Title

Modernization of Center-to-Center Data Communication Standards: Gap Analysis Technical Memorandum

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Modernization of Center-to-Center Data Communication Standards
Task 3713 (65A0761)

Gap Analysis
Technical Memorandum

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Partners for Advanced Transportation Technology works with researchers, practitioners, and industry to implement transportation research and innovation, including products and services that improve the efficiency, safety, and security of the transportation system.

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1. INTRODUCTION

This document provides a gap analysis based on three previous technical memorandums delivered as part of this project, including a review of the Traffic Management Data Dictionary (TMDD) standard, a review of current and future transportation needs, and a review of the state of the art in technology and systems development. The intention of this document is to provide a review of this standard for transmission of data between traffic management centers (TMCs), with explicit commentary on usability of the standard with specific examples based on its implementation in the Caltrans I-210 Connected Corridors program.

The strategic objectives of this gap analysis are:

- Identify specific improvements for the TMDD specification
- Identify specific recommendations for implementation of TMDD compliant communications
- Improve the use of technology within the TMDD specification
- Allow for improved processes and ability to update the TMDD specification as transportation requirements and technology baselines change with time
- Prioritize actions and the recommendations for implementation within the standard
- Improve the usability of the TMDD specification

1.1. PURPOSE OF DOCUMENT

This document is prepared as a gap analysis, primarily using the current state, or as-is state, of the TMDD standard, and a review of future transportation needs and the state of technology as the desired state. In addition, the issues identified within the TMDD standard review are addressed within the desired state of the gap analysis.

The gap analysis is completed in order to identify and support specific recommendations for implementation in the proposed standard changes that will be developed in this project.

The document is intended to provide a basis for recommendations for improvement to the standard, along with three additional documents:

- TMDD Modernization Software and Systems Standards Recommendations Technical Memorandum
- TMDD Modernization Current and Future Transportation Management High Level Requirements Technical Memorandum
- TMDD Modernization TMDD Standards Review Technical Memorandum

Together, these documents, including this document are intended to form the basis of a set of proposed modifications to the standard.

1.2. INTENDED AUDIENCE

The primary audience for this document includes:

- The Caltrans Division of Research, Innovation, and System Information
- TMDD Steering Committee
- Caltrans Operations personnel involved in specifying, procuring, and implementation of systems requiring C2C communications
- Transportation systems vendor community

1.3. DOCUMENT ORGANIZATION

The remainder of this document is organized as follows:

- **Section 2** presents the approach and objectives of the gap analysis
- **Section 3** provides a summary of the analysis of the current and desired state for the standard, identified gaps, and recommendations
- **Section 4** provides a list of the recommended actions and assigns a priority to each action

2. GAP ANALYSIS OBJECTIVES AND APPROACH

2.1. OBJECTIVES

The objective of this analysis can be simply stated as follows:

Improve the Traffic Management Data Dictionary to:

a. Reduce future traffic and transportation management system deployments and integration costs
b. Support high availability, high volume, real-time communications required for support of future transportation advances
c. Achieve off-the-shelf system integration across jurisdictions and between multiple vendor systems with minimal implementation effort
d. Allow the standard to be flexible enough to adapt to future technology advances and remain relevant in an environment dominated by advances in transportation technology

2.2. APPROACH

The methodology of a gap analysis is to look at the current state of a defined topic or issue, define a desired future state for that topic, and define the gaps between the current state and the future state. The goal of a gap analysis is to allow organizations to identify and prioritize actions to address the gaps identified and to improve operations.

In general, gap analysis is a common analysis done by businesses, typically done with the goal of improving business performance. Again, looking at the current state, desired future state, and then identifying the gaps between those two states. The objective may be to improve production processes, market strategy, market penetration, unit productivity, review performance when missing Key Performance Indicators, or other specific business objectives. To accomplish this, there are many standard, proven methodologies and tools for conducting a gap analysis, such as the McKinsey 7s Framework, Nadler-Tushman Congruence Framework, PESTEL Framework, Fishbone Framework, and others. However, these methods are typically designed around business needs, objectives, and processes, not to address a technical specification. For instance, the seven S's identified within the McKinsey 7s Framework are structure, strategy, systems, shared vision, skills, style, and staff. However, the basic premise remains valid, and a basic model that breaks the analysis into three areas: technology, transportation, and the standard itself would be valuable. Other areas of analysis, such as looking at the current market for transportation solutions or government support for effective standardization could, and perhaps should be reviewed, but this analysis will not include those elements.

