior to the TODSS operational trial period was used in comparison with data collected during the operational trial period. The focus of the analysis of the data is on before and after changes in the number of incidents that dispatchers are presented, their responses to incidents, and the changes in the kinds of service disruptions encountered.

Stakeholder Perceptions

Dispatcher Attitudes

In preparation for the TODSS implementation, while developing their local Concept of Operations, Pace developed a survey that sought to understand dispatcher attitudes with respect to the IBS and a hands-on IBS test to measure dispatcher's skill level. The survey was intended to be used to measure changes in dispatcher attitudes once the TODSS was in operations. The skills test was intended to guide development of future dispatcher training.

The skill levels at first look were lower than expected but upon examination were understandable. There are nine dispatch centers to staff and Pace relies on the Dispatcher/Road Supervisor position to fill weekend, nights, and at other times as needed to meet dispatch staffing requirements. In addition, the communications dispatcher and window dispatcher roles are combined into one position for a majority of time at each of the dispatch centers. This divides the dispatcher's attention between operator management and real-time dispatching. Given these factors, it is understandable that many of the Dispatcher/Supervisors had little time to develop their IBS skills.

As planned, there will be dispatcher skills training later this year. The training will address the skills gaps, new policies and procedures related to the TODSS changes, and the new capabilities of the IBS upgrade including TODSS. The level of dispatcher expertise should not be as big an issue with the built-in TODSS automation, prioritization, and workflow capabilities.

The attitude survey administered when the project was kicking off was designed to gauge the overall user impressions of the TODSS prototype of all Dispatchers and Dispatcher/Supervisors and Supervisors that are scheduled to dispatch as part of their job description. The survey was repeated a second time after the TODSS operational test period completed. Over 40 surveys were returned in each of the trials. The following table summarizes the results of the two survey trials. The answers were based on a scale of one (strongly disagree) through five (strongly agree).

Table 6 - Dispatcher Attitude Survey Results

	Dispatcher Question	Pre TODSS	Post TODSS	Change
1	I have time to explore all the TransitMaster information provided by IBS.	3.14	3.6	0.46
2	IBS provides important data that helps me do my job.	4.73	4.65	-0.08
3	When I need information it is often hard to find in IBS.	2.92	2.4	-0.52
4	IBS helps me recognize where service problems are before they get too serious.	3.86	3.75	-0.11
5	IBS helps me make the right decisions to correct service problems.	3.92	3.875	-0.045
6	For the most part, I rely on IBS for radio communications only.	2.89	2.75	-0.14
7	I know the preferred and proper solution to most any service problems that arise.	4	4.05	0.05
8	Other dispatchers usually use the proper and preferred solution to service problems.	3.73	3.7	-0.03
9	Service and procedure reference material is readily available in IBS.	3.7	3.85	0.15
10	When I need information to make an operational decision I usually rely on the printed materials provided.	3.41	3.9	0.49
11	I know where to go to get the information I'm looking for.	3.84	4.375	0.535
12	I know how to easily access related information.	3.62	4.225	0.605

The results indicate two areas of significant change when analyzing those questions with changes of .5 or greater. One change is the amount of time that dispatchers have available and the second observation is the confidence the dispatchers have in finding and using information. These changes are likely explained by the additional time available to access information due to TODSS identification and prioritization of service disruptions and the TODSS service restoration assistance.

The responses indicate that TODSS has proven to reduce the amount of information not related to actual service disruptions to the point where dispatchers now have the time to pay attention to the important information presented (questions 1 and 3). There are dramatically fewer incidents presented to dispatchers and it has been observed that they are acting on all incidents as soon as they enter the queue. In IBS, prior to TODSS, there were hundreds of messages not acted upon by the end of the day because they were not important, with important messages lost in the number of messages in queue, and many messages without clear restoration actions.

The automation that TODSS provides appears to have had a positive effect on dispatchers knowing where and how to find related information (questions 10, 11, and 12). The action links eliminate the time that used to be required to set up the existing tools to find the pertinent information. Instead of ignoring other views of the data, the action item links take them directly to the supporting CAD/AVL information and have broadened their view of the system. The positive change in dispatchers using printed material to make decisions implies that dispatchers may be acting in a uniform fashion throughout the agency.

Dispatcher Performance

At the conclusion of the of the implementation acceptance test period, dispatchers at the three selected garages from the TODSS project team were observed at work with one key dispatcher interviewed at each location to determine how TODSS was being used, changes dispatchers experienced in operating procedures, and the effectiveness of TODSS in their daily job activities.

The observations and interviews focused on confirming the acceptance test results by seeking dispatcher confirmation on ease of use, automation capabilities, incident priority, and effectiveness of providing service restoration assistance. A standard set of questions served as a framework for the session that included:

- How did the upgrade process go? Is there anything that could have been done better during the transition?
- How has the system run since the upgrade? Has the system performance changed, how is the application running?
- Are there any new features you like/dislike? Anything you miss from the old version?
- What is your reaction to the new incident queue and how it works? Discuss the priorities, sorting, and would you use second queue.
- Do you use the links in the action plans? Do they help – are you finding the related information quicker with the links to schedule, vehicle, and map tabs etc.?
- Overall, do you sense there are fewer events coming into your IBS system?
- Are you ready for more schedule and line management type incidents to be added? What else would you like to see in the incident queues?
- How are creating manual events working for you. Do you see any value in creating them?
- Are you sending more emails than you did before?
- Is Incident Reports any easier to create than before and are you doing more of them?
- Has the change in the driver's canned message lists changed their use of them. What is your reaction to the changes made? Any suggestions?

The outcome of the dispatcher feedback validated the findings of the implementation, acceptance test process, and comparative data. The major themes and comments from the dispatchers provided below are instructive from the primary user perspective.

Implementation Process

Training needs to be equalized, follow-up training needs to occur, but otherwise the implementation went smoothly. Dispatchers would like the manuals readily available in hard copy for easy reference.

System Performance

IBS is significantly quicker to load, tab views load quicker, calls initiate faster, and the return of information after data queries is faster. The Mobile Dispatcher application is much quicker in all around performance and is a much more powerful tool with the TODSS interface by focusing attention on the trouble spots.

Important New Features

The Timepoint Tab is used to support field supervisor activities. The railroad-crossing incident with the 5-minute delay is useful especially the quick links for traveler services notification. Instant playback is great. The dispatcher chat function is powerful and there are hopes that more dispatchers get familiar with using it. Mobile Dispatcher is greatly improved by having the map in tab views. Action items with direct links for sending text messages are a time saver.

Functions to Improve

Need to re-consider locks on critical incidents and perhaps not allow deletion by anyone other than the original owner. It is time to eliminate the need to duplicate data entry into the legacy incident reporting system known as Jupiter since TODSS provides ample data notification methods. South Garage would like two dispatch workstations to meet the challenges of line management during peak operations. Double-click action that goes straight to a voice call is not always appropriate (the system administrator made changes related to this comment).

TODSS Incident Queue

The automation capabilities of TODSS are great and the more we use them the more we can streamline our current practices. It is much easier to find and respond to bus operator canned text message. The use of color codes for TODSS incidents (need to publish color code chart) works well. Dispatchers would like the highway congestion incident enabled so that it is available to all dispatchers for monitoring Interstate 290 and Interstate 294 delays. Adding the Metra website action item to more action plans would be helpful. There are significantly fewer incidents in the TODSS queue to work on and there is a general recognition that each incident in the queue requires attention and action.

Service Management

The 15-minute late schedule adherence incident for Traveler Services notification is a time saver and should be used for all routes system-wide. Early adherence incidents can be improved by looking at two timepoints to compare actual and predictive adherence. Currently, each early adherence has to be examined using the research list links to see if the predictive adherence is accurate.

External Sources of Data

Creating manual events is new and getting everyone to use it is a challenge but the potential for improvement of this function is great. The more you enter into TODSS the less work after the fact that will lead to elimination of duplication of data entry and effort.

Outside Communications

Many more email service bulletins are being sent to traveler services and RTA; more emails are being sent to management and maintenance related to lift alarms and equipment failure, more emails to division management are sent due to TODSS actions within the action plans.

Use of Data Messaging With Operators

The new list of vehicle canned messages available to drivers is an improvement. When drivers use their canned data messages, the workflow is created and is much easier to follow through to completion. Dispatchers are training drivers by asking them to send the appropriate data message if a voice call (RTT) was used in place of a canned data message. Otherwise, the dispatchers are manually creating a 'matching event' which in effect is doing the bus operator's job.

Management Perceptions

The IV&V review was conducted over a 2-week period after the completion of the operational test period to gain perspectives from an array of Pace employees, including senior management, regional management, division management, department management, and technical analysts. The individual opinions and findings from this review were considered when developing the project recommendations and lessons learned that follow at the end of the report. To gain an understanding of the impact of the TODSS deployment the following topics were explored:

- Noticeable improvements or disruptions to service delivery
- Ability to improve business processes
- Ability to improve dispatcher performance
- Alignment of meeting goals and objectives to TODSS capabilities
- Ability to get necessary real-time and historical feedback on transit system performance
- Lessons learned
- Applicability to other agencies

The following Pace employees were interviewed for their insight into the TODSS application:

- Melinda Metzger – Deputy Executive Director, Revenue Services
- Michael Bolton – Deputy Executive Director, Strategic Services
- Cecil Crum – Regional Division Manager
- Will Heelan – Division Manager, North Shore Division
- John Braband – Department Manager, Bus Operations

- Tariq Khan – IBS Operations Coordinator

While the interviews were predominantly give-and-take between the Booz Allen team member and interviewee, a standard set of questions served as a framework for the sessions that included:

- What do you see in TODSS that has made an impact or enhanced the Pace dispatching function?
- Has the implementation of TODSS been disruptive to the Pace Operations? If so please describe.
- After seeing how TODSS is being used, do you see TODSS as being able to improve the performance of your dispatchers (and potentially dispatchers at other agencies)? Has there been any immediate impact that you can see?
- What would you like to see Operations do next with TODSS to enhance and/or improve the real-time dispatching effort at Pace?
- Is there any other mid to long-term benefits that TODSS has the potential to provide Pace?
- Is there anything you expected TODSS to do that does not meet your expectations?
- Based upon what you know about TODSS today, do you think that this is an improvement to your IBS and would you recommend that other agencies consider this decision support capability in their CAD/AVL systems?

