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
FTA Office of Mobility Innovation (TRI-10)
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Acronyms And Abbreviations

APC	Automatic Passenger Counter
APTS	Advanced Public Transportation Systems
AVL	Automatic Vehicle Location
BRT	Bus Rapid Transit
CAD	Computer Aided Dispatch
EMS	Emergency Management Systems
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GIS	Geographic Information Systems
GPS	Geographic Positioning System
GS.#.#	General System Function Requirement #.#
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
MDT	Mobile Data Terminal
NTCIP	National Transportation Communications For ITS Protocol
RFP	Request For Proposal
ROW	Right of Way
SD.#.#	Service Disruptions Functional Requirement #.#
SDO	Standards Development Organization
SI.#.#	Sources of Information Functional Requirement #.#
SR.#.#	Service Restoration Functional Requirement #.#
TCIP	Transit Communications Interface Profiles
TMC	Transportation (Traffic, Transit) Management Center
TODSS	Transit Operations Decision Support Systems
US DOT	United States Department of Transportation

1. PURPOSE

The Transit Operations Decision Support System (TODSS) Project was initiated to address concerns raised by transit agencies that have implemented and are using Automated Vehicle Location (AVL) and Computer Aided Dispatch Systems (CAD). These can be summarized as:

- "Dispatchers do not have time to digest huge quantities of data for decision making in a normal operating environment".
- "They are unable to recognize patterns of operational problems."

This document provides core functional requirements for AVL/CAD systems to use in identifying and prioritizing service disruptions and providing options service restoration strategy options to in response. When these are incorporated into Core TODSS AVL/CAD systems they should help address the above concerns and assist dispatchers in responding to service disruptions more quickly and effectively than they are able to do today. Once finalized these functional requirements should also:

- *Provide for a common understanding between vendors and agencies concerning TODSS*. The ability to identify service disruptions and provide restoration options depends greatly on the inputs available for each specific TODSS implementation. Confusion has also arisen in the past between agencies and vendors on the meaning of different terms (e.g. what is an incident, a run, a trip?). The functional requirements provide definitions and functions that can help reduce misunderstandings and act as a common reference on what is feasible in any specific implementation.
- *Help vendors reduce the cost of customization*. Once vendors develop systems around the core functional requirements and agencies use them as a basis for procurement, the requests for customized features should diminish. This in turn should reduce the costs of system development and implementation.
- *Help agencies with procurement specifications*. Likewise, the core functional requirements should help agencies understand what features are needed to meet their needs, and what is feasible in their environment (type of service, size, cost, resources).

2. BACKGROUND

Transit Operations Decision Support Systems (TODSS) are systems designed to support dispatchers and others in real-time operations management, and in response to incidents, special events, and other changing conditions. Typical systems currently implemented in the United States include: Automatic Vehicle Location (AVL); Computer Aided Dispatch (CAD); advanced data communications through mobile data terminals; identification and notification of off route, schedule adherence, silent and vehicle mechanical alarms, and other incidents; and displays of geographic vehicle location, event queues, and service performance.

The need to develop enhanced capabilities for Advanced Fleet Management Systems (AVL/CAD) for real time operations was identified during the broad industry consultation and outreach conducted for the FTA Research & Technology 5-Year Plan (FTA, 1999). Issues raised at that time with Advanced Fleet Management systems can be summarized as:

- "Dispatchers do not have time to digest huge quantities of data for decision making in a normal operating environment".
- "They are unable to recognize patterns of operational problems."

In other words, dispatchers and field supervisors need tools accessing real-time data to help:

- Identify and prioritize problems as they occur
- Make decisions to resolve operational issues before they become problems
- Manage problems or incidents as they arise
- Restore service with minimal disruption to the transit system.

In response, the FTA Office of Mobility Innovation and the U.S. DOT ITS Joint Program Office initiated a project on Decision Support Systems for Real Time Operations to: further investigate the issues and needs; determine appropriate roles for transit operators, suppliers, and the Federal government; and develop/carry out an action plan for creating enhanced systems. Initial activities carried out as part of this effort include:

- Interviews with transit agencies operating existing advanced fleet management (AVL/CAD) systems (Volpe)
- Transit Agency AVL Fleet Management Workshop (Volpe)
- Interviews with Vendors providing Decision Support Systems for Operations and/or their components. (Volpe)
- Vendor Advanced Fleet Management (AVL/CAD) Systems for Real Time Operations Workshop (Mitretek)
- Joint Transit Agency/Vendor Transit Operations Decision Support Systems Workshop (Mitretek)

Two efforts emerged from the Joint Transit Agency/Vendor workshop that took place in March 2002.

1. **Core Functional Requirements For Identification of Service Disruptions And Provision Of Service Restoration Options**. The highest priority needs emerging from the workshops from the transit agencies perspective focused on how to identify *and prioritize* service disruptions, and then provide service restoration strategies to address them. On the other hand, vendors indicated that agencies often require customized

features within their procurements that result in multiple versions of their software that are costly to implement and maintain. Agencies also often request features that may not be appropriate for their system and resources, or may not understand how to use the features of the systems they do have. Consequently, the goal of the first TODSS effort was to bring users (transit agencies) and developers/vendors/integrators of AVL/CAD systems together to identify a core set of functions and system attributes needed to identify service disruptions and to provide options for service restoration strategies to address them.

Once finalized these functional requirements should:

- *Provide for a common understanding between vendors and agencies concerning TODSS*. The ability to identify service disruptions and provide restoration options depends greatly on the inputs available for each specific TODSS implementation. Confusion has also arisen in the past between agencies and vendors on the meaning of different terms (e.g. what is an incident, a run, a trip?). The functional requirements provide definitions and functions that can help reduce misunderstandings and act as a common reference on what is feasible in any specific implementation.
- *Help vendors reduce the cost of customization*. Once vendors develop systems around the core functional requirements and agencies use them as a basis for procurement, the requests for customized features should diminish. This in turn should reduce the costs of system development and implementation.
- *Help agencies with procurement specifications*. Likewise, the core functional requirements should help agencies understand what features are needed to meet their needs, and what is feasible in their environment (type of service, size, cost, resources).

2. Training and Education Assessment and Action Plan Development. The workshops also raised concerns: there are no industry wide training/education opportunities or understanding of how to identify disruptions and provide service restoration actions, or how to use TODSS to assist in these activities; the roles, responsibilities, and content of vendors training to customers on the use of their systems; and a lack of understanding by agencies on how to procure TODSS. Consequently, a task to assess both the industry wide and site specific (vendor supplied) training and education needs and develop an action plan to address them was also defined. This effort is also being conducted in 2003.

This document provides the core functional requirements for identifying service disruptions and providing options on service restoration strategies that emerged from the first effort. The needs analysis and concept of operations used to develop the functional requirements are provided first in Sections 2 and 3. This is followed by the functional requirements in Section 4. Last, some additional comments are provided in Section 5.

3. NEEDS ANALYSIS

Carrying out a needs analysis is the first step in a systems engineering approach to developing functional requirements, and ultimately deployable systems (Gonzalez, P. Fowler, T. 2002). It is the needs analysis that helps identify why a project is being carried out, and the problems that the project is intended to address. In a needs analysis three basic questions are examined (Gonzales, P. Fowler T. 2002):

- What is less than satisfactory with the current situations and how does the proposed project fill that need?
- Do all stakeholders have a common understanding of the project's goals and objectives?
- How should conflicting stakeholder goals be resolved?

The answers to these questions are then used to help develop the concept of operations and functional requirements for a project.

As mentioned in Section 1, one of the initial activities of the TODSS effort was a needs analysis. Initial surveys of agencies and vendors and the January 8, 2001 Transit Agency AVL Fleet Management Workshop were first carried out to identify stakeholders and articulate major problems and needs faced by transit agency operations personnel in making real-time operations decisions using existing TODSS. These were followed by a TODSS vendor workshop in March 2002, and a Joint transit agency/ vendor workshop in September 2002. These were focused on resolving the differences in perception between stakeholders and further refinement of the needs statements. A summary of the final set of perceived needs from the three workshops is provided below (a detailed list of the needs is provided in Appendix 1):

- Operational Needs/Issues
  - Headway based service support (bunching)
  - Schedule based service support (early / late)
  - Incident/emergency event support
  - Connection protection (scheduled)
  - Real-time requests for transfer connections
  - Variable thresholds for notices/alarms
  - Early warning signs and impacts of actions
  - Provision of recommended actions
  - Prioritization of problems and solutions

- System Needs/Issues
  - System wide impact analysis
  - Two-way communication between vehicles, supervisors, and management center
  - Projection of emerging problems and response
  - Integration of system with other modes and ITS components
  - Understandable display of information (human factors)
  - User defined reports and data screens
  - Use of standards, open architecture, and data definitions
  - Modular, incremental implementation of functionality

- Industry wide needs/issues
  - Procurement process and RFPs can be improved

- Low bid is not always the best approach
- Limit customization and unnecessary functions
- Recommend modular, phased implementations
- Some needs are currently provided by operations management systems
- System customization and maintenance of modifications is costly and hampers new improvements. Need a "Core" system that meets most important agency needs
- Identification and response to service disruptions is an area likely to have a large percentage of core functions
- Education and training of all staff on new approach to providing service enabled by TODSS important
- Maintenance and obsolesce of TODSS software and components is a concern

4. CONCEPT OF OPERATIONS

The "concept of operations" describes how the system will work once it is implemented. It should include descriptions of the overall system and its components; the stakeholders, and an operational plan (roles and responsibilities, interaction, and coordination in operating the system). Creating and understanding the concept of operations is a key step in the development of functional requirements since it sets the context and defines the purpose that each functional requirement is defined to meet. Descriptions of the Core TODSS system boundaries, users, and the operational concept (environment and flow of decisions) follow.