The approach for this gap analysis is to summarize the current state and desired state findings from the three previous technical memorandums and to then identify the gaps that exist between those two states.

3. ANALYSIS

Three areas have been examined in each of the three previous technical memorandums provided in this project. These areas include:

- Technology
- Transportation
- TMDD Specification and its Implementation

The analysis of these three areas described in each of the reports is summarized below, looking at the current state, a desired future state, and resulting insights from that analysis. In each area, the specifics of the analysis are directly tied to the implementation within the specification, thereby focusing on identifying gaps in the specification itself. Often times, the elements of this analysis cross boundaries between these areas. In some cases, we've put the elements within the area most relevant, in others, we've left the elements in both when the relevant insights might be slightly different, but informative.

3.1. TECHNOLOGY ANALYSIS

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
1	**Data transmission format is limited to XML.**	Data formats vary depending upon the intended usage and requirements of the information being exchanged.	Limiting the data representation to XML limits the technology options available for solution implementation and increases the amount of data needed to transmit any specific set of information. This results in increased network traffic, increased computational loads, increased operational costs, and decreased performance.	Need for additional transmission formats such as JSON, binary, or others.	Increased efficiency, performance, scalability of data transmitted. Improved transmission speeds. Improved ability to handle modern data transmission needs and large-scale real-time data requirements.	Change the TMDD standard to allow additional data transmission formats beyond XML. Create a list of recommended data formats and implementation guidance for each format.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
2	**SOAP is the only authorized method of data exchange. Alternatives are not readily available to take advantage of changes in technology.**	Data exchange and systems developed are allowed to improve along with improvements in technology. Implementations may take advantage of more advanced data transmission protocols and methods.	Data exchange limitations limit the usability of the standard in real-time, large scale implementations and severely limit its ability to address new requirements and opportunities as transportation itself evolves and becomes more technically advanced.	Need for additional data transmission technology options.	Increased efficiency, performance, scalability of data transmitted. Improved transmission speeds. Improved ability to handle modern data transmission needs and large-scale real-time data requirements.	Change the TMDD standard to allow for additional data transmission methods beyond SOAP. Create a list of recommended data transmission methods and implementation guidance for each.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
3	**High volume, real-time communications are not supported at scale.**	Data protocols and formats should be available for high volume, real-time communications.	Data transmission methods and protocols should be identified to support the scale required for future transportation projects at scales from local through national level programs. This should include methods for both low volume, large messages to real-time, high-volume messaging.	Need for newer data transmission standards and formats.	Improve transportation technology programs with additional capabilities and innovation.	Select appropriate technologies that will allow for scalable real-time, high volume communications for use with the standard.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
4	**Only one protocol, SOAP, is supported, regardless of the data transmission requirements. As a result, a mismatch between the capabilities of SOAP and the needs of the program can result.**	Data protocols and formats for data transmission should be selected based on the transmission size, volume, and speed requirements needed for a program or project.	Programs should be allowed to choose the correct format and protocol appropriate for the data transmission needs of the program. This may include a program choosing multiple formats or protocols to fit specific communication exchanges within the program.	Need for data transmission protocols, formats, and methods choices that can be selected to fit specific project requirements.	Improve flexibility within programs to meet data exchange requirements with the correct technology tools for the use case that exists.	Allow for the data transmission technology to be selected appropriate for each individual data exchange requirement. Separate the technology selections available from the data structure standards to allow choice and flexibility within the standard, even across different dialogs within any individual implementation.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
5	**Security requirements and guidance within the standard are limited.**	Security requirements are robust with specific guidance on practices and methods suitable for the technology currently available in the field.	Security has become a critical component of maintaining a modern technology infrastructure. Current transportation infrastructure security practices are still catching up with the change from isolated control systems to connected traffic management systems.	Need for security guidance and minimum requirements within the standard appropriate to the technology selections specified within the standard and maintained as security and technology standards are updated.	Lack of security guidance results in additional risk and potential for security incidents, including potential loss of control of traffic management assets. Significant risk currently exists for disruption to delivery of transportation infrastructure management services. Security implementation recommendations within communication standards would help to reduce this risk and impact of security incidents.	For the data exchange technology requirements or recommendations within the standard, provide recommendations or minimum requirements for security implementation, along with references to external security standards appropriate for implementation.

