A321a
Understanding User Needs For Traffic Management Systems Based on TMDD v3 Standard

STANDARDS ITS TRAINING

STUDENT SUPPLEMENT

RITA Intelligent Transportation Systems Joint Program Office

A321a

Understanding User Needs for Traffic Management Systems Based on TMDD v3 Standard

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Traffic Management Operational Environment

To understand the potential uses of a C2C interface, one must first understand the operational context in which it would function.

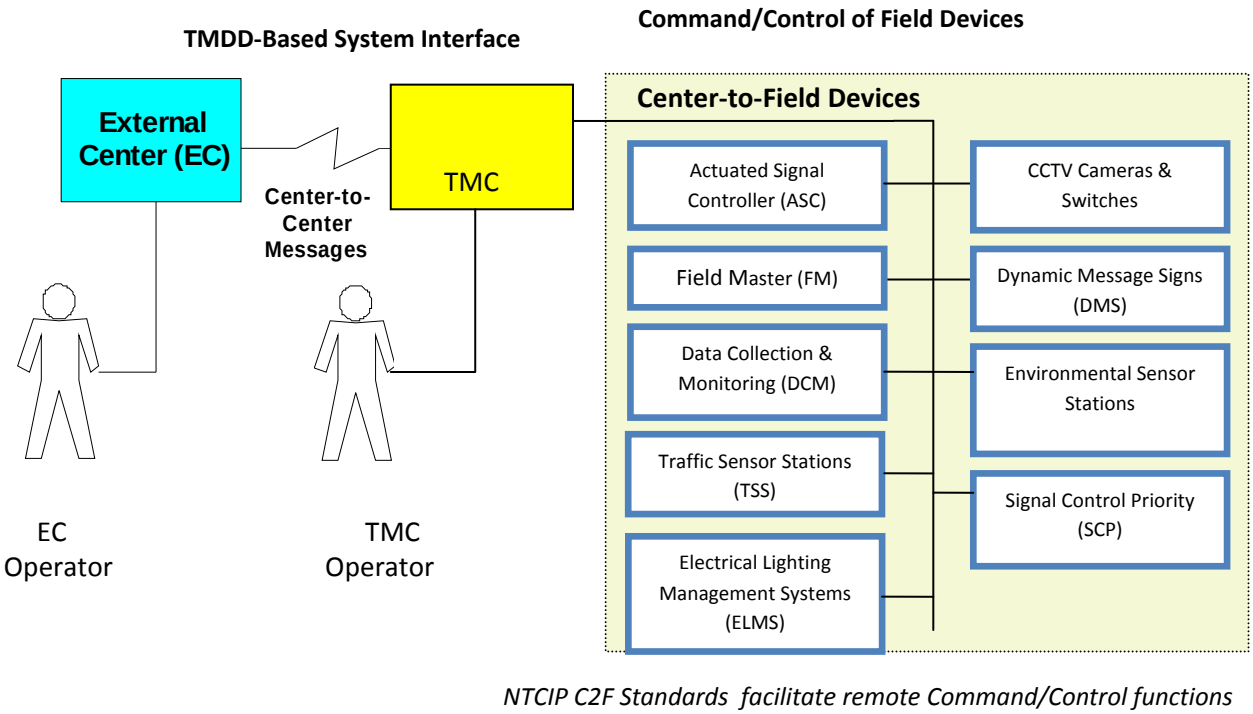


Figure 1: Conceptual Representation of Operational Environment

The concept of operations of *traffic management* is highly dependent on the *command and control* of the field devices and *coordinated response* to manage traffic flow conditions and resulting *events* on the regional transportation network. The traffic management concept of operations, when one emerges across the jurisdictional boundaries, aids both the traveling public, customers, and operators of the road networks who are concerned with safe and efficient operations of networks in the region. Regional traffic management activities such as congestion or incident management are dependent on interagency coordination in real-time. This impacts their customers—the traveling public and their need for travel information about the current conditions in the region. This in turn requires information exchanges within the C2C operational environment.

A modern Traffic Management Center (TMC) facility has become a focal point for agency operations—it houses the central system hardware and software, including operators and maintenance personnel; follows policies and procedures and other entities; carries out internal agency coordination; performs command and control of the field devices; and maintains coordination with the neighboring centers through the exchange of information in real-time as shown in Figure 1.