4.1 Core TODSS System Boundaries

Decision Support is the use of advanced technologies for data collection and analysis to help decision makers to identify options, predict and evaluate their impacts, and make informed choices. A Transit Operations Decision Support System (TODSS) could be implemented to assist in many levels of decision making within a transit agency, from immediate operations, to asset management, to scheduling and route planning, and even long-range system planning. All are important, but cannot be implemented at one point in time with high probability of success. Consequently, it was decided to focus on a defining a Core TODSS that is:

- Feasible using existing technology or technology that will soon be deployable
- Implementable
- Meets the highest priority needs from the needs analysis (see Section 2).
- Defined by the stakeholders (vendors, transit agencies, U.S. DOT)

Therefore, the Core TODSS system has been defined to provide real time operational support to dispatchers to identify and prioritize service disruptions, and to provide service restoration strategy options in response (hereafter this is simply referred to as the Core TODSS). 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. A *Service Restoration Strategy* is a response to an event designed to restore service to scheduled or planned contingency levels for a given scenario (additional definitions of terms are provided in Appendix 4). A fundamental principle that is also part of the Core TODSS definition is that only options for service restoration strategies will be provided and not an "optimal solution". The final decision on which strategy to implement is always left up to dispatch or other personnel.

The Core TODSS was also defined to be implemented:

- Within a **single operating agency**
- For **fixed route bus service**
- Using **transit agency information** (generated, owned, and controlled by the agency)
- With **centralized communications control** through the radio dispatch center

4.2 Core TODSS Users

It is also important to understand the expected users of the Core TODSS and their roles and responsibilities. These include the primary users that interact with the TODSS and play a role in identifying service disruptions, or carrying out the service restoration strategy; and the secondary users that may provide inputs or use the TODSS information but are not involved in system operations. While the Core TODSS functional requirements focus on meeting the needs of the primary users, the overall needs of the secondary users should not be forgotten in any full system implementation.

The primary users of the Core TODSS are assumed to be:

- Operations center (dispatch) personnel
- Operators
- Field and bus facility supervisors
- Maintenance personnel
- Emergency responders
  - Police
  - Fire
  - Ambulance

The secondary users of the Core TODSS are assumed to be:

- Other operations centers
  - Incident and emergency management
  - Rail operations
  - Paratransit operations
  - Traffic management (arterials)
  - Freeway management
  - 511 regional multimodal traveler information
- Other users within the transit agency
  - Senior management
  - Service planning (routing and scheduling)
  - Customer service
  - Payroll
  - Maintenance (scheduled)
  - Personnel
- Other
  - Regional planning organizations
  - Other state and local agencies
  - Information service providers

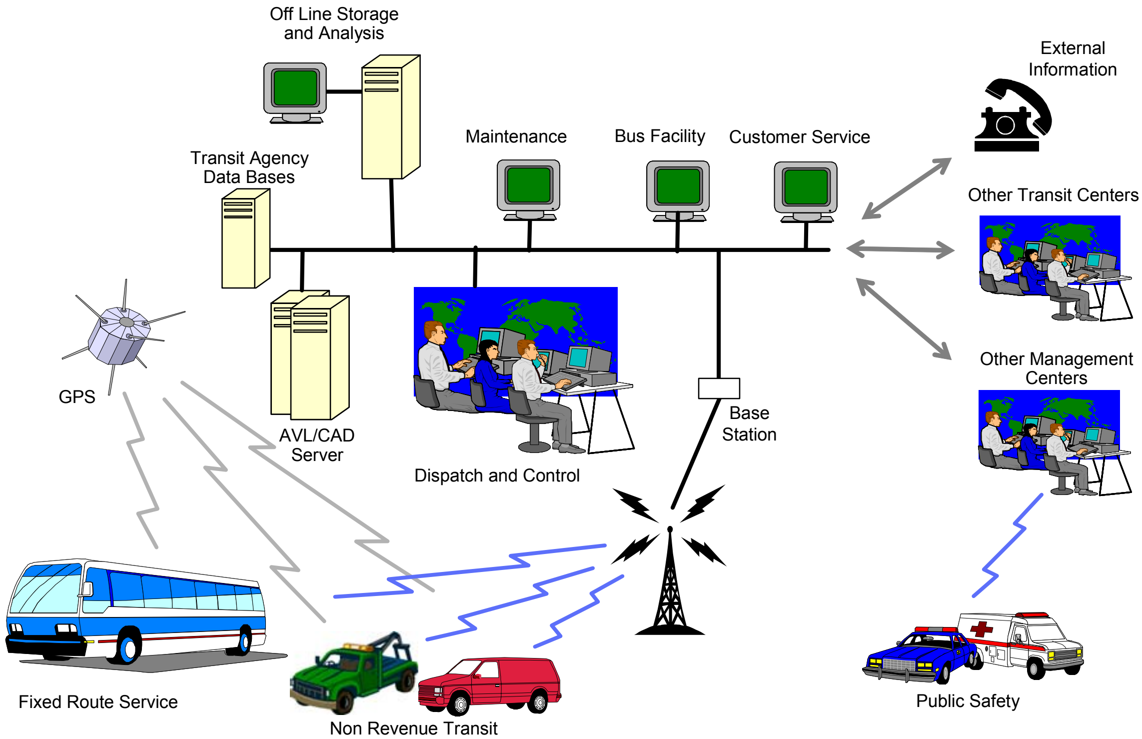
4.3 Core TODSS Operational Concept

This section describes the expected operational environment and flow of operations that are assumed as part of the Core TODSS. Figure 4-1 provides a graphical representation of the assumed components and operational environment in which the Core TODSS primary users must function. These include:

- AVL – GPS for fixed route vehicles that are both in and out of revenue service
- AVL – GPS for non-revenue transit vehicles (maintenance, field supervisors, security)
- Other ITS Transit services (e.g. Automatic Passenger Counters (APC), Vehicle and equipment status, Alarms, and Surveillance)

- Data, Mobile Data Terminals (MDT), and voice communications to/from a base station, and then through the internal network to the dispatch and control center. This may be through an agency controlled radio system or other means such as commercial wireless services, or shared communications networks
- AVL/CAD server and software
- An internal agency wide computer network

Figure 4-1 Expected TODSS Operating Environment



- Connections to other internal agency databases (scheduling/runcutting, maintenance, payroll, personnel, historical performance and ridership, etc.)
- Connections to a data archive system to provide for storage/archive of system information for offline analysis or replay.
- The Dispatch and Control center
- Remote terminals within the transit agency (Maintenance, Bus Facilities, Customer Service, etc.)
- The ability to communicate with other transit operations centers (rail, paratransit, BRT)
- The ability to communicate with other management centers (incident and emergency, public safety, rail, paratransit, traffic) by voice or through the internet. No integrated operation or network sharing of information is assumed.
- The ability to receive external information on system status, service disruptions, and other events from other sources.

The flow of operations and roles and responsibilities of the primary users also has to be defined in order to develop the Core TODSS functional requirements. Roles, responsibilities and actions can be separated into offline setup and analysis, and real-time operations activities. An overview of each is provided below.

Offline setup and analysis begins with converting the agencies policies and standard operating procedures into the TODSS parameters and the “response rules base”[1]. These are used to identify and prioritize service disruptions and determine potential service restoration strategy options. It also includes entering the service descriptions into the system that the TODSS requires as a baseline for comparison. Last, past performance of the TODSS can be analyzed and used to update the parameters and rules based on an ongoing basis.

It is important to point out that what is to be considered a service disruption and what to restore service to can only be defined within the context of the agency’s service policies and standards *for a given operational scenario*[2]. Consequently, the first action that must be taken is to determine the set of operational scenarios and their associated service policies and standards that will be recognized by the TODSS. Conditions and circumstances that might be used to define operational scenarios include but are not limited to:

- Type of service (e.g. peak, off peak, late night, weekend, and holiday)
- System failure (e.g. majority of service not meeting schedule, labor strikes, lack of spare vehicles operators, communications or other equipment failure)
- Severe weather conditions (snow, ice, flooding)
- Special events (e.g. annual festivals, parades, protests, sporting events)
- Emergency response situations (e.g. terrorists attacks, hazardous material spills, fires)
- Evacuation due to hurricanes, flooding, fires, etc.

The dispatch center staff is responsible for clarifying which operational scenarios will be entered into the system; determining the service standards and policies and response rules for those selected; and then entering them into the TODSS system. Potential parameters for capturing each scenario include the service disruption and other thresholds[3], prioritization criteria, and response rules. Note, that the response rules may lead to a set of potential service restoration strategy options, or to a sequence of questions and actions designed to clarify the situation and determine an appropriate action (e.g. an operator reports a suspicious package has been left on the bus. Prior to taking an appropriate action dispatch must gather additional information such as: Is the package leaking? If so is the substance a white powder, or does it have other characteristics? Is the package making any noise?, etc.).

The description of the baseline service must also be entered into the TODSS. This includes two types of information. First, the TODSS must be updated every time there is a new publicly released schedule or operator signup. Second, planned modifications to the day’s scheduled service must be entered prior to each day’s pullouts (vehicle blocks and operator runs). If performance (schedule and location) is monitored by on-vehicle computers then this updated information must also be transferred to each vehicle during operator logon prior to pullout.

[1] The database of rules and criteria used to respond to a service disruption. See Appendix 4 for a more complete definition.