3.2. TRANSPORTATION ANALYSIS

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
6	**Data exchange volumes are limited in nature, due to the limited sizes of implementations, limited capabilities of local, regional, and state entities, and the type of information exchanged.**	TMCs will be able to take advantage of the advancement of technology, new data sources available, real-time data analysis capabilities, and the increased volume of data available.	The growth in sources and the volume of data they generate is growing significantly. New capabilities are being made available that will significantly increase the effectiveness of TMC operations at a time when past strategies of traffic management have been limited.	TMCs will need to modernize their information technology capabilities. This will necessitate the need for new methods of data exchange built for high-volume, real-time performance. TMDD must modernize to facilitate this need.	New data sources and new capabilities will be available for real-time analysis of traffic, new decision support capabilities, regional cooperative traffic management strategies, and big-data analysis of transportation management effectiveness at the federal, state, regional, and local levels.	Provide new methods of data exchange capable of scaling to real-time data exchange across large geographic areas and a large number of devices.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
7	**Data exchange is limited to legacy information sources (e.g. intersection signals, detectors, CCTV, ramps, etc.).**	Data exchange can be expanded to include new transportation elements, assets, and technologies. Data exchange will include information appropriate to the needs of transportation management centers (TMCs) to enhance TMC operational capabilities.	The amount of data available for management of TMC operations is expanding with the increase of devices and advances in both technology and transportation. Existing devices, such as signals and ramps, are becoming increasingly complex and no longer fit within the information exchange dataframes and elements described within TMDD.	There is a need for the standard to: 1. Add additional dialogs, messages, dataframes, and elements to accommodate the capabilities of more advanced transportation management devices. 2. Increase its flexibility and speed of change to adapt to new ideas and technologies as they are implemented in the field and TMCs.	There is significant risk that the standard will become obsolete and unusable. There is also risk that the implementations of data exchange that include data from more advanced devices or new data sources, utilizing the extension capabilities within the standard will be custom, vendor specific implementations, limiting the ability of jurisdictions and TMCs to communicate. Future implementation costs between TMCs with different vendor solutions will increase over time.	Increase the release cycle of the TMDD standard, incorporating experience of implementations that require new information sources and more advanced devices. Provide a more active method of review and incorporation of implementation specific extensions within the standard with the goal of adding them to the standard. Actively review the current standard requirements and advances in transportation technology, with the specific purpose of identifying and incorporating new user needs and requirements to prepare the standard for the future.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
8	**TMDD does not provide a method for TMCs to exchange TMC-to-traveler/public information communications outside of dynamic message sign messages and highway advisory radio (HAR).**	TMDD provides a method for TMCs to exchange their communications with the public executed in a variety of methods beyond signs and HAR.	Communications from TMCs to the traveling public and other agencies have many new opportunities for communication channels. Cooperation with third party communication providers is increasing for in-vehicle, web-based, and mobile communications. Coordinated traffic event and other TMC efforts require communications to be coordinated within a state or region.	TMDD needs to provide dialogs, messages, dataframes, and data elements to support public messaging in other communication channels beyond dynamic signs and HAR. These dialogs should be designed to ensure that the message and the delivery mechanism are abstracted to make them extendable to new delivery mechanisms as they become available.	Improved ability to share messaging and coordinate public messaging between TMCs.	Add dialogs, messages, dataframes, and data elements for exchange of public messaging activities.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
9	**TMDD does not provide a method for TMCs to exchange coordinated event response plans.**	TMCs can exchange and coordinate response plans and associated activities and provide review and approval of coordinated response plans.	Multiple jurisdictions are typically involved within a specific geographic area. Multi-modal response activities require coordination between modes and jurisdictions. Traffic and transportation management activities, in order to be more effective, require coordination across jurisdictions, participating parties, and transportation modes.	TMDD needs a set of dialogs, messages, dataframes, and data elements for exchanging information and coordinating activities between jurisdictions and within a multi-jurisdictional, multi-party environment.	Without the ability to exchange this information, TMCs are unable to coordinate activities within and across the information systems they use to manage traffic and transportation activities at their respective TMCs.	Add the dialogs and associated data structures developed by the I-210 Connected Corridors implementation for use in coordination of response plan and response plan approval activities. Review TMDD for additional needs related to other coordinating activities. Review TMDD for applicability within a multi-jurisdictional, multi-party environment.