Common Themes
All respondents gave high praise for TODSS. Dispatchers have praised TODSS for simplifying and streamlining their duties. Management has praised TODSS for standardizing processes and, subsequently, providing detailed action plans to aid continuity among the division's responses to incidents. Management also commented on their newfound ability to view TODSS from their desktop and monitor responses without the need to call/radio to divisions.

From the user's perspective, the TODSS requirements seem to have not only met but have far exceeded any expectations the Pace users may have had prior to implementation. All respondents felt that any similar agency would greatly benefit from having TODSS implemented. There appeared to be a clear need for a system like TODSS to fill gaps in the service offerings of Pace and TODSS filled those gaps successfully. Users seemed to recognize not only the direct positive impact TODSS has had on their day-to-operations but also the potential for a much larger impact as the system becomes fully utilized and Pace radio functionality and reliability increases.

Impact of TODSS Deployment
Service Delivery Improvements
Respondents identified several improvements of their overall service delivery since TODSS has gone live. Canned messages have been moving between parties quicker than

before. Due to the given detailed action plans, responses to action items have improved.
These detailed action plans have also led to managers noting the decrease in the backlog
of incidents they see in the system queue. Supervisors have noted that they are able to
respond to emergency situations quicker. One note: users have recognized an increase in
the speed of the Pace database and systems; part of this may be due to the use of newly
purchased servers.

Improving Business Processes

A sore point of pre-TODSS activities is the large number of reports that dispatchers and
managers must produce; TODSS has improved this tremendously, reducing the amount
of paperwork that is required. For example, regional members identified farebox and lift
check reports that are now located within the TODSS system and do not require printouts
for processing. Due to this reduction for paperwork, managers and supervisors have
more time to perform other duties in support of the garages, improving efficiency.
Another improvement within Pace business processes is due in part to the standardized
messages and action plans provided by TODSS. These standardized messages enable
multiple divisions to respond consistently to similar incidents that may occur, no matter
the location. It was also noted that the alarms function within TODSS (e.g., notification
of Priority Request to Talk (PRTT) from operators) has been a key to seeing performance
improvement.

Improving Dispatcher Performance

In its short period since going live, TODSS has improved the overall performance of
Pace dispatchers. The new functionality of prioritizing incidents and actions plans has
removed all guesswork for the dispatcher to determine priorities. Furthermore, these
action plans have a significant amount of detail, which also removes the guesswork for
the appropriate steps to respond to specific incidents. In the end it is up to the dispatcher
to make any final decisions. TODSS has improved the efficiency of the Pace dispatchers
by reducing the amount of time normally needed to perform manual checks for incidents
such as cycle lifts. The new instant playback function within the system allows
dispatchers to review accident information immediately, reducing the amount of wait
time seen prior to TODSS deployment. It has also reduced the amount of technical
"clutter" that appears on the monitors of the dispatchers. TODSS was also lauded for its
ease of use, serving as a simple training tool for new dispatchers. There are also several
part-time dispatchers at Pace (e.g., alternate dispatchers or relief dispatchers). Due to the
standardization of TODSS, the interface looks the same for each dispatcher (previously,
the screens would look different depending on which full-time dispatcher passed along
their duties to the part-time dispatcher). Overall, managers have noted that they have
observed fewer mistakes from their dispatchers.

Feedback on System Performance

TODSS provides additional technical capabilities to not only dispatcher but also to their
management teams. Regional and division managers are able to actively monitor live
transactions within the database and check on-going incidents without having to call
dispatchers. TODSS has also added the functionality of email notifications. Email
notifications are sent to the Pace technical analyst if any IBS towers go down or if other

pre-defined thresholds are crossed such as early notification of a system loading problem (e.g., if more than 80 buses are pulled into a tower).

Lessons Learned

An additional benefit stemming from the TODSS implementation is a more detailed understanding of the limitations of Pace's current IBS system. The regional and division managers felt that the TODSS' functionality could not be fully utilized due to some of the issues currently seen at Pace. For example, some of the dispatchers have noted that some messages coming from TODSS may display incorrect information. However, this is due to data cleanliness issues within IBS with TODSS simply relaying existing IBS data. In addition, the Pace technical analyst noted that, when reviewing incident reports, there are many more error messages that appear. Again, this is due more to data being loaded from Pace's legacy system and not a TODSS issue. Dispatchers and managers also noted that real-time communication was much more accurate than Pace's current IBS system for the tracking of buses (this most likely is a result of the hardware upgrades and not the TODSS functionality). However, dispatchers, technical analysts, and managers expressed their frustration with the limited amount of radio communication towers leading to radio gaps between dispatchers and operators, and that the TODSS implementation highlighted the glaring need for improved radio coverage.

Other Agency Applicability

The regional manager noted that, any other agency in the country with services similar to Pace would gain a tremendous amount of benefit from implementing TODSS. All respondents seemed to recognize not only the immediate positive impact that TODSS has had on operations, but also the broad potential that such a system will have on their business and industry as a whole. Managers seemed eager to expand existing TODSS capabilities as well as continuing to serve as a testing/research & development shop for upgraded versions of the system.

Issues

From a Pace perspective, most of the "issues" seen from a TODSS perspective were more of a reflection on the limitations of Pace's current radio/IBS setup than with TODSS. Dispatchers noticed that the functionality of TODSS could not be fully utilized due to the technical issues with IBS. The division manager felt the system would have been much more effective if it had been rolled out prior to or with IBS (he compared it to "learning how to drive a car and then, later, getting the functionality of cruise control"). As mentioned before, data provided through legacy interfaces to IBS, if incorrect in the legacy system, is shown as incorrect or incomplete data to dispatchers (e.g., a route path incorrectly placed within the legacy GIS.

Respondents noted several technical upgrades that they would like to see with future versions of TODSS. First, dispatchers may provide a waiver to an operator who is running late (essentially, giving the operator a "free pass" to continue the route). However, TODSS will not free up the system to move past the waiver and continue with other tasks. Rather, a warning continues to appear on screen, notifying the dispatcher

that a bus is running late. Dispatchers feel that the waiver, once in place, should allow the driver to continue the route and move any kind of alarm or notification to the dispatcher to a secondary priority level. (Note: parameters are available within TODSS to add this condition to the triggering rule).

Similarly, dispatchers do not like that incident reports cannot be deferred. Even incidents that do not appear as high priority remain on a dispatchers screen until the report is addressed. Dispatchers recognize that, depending on the severity of an incident, some items will need to be addressed immediately. However, dispatchers would like the flexibility to defer some of the lower priority incidents so other issues may be given more attention. (Note: The system allows for incident reports to be entered but not closed with the only condition being that a dispatcher cannot log out at the end of their shift until their Incident Reports are closed. This new feature in IBS requires a change to the existing internal process.)

The division manager noted one process change since TODSS has gone live which actually has added an extra step in a regular process. When dispatchers receive a RTT from an operator, an action plan appears on screen. Before TODSS was in place, action plans would automatically close out as soon as the dispatcher spoke with operators. However, TODSS now requires (by TODSS administrator design) that dispatchers go back into the system and manually complete an action plan. It is important to note, however, that the division manager felt that the extra step would eventually make the overall RTT process more efficient.

Finally, while managers and full-time dispatchers felt that TODSS provides a tremendous upgrade in the efficiency and accuracy of new, part-time, and alternate dispatchers, "seasoned" dispatchers may not receive as much benefit from TODSS. Dispatchers who have been performing these duties for multiple years have much of the institutional knowledge of their duties "in their head." Because of their experience, they know exactly what steps should be performed as soon as an incident appears on screen (this does not imply they can ignore the required actions prescribed in the TODSS restoration strategies). Along those lines, however, these seasoned dispatchers may be able to assist with future configuration and setup of TODSS, providing invaluable input into what changes would make TODSS that much more effective for future users. They may also be able to find inconsistencies with the current setup so that the TODSS administrators and the development team can make changes.

Next Steps

Beyond the respondent's positive feedback for the first several months of the TODSS implementation, each person gave broader perspectives about how TODSS could continue to improve and enhance Pace's business. Suggestions for improvement include:

Existing Systems Replacement and Integration

Managers and dispatchers would like to see many of the reports existing in TODSS to replace similar reports in Pace's Jupiter system. This also includes TODSS replacing the extra-board information within Jupiter. In addition to multiple suggestions to replace the

Jupiter system, all of the respondents highlighted potential tie-ins and interfaces to other systems in use at Pace. These include interfaces to Pace's on-board cameras, planning system, payroll (to track operator attendance), safety system, and (eventually) Homeland Security.

Expand Utilization of Existing TODSS Functionality

As previously noted, users of TODSS recognize that the system has far more capabilities than is currently being used. Because TODSS' learning curve has not been steep, the respondents listed additional functionality that would seem like the next logical steps to add to existing functionality. One manager felt that dispatchers should expand their required data entry duties to include all missed trips, all service adjustments, complete waiver information, and all cancelled trips. In addition, the implementation of TODSS was planned to ease users into the new system by only offering a small subset of service disruptions to dispatchers while users got acclimated to the system; almost all respondents noted that it was time to begin to require active use of operator initiated canned data messages. In addition, TODSS should expand the adherence notification for operators running early.

Expand TODSS Uses and Functionality

The Pace management involved in the IV&V process provided interesting ideas and recommendations for improving the functions and capabilities of TODSS.