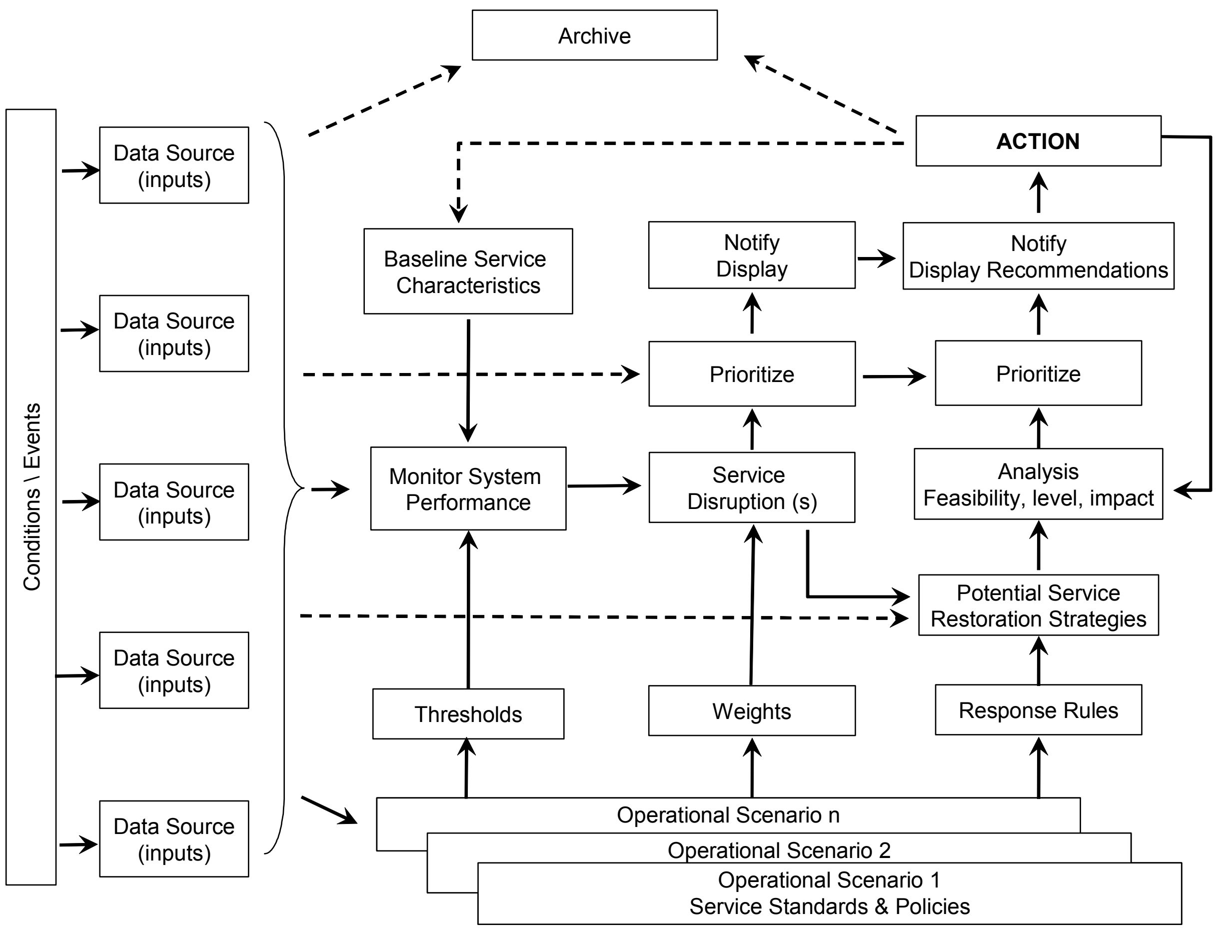
[2] Environmental or service conditions and circumstances where a unique set of service standards, policies, and response criteria are applied.

[3] A threshold is simply a value of a variable that triggers an action

An additional offline activity is the post processing and analysis of past events, system performance, and impacts of the service restoration activities actually taken. This should be carried out periodically by service planning and/or dispatch center personnel. The TODSS system itself does not have to perform the analysis, but must be able to provide data to a data archive to be used for the post processing, and must be able to accept updated operational scenario definitions, thresholds, priority weights, and response rules that may result from the analysis.

After setup is complete, service commences and the real time operations of the TODSS takes place. Figure 4-2 provides a high level representation of the flow of operations while the TODSS is operating.

Figure 4-2 Core TODSS Flow Of Operations



A more detailed description of the flow of operations within Figure 4-2 is:

- Service of a given type, with specified features and characteristics, is operated within a given environment
- Data is collected from vehicles and all other available data sources

- TODSS determines the appropriate operational scenario (either by analysis or direct entry) and activates the associated service standards and policy thresholds, priority weights, and response rules.
- System performance is monitored based upon the identified operational scenario and its parameters (This includes tracking previously identified events and corrective actions and their impacts)
- An event occurs that impacts service (in the real world)
- The impacts of the event on service performance are detected by the TODSS, or external notification of the event occurs (voice communication with operator, other management center, the public, or other means)
- The impacts of the event are propagated to other fixed route service throughout the system (missed connections, bunching, estimated arrival at next stop, etc.)
- Thresholds are evaluated to determine if any action is required. Note, there may be several thresholds that apply in any one instance for event tracking, service disruption, reporting, or other items
- If a service disruption threshold has been triggered:
  - Collect additional information required for prioritization.
  - Prioritize based upon the prioritization criteria for the operational scenario (multi-variable, hierarchical).
  - Notify and display the service disruption based upon criteria for the operational scenario (audio, visual, offline report, sorted, filtered, etc).
  - Collect additional information as needed to determine potential restoration strategies for the type of service disruption. This may be additional real time or transit agency database information, or the initiation of a question sequence with the operator, field supervisors, or others.
  - Determine potential restoration strategies based upon the response rule base for the operational scenario (also see Table 5-4 for examples)
  - Evaluate the feasibility of each potential restoration strategy
  - For each feasible restoration strategy propagate the impacts to other service throughout the system (missed connections, bunching, estimated arrival at next stop,etc.)
  - Prioritize the feasible restoration strategies based upon the prioritization criteria for the operational scenario
  - Display upon request the prioritized list of restoration strategies to the dispatch console
  - Initiate the chosen action by the authorized dispatch staff and assist in transmitting changes to supervisor, vehicle operators, and/or others as defined by the operational scenario response rule base (maintenance, police, public safety, etc.)
  - Set flags to track the service disruption and the chosen actions taken and suppress additional false notifications to the dispatch center. (This may include suppressing notification or placing the service disruption at the end of the queue or in a separate queue. It may also include updating the “baseline” service to reflect the corrective actions: e.g. the exchange of two trip schedules when a vehicle passes another on a route in response to “bunching”)
  - Monitor system

  - Archive information on service disruption for later analysis and issue offline reports based upon operational scenario and response rules base.
- Provide daily archive of event history and supporting data analyses of service disruption identification, prioritization, restoration strategy options and performance
- Continue to monitor the system to:
  - Identify changes in the applicable operational scenario(s) (e.g. peak to midday service, rainy to dry conditions, etc.)
  - Track previously identified events and actions and re-evaluate their status based upon the applicable operational scenario.
  - Send notifications if based upon the operational scenario and thresholds the event is over, or it is time to consult additional sources of information (e.g. operator, supervisor) on the event status.
  - Identify new events and service disruptions

Note, that there are many different types of communication systems, system architecture options, and conceptual designs for implementing AVL/CAD systems using current and emerging technologies. At one extreme are centralized systems that poll field information sources and perform all computational analyses, system monitoring, and evaluation at the centralized operations control and dispatch center. At another extreme are distributed event driven systems where the route maps and schedules are loaded into on-board computers and much of the processing takes place on the “smart vehicle” and the dispatch center is notified when an event takes place. The Core TODSS operational concept and functional requirements are designed to be neutral with respect to specific communication technologies and systems, architectures, and conceptual designs and do not presume or imply any specific system design or configuration.

5. CORE TODSS REQUIREMENTS

"Functional requirements are statements of the capabilities that a system must have ("functions"), geared to addressing the *business needs* that a system must satisfy. Business needs are mission oriented objectives of the organization for which the system is built." (Gonzales, P., Fowler T, 2002). They address what a system must do, not how the system should accomplish the task. The needs analysis (Section 2) and concept of operations (Section 3) laid the ground work for developing high level functional requirements for a Core TODSS to identify service disruptions and provide options for the service restoration strategies to address them. This section provides these high level Core requirements. It is important to note that these are the requirements for the enhanced functionality to identify service disruptions and provide recommended service restoration strategies. Since the focus on the "functions" that the system should provide they are designed to be system and architecture neutral. Consequently, they do not include all of the detailed functional requirements for design or verification test parameters required to implement a complete AVL/CAD that incorporates Core TODSS[4].

The core requirements are described in four sub-sections[5]:

- 4.1 Sources of Information (requirements SI.#.#)
- 4.2 Identification and Notification of Service Disruptions (requirements SD.#.#)
- 4.3 Provision of Service Restoration Options (requirements SR.#.#)
- 4.4 General System Requirements For TODSS (requirements GS.#.#)