3.3. SPECIFICATION/IMPLEMENTATION ANALYSIS

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
10	**TMDD is based on a two-party communication with a single sender and a single receiver. The message elements reflect a two-party communication as well. It does not truly reflect a message structure that supports a multi-party communication with a single sender and multiple receivers.**	TMDD supports a targeted broadcast communication where senders and all receivers are aware of all parties' participation in the communication.	Regional operations involving multiple jurisdictions, third-party participants, multiple modes of transportation, and in some future scenarios, individual travelers will require additional coordination where all parties are aware of the state of the communication and perhaps the resulting actions from that communication.	TMDD needs additional capabilities to support multi-party communications.	Changing to support multi-party communication will allow better coordination of multi-center and multi-party actions within a multi-jurisdictional environment.	Select multi-point broadcast communication technologies along with updates to the data structure to support multi-party communications. Alternatively, hub/spoke system architectures should be recommended within the standard.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
11	**No guidance is provided for populating organization information, including uniqueness of organization identifiers. There is no standardization to ensure unique identifiers for organizations or their assets.**	Organizations may participate in multiple transportation information exchange networks without modification to their information systems or transformation of the data they exchange.	Standardization and uniqueness of organization and other identifiers within data exchanged is critical to operation of information exchange networks. Without such standardization, significantly increased costs for system integration efforts can be expected. In addition, isolated exchange networks are likely to exist with unique, non-compatible, and vendor specific implementations.	Guidance and standardization of unique identifiers and organization registry is required.	Unique identifiers and organization information will reduce implementation costs for integrating systems, reduce ongoing maintenance costs, and open opportunities for multi-party and expanded communication.	Develop a central registry of authorized and standardized TMCs and other party systems that communicate at a state level within the state transportation community. Provide standardized, unique identifiers for each participant, along with other requirements for participation.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
12	**Connection management within TMDD is limited to the exchange of "center active" messages between two parties. Center active messages have no detailed status information except for custom extensions added to any specific implementation. There is no standardization for additional information.**	Connection management is a robust exchange of information that includes not only information regarding the state of an individual center, but each of the communication channels available within the center and the current exchanges of information with the querying party. Connection management will include information regarding channels not currently available or in error.	Robust connection management is a basic component of information exchange systems. Current TMDD connection management results in significant manual intervention to detect and resolve connection or data transmission issues. Providing additional information would allow for automation in both sending and receiving systems to resolve basic issues and reduce support and maintenance effort and cost while improving system reliability.	TMDD connection and communication management is insufficient for modern communication systems. Implementations of TMDD would benefit from an increase in the information available in a standardized data structure including more detailed information such as listing dialogs available, subscription status, data available, data volumes transmitted within existing dialogs, and other communication metadata.	Implementing better communication management would reduce operational costs, improve reliability of systems using the standard, and improve quality of communications using the standard.	Add additional connection management dialogs to the standard such as: 1. Current subscription list query 2. Subscription status 3. Message status and count information 4. System subscription limitations 5. Data content available within a subscription 6. Subscription discovery Add guidance regarding how systems manage subscriptions for both senders and receivers.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
13	**Support for legacy, non-NTCIP compliant, and newer, more advanced device capabilities is limited within TMDD and requires significant use of TMDD extensions for data exchange. Such extensions are project specific and there is little commonality between implementation specific extensions, making reusability and exchange between different implementations difficult.**	All devices deployed within a jurisdiction can be supported within a common communication standard, reducing the need for individual deployment specific communication implementations. A method for sharing non-standard implementations exist with a method to rapidly incorporate these implementations within the standard.	There are a multitude of devices in the field and their compliance with NTCIP or TMDD data content, structures, and semantics is often limited. This includes both older, legacy devices, as well as devices with newer, advanced capabilities. Replacement of older devices is often not economically feasible. Any implementation of communication standards needs to have methods that support the real-world devices owned by different jurisdictions. Standards must quickly be adopted to allow both innovation as well as standardization of communication across a diverse vendor community.	TMDD needs a method of publishing project specific implementation details, specific extensions for legacy equipment, or new equipment capabilities; and quick review and implementation of common or shared extensions. An improved method for vendors to submit draft extensions for incorporation into the base standard would be beneficial.	Project specific implementations are generally, at best, specific to any single vendor's product, or at worst, specific to only one implementation. Off-the-shelf compatibility between vendor products and implementations are unlikely, resulting in additional engineering and implementation costs for new projects.	Provide additional implementation guidance for extensions, along with an improved process for migrating extensions into the base standard. Provide a repository for shared extensions, if not at the national level, at minimum the state level to minimize engineering and implementation costs of new installations.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