- Pace users would like to see TODSS increase its functionality to include more support for incident control and incident management.
- Managers would like to use TODSS more to ensure that all runs are consistently filled.
- While dispatchers have applauded TODSS for having data and plans given directly to them, there is concern that data within the system (e.g., phone number with direct line to fire departments) may not be kept current. It was recommended that when data is included for use in the system a process for maintaining the information should be determined prior to implementation.
- From a technical perspective, the technical analyst would like to set up an email alert once the TODSS database hits an identified threshold amount that begins to have a negative impact on the system performance (e.g. excessive query run time or central processor utilization).
- The dispatcher chat function within TODSS is a positive feature. It was suggested that arriving messages have a more prominent visual and audible cue.

Change Pace Processes to Capitalize on TODSS Functionality

As a final next step, a few Pace respondents noted that existing business processes could be adjusted to better utilize TODSS. Dispatchers and operators could use the given information (e.g., detours around service lines) to adjust current services. This could also include how to move certain routes to maintain service while an emergency is being addressed. One manager would also like to see TODSS expanded to include contracted dispatchers for better Pace oversight.

Additional Comments

Managers applauded the implementation and rollout plan developed by the contractors and Pace TODSS project team. Specifically, managers appreciated that a reduced set of messages were offered in these initial months, allowing dispatchers to learn the system at a good pace without being overwhelmed with too much information. In addition, there was not a large amount of fanfare or "selling" of TODSS prior to rollout; this served the purpose of keeping expectations of a new system within reasonable measurements.

Technical Evaluation Results

Data sets were compared to two similar 60-day periods; April 1, 2008 through May 31, 2008 (pre-TODSS) and April 1, 2009 through May 31, 2009 (post-TODSS). It is important to note that the numbers used in this report are those that were readily available to the project team that best reflect on changes due to the introduction of the TODSS. The sharp increases or decreases that were seen in the comparison of the two data sets may or may not have a strong, direct correlation with the implementation of TODSS; however, such large jumps in numbers would certainly attribute some of these changes to the new system. The following data sets were compared:

- Total Message Activity
- Messages Activity Summary
- Waiver Counts
- Incident Types
- Canned Messages Activity
- RTT Response Time

Data Messaging Volume

To evaluate the effectiveness of TODSS in prioritizing events, reducing data clutter, and providing assistance in digesting large quantities of data the first measure used was the comparisons of the number of incidents (data messages) presented to dispatchers in the pre-TODSS IBS versus the TODSS user interface.

The database table that logs all systems messages was used to determine the messages that would have come into the pre-TODSS IBS system. We were unable to determine the number of adherence messages that would have come into the pre-TODSS IBS system because they automatically enter and leave the queue. This would require a complex program to recreate the display within the queues. Consequently the results will under-report the number of incidents in the pre-TODSS IBS queues. The TODSS audit history database table contains all the incidents that were in the TODSS queue. A comparison was made using these tables for May 1, 2009 as a typical operational day at Pace with the following results.

Table 7 - Data Message Volumes

	# Data Messages
Would have been in the pre-TODSS IBS	7,927 (without adherence warnings)
Actually in TODSS	2,515 (including adherence warnings)

The results are rather dramatic with the TODSS event processing resulting in one third the number of incidents of the old system. The old system would have had another queue with adherence incidents (early and late) that would be in addition to the 7,927 incidents filling the queue on that day. Based on observations and feedback from stakeholders a major benefit from this reduction was being able to respond to important incidents that would have got lost in the clutter of the pre-TODSS system.

It should be pointed out that the time an incident remains in the TODSS queue is handled differently than the old IBS. In the past, incidents remained in queue unless a dispatcher deleted each one individually regardless of whether they looked at or acted on them. In TODSS each incident has a user defined life span and at the end of that period the incident is removed from the queue automatically. The audit history captures the means by which an incident leaves the queue. This capability further reduces message clutter over time.

TODSS allows the dispatcher to create up to four auxiliary incident queues. Only low priority incidents go into the auxiliary queues. The dispatcher selects a priority level from zero to 50 and all incidents that fall below that level are tracked in the auxiliary queue(s). This allows the dispatcher to monitor low priority events as time permits without cluttering the view of the high priority service disruptions being reported.

Communications

It was hypothesized that response time should improve it there were reductions in the number of incidents arriving in the queues. To measure response time the RTT and PRTT messages from the driver to dispatch during the pre-TODSS and TODSS test period were compared. The elapsed time from when a driver initiated the RTT to the time a dispatcher replied to the RTT was computed and used as the response time measure.

Dispatcher responses were matched to the RTT and PRTT messages for the first Friday in May in 2008 and 2009. Over one thousand records were analyzed for each of the two days with the pre-TODSS sample having 22% more RTTs than the TODSS sample with the following results.

**Table 8 - RTT Response Time Comparison**

	Average RTT Response Time	Median Response Time Value	Standard Deviation
IBS (pre-TODSS)	86 seconds	14 seconds	253.11 seconds
TODSS	88 seconds	18 seconds	171.67 seconds

The data indicates little change during the TODSS operational test period in dispatcher response time with a slight increase of 2 seconds over the pre-TODSS. Dispatchers were trained to respond quickly in the pre-TODSS period to RTTs and it appears this level of priority was similarly matched in the TODSS environment.

What was striking when going through the data was the dispatcher response times were more evenly distributed as indicated by the reduction in the dispersion around the average response time. The standard deviation bears this out with a reduction of over eighty seconds. Dispatcher responses are seen to be more consistent with the addition of prescribed action plans and greater reliance on the prioritization of incidents.

Next, a comparison is made between the two periods by comparing the total counts of each communication type within each period. The first graph below includes the voice and data communications activity that occurs at a lesser rate of regularity than the data included in the second graph. Separating the data into two graphs is done to minimize the distortion due to the different scales. This highlights the differences within each category more accurately. The gray bars denote the data from the old IBS system and the blue bars denote the data from the TODSS time period.

Figure 1 - Low Volume Communications
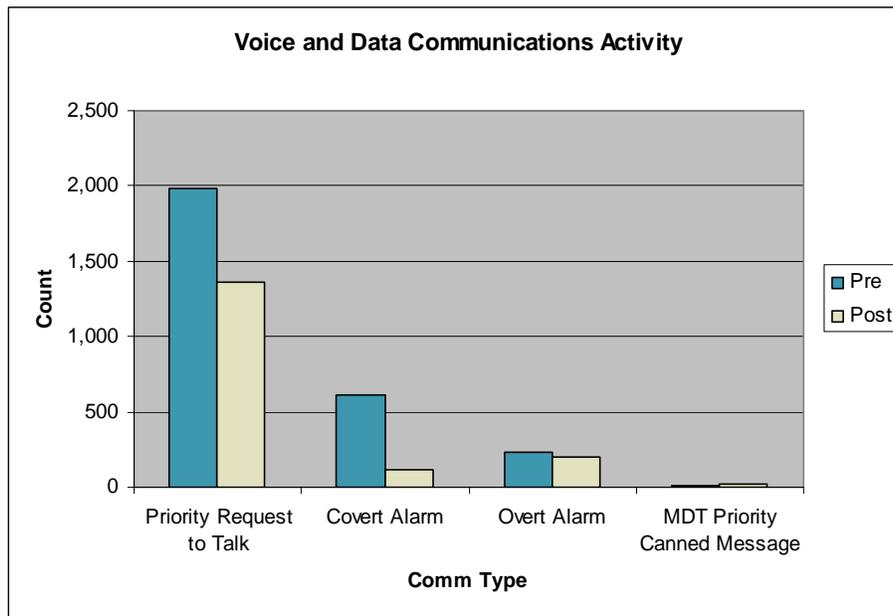
The changes in the Priority Request to Talk (down 45%), Covert Alarms, and Overt Alarms were anticipated. Dispatchers are responding quicker in the TODSS environment and consequently drivers are not escalating routine calls to get the dispatchers attention any longer. For example, in the past a driver would escalate an unanswered RTT to a PRTT in hopes of getting the dispatcher to reply.

Figure 2 - High Volume Communications
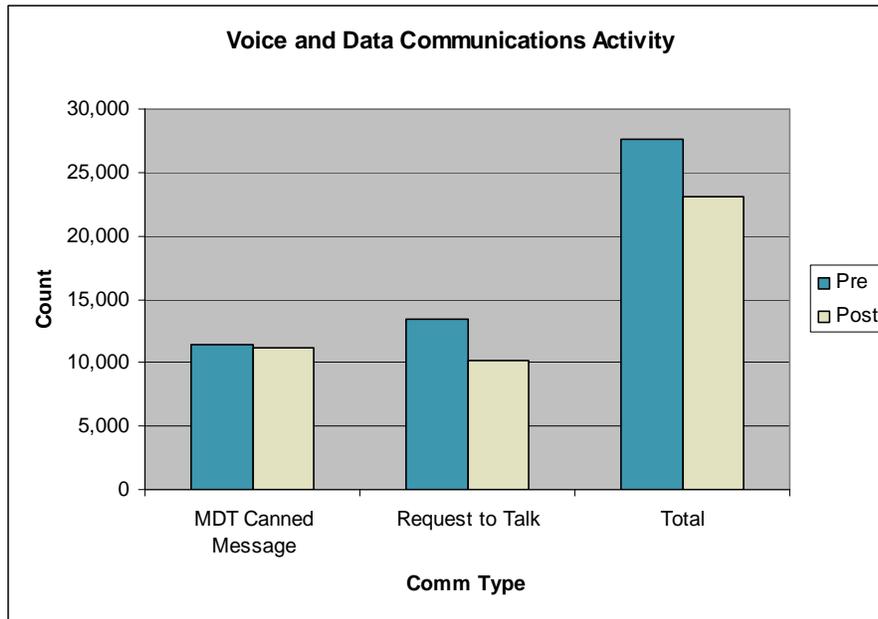
The dramatic reduction in Request to Talk (RTT) communications was unexpected with a drop of over 30% during the TODSS time. The fact that dispatchers were responding to driver requests in a timely fashion may have resulted in fewer retries by drivers. The drop in RTTs during the TODSS period may to some extent be explained by the improvements made in the driver canned data message set that made it easier to navigate and locate an appropriate data message. In any case, this reduction in voice calls directly relates to more time available to dispatchers to be active in service management.