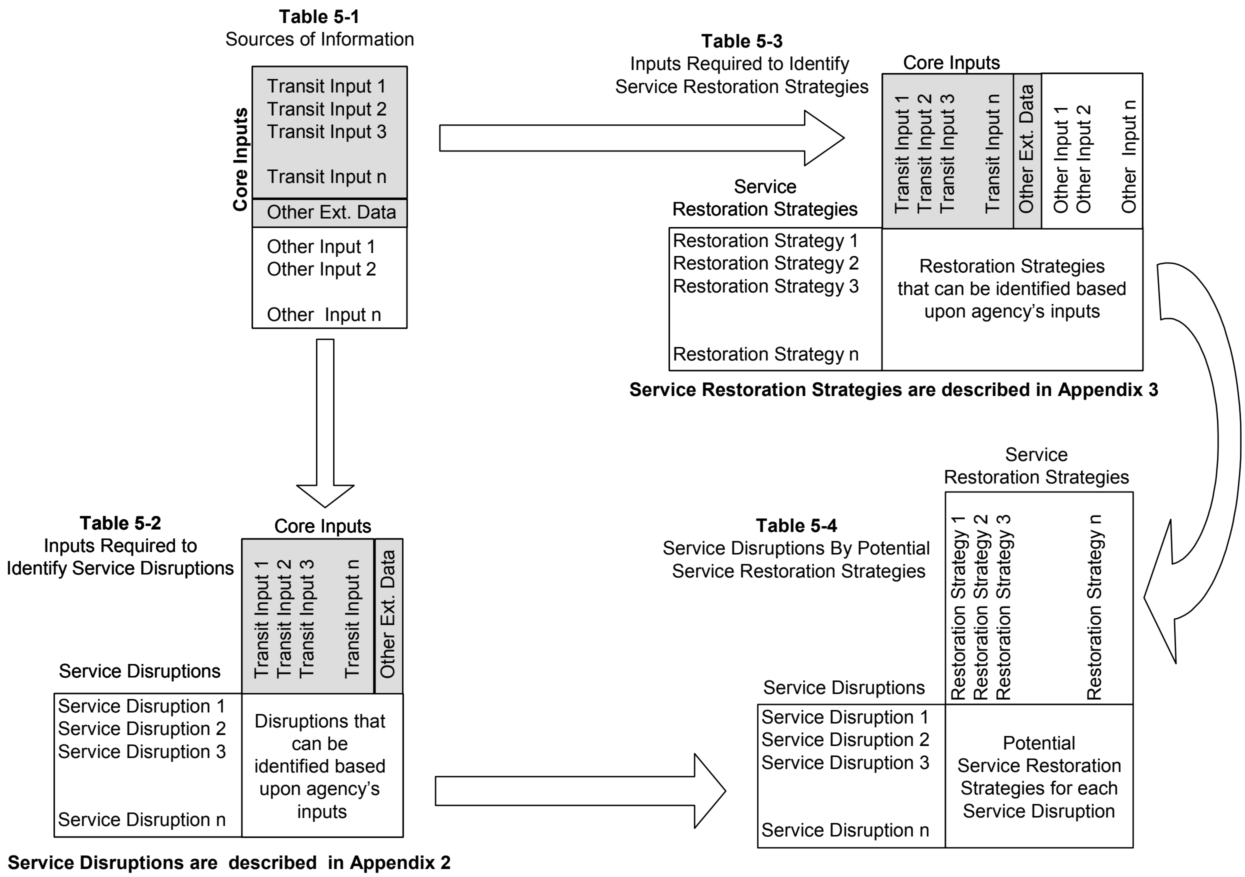
Figure 5-1 provides a visual representation of how the sources of information (inputs), service disruptions, and service restoration strategies relate to one another to provide potential options for each type of service disruption in a given situation. The Core TODSS inputs are shown in Table 5-1 and include those produced and controlled by the transit agency itself (e.g. AVL, APC, MDT and voice communications to transit personnel, schedules and runcutting, payroll, etc.) plus notification by external *non-automatic* data sources (e.g. other TMCs, dispatch, operators, incident management, and to the public). While overall TODSS packages developed to meet the core requirements must be able to incorporate all the core inputs each specific agency's TODSS may only implement a subset of the core inputs.

Table 5-2 provides the service disruptions and the inputs required to identify them. The service disruptions are further described in Appendix 2. Note, that the ability of a specific agency's TODSS to automatically identify each type of service disruption depends upon the core inputs that have been implemented. However, the ability to identify a service disruption (e.g. passenger overload on trip x at location y) manually through operator notification (MDT or voice) or other means, should always exist.

[4] These detailed requirements are very important as examples but should be developed as part of a specific system implementation

[5] The requirements in each subsection are numbered as shown in the parenthesis

Figure 5-1 Inputs, Service Disruptions, and Potential Service Restoration Strategies Relationships and Location



Likewise, Table 5-3 provides the service restoration strategies and the inputs required to identify when they should be applied. The service restoration strategies are further described in Appendix 3. Different inputs may be required to determine the potential restoration strategies than those needed to identify the service disruptions that they are for.

Last, Table 5-4 provides the potential restoration strategies that may be applicable for each type of service disruption. A core TODSS package should be able to discern, for a given service disruption, which restoration strategies from Table 5-4 are feasible and desirable. However, the ability of each specific TODSS implementation will again depend upon the sources of information that have been included in the system. Equally important are each agency's service policies and procedures under different scenarios, and how they define what actions should be taken under specific situations (i.e. What should service be restored to?).

These interactions, as well as the general system requirements for TODSS, are further explained in the sub-sections that follow.

5.1 Sources of Information

The sources of information that the TODSS accesses and incorporates into its analysis play a key role in determining the service disruptions and their potential service restoration strategies that it can identify. Potential sources of information are shown in Table 5-1.

Table 5-1 Sources Of Information For TODSS

Sources of Information	Core Input	Service Disruptions	Restoration Strategies
TODSS System Parameters			
Detection Thresholds	X	X	
Response Thresholds	X		X
Prioritization Rules	X	X	X
Response Rules	X		X
Transit Agency Static Information			
GIS Data (Street, Route, Stop,Time Point)	X	X	X
Transit Schedule	X	X	X
Vehicle/Block Data	X	X	X
Driver/Run Data	X	X	X
Historical Passenger data (ons/offs/transfers)	X	X	X
Historical System Performance	X	X	X
Transit Agency Dynamic Information			
Operator Availability[1]	X		X
Vehicle Availability (Extra board)	X		X
Time Stamped Location: Flagged rev. vehicle	X	X	X
Time Stamped Location: Other rev, vehicles	X	X	X
Time Stamped Location: Potential responders[2]	X		X
Operator Initiated Data Messages	X	X	X
Voice Messages (Operator, Supervisor)	X	X	X
Silent Alarm/Security	X	X	X
Automatic Passenger Count	X	X	X
Vehicle & Equipment Status	X	X	X
Dispatch Console	X	X	
Other Sources			
Traffic volumes & speeds		x	x
Traffic signal phase and status		x	x
Network Status[3]		x	x
Highway/Rail Intersection status		x	x
ROW weather surface conditions		x	x
Other mode schedules and status		x	x
Special event data (schedules, demand)		x	x
Emergency Command Center Ops.		x	x

X = Part of Current TODSS Core, x = Desirable but not part of Core

1. Extra board, time on, work rules
2. Transit Police, Public Safetey (Fare, Ambulance, EMS), Maintenance, Supervisors)
3. Accidents, work zones, road closures, direction

As discussed in Section 4, 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. These are shown in Table 5-1. Note, that these include both "dynamic"[6] real time information from system monitors (e.g. AVL, APC, vehicle & equipment status, alarms, etc.) as well as information from other "static"[7] internal agency databases (e.g. GIS, schedule, vehicle/block, driver run, driver availability, and historical performance and ridership data, etc.).

The requirements for sources of information are:

SI 1 Core TODSS shall have the ability to interface with the core TODSS sources of information highlighted in Table 5-1

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

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[8]

SI 3.1 Core TODSS shall have the capability to obtain information from each of the "Transit Agency Static 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)

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[9]

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[6] "Dynamic" with respect to Core TODSS refers to sources of information that may change during a 24 hour period of operations (i.e. during a vehicle's block or vehicle assignment).

[7] "Static" with respect to Core TODSS refers to sources of information that are updated daily or less frequently (i.e. daily, weekly, monthly, quarterly, or on an ad-hoc basis).

[8] 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).

[9] 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.

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 (SD.x.x in Section 5.2) and Provision of Service Restoration Options (SR.x.x in Section 5.3) requirements

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.

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.

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

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)

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

SI 6.1 Core TODSS shall have the 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.

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

SI 8 Core TODSS design shall provide for modular implementation and incorporation of each Core source of information shown in Table 5-1

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 5-2 and Table 5-3)

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 5-2 and Table 5-3)

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

5.2 Identification and Notification of Service Disruptions

To review, 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. Table 5-2 provides the service disruptions and the inputs required to identify them. The service disruptions are further described in Appendix 2. Different parameters (disruption thresholds, prioritization criteria, and response rules) are entered into the TODSS based upon the service standards and policies defined by the agency for each operational scenario. The TODSS then collects data to determine which operational scenario applies, and identify and prioritize any service disruptions that occur. It then filters, sorts, and displays the disruptions to the dispatch center (or others as called for by the response rules) and begins the analysis for determining the recommended service restoration strategies. This section provides the functional requirements for the service disruption identification and notification. The requirements for determining the potential responses are described in Section 4.3. Note that the functional requirements do not specify where in the system the identification of service disruptions occurs. For example, it may take place either on the vehicle, at the dispatch station, or within the central server.

The requirements for identification and prioritization of service disruptions are:

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.

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)

SD 1.2 Core TODSS shall also provide the ability for dispatch to directly set the operational scenario

SD 1.3 System parameters for each operational scenario shall include: service disruption and other thresholds; prioritization criteria; and a response rules base

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

SD.1.4.1. Core TODSS shall provide for entry of service changes due to release of a published schedule, or operator signup

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

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

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".)

Table 5-2 Inputs Required to Identify Service Disruptions

	Transit Inputs for Identification											
Service Disruptions	GIS Data (Street, Route, Stop, Time Point)	Transit Schedule	Vehicle/Block Data	Driver/Run Data	Time Stamped Location: revenue vehicle	Driver Initiated Data Messages	Voice Messages	Silent Alarm/Security	Automatic Passenger Count	Vehicle & Equipment Status	Detection Thresholds	Other External Data Source
Schedule: Vehicles are either too early or late based upon thresholds												
Vehicle Early	X	X	X		X						X	
Vehicle Late	X	X	X		X						X	
Route Early	X	X	X		X						X	
Route Late	X	X	X		X						X	
System/Corridor Late	X	X	X		X						X	
Vehicles through time point early	X	X	X		X						X	
Vehicles through time point late	X	X	X		X						X	
Missing / late logon		X	X	X		X					X	
Headway: Vehicles are gapping and bunching along route, at a specific point, or along segment												
At point location (time point)	X	X	X		X						X	
Along Route (Distance based)	X		X		X						X	
Coordinated (shared segment)	X	X	X		X						X	
Passenger Load: Passenger loads exceed thresholds (from APC or MDT)												
Automatic Vehicle Overload			X						X		X	
Manual Vehicle Overload			X			X						
Route overload			X						X		X	
Off Route: Vehicle leaves route												
Notified			X			X						
Detected by System	X		X		X						X	
Vehicle Performance: Vehicle is incapacitated or crippled												
Mechanical Breakdown			X							X	X	
Mechanical Malfunction			X							X	X	
Accident			X			X						X
Driver Incident: Driver sick, incapacitated/emergency, inappropropriate performance												
			X	X		X						
Passenger Incident: Passenger sick, incapacitation/emergency, inappriopriate behavior, crime												
			X			X						
Emergency Alarm: Emergency alarm on vehicle is activated												
			X			X	X	X				
Connection Protection: Request for unscheduled transfer, or scheduled daily connection												
Passenger Requested	X	X	X		X	X					X	X
System Managed	X	X	X		X						X	
Communication Status (on/off): Loss of communications with vehicle for unknown reason												
No Data Transmissions										X	X	
No Contact at All										X	X	
External Event: Notification of event from outside source.												
External Event							X					X

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

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

SD 3.1 Core TODSS shall provide the ability to calculate thresholds using arithmetic, logical, and Boolean operators

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

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)

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

SD 5 Core TODSS shall trace the impacts of an event/disruption across the network to other fixed route service within the system

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

SD 6.1 Core TODSS shall provide the capability to set thresholds for event tracking

SD 6.2 Core TODSS shall provide the capability to toggle event tracking at any point in time

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

SD 6.4 Core TODSS shall have the ability to set additional thresholds for determining the end of the event and conclusion of tracking.