14	**Dialog behaviors are not defined within the standard.**	Dialog behaviors are well defined within the standard.	Data structure, data types, and limited content standardization is insufficient to enable different implementations to exchange information reliably with minimal development, testing, and integration effort. Dialog behaviors such as required behavior for inventory messages (either CRUD information or requirements to include full inventory in each message) as well as defined temporal behavior are required to improve compatibility between different implementations of TMDD.	Additional behavior information and guidance is required within the standard.	Exchange of information is specific to each implementation. A true common standard allowing different implementations of the standard to communicate and make use of the data is limited without additional guidance and behavior requirements within the standard.	Add guidance and requirements for each dialog for dialog behavior. This should take into account the temporal behavior of the dialog, as well as ensuring compatibility with the type of data being transmitted and its temporal characteristics.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
15	**Guidance is limited to indicate which type of information exchange (request/response, one-time/periodic/on-change subscription) should be used in specific use cases. Time-domain guidance and requirements to match field equipment capabilities to request/response or periodic subscriptions is not required.**	The type of information exchange matches the usage of the data for any specific project. Implementations are capable of any type of exchange, allowing maximum usage of any specific implementation. Guidance for time-domain matching the type of information exchange, intended data usage, and field equipment capabilities is provided.	As "intelligent" transportation systems become the norm, data usage will grow beyond just informational and situational awareness for operators, to driving those "intelligent systems" and the decisions and automation provided by those systems. Data quality and data semantics standardization will become critical for these systems. Standardization and matching of how the information is exchanged and its time-dependent nature will be critical to moving to an intelligent transportation system.	Guidance and standardization of dialog type usage and time-domain dependencies need specification.	The ability to develop future transportation systems is currently limited by the lack of such guidance. Higher costs, longer development times, and limited "off-the-shelf" integration capabilities will result from a lack of standardization in these areas.	Add guidance for the selection of dialogs and methods to limit dialog behavior to match time-domain behavior of field equipment.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
16	**Guidance on dialog start-up behavior is not provided within TMDD.**	Dialog start-up behavior is well defined within the standard. Examples of this include providing initial status information upon starting status subscriptions for devices for which status changes infrequently, including full inventories for first messages with a CRUD indicator for future or including full inventories for all messages.	Without guidance and standardization of dialog startup behavior, projects are likely to create different behaviors for their implementation of TMDD. This limits exchange of information between different implementations.	Guidance is required on dialog start up behaviors.	Current lack of guidance results in implementations that are not capable of exchanging information with common semantic meaning. In addition, individual projects, without guidance, are likely to learn as they go, resulting in higher program development and testing costs.	Provide dialog start-up behavior requirements within the standard.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
17	**Guidance on triggers for "on-change" updates is not provided in the standard.**	All implementations have a common implementation of what triggers an on-change subscription update.	Currently, implementations are allowed to specify their own triggers for what creates an update message for an on-change dialog. Technical limitations as well as practical implications of triggers will limit what data changes create an on-change update message. Guidance regarding which data elements within each message should trigger an update would ensure compatible implementations of the standard.	On-change dialogs should include requirements for data changes that trigger an update message.	Creating data trigger standards for on-change dialogs will ensure compatibility between different TMDD capable products and implementations.	Add to the TMDD standard data trigger standards for each on-change dialog.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
18	**Guidance is limited for how data content should be populated within messages. It is left to the entity implementing the standard to decide how data elements are populated.**	Guidance is provided on how the full set of content within a message should be populated. Both general rules and specific examples within messages should be provided.	To allow multiple implementations of TMDD to be truly capable of communicating without extensive project specific development and implementation related costs, the ways in which data is populated within the standard need to be more standardized. Simple rules, such as those that deal with implicit versus explicit description of event lane location, would increase the likelihood that two implementations of the standard can communicate with a common understanding of the meaning of the data.	Additional guidance is required within the standard to ensure common data and message semantics.	Increased guidance regarding how data is assigned at the message level and the fields available within data frames and elements are utilized will decrease implementation costs across multi-jurisdiction, regional, and state transportation systems. It will enable transportation data systems to be standardized across large multi-TMC, multi-vendor environments and projects.	Provide additional guidance in how messages, dataframes, and data elements are populated. Provide guidance on enumerations usage.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
19	**Guidance is not provided regarding temporal dissonance issues (F2C, C2C, technology/system capabilities, others) that arise in more complex environments with more than two centers.**	Guidance is provided for systems that receive data from many varied sources with different capabilities, specifically regarding time-based dissonance and related issues.	Temporal issues can arise from multiple sources; legacy field assets with limited capabilities, legacy software at centers, differences in TMDD implementations. The temporal data handling differences that arise can make it difficult to integrate in a multi-center environment or to develop systems that can easily be reused in other environments.	Additional guidance regarding standardized methods for handling temporal data issues are necessary.	Additional guidance in this area will improve compatibility between systems that implement TMDD and reduce integration and operational costs of such systems.	Update TMDD to provide guidance in resolving temporal dissonance issues to ensure a common implementation standard.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