The results show that driver initiated MDT Canned Messages stayed about the same between the two time periods. As part of the TODSS implementation, Pace streamlined the categories and reduced the number of available canned messages over 60%. The changes were based on historical use of canned messages with an attempt to better support TODSS automation potential. Little emphasis was placed on the change to see how drivers and dispatchers reacted. The only management change was the issuance of new pocket sized cards that included the new canned message data set to drivers prior to the TODSS operational test. Judging from the results this was a successful effort in using operators and dispatcher's time more efficiently given that there were 60% fewer messages available and yet the number of messages sent is similar to those sent during the old IBS time period.

Overall, there was a decline of 20% in communications between drivers and dispatchers suggesting that TODSS event processing and prioritization reduced the clutter through reduced data/voice communications and enabled better access to the data leading to improved dispatcher response times to drivers' requests.

MDT Canned Messages

The use of each canned message was measured in order to see if changes in the MDT Canned Message set in support of TODSS automation were worthwhile. A count of each message during each of the two periods was calculated and is compared between periods. Those messages from pre-TODSS that did not correlate to any of the new TODSS canned messages are put into their own separate category. The results contained in the following table include the message, the category the operator would find the message, total counts for all divisions for each time period, and the percentage change between periods.

Table 9 - Operator Canned Message Comparison

Message	Category	TODSS Count	Pre-TODSS Count	% Change
Pre-TODSS not carried forward		-	713	-
Late Due to Traffic	Schedule	2,029	1,259	61%
Railroad Gates Down	Schedule	1,820	2,368	-23%
Railroad / Bridge - Back in Service	Schedule	838	-	-
Late Due to Heavy Load	Schedule	386	302	28%
Late Others	Schedule	237	-	-
Need Detour	Schedule	208	311	-33%
Bridge is Up	Schedule	156	-	-
Road Blocked	Schedule	77	317	-76%
Road Flooded	Schedule	12	-	-
Refuse Lapbelt	Passenger Issue	1,323	761	74%
Request Hold at Pulse Point	Passenger Issue	223	-	-
Standees on Bus	Passenger Issue	82	-	-
Bus Full Unable to Load	Passenger Issue	26	89	-71%
Fare Dispute	Passenger Issue	19	20	-5%
Passenger Asleep - End of Line	Passenger Issue	7	2	250%
Fleet Watch	Passenger Issue	3	-	-
Unable to Board Wheelchair	Passenger Issue	3	15	-80%
10-8 Back in Service	Operator Issues	2,732	3,501	-22%
10-7 Out of Service	Operator Issues	2,505	2,416	4%
I Need Relief ASAP	Operator Issues	44	24	83%
Farebox / BTPU Issue	Equipment Issue	264	84	214%
IBS / Radio Issue	Equipment Issue	54	-	-
Bus Down - In Service	Equipment Issue	51	64	-20%
Bus Down - Unable to Move	Equipment Issue	44	10	340%
DriveCam Manual Event	Equipment Issue	22	-	-
Smoke on Bus	Emergency	11	-	-
Police / Paramedics Required	Emergency	5	2	150%
Involved in Accident	Emergency	2	-	-
Ignore Emergency Alarm	Emergency	4	10	-60%
TOTAL		**13,187**	**12,268**	7%

Observations and highlights from this data include:

- A sizable number (6% decrease) of low priority messages no longer reach the TODSS event-processing engine.
- There was a 60% reduction in total available messages in the TODSS environment yet there is a 7% increase in total message usage.
- Most encouraging was the increase in schedule category data messaging (26% increase) that improves TODSS service restoration automation capabilities.
- There is growing driver involvement in reporting equipment problems (488% increase) which supports TODSS automation.
- Dispatchers recognized early on that the more they used TODSS automation the quicker legacy systems would be retired. During the TODSS operational test period increases in Farebox and Radio messages are an example of this phenomenon. Dispatchers are actively instructing drivers to use these messages in support of auto-logging in their effort to end duplicate data entry regarding these issues.
- Operator management of drivers leaving their vehicle that includes monitoring operator generated 10/7 - Out of Vehicle canned messages and corresponding 10/8 – Return to Vehicle canned messages are the most active data messaging in both time periods. However, the gap between the 10/7 and 10/8 canned messages decreased in the TODSS period suggesting better driver compliance of informing the dispatcher of not only when they leave the vehicle but also when they return to their vehicle.
- The Refuse Lapbelt message was the only MDT canned message that is not used as a source for a TODSS incident (used for driver protection only) yet use increased, most likely because of improvements made to the category and message layout on the MDT.

These results are encouraging to Pace. They occurred without any new emphasis placed on using data messaging with the drivers. Based on these results, to further reduce voice call requests and instead rely on data messaging for incident notification, the driver refresher training program will include a section emphasizing driver data messaging.

Incident Reporting

Incident Reporting is used to document service disruptions that need to be shared with other departments especially when a written record needs to be maintained on file. Pace discovered that the TODSS capability to integrate automated emails in an incident response eliminates the need to create a separate incident report in many instances. The following table demonstrates this fact showing a 36% reduction in the number of incident reports created during the TODSS operational test.

Table 10 - Incident Report Comparison

	TODSS	Pre-TODSS	Percentage Change
Accident	91	100	-9%
Bus Down	25	0	-
Covert	19	14	36%
DriveCam Manual Event	3	0	-
Emergency	52	20	160%
Farebox/BTPU	106	0	-
IBS / Radio	40	3	1233%
In Service	182	117	56%
Manual Event	4	0	-
Need Relief ASAP	2	0	-
Passenger Issue	97	98	-1%
Schedule Issue	220	254	-13%
Generic Incident Report	66	811	-92%
TOTAL	**907**	**1417**	-36%

A generic report uses a standard format and includes no meta-data (data about other data) related to the incident. By classifying a report by type and sub-type, other users can create queries of historical incident reports that are tailored to the user's interest and job function. TODSS automates the selection of form and the type classification when the source of information is a data message. The table shows the use of generic reports dropping dramatically directly leading to the drop in incident reports. Most generic reports were either correctly classified given the gains in some form types and the remainder were handled through other TODSS directed actions.

By removing the generic incident report numbers to minimize the effect on the graph scale, the following graph shows how the incident classifications have changed during the TODSS operational test period.

Figure 3 - Incident Report Type Comparison
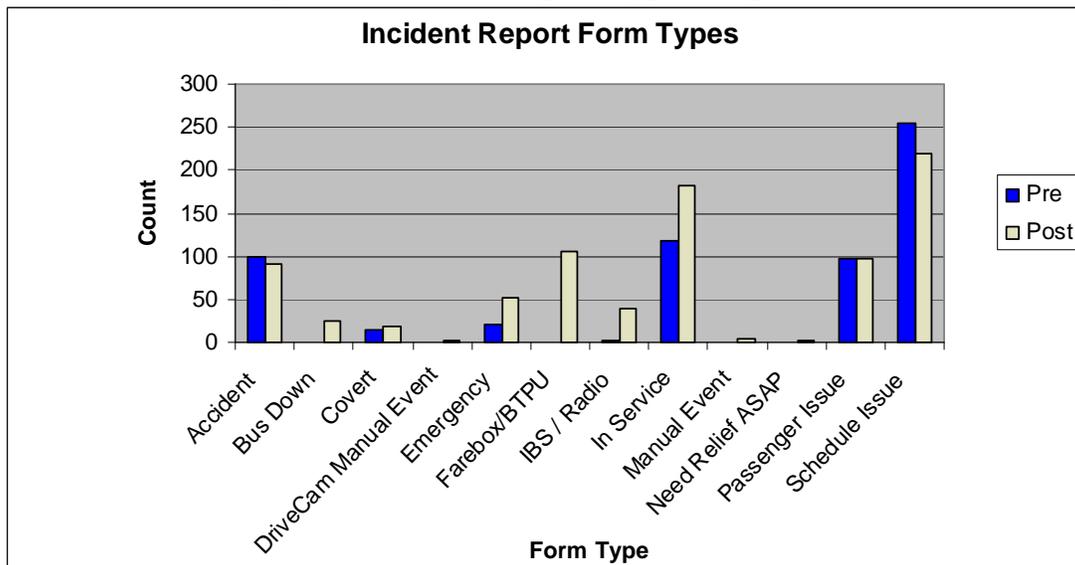
Observation and highlights from this data include:
- Accident and Schedule Issue reports have dropped during the TODSS period because email action items are beginning to replace the need for incident reports.
- Bus Down, IBS/Radio/, Farebox/BTPU, and In Service (a vehicle problem but still moving) all show increases. This supports the movement toward using Incident Reporting capabilities as a logging of data function, improved through TODSS automation, for the single point of data entry in lieu of duplicate entry into manual and legacy systems.
- Covert Alarms and Emergency reports have increased most likely due to the automatic assignment of the form type field set within the TODSS rules base.

Pace will likely reconsider policies and procedures related to Incident Reporting as they refine and add to the TODSS incident rule base. Comment fields in the communications dialog box and the TODSS action plan links provide enough information in the historical data record to recreate most incidents. Email provides the immediate notification of the complete details of an incident. Therefore, Incident Reporting becomes more narrowly defined in the future serving as a formal written record of an incident for those incidents required to include in the daily report of operations.

Cost Impacts

During the TODSS operational test period no additional dispatcher, supervisor, or administer positions were added. Pace relies on decentralized dispatching at nine different divisions and the staffing requirements were not changed. They were already operating a CAD/AVL system and results indicate that TODSS made the existing workload easier to handle with the improvements introduced in the new system.