These centers often have different computer systems and software platforms, data formats, and databases, making system-to-system communication difficult, if not impossible to achieve. The TMDD-based C2C system interface is independent of all of these issues. It is effectively used to combine information from multiple centers; it allows operational staff to utilize assets across jurisdictions to improve operations; and it allows data to be fused and provided to centers across jurisdictions. (During the development of the TMDD v3.0 standard, users had stressed such needs to be supported by the C2C system interface).

Figure 1 depicts a conceptual view of an operational environment in which operators from a variety of diverse centers may use the TMDD-based system interface to request and receive information from a TMC about a field device or service (typically part of the ATMS) while also allowing them to contribute to the TMC.

In the above exhibit, an external center can be a public safety agency or another transportation center that may seek or provide information that is valuable to another center's operations. Such external centers often desire system-to-system communication to exchange information in real-time (compared to manual process) to coordinate their responses in a regional setting. As stated earlier, the types of information exchanged may include incident event information and control and command of the field devices, such as altering traffic signal timing or displaying a new message on a DMS.

In recent years, centers have also become more aware of the value added by the availability of real-time information (e.g. regional 511 and road weather services) and the benefit of mutual agreements that actively encourage the sharing of each other's ITS resources to improve response to an emergency or event in the region. For example, better incident detection and notification in real-time can engage appropriate public safety resources, provide more rapid medical care to save lives and minimize injury consequences, and reduce transportation infrastructure disruptions, as well as avoid secondary accidents. Better road situation information made available to all parties simultaneously also helps in the overall management of roadway incidents. In such an operational environment, multiple (and diverse) centers work effectively due to the smooth integration of information-ITS technologies and procedures.

The TMDD-based C2C system interface plays a key role in the above operational context by supporting the following to:

- **Facilitate Remote Command and Control of Field Devices:** For example, as shown in

Exhibit 1, a neighboring EC (through prior arrangements) may be able to remotely control certain traffic devices that belong to another jurisdiction during after-hours or when a TMC may be closed, or at other times may "command" to take some action. Although such occurrences may not be common, during a major emergency such as a natural disaster in the region, such a need may arise.

- **Share/Exchange Event Information:** Information exchange is key to improved operational coordination and collaboration in the regional context. For example, within a C2C operational environment, the TMC and public safety external center often have information that is valuable to each other's operations. These centers often desire system-to-system communication to exchange information that will help them coordinate responses to transportation conditions that have regional impacts. The types of information may include incident event information or traffic congestion levels during a planned event.
- **Provide Coordinated Response to Transportation Conditions:** For example, a local traffic incident may have an impact on a region that necessitates a change in current signal timing on an arterial passing through multi-jurisdictions. In such a case, all TMCs in the region will attempt to coordinate a pre-planned or new response pattern.
- **Share Roadway Network Data:** For example, participating centers can make available to each other information on their roadway network, such as nodes, links, and routes. Centers can exchange route travel time with other centers, which in turn may be provided to travelers and other public organizations to help them plan routes. Other uses may include collecting transportation data for planning and research purposes (archiving).

Figure 2 illustrates how four areas of operation needs are served and the example in Figure 3 depicts how information about an event is being shared by the operation centers. Please also note that centers use such information to serve an overall "operational need", traffic flow management and or congestion management and to provide travel information.