20	**Control message usage does not define how to achieve critical needs for control of owner center assets, including returning assets to owner center normal operation.**	Control message specifications include standardized methods to release control back to normal operation.	Lack of standardization of return to local control requires those implementing external center commands to create custom implementations of command generation depending upon each owner center implementation. This increases complexity of large multi-center, multi-vendor system implementations.	TMDD needs to address standardization of command usage to ensure usable implementations that do not require extensive customization.	Increased standardization will reduce implementation and operational costs of future systems developed using TMDD communications.	Standardize the usage of command messages.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
21	**Time related data elements and data frames, such as event time, rely on user understanding and interpretation of the meaning of the time-based fields. These interpretations are often inconsistent.**	Time related data has clearly written definitions that remove ambiguity and reduce the potential for different interpretations. Usage guidance should be provided with real-world examples.	Time-based information is a critical element of any data described within traffic and transportation related data. Clear definitions and guidance ensure common understanding and improves usability of data and real-time analysis in more complex transportation systems.	Time data elements and dataframes need clear field definitions with real-world examples.	Improving time field definitions will improve more advanced traffic management system capabilities, such as traffic prediction and artificial intelligence.	Add clear time field definitions and examples to the standard.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
22	**Required SOAP protocol limits performance for large scale implementations. Limited speed and volume of information transmission, large message sizes, and high serialization computational costs resulting from SOAP usage, limit its performance.**	SOAP protocol is an option for some dialogs where appropriate, but real-time and high-speed, large volume, high-throughput communication requirements are supported with more appropriate communication protocols.	SOAP is a 20-year-old technology with significant limitations. Performance limitations cap usage of the standard to point-to-point local and regional implementations with limited information exchange needs. Significant increases in infrastructure requirements and system complexity required by SOAP will limit the growth potential of existing implementations and the state and national transportation infrastructure.	Improvements in the technology that is used to support the TMDD standard are necessary to support future transportation infrastructure needs. Supporting technology selections should be expanded to support both current and future needs.	Allowing additional protocols will allow for expansion of traffic management and transportation management capabilities. Improvements in real-time decision making, response capabilities, and data usage and analysis can be vastly improved with the addition of new data sources and data types, supported by real-time data consumption and analysis.	Provide technology options for implementation of the standard.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
23	**SOAP messages using the standard can become excessively large and create issues including poor performance, server timeouts, increased computing requirements, lost communications, and high serialization times. Inventory messages, especially secondary asset inventories such as signal plans are particularly problematic.**	Methods are implemented to limit message sizes. Methods may include: • Adding action elements to inventory messages to provide CRUD operations – create, read, update, delete. • Allow additional formats and serializations, including JSON, binary, or others for data messages.	Large message sizes and the resulting performance issues negatively impact the reliability of communications between centers. In addition, scalability of communications is negatively affected as the number of assets within an owner center's inventory grows.	There are insufficient methods available to optimize message contents and the resulting size.	Allowing additional data formats that are less verbose than XML and additional protocols that minimize message size will improve communication reliability and performance. Adding CRUD actions to inventory messages will allow individual asset messages within these dialogs, significantly reducing the size of these messages. These actions will also significantly improve the ability to scale communications to larger sets of transportation assets.	Add action elements to inventory messages to provide CRUD operations – create, read, update, delete. Allow additional formats and serializations, including JSON, binary, or others for data messages.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
24	**Legacy local and regional system architectures limit the ability to provide real-time performance at scale. The standard's requirement for backward compatibility limits newer implementations.**	Legacy local and regional systems continue to be supported within the standard, while allowing for innovation and larger regional, state, and federal data exchange programs.	SOAP, XML, and the defined data structures within the standard significantly limit future innovation. The standard needs a technology upgrade and a review of its data structures to maintain relevance. However, existing implementations need to be supported as well within any standard update. Legacy system architectures and technology often cannot support the needed real-time performance at scale.	A review of dialogs, messages, dataframes and data elements is required to address advances in technology, both within the information technology space and the transportation space. In addition, the protocols for data transmission need review and updated methods should be provided as options for existing and future implementations.	Updating the standard will ensure it remains relevant with advances in technology and be better prepared for the changes happening now and in the future in transportation and traffic management.	While maintaining SOAP as a protocol, add additional data communication protocols/technologies as options in TMDD implementations. Review, update, and add as necessary additional dialogs, messages, dataframes and data elements to the standard. While maintaining the current methods within the standard, with some improvements, add parallel methods of information exchange suited for larger, real-time implementations of the standard. Implementation guidance for minimum system performance should be provided.