A planned half-time IBS technical support position is being filled that was open prior to the TODSS implementation. Pace is considering improvements to the way dispatch staff is deployed in the divisions to make the best use of available resources. It is too early to tell what impact the TODSS will have on this effort. It is also too early to determine any system-wide cost saving based on TODSS. There are too many variable at work affecting route and system schedule adherence changes in this short period that comparisons with baseline adherence data was inconclusive.

TODSS Prototype Experience

Lessons Learned

After working with the TODSS in the design phase and during the operational test there are lessons learned that are important to share with other agencies and vendors to improve the understanding of the core TODSS requirements for future implementations. Pace found the following issues had a direct impact on their business processes and how TODSS changed their approach to daily operating procedures.

Delay and Suppression Parameters

When creating the business rules, or trigger, to define a service disruption it was discovered that an event might need to be delayed, paused, or suppressed before it reached the threshold to become a TODSS incident. Pace determined that it was important that an adherence incident be monitored but delayed before bringing it to the attention of the dispatcher.

To exclude momentary adherence problems from the TODSS queue, if the condition still existed after the delay period, it would then be indentified as a service disruption. In the case of a vehicle maintenance alarm the suppression parameter was important so that the incident did not retrigger after a dispatcher responded to the incident. The vehicle remains in the alarm state until the problem is fixed which may be after a vehicle switch is initiated or a service call dispatched. A suppression value was needed after it became a TODSS incident so that when the dispatcher completed all their required actions and the incident was removed from the TODSS queue it would not retrigger due to the continued alarm state. The deleted incident retriggers if the condition is not fixed before the suppression time expires.

Incident Reporting

After several weeks of using TODSS, it was recognized that Incident Reporting was duplicating other dispatcher actions and was not nearly as important to complete as it was in the previous IBS system. A TODSS incident is easily linked to an automated email action with the ability to widely share all pertinent information in real-time to those with access to computers or internet enabled personal devices. The email option pushed the information out instead of users relying on after-the-fact printed reports.

The exception to this was the need for incident reports related to equipment problems that relied on gathering more incident details that were included in the written logs of the past. The automated incident report replaces the written log, creates a historical data record, and can be printed on demand as a step in the work order process. With an integrated Work Order Management system this step could be eliminated in the future.

Operator Data Messaging

After evaluating operator data messaging over the past three years, Pace determined that there was a better approach to this operator function. There was a safety concern that it took too long to find a message distracting operators from their other duties. The goals of

the redesign effort were to simplify the operator's ability to find messages, use the data
messages as service disruption notification, and rely on the dispatcher's expertise to
gather additional details as required. Only those messages that were heavily used in the
past were carried over. Detailed messages were removed and the available data messages
included a level of detail such that the TODSS rules base could identify it as a defined
incident in the rules base and provide the associated action plans. The guiding principle
was that if a data message was important enough for an operator to send then it must
require action on the dispatcher's part and not be ignored.

Training

What became clear early on was the power of TODSS to manage and effect change in
daily operations. However, this was only going to be realized through an investment in
ongoing system management that required an agency focus on ongoing refinements and
process improvements. Training would be critical to sustain this effort. There are three
training programs needed for long-term success for system administrators, dispatchers,
and operators. The TODSS system administrator(s) needs to grow with the system and
broaden their understanding of the event-processing environment to make the refinements
to the business rules that the agency requires. Dispatchers need to improve their skill
levels using the TODSS and CAD/AVL tools and improve their understanding of the
theory and practice of service management. Finally, operator training and operator
refresher training needs to include their role in communicating service disruptions to the
dispatch center.

Bus Service Theory and Practice

The configuration and setup of a TODSS is much easier if the agency has a theory of
service management articulated in defined standard operating procedures. These can be
translated into TODSS business rules easily without a major review process. In the
absence of these procedures TODSS forces a review of each scenario to the level that
leads to an understanding of "what is in the dispatcher's head" that is not necessarily the
same from dispatcher to dispatcher. This makes the process of identifying service
disruptions and defining the potential restoration strategies difficult. Ultimately the
TODSS becomes the repository when these business rules are captured.

Aural Cues

One of the early suggestions provided by the dispatchers was the need to pay more
attention to audible warnings to differentiate incidents as they enter the queue. The role
that sound (and color) played in the dispatcher's routine duties was underestimated
during setup and changes were made to the assigned sounds once this input was received.
The lesson learned was that the operators rely on color-coding and sounds to a greater
extent than was previously recognized by the entire TODSS working group. The reliance
on these cues to supplement the information being presented is especially important when
distracted by external events within the dispatch center.

Issues

There were a few core requirements that were not as fully developed as part of the
prototype process. These requirements can be characterized as being more complex in the

sense that without experience working with TODSS it was harder to imagine and design these requirements. Now that there is an understanding of how the dispatcher interacts with the TODSS and the capabilities of TODSS, these areas require future focus to realize the full potential of TODSS.

Priority of Action Plans

The TODSS prototype required advance planning to assign up to three action plans (restoration strategies) for each incident. What was missing was a method to prioritize or rank each of the multiple strategies to provide a best guess at the default action plan to present to the dispatcher based on the real-time conditions. The first time going through the exercise of defining and prioritizing each incident (service disruption) took some effort to master. A second level of prioritization was difficult to imagine how to implement, and would have been a daunting task during this learning phase of designing and implementing a TODSS. Now that there is a basic understanding of the TODSS event-processing capabilities, it is now possible to go back and add business logic to the available choice of strategies.

Another available strategy is the TODSS ability to create and save complete sets of rules that apply to known conditions such as a weather emergency, an evacuation emergency, or a recurring special event. The saved set of rules can be loaded by the TODSS administrator when instructed by operations management. Alternately, work assignment roles could be defined to include roles based on different operating conditions. Another method provide by TODSS is the ability to actively manage the enable/disable property in real-time by the TODSS administrator. Each of the available methods relies on a staff decision and manual intervention based on external sources of information.

The core TODSS requirements envision business logic to affect the choice of the most appropriate strategy. Providing some automation to this process would be an improvement to the manual intervention required in the prototype. This could be accomplished by another rules base similar to that used by the manual event to permit selection of operating conditions to trigger the corresponding set of rules. Another method may be to create new algorithms that recognize current operational states from available sources of information and apply the selection of restoration options based on matches to pre-defined states based on historical patterns.

System Complexity

The first reaction of many transit professionals when first seeing the TODSS prototype was that this was going to be too hard for them to implement. This reaction came about by showing the setup and configuration requirements of TODSS prior to them experiencing the TODSS user interface in operation. When they were shown the user interface in action their reaction was the opposite; the TODSS was simple to master. The most challenging part of the project was the initial learning curve to implement the TODSS setup and configuration. Out of that experience it was recognized that improvements in the configuration management of the TODSS rule base(s) needed to be made to the IDS. These improvements would simplify the management of the various

aspects of the rules, make it more understandable to operations personnel, and more efficient for the TODSS administrator.

Detours and Routing Changes

CAD/AVL in general and TODSS in particular need to get smarter at real-time routing changes. Changes to headway and schedule can currently be accommodated but when a new path of travel, which deviates from the planned schedule, is assigned ad-hoc in real-time then route and schedule adherence reporting falls apart. Improving detour management to include route and schedule adherence reporting and allowing TODSS to assist with detour development is an area for potential growth. Included with this is route deviations used to meet transit demand in fringe areas with lower population densities. These special cases of detours for adjusting service to meet passenger requests and real time passenger requested connection protection are becoming more prevalent in use by agencies of all sizes.

Demonstrating the Value of a TODSS

When programmed funding for a radio replacement, that includes CAD/AVL, it is likely the project is more technically oriented towards communications and not the theory and practice of bus service management. Computer Aided Service Restoration (CASR) requirements are commonly included in these types of RFPs but the requirements are usually written at a very high level. When it comes time to evaluate the RFP responses, CASR is not typically assigned a high evaluation priority. The vendors are not familiar with CASR and the agencies are not providing the CASR theory and practice in their RFP.

Not much has changed in this respect since the original needs analysis work done by the TODSS project. Transit agencies act like monopolies in their market space without competition forcing needed improvements that is further complicated by the existing funding structures. Much work has been done at the service planning level to improve quality of service. But there is far too little operational investment in developing a theory and practice of real-time bus service management that directly translate to improvements in the delivery of quality service. Up front this effort is labor intensive, requires operational funding, and difficult to demonstrate return on investment in the short-term.

Somehow, the word needs to get out that TODSS is an approach to actively manage the data from CAD/AVL systems and finally use it to improve the delivery of service. Second generation CAD/AVL users understand this better than first time users of CAD/AVL. They know that there is so much more the CAD/AVL system can be doing for them. Hopefully, an effective means of sharing the findings from this TODSS prototype can be developed.

The challenge, as the follow up to the TODSS prototype, is how to make transit boards and senior management insist on TODSS requirements in the future, especially if the operations staff thinks it may be hard to implement and takes additional work to sustain. One way to sell this concept is the linage with real-time traveler information systems. These systems publicly show both the good and the bad of the transit system and the

better real-time operations are managed the better the agency looks. TODSS goes a long way in supporting improvements, of which real-time traveler information systems can take advantage.

Benefits

Many benefits from using TODSS have been noted in previous sections of the report. All levels of management and dispatchers have confirmed that the TODSS functions have improved dispatcher response times, the quality of the dispatcher responses, uniformity of action among dispatchers, and real-time operations communications beyond the dispatch center. These benefits include:

- Reduction in reported incidents including only those incidents that require attention resulting in no backlog of incidents
- Prioritization of all incidents that directs dispatcher activity based on the severity of the service impact
- Required restoration strategies, through action plans, resulting in a uniform response throughout the divisions
- Integrated internet and email capabilities are providing more immediate internal and external communications
- Reduction in paperwork due to the greater accuracy in capturing data
- Greater use by dispatchers of available CAD/AVL tools to find and review data related to incidents through TODSS action item link guidance

There were many other benefits encountered during the TODSS operational test. Many were related to the servers and workstation hardware upgrade (e.g. improved computing speed). New or improved CAD/AVL features related to TODSS requirements were included in the upgrade to the IBS (e.g. Instant Playback, more hot linking capabilities, and improvements to Incident Reporting). However there were several benefits that are directly related to the TODSS development as described below.