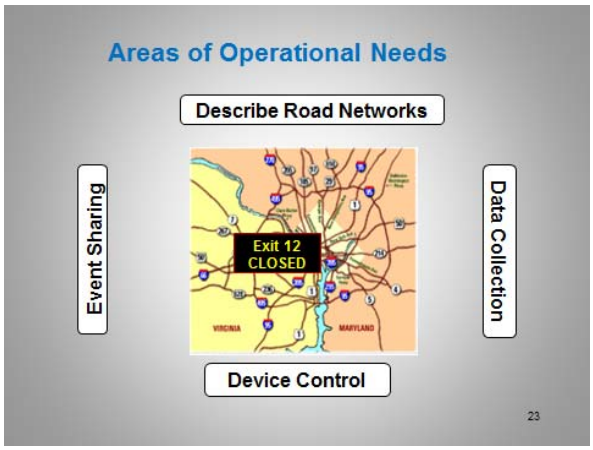


Figure 2: Key Areas of Operational Needs

Figure 3: Center to Center Event Information Exchange

Conceptual Representation of a System Interface

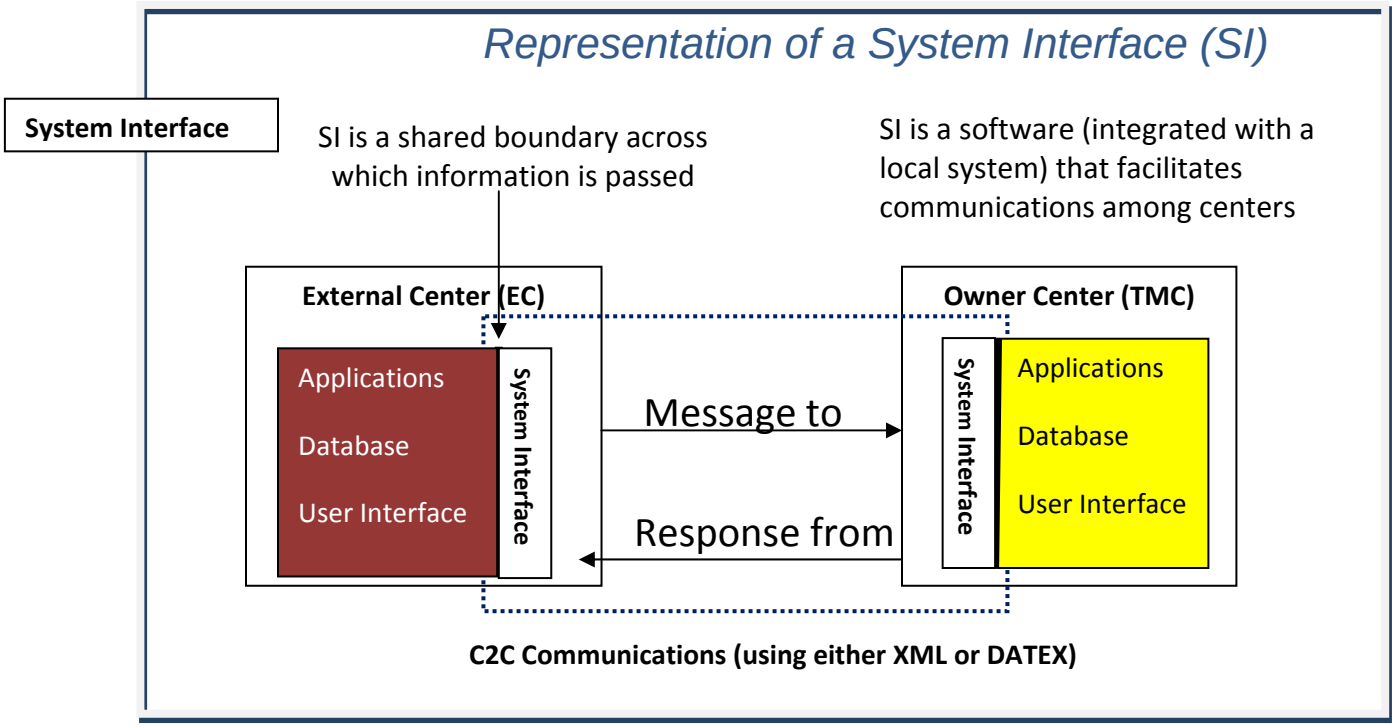


Figure 4: Conceptual Representation of System Interface

Figure 4 shows a conceptual representation of a system interface (SI). It shows that SI is a separate entity from the native applications that may exist and clearly **<u>SI is the one that handles messages across</u>** (conversation). Furthermore, this is done in a protocol-independent manner, meaning user can deploy either currently preferred XML application protocol or somewhat older DATEX protocol or any other in the future.

Thus, we learn here that agencies seeking interoperability among centers/systems must have a common SI and implement the same protocol to conduct information exchange.

System Interface Specification

Figure 5 shows three logical steps that make up a system interface specification; user needs, requirements, and design concepts. They in turn drive the ***system interface*** development, an agency's ultimate goal (additional factors may exist and form part of the specification). User must recognize that "all needs" solely exist to support operations. Conversely, if user needs don't support operations, they are not needed, and hence should not be included in a specification.