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

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.

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

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

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

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)

SD 7.2 Core TODSS shall provide the ability to calculate priority levels using arithmetic, logical, and Boolean operators

SD 8 Core TODSS shall provide the ability to display a summary of current and historic system status upon request

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

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

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

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

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 9.1 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

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

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

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

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).

SD.9.1.5. [Desired but not required] The 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)

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

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

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

SD.9.2.2. Core TODSS shall provide the capability to display tables of prioritized service disruptions and events for both current and estimated/predicted conditions

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

SD.9.3.1. Core TODSS shall provide the capability to filter the service shown by type of service, route, corridor, and sub-area.

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 10.1 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 (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

SD 10.3 Core TODSS shall provide the capability for the user to control the colors used to display information on any screen

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

5.3 Provision of Service Restoration Options

A service restoration strategy is a response to a service disruption designed to restore service to scheduled or planned contingency levels for a given operational scenario. (i.e. what you restore to depends upon conditions: a snow day may be different from regular day). The service disruptions are further described in Appendix 2. Table 5-2 provides potential service restoration strategies and the inputs required to identify them. Table 5-4 provides the potential service restoration strategies for each type of service disruption. Once the service disruptions are identified and prioritized the TODSS determines potential feasible restoration strategies, propagates their impacts, prioritizes them, and then provides options for dispatch to consider. The TODSS also assists in executing the chosen restoration strategy once it is made by sending additional notifications, or other actions. Additional information may be required to analyze the potential restoration strategies, determine their feasibility and provide a set of options that the dispatcher can choose from. This section provides the core functional requirements for the provision of the service restoration options.

The requirements for identification and recommendation of service restoration strategies are:

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

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

SR 3 Core TODSS shall have the ability to determine for each service disruption type shown in Table 5-4 the set of potential service restoration strategies as also identified in Table 5-4

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

Table 5-3 Inputs Required To Identify Service Restoration Strategies

	Transit inputs for analysis and implementation																	Other Sources							
Potential Strategy	GIS Data (Street, Route, Stop, Time Point)	Transit Schedule	Vehicle/Block Data	Driver/Run Data	Operator Availability[4]	Vehicle Availability (Extra board)	Time Stamped Location: Flagged rev. vehicle	Time Stamped Location: Other rev, vehicles	Time Stamped Location: Potential responders[2]	Driver Initiated Data Messages	Voice Messages	Silent Alarm/Security	Automatic Passenger Count	Vehicle & Equipment Status	Historical Passenger data (ons/offs/transfers)	Historical System Performance	Response Thresholds	Traffic volumes & speeds	Traffic signal phase and status	Network Status[3]	Highway/Rail Intersection status	ROW weather surface conditions	Other mode schedules and status	Special event data (schedules, demand)	Emergency Command Center Ops.
Adjust Travel Time																									
Selective Hold	1	1	1				1	2					2		3	2		3		3	3	3	2		
Speed Control (along route)	1	1	1				1	2								2		3		3	3	3			
Signal Prioritization[1]	1	1	1				1	2					3		3	2		1	1	3	3	3			
Schedule shift	1	1	1				1	2								2		3		3	3	3	3		
Adjust Travel Time & Passenger Access/Egress																									
Egress Only	1	1	1				1	2					1		2	2		3		3	3	3			
Express along route	1	1	1				1	2					1		1	2		3		3	3	3			
Deadhead	1	1	1				1	1					1		1	2		3		3	3	3			
Passing		1	1				1	1					1		2	3		3		3	3	3			
Short Turn		1	1				1	1					1		2	3		3		3	3	3			
Adjust Travel Time, Passenger Access/Egress, Route																									
Re-Route	1	1	1				1	2	4	4	4		1		1	3	1	2		2	2	2		3	3
Express re-route	1	1	1				1	2	4	4	4		1		1	3	1	2		2	2	2		3	3
Additional Driver																									
Provide driver relief	1	1	1				1		1	2	3							3		3	3	3			
Additional Vehicle																									
Insert/Replace vehicle																									
From barn	1	1	1	1	1	1	1			4	4	3		2			1	2		2	2	2		3	3
From standby location	1	1	1	1	1	1	1		1	4	4	3		2			1	2		2	2	2		3	3
From other in service route	1	1	1	1	1	1	1	1		4	4	3	1	2	1		1	2		2	2	2		3	3
From other out of service route	1	1	1	1	1	1	1	1		4	4	3		2			1	2		2	2	2		3	3
Relay Vehicle																									
From barn	1	1	1	1	1	1	1			4	4	3		2			1	2		2	2	2		3	3
From standby location	1	1	1	1	1	1	1		1	4	4	3		2			1	2		2	2	2		3	3
From other in service route	1	1	1	1	1	1	1	1		4	4	3	1	2	1		1	2		2	2	2		3	3
From other out of service route	1	1	1	1	1	1	1	1		4	4	3		2			1	2		2	2	2		3	3
Field Support																									
Transit Police	1								1	2	3	1						2		2	3			3	3
Public Safety	1								1	2	3	1						2		2	3			3	3
Maintenance Crew	1								1	2	3			1				2		2	3			3	3
Supervisor	1								1	2	3	2						2		2	3			3	3
NoAction																									
Monitor	1	1	1	2				1		2	3	2													

1. Note: Transit Signal Priority requires inputs and communications to the traffic signal system. This is not part of the Core Inputs and interfaces.
2. Transit Police, Public Safety (Fire, Ambulance, EMS), Maintenance, Supervisors
3. Accidents, work zones, road closures, direction
4. Exra board, time on, work rules

1 = Necessary; 2 = Desirable but not required; 3 = Useful, or in rare cases needed; 4 = When other data not available

Table 5-4 Service Disruptions by Potential Restoration Strategies

	Service Restoration Strategies																																	
Service Disruptions	**Adjust Travel Time**	Selective Hold	Speed Control (along route)	Signal Prioritization	Schedule shift	**Adjust Travel Time & Passenger Access/Egress**	Egress Only	Express along route	Deadhead	Passing	Short Turn	**Adjust Travel Time, Passenger Access/Egress, Rou**	Re-Route	Express re-route	**Additional Driver**	Provide driver relief	**Additional Vehicle**	Insert/Replace vehicle	*From barn*	*From standby location*	*From other in service route*	*From other out of service route*	Relay Vehicle	*From barn*	*From standby location*	*From other route*	*From other out of service route*	**Field Support**	Transit Police	Public Safety	Maintenance Crew	Supervisor	**No Action**	Monitor
Schedule: Vehicles are either too early or late based upon thresholds																																		
Vehicle Early		1	1																															3
Vehicle Late				1	1			2	3	3	2		3	3					1	1	3	2		1	1	3	2							
Route Early		1	1																															
Route Late			1	1	2			2	3		2		3	3					1	1	3	2		1	1	3	2							
System/Corridor Late					1			3	3		3								2	2	2	2		2	2	2	2							
Vehicles through time point early		2	1																															3
Vehicles through time point late			1	1	2			2	3		3		3	3					2	2	3	2		3	3	3	3							
Missing / late logon																1			2	2		3										1		2
Headway: Vehicles are gapping and bunching along route, at a specific point, or along segment																																		
At point location (time point)		1	1		2		2	2	2	2	2																					2		
Along Route (Distance based)		1	1	2			2	2	2	2	2																							
Coordinated (shared segment)		1	1		2		2	2	2	2	2																							
Passenger Load: Passenger loads exceed thresholds (from APC or MDT)																																		
Automatic Vehicle Overload							1	1	1	1									1	1	3	2												
Manual Vehicle Overload							1	1	1	1									1	1	3	2												
Route overload							2	3		3									1	1	3	2										2		
Off Route: Vehicle leaves route																																		
Notified (approved)					1				1				1	1					2	2	3	2							3	2		1		2
Detected by System					1				1				1	1					1	1	3	2		1	1	1	1		1	2		1		1
Vehicle Performance: Vehicle is incapacitated or crippled																																		
Mechanical Breakdown					2				2				1	1					1	1	3	2									1	1		
Mechanical Malfunction					2		2	3	2				1	1					1	1	3	2									1	1		3
Accident					2			3	2				1	1					1	1	3	2							1	1	2	1		
Driver Incident: Driver sick, incapacitated/emergency, inappropropriate performance																																		
Driver Incident							2		2							1			2	2	3	2							2	2		1		
Passenger Incident: Passenger sick, incapacitation/emergency, inappriopriate behavior, crime																																		
Passenger Incident									2		3		2	2					1	1	3	2		2	2	3	2		1	1		1		
Emergency Alarm: Emergency alarm on vehicle is activated																																		
Emergency Alarm									1				1	1					1	1	3	2							1	1		1		
Connection Protection: Request for unscheduled transfer, or scheduled daily connection																																		
Passenger Requested		1	2	2				1						3																				
System Managed		1	2	2				1						3																		2		
Communication Status (on/off): Loss of communications with vehicle for unknown reason																																		
No Data Transmissions																															2	1		2
No Contact at All																			3	3	3	3							1			1		2
External Event: Notification of event from outside source. Event may have direct impact on service or request transit assist																																		
Event Notification					2				2		2		1	1					1	1	3	2							1	1		1		2

1 = Common practice, likely response

2 = Used by some agencies, in some situations

3 = May be applicable in certain situations

SR 5 Core TODSS shall verify the feasibility of all potential restoration strategies based upon the available sources of information

SR 5.1 Core TODSS shall provide feasible options

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).