Transit Programming Language

After using and experiencing the TODSS IDS, the user development environment was compared to using a visual programming language specific to transit operations. Using the conditional logic and syntax to manipulate the breadth of parameters and values for each real-time event was intuitive to those with experience in programming with languages such as Microsoft Visual Basic. The flow of operations controlled through the TODSS interpreter transformed the way the dispatcher now interacts with the CAD/AVL system. This "programming language" has the potential to support the improvements in bus service management practice.

Audit History

The TODSS audit history made available through the IDS proved to be invaluable not only to the evaluation of the TODSS prototype but also when making ongoing operational improvements. Pace operations management used the audit history to test the results of newly created incidents in a controlled work group and make refinements based on the results prior to the release to dispatchers. The audit history is used to identify the

performance level of individual dispatchers, recognize patterns of dispatcher responses, and identify service disruption patterns using the query and filter capabilities of the audit history. With the ability to target complex service disruptions and capture them as TODSS incidents, the audit history will be another tool available to the service planner when needing feedback on route and schedule performance. All of this is accomplished without the assistance of IT support.

Filter External Factors From Service Impacts

An unexpected benefit was the ability to isolate true service impacts from service impacts that were being reported based on onboard equipment malfunctions, communications problems, or operating conditions not pertinent to the service disruption. The TODSS "programming language" makes it possible to include compound rules that include tests of subsystem health messages from the vehicle (e.g. working odometer, working GPS, and time since last good message was received). Tests on whether the operator is logged on, the vehicle is in revenue service, there is scheduled recovery time, a service waiver has been placed, and/or the vehicle is in an exclusion zone, assist in fine tuning service disruption detection. This resulted in many false alarms caught by TODSS resulting in savings in time for dispatchers.

Service Improvement Campaigns

Pace demonstrated how TODSS could be used to quickly help solve an operational issue through a targeted campaign. During the operational test period, the issue was raised that fixed route operators may not be checking their lifts in a timely manner as required when leaving the garage. A TODSS incident was configured including a detailed action plan. The incident was tested and reviewed in the audit history by the TODSS administrator and it was determined that too many lift checks were not being made in a timely fashion. Within a week, the incident was enabled in TODSS, instructions provided to all dispatchers, and the number of incidents reduced by more than 50. Compliance continued to improve during the next two weeks with the agency surprised at how quickly they could effect change.

Vendor Benefits

During post implementation interviews with the Continental team, they identified several potential benefits. They found that, with the flexibility in configuring service disruptions, they would be able to more easily meet new customers' custom requirements encountered in RFPs. They can translate new operational scenarios into complex TODSS rules when an agency provides the concept of operation for the requested situation.

Continental was able to build the TODSS on top of their existing messaging design. The CAD/AVL will be tightly coupled with any future TODSS development for the near future. However, if standards such as TCIP can be successfully demonstrated in the future then the prospects for a stand-alone TODSS application would be more likely.

Route Summary

TODSS introduced many new route summary parameters not available in the previous IBS that can be used to determine whether an event becomes an incident. Actions can be

tailored based on recognition of the over-all performance of all vehicles operating on a route. These new parameters are valuable for support of the emerging corridor management concept that is beginning to be used in transportation management.

Summary of Recommendations

Recommendations for Continued Pace TODSS Operations

Pace should go forward with their planned dispatcher training and offer it to all employees that dispatch as part of their job assignment. This will set a baseline of expectations for performance for the dispatch position. This will help meet the goal of uniform system management through the operating region and avoid any complaints of unequal levels of service management.

Based on input from the internal stakeholders, Pace should continue to develop operational scenarios within the TODSS environment. In particular the stakeholders identify increased emphasis on early adherence monitoring, external information regarding road conditions, and on-time pull-out compliance.

TODSS provides for manual events that add external sources of information into the TODSS environment. This is an effective means for having all dispatcher actions entered and documented into a single system for archival, reporting, and future analysis. This function should be included in dispatcher training if it is decided to be used on a wider basis.

The agency should decide on a strategy for building multiple TODSS rule sets to be prepared for any extraordinary operating scenarios that will be encountered in the future. Once an approach is decided, the TODSS administrator should begin the work of configuration and setup to meet the business rules for these alternate sets of operating conditions.

The use of TODSS audit history should be expanded to the regional and/or division level for closer oversight of dispatcher activity until such time that there may be realignment in the way dispatching services are deployed. Development of metrics derived from the audit history aimed at dispatcher performance should be considered as a means for improving the performance level within the position.

Work should continue on updating the dispatcher training manual and documenting the dispatcher's operating procedures. Documented procedures should be linked to each of the TODSS incidents for easy access.

Integration with the RTA GoRoo Travel Planner should evolve into automated incident notifications from TODSS and replace the need for dispatcher initiated email notifications.

Recommendations for TODSS Prototype Improvements

The IDS will begin to be unwieldy as the number and complexity of incidents grows at an agency. A means for configuration management and assistance with structured development of the TODSS rules base would be beneficial. Further requirements

definition should investigate the best means for an agency to manage their library of active business rules and how to exercise version control on saved sets of business rules.

Expansion of the view into historical data that can be used as an event parameter to include a time period greater than 24 hours would be beneficial. Expanding the domain of historical data beyond just TODSS data and including access to a fact table or summary set of data would increase the utility of this function.

When CAD/AVL tools such as the Route Ladder are exposed in the interface then a TODSS action item can be created to direct the dispatcher to the tool with focus placed on the data pertinent to the incident. Waivers are an important tool for dispatchers to flag service disruptions such as an unscheduled off route condition. However, this tool is not exposed in the user interface and therefore TODSS is limited in assisting the dispatcher in placing a waiver. The TODSS event processing engine can test for the different waiver classes but until the dispatcher action item is improved this valuable function will be under utilized.

Developing the means to better manage the choice of alternative restoration strategies would improve this function. The prototype provides many alternatives to implement this concept but all require manual input after receiving information that would necessitate a change in action plans. A simple rules base for this function to provide an order of preference of action plans or change of rules set would assist the TODSS administrator and provide further direction for dispatchers.

TODSS uses RSS feeds to bring external sources of information into TODSS and make them available as parameters for event-processing. This is used for traffic volumes, traffic speeds, road closures, weather, etc. TODSS should provide a means of publishing incident information for external entities to subscribe to for transit information updates. Core TODSS should include this or similar internet based standards for sharing data.

Good candidates for future research, if available, would be simulation applications that can use historical data and prediction algorithms to test the outcome of applying a restoration technique and provide the ability to identify when service should return to normal operations. It would be interesting to answer the question if dispatchers would use this in real-time or if it is a training and service development tool. A concern is if this would take responsibility away from the dispatcher and transit agency and place it on the software developer.

Although the prototype TODSS was aimed at fixed-route bus service, there is no reason why it could not be applied to other transit modes operated by agencies including paratransit, flex route, and light rail operations. However, TODSS integration requirements with other transit agencies, traffic management centers, and other centers require more definition and feasibility research.

Recommended Changes to the Core Requirements

The following recommendations are focused on chapter five "Core TODSS Requirements" of *Transit Operations Decision Support Systems (TODSS): Core Functional Requirements For Identification Of Service Disruptions And Provision Of Service Restoration Options 1.0* (Mitretek Systems for the FTA and USDOT ITS JPO; May 3, 2003). Chapters one through four serves as an historical record and form the basis for the requirements. Chapter five should be able to be pulled out and used as a guideline when an agency creates their local requirements to procure a TODSS. In other words, transit agencies may develop their detailed TODSS requirements based on the core TODSSS requirements when creating a specification for procuring a TODSS.

TODSS requirements are separate from CAD/AVL requirements and interweaving the requirements together leads to some irrational requirements given that there are multiple CAD/AVL designs. For example, defining the detailed properties of an AVL map are better left to AVL requirements since they do not directly impact the ability to identify a service incident through real-time event processing. Since the core requirements were written, the number of mature and tested transit CAD/AVL systems available has grown. The existing CAD/AVL requirements in the TODSS requirements should be separated and used as a reference to compare with an agency's existing CAD/AVL or supplement the requirements they develop for a new CAD/AVL.

Following is a summary of proposed changes to chapter five of the core functional requirements document based on the above discussion:

Figure 5.1 – This figure confuses just about everyone that has studied it working on the prototype project. It is suggested that the arrow going from Table 5-1 to Table 5-3 be removed. Even though the Transit Inputs may be the same, the flow confuses the temporal relationship the figure is trying to demonstrate. In fact the inputs for Table 5.3 are more likely the results of tests from the available sources of information and not the sources of information.

Table 5.1 – Consistent with the previous suggestion the removal of the TODSS System Parameters category is suggested. System parameters are used to test against primary sources of information. Inclusion within the sources of information is misleading. System parameters are defined and discussed in other sections of the requirements.

The opening paragraph of section 5.3 in the core requirements introduces two tables included later in the section. Table 5.3 is incorrectly identified as Table 5.2. This led to some confusion during the design phase.

SI 3.4 Core TODSS shall have the ability to regulate the frequency of information updates (e.g. polling or event triggered reporting) in response to an event notification, service restoration action, or system status notification.
(Suggest that the word "updates" be deleted, because it has several meanings within the TODSS environment, and replaced with "reporting".)

SI 3.5 Core TODSS shall have the ability to regulate the frequency of updates based upon the priority of the event or action being monitored and the data network's capacity to transmit and receive information. *(Suggest substituting "frequency of data reporting" instead of "frequency of updates". The updating process in TODSS is independent of the data reporting from the communications system. The term "updating" in TODSS is the concept of priority updating of an event that has been previously evaluated and generated as a TODSS incident based on changing conditions.*
This requirement may be better suited in the Service Disruptions section.)