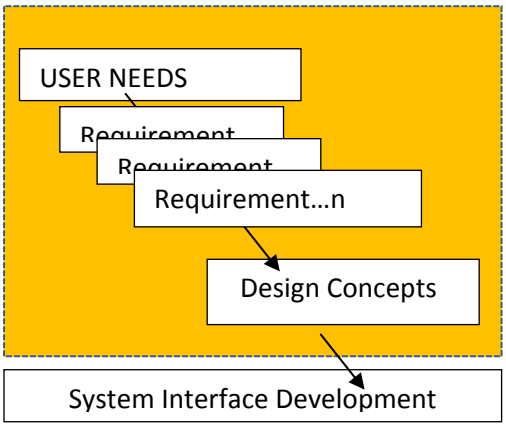


Figure 5: System Interface Specification

A Requirement is a condition or capability, "solidly" expressed in "shall" language. Requirements link us to the next step, design content. We stop here for specification items. Next stage is system development stage, which is part of the local ITS project, a **system interface** will emerge with "construction" using TMDD design content (which contains data concepts…)

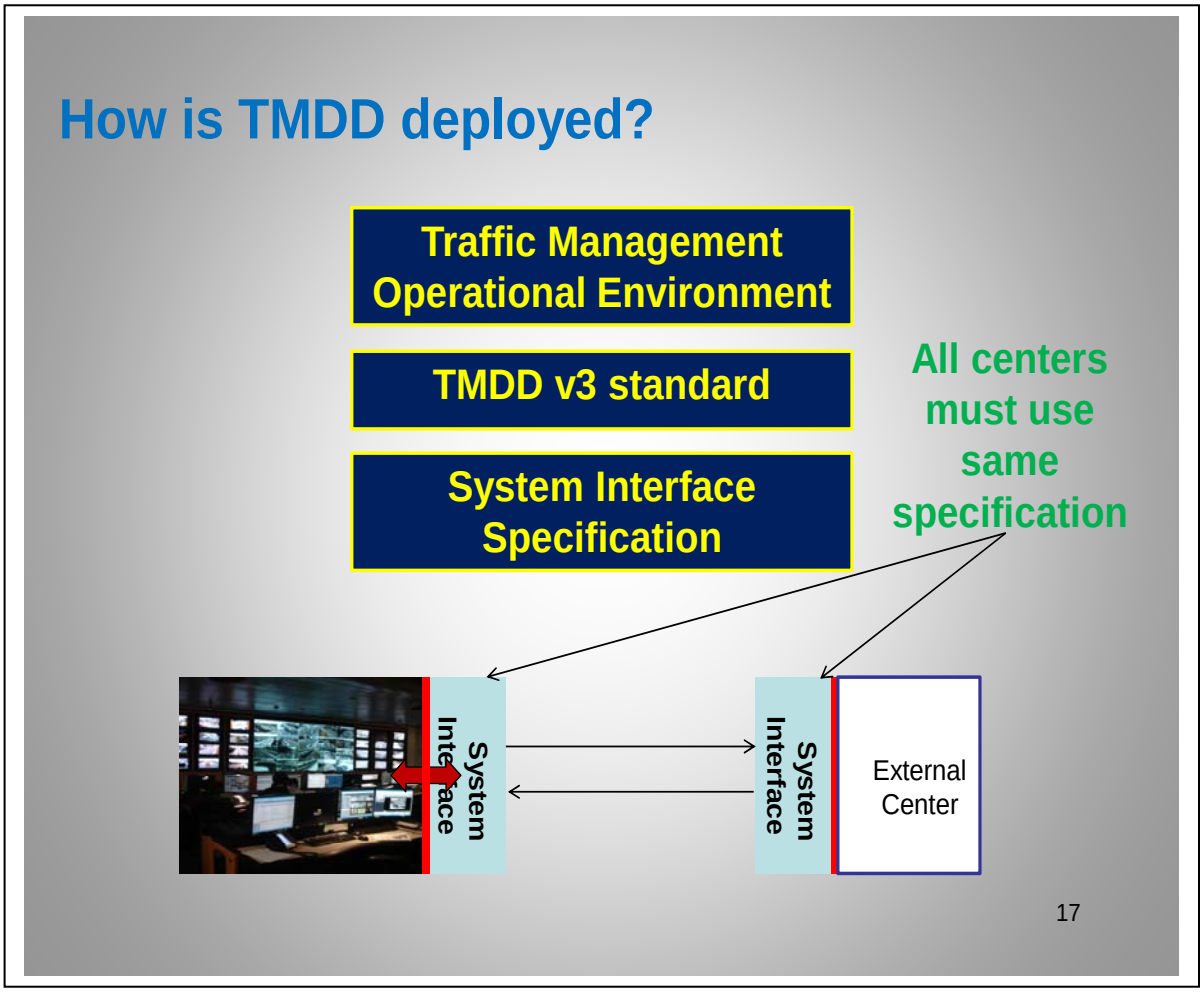


Figure 6: Overall Context of TMDD Deployment

QUICK SUMMARY

The TMDD itself is not an interface or software. We have a task to write an unambiguous specification based on the TMDD v3 standard to get an interoperable system interface, which is additional software that works with a native system. Figure 6 outlines related topics from which a TMDD-based system interface emerges.

This course and others in the PCB series have provided an opportunity to explore ITS standards with an emphasis on how to identify and write user needs, requirements and design elements for a specification. The following sections will help us to understand underlying issues.

Introduction to TMDD v3.0 Standard

Need for a Standard-based System Interface

In recent years, a significant number of ITS standards have been developed and public sector agencies have deployed ITS systems based on such standards. However, prior to the standardization, agencies either had no interfaces at centers and performed communications tasks manually or had to opt for costly proprietary solutions, which required multiple interfaces as shown in Figure 7. Both situations are depicted in the following figures.