Item	Current State	Desired State	Insight	Gap	Impact	Recommendation
25	**TMDD has not been updated to the latest SOAP version and is not WS-I compliant.**	TMDD's SOAP implementation uses the latest available SOAP standard and ensure WS-I compliance.	TMDD should have a process to ensure it is updated as the underlying technologies used by the standard are updated. Such updates can impact its usability, security, and performance attributes.	The standard needs to be modified to utilize the latest technology standards for the technology protocols it uses. The standard also needs additional technical and financial support to ensure future updates and maintain the standard's relevance.	Updating the standard to use the latest SOAP version and ensure WS-I compliance will improve its usability and relevance. Ensuring a process to maintain the standard as technology improves will safeguard its usefulness in the future.	Update the standard to comply with the latest SOAP standard and WS-I. Ensure that future technology updates are implemented in future standard updates.

4. RECOMMENDED ACTIONS AND PRIORITIZATION

As a result of this gap analysis, the following recommendations were provided. A priority is suggested for each recommendation. Priorities are assigned simply as high, medium, and low. No recommendations received a low priority.

It is not recommended that each recommendation, however, be implemented as an individual change to the specification. Rather, it is recommended they be implemented as a whole, as many of them address different issues identified in the previous related technical memorandums, but with similar solutions. For example, it is clear that changing the standard from dictating XML and SOAP implementations to other technologies is a repetitive theme within the recommendations, but doing so addresses many different issues identified within the gap analysis such as performance, scalability, and others. Categories have been added to the recommendation list in an attempt to provide a way to group related recommendations. These categories include:

1. Technology improvements and updates
2. Process improvements
3. Improved implementation guidance
4. Usability updates
5. Improvements required for changes in transportation and infrastructure
6. Security related improvements

These priorities and categories assume a strategy of first separating the standard into additional volumes as suggested throughout this project to include:

Volume 1 – Concept of Operations and Requirements
Volume 2 – Data Structures and Semantics
Volume 3 – Communication Protocols
Volume 4 – Security Requirements and Recommendations
Guide to the Traffic Management Data Dictionary

Each volume would contain not only the technical requirements, but additional implementation guidance for use of the contents of the volume.