SI 6 Core TODSS shall have the capability to accept overrides and modifications to threshold status for each source of information shown in Table 5-1. *(This requirement needs to be more specific and indicate if this refers to automated modifications, real-time user modifications, or near real-time modifications to system configuration. It is too ambiguous as written.)*

SI 8 Core TODSS design shall provide for modular implementation and incorporation of each Core source of information shown in Table 5-1. *(This requirement needs to be rewritten. An explanation of what a modular design means is needed. It is recommended that the requirement be changed to "…modular design that permits the addition of information sources as they become available in a local implementation of each Core source of information shown in Table 5-1.")*

SI.8.2.1. Core TODSS shall notify dispatchers when a source of information ceases to function on its status and the functions it impacts *(Recommend adding TODSS administrators and/or IT personnel to this requirement.)*

SD 1.1 [Desired but not required] The operational scenario should be identified based upon the sources of information shown in Table 5-2 and additional internal system variables (e.g. time of day, type of day) *(Recommendation is that this becomes a requirement. The power of TODSS was demonstrated when combining sources of information and internal system variables.)*

SD 1.3 System parameters for each operational scenario shall include: service disruption and other thresholds; prioritization criteria; and a response rules base. *(Recommend changing to "Properties for each operational scenario shall include: service disruption parameters and thresholds; prioritization ….")*

SD 1.4 Core TODSS shall have the ability to accept updates to the service baseline as required to identify service disruptions within the appropriate operational scenario. *(Recommend SD 1.4 and sub-sections 1.4.1, 1.4.2 be removed to a supporting CAD/AVL requirements section. SD 1.4 should be replaced with "Operational scenario parameters and thresholds shall be provided to recognize any planned or modified service changes. The level of sophistication of service modifications within the CAD/AVL shall be supported within TODSS by making available the appropriate parameters and thresholds to make intelligent decisions in identifying real service disruptions.")*

SD 2 Core TODSS shall have the ability to identify each service disruption type shown in Table 5-2 using the Core TODSS sources of information also shown in Table 5-2. *(Table 5-2 serves as a good model for identifying service disruptions. The introduction to the table should qualify that there are many other service disruptions encountered and those provided in the table serve as a guide to mapping inputs to disruptions Also, Connection Protection does not serve as a good disruption category. It should be renamed to Passenger Transfers with line items for Connection Protection (a connection that includes a spatial element), Protected Transfer (a known transfer to be actively managed), and Coordinated Transfers (route intersection where transfers are determined by the system upon request). A new transit input, Passenger Request, should be included.)*

SD 4.2 [Desired but not required] Core TODSS should also have the ability to set additional thresholds for each event. These should include: type of notification by contact (visual, audio, alarms), increased data collection, warnings of potential disruptions, or report generation. *(This requirement would make more sense if the word "properties" replaced the word "threshold". Thresholds imply some sort of test being applied whereas properties imply other associated behaviors. A threshold is simply a value of a variable that triggers an action according to the definition provided in Core Functional Requirements.)*

SD 6.3 Event tracking shall consist of monitoring the service associated with the service disruption and all service affected by the disruption identified in meeting functional requirement SD 4. *(Recommend this requirement be moved to 6.1 since it provides an explanation of the term "event tracking" that would be helpful for understanding the other requirements in SD 6)*

SD.6.4.2. Core TODSS shall provide notification to the dispatch center and others as called for in the response rules base when an end of event threshold is triggered. *(Recommend that the requirement be used sparingly if at all and follow the principle that dispatchers shall make all final decisions. The external communications should be left to dispatcher discretion and not automated based on end-of-life of an event.)*

SD 7 Core TODSS shall provide the ability to prioritize all service disruptions and notifications/actions triggered by defined thresholds in order to determine their importance/severity and order in event queues *(Recommend that SD 7.1 and 7.2 be removed. Recommend adding, "Priorities shall be assigned as part of the TODSS service disruption event processing based on the operational scenario requirements and associated parameters and values.)*

SD 8.1 The system status summary shall have the capability to summarize the amount (percentage) service by threshold value for each type of service disruption shown in Table 5-2. *(Recommend changing to "The system status summary shall have the capability to summarize the service by user-definable statistics including percentage values for route schedule, adherence, and load. The system status summary shall provide counts and other summary statistics as appropriate for the other service disruptions shown in Table 5-2.)"*

SD 8.2 [Desired but not required] The system status summary should have the capability to summarize the amount (percentage) of service by threshold value for additional thresholds and performance measures defined by the transit agency. *(Recommended change: "The system status summary shall have the capability to summarize multiple performance measures using different threshold values as defined by the transit agency.)*

SD 8.4 [Desired but not required] The system status summary should allow the playback, or display, of performance and trends for the time preceding the request, or of historic performance from previous days, weeks, or months. *(In practice, this is two requirements one for historical performance and one for historical system summarization and should be in separate line items.)*

SD 9 Core TODSS shall provide the ability to define and select as needed displays and notifications of current system performance and service disruption/event status *(SD 9 sub-sections are primarily CAD/AVL requirements. Public transit CAD/AVL products have matured to the point where this level of detail is no longer needed in TODSS requirements. Subsection 9.1 – 9.3 should be used as guidelines for CAD/AVL requirements.)*

SD 10 Core TODSS shall provide the capability to select and control the display of all potential screens and notifications identified in Requirement SD 9. *(SD 10 sub-sections are primarily CAD/AVL requirements. Public transit CAD/AVL products have matured to the point where this level of detail is no longer needed for TODSS requirements. Recommend subsection 10.1 – 10.4 be deleted and SD 10 changed to "Core TODSS shall provide the capability to select and control the display of all potential screens and notifications identified in Requirement SD 9 through filter capabilities, display order, and use of color, and screen size.)*

GS 1 Core TODSS shall provide the capability to select operators, supervisors, maintenance, public safety, and dispatch terminals individually or in groups for one or two way data and voice communications. *(Suggest that a more general requirement for GS 1 be written and delete the subsections.)*

GS 2 Core TODSS, hardware, software, and protocols shall use applicable ITS standards and interoperability tests that have been officially adopted through rulemaking by the United States Department of Transportation (No ITS standards or interoperability tests have been officially adopted by the U.S. DOT as of January 2003) *(Recommend updating the requirement)*

GS 3 [Desired but not required] Core TODSS should use ITS standards that have been approved and published by their associated Standards Development Organization (SDO) where it is affordable and practicable to do so. These include but are not limited to the SAE 1708/1587/1455 Vehicle Area Network standards for the vehicle sub-system, and the NTCIP Transit Communications Interface Profiles (TCIP) dialogues published by the

American Public Transportation Association (APTA) when they become available *(Recommend updating the requirement; TCIP has been published by APTA)*

GS 4.1 [Desired but not required] Where functions and interfaces do not exist within the National ITS Architecture suggested additions should also be included. The Turbo Architecture Tool developed by the Federal Highway Administration's ITS Joint Program Office may be used for this purpose *(Recommend updating the requirement; the ITS Joint Program Office is now a part of the Research and Innovative Technology Administration)*

GS 5 Core TODSS shall have an open system architecture and provide for interoperability, interconnectivity, portability and scalability across various hardware platforms and networks. *(Scalability is important but not necessarily among hardware platforms and networks. What is most important today is that TODSS works in a TCP/IP network environment, that the CAD/AVL/TODSS data is publicly available, and the CAD/AVL system follows industry interface standards or provides open protocols for integrating ITS systems as they become available. If standards such as TCIP can be successfully demonstrated in the future then the prospects for a stand-alone TODSS application would be more likely.)*

GS 7 Core TODSS shall be modular in order to minimize the time and complexity involved in upgrading existing components, incorporating new sources of information and interfaces, or adding new functions and capabilities. *(Too much ambiguous detail in this section. Suggest GS 7 address meeting standard software engineering practices and require a Quality Assurance program. Delete GS 7.1 and GS 7.2.)*

GS 7.3 Where ever possible all system options and application logic shall be maintained as separate parameter files and not directly coded into the TODSS system. *(This is an important TODSS requirement and should be moved into the Service Disruption and Service Restoration requirements sections. The requirement should strongly state that setting parameters and values are a user defined activity).*

GS 8 Core TODSS shall provide the capability to update the service disruption identification thresholds, disruption and restoration strategy priority weights, and restoration strategy response rules using user supplied inputs and parameter values. *(This is an important TODSS requirement and needs to be moved into Service Disruption and Service Restoration sections.)*

GS 9 Core TODSS shall provide for identification and notification of the failure of key components of the system or its core information sources. *(This is an important TODSS requirement and should be moved into the Service Disruption section.)*

GS 10 Core TODSS shall provide the capability to monitor and archive an audit trail of all system events, parameters, data communications, screen displays, notifications and alarms, logons, and actions performed by the system and those interfacing with it

(dispatch, supervisors, operators, public safety, maintenance and remote terminals) *(This is an important TODSS requirement and should be moved into the Service Restoration section. The focus of the requirement should be on TODSS and not CAD/AVL data. The audit should be on the displayed service interruptions, dispatcher actions, and all related rules and actions.)*

GS 11 [Desired but not required] Core TODSS should provide the capability to replay system conditions and events either from short term on-line storage or longer term archived information. *(This section is too detailed and sections GS 11.1 and 11.2 should be deleted. GS 11.3 is not a playback function but rather a simulation and modeling tool that should be a separate requirement.)*

GS 12 Core TODSS shall provide multi-level password protected access control through logon and logoff procedures for all terminals, monitors, and data ports. *(This section is too detailed and GS 12.1, 12.2, and 12.3 should be deleted. GS 12 should be in Service Disruption and Service Restoration sections with an express concern of adding TODSS to the CAD/AVL security scheme.)*

Recommended Next Steps

The results of the prototype development validated the core TODSS requirements and demonstrated that a TODSS development effort is feasible and within the means of transit agencies with CAD/AVL systems. Efforts should be made to further the development of TODSS for the transit industry. The following actions are recommended as follow-up activities to the TODSS prototype development project.