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

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)

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

SR 7 Core TODSS shall provide the ability to prioritize all feasible service restoration strategies.

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)

SR 7.2 Core TODSS shall provide the ability to calculate priority levels using arithmetic, logical, and Boolean operators

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

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)

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

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)

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

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

5.4 General System Requirements For TODSS[10]

While not directly related to identifying service disruptions or providing options for service restoration these general system requirements have been identified as important elements to: ensure consistency with the overall U.S. DOT ITS program; assist in risk management concerns (liability, privacy, security); and provide a base for future expansion and integration of additional ITS components.

The general system requirements are:

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

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

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

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

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)

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

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

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[10] Overall Functional Requirements within the TODSS that incorporates service disruption identification and provision of options for service restoration.

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

GS 5 Core TODSS shall have an open system architecture and provide for interoperability, interconnectivity, portability and scalability across various hardware platforms and networks

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)

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

GS 7.1 System design shall include the separation of hardware interface modules from other software modules

GS 7.2 Logic and data shall be separated into distinct modules

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

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

GS 9 Core TODSS shall provide for identification and notification of the failure of key components of the system or its core information sources

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)

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

GS 11.1 If implemented, replay shall recreate the exact system conditions that occurred over the selected time interval

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

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

GS 12 Core TODSS shall provide multi-level password protected access control through logon and logoff procedures for all terminals, monitors, and data ports.

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

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

GS 13 Core TODSS shall also provide the capability to archive information for use in performance monitoring, route and schedule planning, and subsequent operational analyses

6. ADDITIONAL COMMENTS

The TODSS effort to date has carried out a needs analysis (Section 2), defined a concept of operations (Section 3), and provided high level functional specifications for a "core" TODSS that includes identification of service disruptions and provision of options for service recovery (Section 4). However, currently no known installed system in the country now has service restoration functions in operation, and the implementation of the "core" functions has not been tested.

To date, the TODSS effort has focused on defining the core TODSS requirements for a single agency's fixed route bus service that uses the information generated, owned and controlled by the agency (e.g. AVL, APC, scheduling and runcutting, payroll, historical system performance, etc.). This was done intentionally to ensure that the initial set of core requirements: could be implemented by both vendors and agencies; and once proven, also provide a sound base for future extensions.

Several potential extensions have been identified as the initial set of core requirements were being developed. These include:

- Additional inputs from non-transit sources to help identify service disruptions and determine appropriate service restoration strategies.
  - Incident and emergency management center information.
  - Traffic volumes and speeds
  - Traffic signal phase and status information
  - Roadway status and closures and delays due to incidents, accidents, work zones, special events, or simple congestion
  - Highway/Rail Intersection status
  - Right-of-way weather surface conditions, and general weather information
  - Special event data (schedules and demand)
  - Other transit agency and mode schedules and status
- Integration of additional modes (both within and between agencies). This is especially important for providing connection protection, and improving overall system mobility.
  - Paratransit
  - Bus Rapid Transit
  - Urban rail transit (heavy and light)
  - Intercity and commuter rail
  - Intermodal terminal parking and other information (e.g. airports, ferries)
  - Connections to traffic management centers (see above)
- Integration of other ITS Transit services that were not required for identification of service disruptions or provision of potential service restoration options:
  - Passenger information systems. (511 systems, en-route kiosks, next bus, vehicle enunciators, 511, itinerary planning)
  - Electronic payment
- New features and functions enabled by the integrated TODSS system:
  - Predicting system impacts of restoration strategies and future network status through simulation or other techniques
  - Increased ability to identify when service should return to normal operations
  - Route deviation

- Real time passenger requested connection protection
- Dynamic itinerary planning (adjusting service to meet passenger requests)

How and when to consider these potential extensions will be addressed as we learn more from Core TODSS implementations.

REFERENCES

1. Gonzales, P., 2002, "Building Quality Intelligent Transportation Systems Through Systems Engineering", Mitretek Systems Inc. for U.S. DOT ITS Joint Program Office, Report FHWA-OP-02-046, Washington D.C.
2. Gonzales, P, Fowler T, 2002, "Developing Functional Requirements For ITS Projects", Mitretek Systems Inc. for U.S. DOT ITS Joint Program Office, Report FHWA-OP-02-047, Washington D.C.

APPENDIX 1: TRANSIT AGENCY AND VENDOR PERSPECTIVES ON TODSS NEEDS

Table APP - 1 Transit Agency and Vendor Perspectives on TODSS Needs

Transit Agency Needs	Relative Priority	Vendor Comments
Headway Based Service (Routine Operations)	High	
• Identify service irregularities (bus bunching, gaps)	High	Some European operations management systems can identify service irregularities for headway based service. Gapping and bunching on a particular route was shown on a “race track” by some systems 10 years ago.
• Variable thresholds by route/service type	High	No disagreement
• Determine cause(s) of problem using transit information sources	Medium	No disagreement
• Determine cause(s) of problem using other information sources (e.g., traffic, weather data)	Low	No disagreement
• Provision of recommended corrective actions o Short turns o Run express or egress only o Extra vehicle insertion (from barn, or stationed in field) o Selective Holding o Transit priority	High	No disagreement
Schedule Based Service (Routine Operations)	**Medium**	
• Identify vehicles NOT on time (running hot, late)	High	Most operations management systems today meet this need.
• Variable thresholds by route/service type	High	Most operations management systems today meet this need.
• Determine cause(s) of problem using transit information sources	Medium	Agree
• Determine cause(s) of problem using other information sources (e.g., traffic, weather data)	Low	Agree
• Provision of recommended corrective actions o Short turns o Run express or egress only o Extra vehicle insertion (from barn, or stationed in field) o Selective holding o Transit priority	High	Agree

Transit Agency Needs	Relative Priority	Vendor Comments
Incident/Emergency Event Service Disruption	**Medium**	**Decision support for incident/emergency events are immature.**
• Identification of event – transit related (includes vehicle monitoring)	High	AVL systems can identify that an accident has occurred.
• Identification of event – other sources (traffic, weather, EMS)	Medium	Event identification is dependent on the data received (see the following comment).
• Emergency response notification to appropriate entities (transit, public safety)	Medium	Emergency response notification to appropriate entities is highly dependent on the data received and on the operating procedures of agencies.
• Determination of impact on service throughout system	Medium	No disagreement
• Provision of recommended corrective actions o Above recommended actions o Diversion/detour o Supervisor location and dispatch to scene	High	Recommended corrective actions should be provided if an accident occurs on a route. Routing around incidents is currently being accomplished for automobiles.
Connection Protection (Transfers)	**High**	
• Scheduled transfer connections	High	Connection protection for designated scheduled transfer points is fairly easy to accomplish.
• Identification of potentially missed transfers (non-scheduled transfer connections)	Medium	Connection protection for non-scheduled transfers and transfers at undesignated transfer locations (e.g., between non-intersecting routes) is difficult to accomplish. Challenges may be overcome with reasonable effort, however.
• Real time requests for transfer connections	Low	Real-time requests for transfer connections can be satisfied for small transit systems. It is much more difficult to accomplish for large transit systems.
• Determine cause(s) of problem using transit information sources	Medium	No disagreement
• Determine cause(s) of problem using other information sources (e.g., traffic, weather data)	Low	No disagreement
• Interface with other transit modes - rail	High	No disagreement
• Interface with other transit modes - paratransit	Low	No disagreement

Transit Agency Needs	Relative Priority	Vendor Comments
• Provision of corrective Actions o Apply hold strategy thresholds by service type, passenger loads, and requests (high) o Calculate service impact on overall transit network (medium) o Provide targeted communication to support coordination (operator to operator, dispatch to selected routes) (high)	High	Some ability to trace impacts beyond the transfer point already exists in operations management systems.
• Ability to turn connection protection function on and off	High	No disagreement
Overall System Needs/Issues		
• Prioritization of problems that have been identified across system	High	No disagreement
• Prioritization of recommended solutions that have been identified across systems	High	No disagreement
• Prediction of system impacts of problems as they occur	Medium	No disagreement
• Prediction of system impacts of recommended solutions	Medium	No disagreement
• Two way communication of information and actions between dispatch, field supervisors, and operators (hierarchy depends on operating rules and organizational structure) with a mechanism for dispatcher control of bus-to-bus voice communications	High	Bus-to-bus data communications is common, but bus-to-bus voice communications is not. Basic AVL/CAD systems provide full communications capabilities to street supervisors but the feature may not be activated. There are multiple ways of accomplishing the communications issue.
• Projection of emerging problems using lead indicators and pre-conditions, and provision of recommended correction actions	Low	No disagreement
• Integration of system with other modes and ITS components	Medium	No disagreement
• Understandable display of all of the above in dispatch centers and field supervisor stations based upon human factors analysis to avoid information overload under all conditions	High	Some customization of the operations management system interface is warranted; however, some standardization is advisable (e.g., color coding). Research should be conducted on the best practices for screen displays and/or on the human factors of interfaces.
• User defined reports and data screens	High	Crystal Reports can be used to create customized reports. This need can be addressed through training.