As shown in Figure 8 a TMDD-based interface installed at participating centers alleviate that situation. With TMDD v3.0 standard, agencies can develop a common interface based on their local traffic management needs and conduct real-time communications among centers.

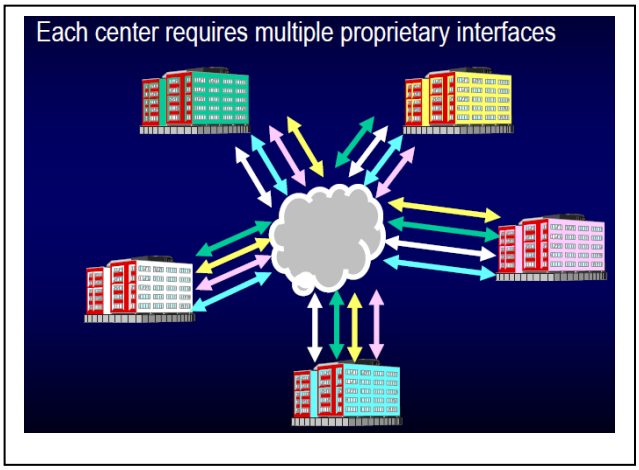


Figure 7: Centers without a Common Interface

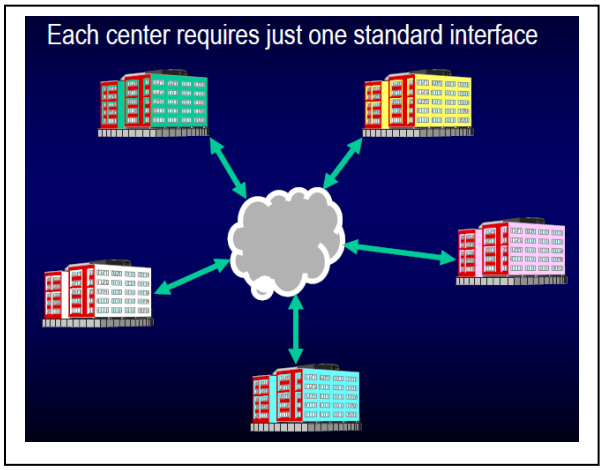


Figure 8: Centers with a Common Interface

The Purpose of the TMDD v3 Standard

The overall purpose of the TMDD is to aid in system interface development. The specific purpose of the *TMDD Standard for Traffic Management Center-to-Center Communications* is to assist users in the procurement process by describing the potential user needs, establishing requirements, and tracing them to data content for system interface to facilitate information exchanges among centers. Consistent with the systems engineering approach, the TMDD standard aims at providing standards-based design content, high-level definitions in a protocol-independent manner, with which a system interface specification can be prepared. As the title of the standard implies, the focus is placed on the operational needs of traffic management

within the C2C context. (The reader should also note that the TMDD is not an application-specific data dictionary).