Outreach

An outreach program needs to be developed in order to demonstrate to the vendor and transit agency communities the outcome of the prototype development. Both vendors and agencies need to share in the findings of this project to realize the TODSS project goal of developing a joint understanding of TODSS.

- Publicize and make the TODSS prototype reports publically available
- Make public presentations aimed at the transit industry at American Public Transportation Association (APTA) conferences such as the Annual Meeting and the Bus and Paratransit Conference
- Make public presentation aimed at a broader transportation audience where transit is involved such as regional and national ITS conferences, annual state transit conferences, the annual Transportation Research Board conference, and Transit ITS regional workshops
- Present articles to transit trade magazines and publications such as Metro Magazine, Mass Transit, Bus Ride, and Passenger Transport
- Conduct online webinars such as a T3 webinar

Core Requirements and Procurement Support

The core requirements should be reviewed and edited based on the findings of the prototype development. This could be led by FTA. Consider involving APTA in this effort. The core requirements should be formatted such that there are no overlaps with CAD/AVL requirements. This way the TODSS requirements could be directly dropped into an agency's TODSS requirements section. Guidance on CAD/AVL requirements related to a TODSS should be provided as an accompanying guideline.

In the interim, while awaiting an updated set of core TODSS requirements, this report and the other documents produced during the project should assist those agencies that are in the process of a solicitation, or will be shortly, for a TODSS. Questions they may have could be directed to the members of the project team by FTA. Future efforts to put in place peer assistance, such as refining the Concept of Operations or reviewing an agency's local TODSS requirements, should be considered as TODSS development emerges.

Further Study

Following is a discussion of concerns related to TODSS that further study would improve the state of the art of TODSS development.

A synthesis of the current practices of bus service management techniques, strategies, and practices would be a first step in creating an inventory of service restoration for general industry use. An expansion on the synthesis should include the theory behind the techniques. The theory should explore the conditions surrounding each strategy, the best alternative techniques to apply based on conditions, the necessary information, and expected outcomes. In addition to using this knowledge for real-time service management, guidance should be given on how to apply this knowledge into the route planning and development process for operational guidance to handle known service disruptions based on available historical data along route segments.

More research and study on the requirements to build forecasting and simulation tools that could be used for real-time modeling is needed. The developers of the TODSS prototype were hesitant to work in this area because of the lack of definition and the concern for future liability. The study needs to look at the technical and institutional issues related to predicting the future state and effect on the transit route, corridor, or system applying alternative restoration strategies. The same tools could be used on historical data to test different strategies to determine the optimal solution for future consideration.

Finally, transit needs to understand what will be expected from them in the future based on other ongoing initiatives related to transportation management. In particular, the TODSS peers that are involved with the Integrated Corridor Management (ICM) program expressed a need for real-time transit and traffic data to complement their situational awareness so they are aware of available transit assistance and have current knowledge of

the state of the transit and roadway networks. Further efforts and analysis to determine how to utilize a TODSS within the ICM initiative should occur in the near future so to reflect each of their needs in the requirements and designs.

Appendix A – Pace Defined TODSS Service Disruptions

The Pace system administrator and the TODSS working group worked together during the design phase of the project to identify a set of incidents to implement for the TODSS operational test period. The following table is an early version of their work that served as a guide to the initial setup required for setting up the decision support system. After learning more about the system design, this configuration went through several iterations until the triggers and priorities were refined to a level to support Pace daily operations. The description field describes the service disruption followed by a priority designation, the rules to trigger the incident, and the life span of the incident.

Table 11 - Pace Local Incidents

DESCRIPTION	PRIORITY	TRIGGER CONDITION	LIFE SPAN (MINUTES)
Driver away from Radio.	15	MessageItem = 102 // Out of service 10-7	30
Driver back in Radio Contact.	16	MessageItem = 103 // Back in service 10-8	300
A Biological Detection System Alarm has been issued	90	ManualEventID = 4	300
A vehicle is held up behind a Bridge	69	MessageItem = 25 // road blocked	30
The vehicle has reached its capacity limit.	60	MessageItem = 18 // wheelchair doesn't fit bus full OR MessageItem = 19 // bus full	300
South division dispatchers may receive an after hours call from a Pace fixed route or paratransit carrier requesting to report an accident.	51	ManualEventID = 6	60
A Covert Alarm has been issued	90	EmergencyState < 2	0
A Covert Alarm has been issued	90	EmergencyState > 0	0
A Covert Alarm has been issued	95	CovertMicInitiated = 1 AND EmergencyState = 2	0
A Covert Alarm has been issued	100	EmergencyState = 2	600
South division may take an after hour call on the CTAN line from Metra or CTA with a CTAN alert.	51	ManualEventID = 7	60
Operator has reported Drive Cam Manual Event.	69	MessageItem = 70 OR // engine died MessageItem = 77 // flat tire	60
Adherence is too early	48	AdherenceStatus = 1 // too early AND RouteType = "Local"	30
Alarm from Vehicle Indicating Engine Fire.	76	Engine_Fire = 1	60
Operator has reported Equipment problem can not proceed.	85	MessageItem = 70 OR // engine died MessageItem = 77 // flat tire	60
Operator has reported Equipment problem and still in Service.	62	MessageItem = 74// Farebox / BTPU problem	300

DESCRIPTION	PRIORITY	TRIGGER CONDITION	LIFE SPAN (MINUTES)
An after hour call may come into South division dispatch from police, fire, , or a municipality reporting damage to a bus stop, shelter, transit center	51	ManualEventID = 8	60
Operator has reported a farebox problem	60	MessageItem = 76// Farebox problem	300
Fleet Watch Incidents	50	MessageItem = 10	300
I Need Relief ASAP.	75	MessageItem = 70 OR // engine died MessageItem = 77 // flat tire	60
IBS - System Back in Service	0	ManualEventID = 3 // voice fallback resolved	30
Adherence is too late	49	AdherenceStatus = 3 // too late	30
Late due to Heavy Load	49	MessageItem = 25 // road blocked	30
Late due to Heavy Traffic	49	MessageItem = 25 // road blocked	30
The System has not detected a logon after schedule pullout.	50	AlarmStatus = 2 AND IsPulloutPiece = 1 // late logon for pullout from garage	60
Late Other	55	MessageItem = 25 // road blocked	30
The Driver left the Garage without Lift / Ramp Cycled.	55	Wheelchair_not_cycled = 1 // Lift or Ramp not Cycled on pullout	60
Driver has manually logged on and needs to be logged on to IBS from dispatch or call driver to have them log back on.	50	IsManualLogon = 1 // manual logon	60
A TransitMaster system error has been detected.	95	ManualEventID = 2	60
A TransitMaster system error has been detected.	95	Component = MCC AND SystemParameter = "Fallback" AND ParamValue = 1	100
Metra Service Interruption.	80	ManualEventID = 5	300
Need Detour	70	MessageItem = 25 // road blocked	30
Need Transfer Assistant	71	MessageItem = 25 // road blocked	30
The vehicle is in Open Mic off mode	0	InOpenMicMode = 0	0
The vehicle is in Open Mic mode	20	InOpenMicMode = 1	20
A driver logon operation failed	71	LogonResult = 1 // logon denied // Not enable may be later.	60
Ignore Emergency - Driver hit by mistake.	90	MessageCategory = 0	300
An Emergency Pace accident	98	MessageItem = 10	300
An Emergency Canned Message need Paramedics	98	MessageItem = 10	300
An Emergency, Smoke on Bus.	98	MessageItem = 10	300
A passenger on Pace bus creating problem to operator. Send Supervisor and / or Police.	90	MessageItem = 6 OR MessageItem = 7	300
An overt alarm has been issued	0		1
An overt alarm has been issued	90	EmergencyState > 0	600
Passenger Sleep End of Line	0	MessageItem = 10	300
PRTT	80	HighPriority = 1	300
Railroad / Bridge - Back in Service	55	MessageItem = 25 // road blocked	30

DESCRIPTION	PRIORITY	TRIGGER CONDITION	LIFE SPAN (MINUTES)
A vehicle is held up behind a railroad X-ing	69	MessageItem = 25 // road blocked	30
A passenger refuses to use the lap belt	5	MessageItem = 23	1
RTT	0	HighPriority = 1	1
RTT	70	HighPriority = 0 AND EmergencyState = 0 // This is a RTT but no emergency.	300
An RNC channel is overloaded.	70	Component = "TMMCC" AND SystemParameter = "ChannelLoadStatus" AND ParamValue2 > 90 // Some RNC has a load above 90%	300
The IBS system reports unidentified RNC is dead.	97	Component = "TMMCC" AND SystemParameter = "ChannelLoadStatus" AND ParamValue2 = 255 // MCC detected a dead RNC	300
Road Blocked	71	MessageItem = 25 // road blocked	30
Road Flooded	72	MessageItem = 25 // road blocked	30
Standees on Bus	0	MessageItem = 10	300
A call has been received stating that an ADA passenger has missed the last bus and is left behind at a stop.	80	ManualEventID = 1	60
A route's schedule is getting messed up due to traffic	0	AverageAdherence < -3	30
A route's schedule is getting messed up due to traffic	68	FeedsName = "Traffic Conditions" AND EXTRACT_NUM(ItemTitle "Jamfactor\s(?<NUM>\d+(\.\d+)?)") > 4.5	30
The bus has stopped and unable to pick up a passenger with wheelchair.	92	MessageItem = 17 // wheelchair doesn't fit	60
A vehicle has become unusable.	0	LastMessageReceivedDuration > 15	45
Wait at Pulse Point	73	MessageItem = 10	300

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Federal Transit Administration

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