Transit Agency Needs	Relative Priority	Vendor Comments
• Software security/risk (e.g., source code in escrow, bonding)	Low	Transit agencies can and do have software / source code security agreements with vendors. Vendors agreed with the low priority ranking.
• Modular multi platform implementation of all functions	Required	Delete "multi-platform" -- providing a multi-platform system is not feasible. Vendors disagreed with the "required" priority ranking. Vendors agreed with the modular and phased implementation need.
Project Needs/Requirements		
•		
• Support innovative procurement o Example specifications o Use of system integrators o Pooled fund and/or consortium for system development	Medium	No disagreement
• Public private partnership (transit agencies, vendors, federal government)	Required	No disagreement
• Incremental and modular development of system	Required	No disagreement
• Use of NTCIP (including TCIP, TSP, Transit Vehicle Bus, and others) standards: i.e., data definition and open architecture	Required	No disagreement, but vendors stated that transit agencies need to more clearly specify in requisitions how to comply with the TCIP standard.
• Address maintenance and how to avoid obsolesce of operations management systems as part of project	Medium	No disagreement
• Support peer-to-peer sharing of information and requirements among transit agencies	Medium	No disagreement
• Support education of all staff (not just dispatchers) in use and benefits of operations management system functions	Medium	No disagreement
• Work through the APTA/ITSA committees	High	No disagreement

APPENDIX 2: CORE SERVICE DISRUPTION DESCRIPTIONS

Table APP - 2 Service Disruption Descriptions

Service Disruptions	Description
Schedule: Vehicles are either too early or late based upon thresholds	
Vehicle Early	Vehicle on trip arrives and departs from time point prior to scheduled time. In some systems a prediction that vehicle will arrive and depart early from next (or next n) time points will also be classified as a potential disruption. Likewise, being early at egress only stops (time points) may not be considered a disruption.
Vehicle Late	Vehicle on trip arrives and departs from time point X minutes later than scheduled time. Threshold X is determined by service policies and may vary by route type, transfer connections, time of day, etc. In some systems a prediction that vehicle will arrive and depart late from next (or next n) time points will also be classified as a potential disruption.
Route Early	X% of trips on route are running early as defined above.
Route Late	X% of trips on route are running late as defined above.
System/Corridor Late	X% of trips in system, corridor, or sub-area are running late as defined above. Will often trigger a special scenario for service restoration.
Vehicles through time point early	X% of trips through specific time point or transfer location are running early as defined above. May want to flag first time point on route where this occurs.
Vehicles through time point late	X% of trips through specific time point or transfer location are running late as defined above. May want to flag first time point on route where this occurs.
Missing / late logon	Operator does not log on to system, or is X minutes late logging on to system, and starting run or block
Headway: Vehicles are gapping and bunching along route, at a specific point, or along segment	
At point location (time point)	Interval between trips at a specific time point for a route is +/- X minutes from scheduled (or planned) interval.
Along Route (Distance based)	Y% of intervals between vehicles on a route are +/- X minutes from scheduled (or planned) interval. May also be defined by standard deviation of intervals between trips.
Coordinated (shared segment)	Y% of intervals between vehicles (multiple routes) on road/right-of-way segment are +/- X minutes from scheduled (or planned) intervals. Often may cause congestion and additional delays at stops and/or transit center and stations.
Passenger Load: Passenger loads exceed thresholds (from APC or MDT)	

Service Disruptions	Description
Automatic Vehicle Overload	APC observation that passenger load for an individual vehicle exceeds service policy loading standards for scenario (time of day, type of service, external conditions). Loading standards can be based upon seated, standing (seated + standing), or short duration "crush" loads (seated + maximum standing). Separate standards may also exist for special service customers (e.g wheelchair, bikes)
Manual Vehicle Overload	Operator notification that individual vehicle is overloaded at specific point in time, and direction (a trip, or run). Notification, can be through MDT as canned message, or by voice.
Route overload	X % of vehicles on route (or corridor) exceed loading standards (i.e. thresholds)
Off Route: Vehicle leaves route	
Notified	Operator notifies dispatch center that vehicle is leaving pre-determined route. Diversion may be to pick up/drop off passengers, avoid congestion or blockage, or for some other reason. Some systems will also flag temporary scheduled diversions from normal route as a Off Route Disruption. These are not considered service disruptions for the purposes of TODSS and real time dispatch response. Service Policies may require non-emergency diversion to be approved by dispatch. If external or other events cause emergency diversion then this would also trigger actions under appropriate scenario.
Detected by System	Vehicle location is detected to be off route by AVL/GPS system. There has been no notification or approval for the diversion.
Vehicle Performance: Vehicle is incapacitated or crippled	
Mechanical Breakdown	Vehicle or equipment out of service at a specific location. May need additional information to determine if service can continue for trip or block and initiate proper response. In some systems vehicle maintenance sensors may signal impending breakdown.
Mechanical Malfunction	Vehicle or equipment malfunctioning, but can continue limited operation. May need additional information to determine if service can continue for trip or block and initiate proper response. In some systems vehicle maintenance sensors may signal impending malfunction.
Accident	Transit vehicle is involved in an accident. Will need additional information to determine type of incident and appropriate response.
Driver Incident: Driver sick, incapacitated/emergency, inappropriate performance	
Driver Incident	Operator incapacitation or emergency (Sudden sickness) that may cause the need to replace or assist at specific location or layover point. Vehicle is not malfunctioning.
Passenger Incident: Passenger sick, incapacitation/emergency, inappropriate behavior, crime	
Passenger Incident	Passenger incapacitation, emergency, or behavior (e.g. rowdiness, criminal, sleeping) that may require emergency assistance to passenger or operator. May cause vehicle to remain stationary. Will likely require additional information to initiate response.
Emergency Alarm: Emergency alarm on vehicle is activated	

Service Disruptions	Description
Emergency Alarm	Alarm indicating emergency or event is occurring on the vehicle. May be silent covert alarm requiring no audio communication, or an overt alarm. Will most likely require additional information to initiate a response.
Connection Protection: Request for unscheduled transfer, or scheduled daily connection	
Passenger Requested	Request by passenger for specific transfer was not successfully made. In some systems the request itself becomes an event that requires dispatch action/decision and disruption occurs when the missed connection is anticipated.
System Managed	Pre-defined connection at location between scheduled trips does not occur. In some systems a disruption is identified when the missed connection is anticipated.
Communication Status (on/off): Loss of communications with vehicle for unknown reason	
No Data Transmissions	When polled there is no response or signal from onboard communications equipment for MDT, or other component (AVL, APC, Fare payment, Maintenance sensors, surveillance equipment.). Voice communications may still exist
No Contact at All	Contact with vehicle is lost entirely.
External Event: Notification of event from outside source.	
External Event	Transit agency is notified of an external event that impacts service or requires a response. This may be a non-transit related accident or road/right-of-way blockage that will cause delay or require detour, weather related information, special event information, fire, explosion, or other event. Response is determined by appropriate policy scenario and may be needed to either restore service or provide emergency assistance.

APPENDIX 3: CORE RESTORATION STRATEGY DESCRIPTIONS

Table APP - 3 Restoration Strategy Descriptions

Potential Strategy	Description	Application
Adjust Travel Time		
Selective Hold	Hold vehicles at specified stations to adjust frequency, spacing, or accommodate connection.	Useful for both headway and schedule based service. Depends upon passenger loading and location along route.
Speed Control (along route)	Direct vehicle to slow down/speed up along its route	Very useful for headway based service. Also may be used for schedule based service. Requires constant monitoring of driver performance along route. Also used in Chicago to "speed up" vehicles prior to known blockage so they may exit the blockage on schedule. This may only be valid for frequent headway service.
Signal Prioritization	Provide signal priority to minimize delay at intersections	Useful for schedule based service. Need to account for its impacts on overall traffic operations.
Schedule shift	Shift schedules of all vehicles on route (and intersecting routes if needed)	Applicable under system-wide and special events (weather, flooding, parade, protest, etc.). Simply adjusts operations to reflect conditions. Should be based upon predetermined service policies and procedures for these unusual scenarios.
Adjust Travel Time & Passenger Access/Egress		
Egress Only	Vehicle stops at all stops along but only allows egress of passengers	Useful for both headway and schedule based service when overloading is occurring. Causes increased waiting time to passengers waiting to board at restricted stops.
Express along route	Vehicle with passengers skips stops along route	Useful for headway based service. May cause passengers to transfer to the following bus. May cause missed transfers at skipped stops.
Deadhead	Vehicle with no passengers runs closed door between stops	Often used to insert a new vehicle into the service along the route.
Passing	Direct trailing vehicle to pass lead vehicle. Vehicles exchange schedules.	Most often applicable in headway based service with bunching. May impact connection protection.
Short Turn	Turn back bus before it reaches the end of the line on its trip	Useful for both headway and schedule based service. Requires on board passengers to transfer to next bus and may cause them significant increases in time. May impact transfer connections.