	Recommendation	Category	Priority
1	Change the TMDD standard to allow additional data transmission formats beyond XML. Create a list of recommended data formats and implementation guidance for each format.	1	High
2	Change the TMDD standard to allow for additional data transmission methods beyond SOAP. Create a list of recommended data transmission methods and implementation guidance for each.	1	High
3	Select appropriate technologies that will allow for scalable real-time, high volume communications for use with the standard.	1	High
4	Allow for the data transmission technology to be selected appropriate for each individual data exchange requirement. Separate the technology selections available from the data structure standards to allow choice and flexibility within the standard, even across different dialogs within any individual implementation.	1	High
5	For the data exchange technology requirements or recommendations within the standard, provide recommendations or minimum requirements for security implementation, along with references to external security standards appropriate for implementation.	6	High
6	Increase the release cycle of the TMDD standard, incorporating experience of implementations that require new information sources and more advanced devices. Provide a more active method of review and incorporation of implementation specific extensions within the standard, with the goal of adding them to the standard. Actively review the current standard requirements and advances in transportation technology, with the specific purpose of identifying and incorporating new user needs and requirements to prepare the standard for the future.	2	Medium
7	Add dialogs, messages, dataframes, and data elements for exchange of public messaging activities.	5	Medium
8	Add the dialogs and associated data structures developed by the I-210 Connected Corridors implementation for use in coordination of response plans and response plan approval activities. Review TMDD for additional needs related to other coordinating activities. Review TMDD for applicability within a multi-jurisdictional, multi-party environment.	5	High
9	Provide new methods of data exchange capable of scaling to real-time date exchange across large geographic areas and a large number of devices.	5	High
10	Select multi-point broadcast communication technologies, along with updates to the data structure to support multi-party communications. Alternatively, hub/spoke system architectures should be recommended within the standard.	5	Medium

	Recommendation	Category	Priority
11	Develop a central registry of authorized and standardized TMCs and other party systems that communicate at a state level within the state transportation community. Provide standardized, unique identifiers for each participant, along with other requirements for participation. (Specific to implementation at the state level, not a standard recommendation)	4	Medium
12	Add additional connection management dialogs to the standard such as: 1. Current subscription list query 2. Subscription status 3. Message status and count information 4. System subscription limitations 5. Data content available within a subscription 6. Subscription discovery Add guidance regarding how systems manage subscriptions for both senders and receivers.	4	High
13	Provide additional implementation guidance for extensions, along with an improved process for migrating extensions into the base standard. Provide a repository for shared extensions, if not at the national level, at minimum the state level to minimize engineering and implementation costs of new installations.	2	High
14	Add guidance and requirements for each dialog for dialog behavior. This should take into account the temporal behavior of the dialog, as well as ensuring compatibility with the type of data being transmitted and its temporal characteristics.	3	High
15	Add guidance for the selection of dialogs and methods to limit dialog behavior to match time-domain behavior of field equipment.	3	High
16	Provide dialog start-up behavior requirements within the standard.	3	High
17	Add to the TMDD standard data trigger standards for each on-change dialog.	3	Medium
18	Provide additional guidance in how messages, dataframes, and data elements are populated. Provide guidance on enumerations usage.	3	High
19	Update TMDD to provide guidance in resolving temporal dissonance issues to ensure a common implementation standard.	3	Medium
20	Standardize the usage of command messages.	3	High
21	Add clear time field definitions and examples to the standard.	3	High
22	Provide technology options for implementation of the standard.	1	High

	Recommendation	Category	Priority
23	Add action elements to inventory messages to provide CRUD operations – create, read, update, delete. Allow additional formats and serializations, including JSON, binary, or others for data messages.	4	High
24	While maintaining SOAP as a protocol, add additional data communication protocols/technologies as options in TMDD implementations. Review, update, and add as necessary additional dialogs, messages, dataframes and data elements to the standard. While maintaining the current methods within the standard, with some improvements, add parallel methods of information exchange suited for larger, real-time implementations of the standard. Implementation guidance for minimum system performance should be provided.	1	High
25	Update the standard to comply with the latest SOAP standard and WS-I. Ensure that future technology updates are implemented in future standard updates.	1	High