Potential Strategy	Description	Application
Adjust Travel Time, Passenger Access/Egress, Route		
Re-Route	Vehicle with passengers diverted to new path between scheduled stops	Useful when an incident or blockage must be avoided.
Express re-route	Vehicle with passengers diverted to new path causing it to skip stops	Useful when an incident or blockage must be avoided. May cause missed transfers at skipped stops.
Additional Driver		
Provide driver relief	Provide new driver for vehicle either through the extra board, or from vehicle going out of service.	May be needed if operator is incapacitated, or their continued operation will violate work rules. May need supervisor to get the new operator to the relief point, and take old one to required destination.
Additional Vehicle		
Insert/Replace vehicle	Put new vehicle in service either to replace a vehicle or to fill a gap	Use to replace disabled vehicle or operator, or fill gaps in service. May also be used to provide shuttle service to address external events (move rail passengers around blockage, evacuate area, respond to special event). If a vehicle is actually replaced, moving it to a secure location must be addressed. This may require maintenance staff, a tow truck, and/or a relief operator.
From barn	*Send vehicle from barn*	Above plus: Requires that extra vehicles and drivers be programmed into the system.
From standby location	*Send vehicle from standby location*	Above plus: Requires that extra vehicles and drivers be programmed into the system. Need to pre-determine optimum standby locations.
From other in service route	*Re-direct in-service vehicle from another route*	Above plus: Requires tradeoffs between passengers on each route. May force transfers to existing riders.
From other out of service route	*Re-direct out-of-service vehicle from another route (split shift, dead heading, long layover)*	Above plus: May be limited by work rules.
Relay Vehicle	Extra vehicle meets delayed vehicle. The extra bus operates on the prescribed schedule until it meets the delayed bus on return trip. Drivers exchange places with original back on schedule. The relay driver finishes the trip and returns to base.	Very useful when driver is close to end of his run. Useful to problems that occur at a specific point in time afterwhich service returns to normal.
From barn	*Send vehicle from barn*	*Above plus: Requires that extra vehicles and drivers be programmed into the system.*

Potential Strategy	Description	Application
From standby location	*Send vehicle from standby location*	*Above plus: Requires that extra vehicles and drivers be programmed into the system.*
From other in service route	*Re-direct in-service vehicle from another route*	*Above plus: Requires tradeoffs between passengers on each route. May force transfers to existing riders.*
From other out of service route	*Re-direct out-of-service vehicle from another route (split shift, dead heading, long layover)*	*Above plus: May be limited by work rules.*
Field Support		
Transit Police	Dispatch transit police to location.	Determined by operating policies.
Public Safety	Dispatch fire, ambulance, other EMS to location.	Determined by operating policies.
Maintenance Crew	Dispatch maintenance crew to location	Respond to disabled vehicle, or other equipment.
Supervisor	Dispatch supervisor to location	Determined by operating policies. Once at scene control may be transferred to supervisor
NoAction		
Monitor	Monitor the disruption with no dispatch action taken.	Determined by operating policies. Response may be constrained due to lack of resources, or unique circumstances. May still want to track condition to see if it gets better or worse.

APPENDIX 4: TODSS GLOSSARY

Table APP - 4 Transit Operations Decision Support Systems[11]

Term	Definition	TCIP business Area Origin
Acknowledge	The confirmation of a reported observation.	Incident Management
Amenities Desired	Lists the types of amenities desired on the trip, including stop point and vehicle amenities.	Passenger Information
Amenity	Features or aspects of public transportation vehicles or facilities.	Passenger Information
Base	[*Operator*] Describes a base from which operators receive their daily assignments. [*Vehicle*] Identifies the location where the transit vehicle is assigned; also known as garage.	Common Public Transportation
Block	See Vehicle Assignment.	Scheduling/ Runcutting
Block Group	A grouping of blocks based on some common characteristics such as use common corridor, terminus location or route direction name.	Scheduling/ Runcutting
Care Facility	A facility to which victims of an incident are taken.	Incident Management
Clear	The condition that occurs after an incident had been responded to and all roadway and transit services have returned to their normal operating conditions.	Incident Management
Delay	The amount of time that transit service is expected to deviate from scheduled service due to an incident.	Incident Management
Destination	The place to where the customer wishes to travel.	Passenger Information
Driver Activation	A specific request for a driver to take an action. This request is a type of event.	Scheduling/ Runcutting

[11] Definitions derived from Balloted TCIP standards unless otherwise noted.

Term	Definition	TCIP business Area Origin
Event	An incident, planned roadway (or right of way) closure, or special event. A report or observation from the field about a potential or existing incident. The source of an event may be an official or "verifying" source (e.g., a transit supervisor or response agency employee) or a "non-verifying" source (e.g., a public witness). An action which is activated at a specified time, location or both. Examples of these types of events include: announcements, changes to route and schedule adherence requirements, changes to variable message signs, request for a driver to take some action, notification of a change of a fare or radio zone, and notification of a change in operator (relief driver).	TMDD, Incident Management, Scheduling/Run cutting.
Inbound [communications]	Communications originating at the mobile radio unit and directed to the fixed end.	Control Center
Incident	An unforeseen situation which negatively impacts normal transit operations and is expected to require some response action to restore operations to normal. An incident may be "verified" or "unverified".	Incident Management
Incident Notification	An official report about a verified incident.	Incident Management
Intersection	The junction of more than one two-dimensional spatial features.	Spatial Representation
Master Schedule	A table that includes all the time points and trips on a route. Contained within the route description is the Master Schedule Header information.	Scheduling/ Runcutting
Master Schedule Header	Sequence of time point identifiers and/or their names used to define the order of time points for all the patterns. This field is used to build timetables, for exterior signs, etc.	Scheduling/ Runcutting
Message	A grouping of data elements, which encapsulate an idea, concept or thing, or convey information. A basic message encapsulates an idea, concept or thing, and a compound message embeds one or more basic messages and other data elements to convey information.	Framework

Term	Definition	TCIP business Area Origin
Mobile Unit	A unit associated with a vehicle operated by a public transportation service provider that may be used to identify the vehicle. For example, the identifier of a mobile radio unit assigned to a person or vehicle may be used to identify the assigned person or vehicle.	Control Center
Nearest Stop	The closest stop to a given location.	Passenger Information
Notification	Shorthand for "Incident Notification."	Incident Management
Operator Assignment	The daily pieces of work assigned to a transit employee.	Scheduling/ Runcutting
Organizational Unit	A division or group within a transit agency, for example, Operations, Communications, South Garage.	Scheduling/ Runcutting
Origin	The place from where the customer wishes to originate his/her travel itinerary.	Passenger Information
Outbound [communications]	Communications originating at the fixed end and directed to the mobile radio unit.	Control Center
Pattern	One of multiple outer route segments served by a single transit route.	Scheduling/ Runcutting
Piece of Work	A task or series of tasks that, when carried out, provide the basic components or building blocks of transit service delivery.	Scheduling/ Runcutting
Priority	The assignment of a value indicating the order in which incidents should be responded to.	Incident Management
Public Transportation /Transit Vehicle	Vehicles owned, leased or subcontracted by a public transit agency to support service provision.	Common Public Transportation Scheduling/ Runcutting
Published Schedule	The text of the all revenue service trips and time points provided in publicly released schedules (does not contain the formatting). The published schedule is a subset of the master schedule.	Passenger Information (revised)
Response	An action by a person or team from police, fire, medical, transit emergency services, transit maintenance, supervisors and/or others to a reported and confirmed incident.	Incident Management

Term	Definition	TCIP business Area Origin
Response Organization	The organization which sends out personnel to an incident site to respond to the incident. May include a transit agency.	Incident Management
Response Rules Base	A data store that defines appropriate procedures to be followed to respond and resolve a verified incident. The response rules may vary by type, severity, and other known attributes of the incident. An automated database, or "expert system," and written policies/procedures/guidelines are examples of an agency's Response Rules.	Incident Management
Roster	Daily operator assignments grouped into weekly assignment packages.	Scheduling/ Runcutting
Route	A collection of patterns in revenue service.	Scheduling/ Runcutting
Run	See Operator Assignment.	Scheduling/ Runcutting
Schedule Adherence	Schedule adherence refers to how closely a public transportation vehicle in revenue service is staying on the schedule it has been assigned to.	Passenger Information
Schedule Time	The time used to define a schedule day. A schedule day spans 48 hours in seconds [–43,2000, 129,599]; the day extends from noon the day before the schedule day until noon the following day.	Scheduling/ Runcutting
Service Disruption	Event where service provision falls outside agency service standard and policies and requires service restoration strategy decision	TODSS
Service Restoration Strategy	Response to an event designed to restore service to scheduled or planned contingency levels for a given scenario.	TODSS
Severity	The degree to which an incident requires emergency attention. High severity requires immediate attention.	Incident Management
Sign Message	Information displayed on a sign at the transit stop point.	Passenger Information
Source	The source of information and/or data about an observation or an incident.	Incident Management
Stop Point	A point where public transportation customers board or alight from a transit vehicle in revenue service.	Common Public Transportation Scheduling/ Runcutting

Term	Definition	TCIP business Area Origin
Stop Point Inventory	An inventory of the stop points (e.g., bus stops, station, terminal) owned, operated maintained and used by a transit agency.	Passenger Information
Time Point	A geographic location which a transit agency uses to schedule transit service and monitor adherence to the service schedule. It is a point at which time is assigned to create trips.	Scheduling/ Runcutting
Threshold	Value of a measure that triggers an action. Can be set at different decision points (e.g. detection, tracking, display, action, and reporting	TODSS
Transfer Cluster	A collection of stop points wherein transfer between routes is accessible and convenient (valid and possible).	Common Public Transportation Scheduling/ Runcutting
Traveler Profile	Describes the customer information related to the transit customer.	Passenger Information
Trip	A one-way movement of a transit vehicle in revenue service between two points.	Scheduling/ Runcutting
Trip Alternative	A recommended customer trip generated by a transit trip itinerary planning engine.	Passenger Information
Trip Constraint	Limitations or preferences identified by a customer or service related to a trip itinerary including cost, time, mode, challenges, etc.	Passenger Information
Trip Itinerary	A plan of the route, stop points, and modes of a proposed trip.	Passenger Information
Trip Request	Lists customer request for an itinerary on a transit vehicle.	Passenger Information
Trip Time Point	A specific time assigned to a timepoint on a trip.	Scheduling/ Runcutting
Vehicle Area Network	A data communications network that is installed on a public transit vehicle. The network supports data exchange between various control center systems. Similar to a Local Area Network (LAN) in an office, a vehicle area network supports data communications primarily in a transit vehicle.	Control Center Vehicle On-board
Vehicle Assignment	The work of a vehicle from the time it leaves the vehicle base until its next return.	Scheduling/ Runcutting

Term	Definition	TCIP business Area Origin
Vehicle Control Head	The primary human-machine interface for control, communications, display and status on the transit vehicle. Typically, the VCH is a device installed in a transit vehicle. It allows the driver of a transit vehicle to log in, to change head signs, and to communicate with transit management centers, etc.	Vehicle On-board
Verifier	A person or device that collects information or data that can be used to verify that an incident has occurred, including scope of the incident (e.g., numbers of people, vehicles, etc. involved).	Incident Management
Verify	The act of confirming the occurrence of an incident through gathering additional information and/or data about the reported events.	Incident Management