Readers are further directed to read the Abstract on TMDD located at end of this document to gain insight on the purpose of the TMDD standard.

The Scope of the TMDD v3 Standard

The scope of the TMDD standard covers user needs, requirements, data concepts, and certain selected architecture data flows to enable C2C communications and for requesting specific action such as command and control of any of the ITS field devices. The TMDD standard supports:

1. A request for road network data (information) and conditions including roadway network inventory and status on nodes, links, and routes.
2. Sharing event information, event management, and other functions performed by the TMC.
3. A request to control and sharing of ITS field devices such as Dynamic Message Signs (DMS), Close Circuit TV (CCTV) Cameras, and Actuated Signal Controllers (ASC), etc.
4. Sharing data for archival purposes for traffic monitoring, roadway characteristics, and event data. Data collection and data fusion across deployment boundaries is a big benefit for regional planning, integration, and operations use (e.g. 511).

TMDD v3.0 Relationship to ITS Architecture

The TMDD standard supports the National ITS Architecture system perspective of centers or subsystems as shown in Figure 9, and identifies and describes the services that may be provided by a traffic management subsystem to external center subsystems by tracing architecture flows (information flows) and corresponding user needs and requirements. The types of centers supported by the TMDD standard include TMCs in adjacent regions or statewide centers (External TMCs), transit dispatching centers, emergency management/public safety 911 centers, maintenance/construction operations centers, and rail operating centers. These centers are different from each other in many aspects: for example, they deploy different equipment and software platforms, collect data and store data in different formats, and conduct different operations.

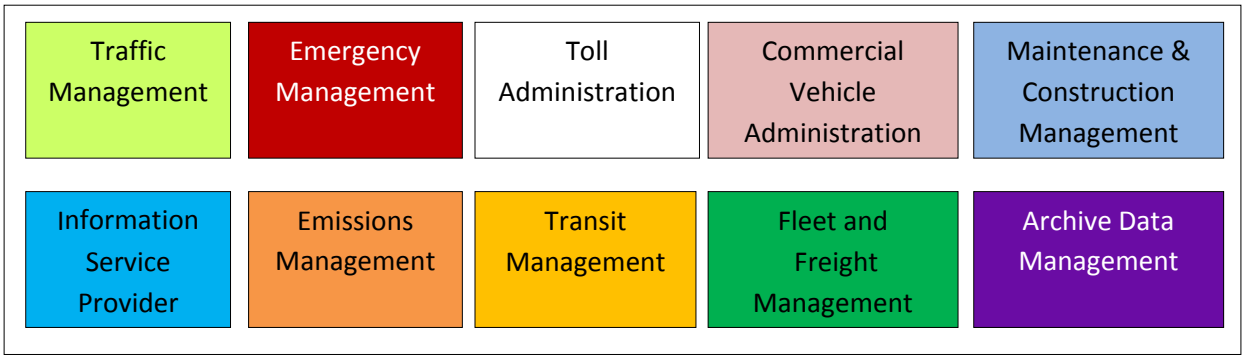


Figure 9: Types of Operational Centers Defined by the National ITS Architecture
(Source: National ITS Architecture v6.1, ITS Architecture 2008)

In addition, media, weather services, surface transportation weather services, and event promoters receive data from the TMC, and the TMC also receives data from some of them. As a common language, the TMDD supports C2C communications to improve coordination and collaboration with information exchanges in real-time. Conversely, without the TMDD standard, C2C communications will remain manual, resulting in a decreased coordination in regional traffic operations and limiting potential opportunities for collaboration.

TMDD v3.0 Relationship to other Standards

Although the main purpose of the TMDD standard is to support traffic management applications, TMDD concepts definitions are reusable across all ITS functional areas, such as emergency management, transit, and travel information for communications needs. The TMDD data concepts can be used with other ITS standards such as the Institute of Electrical and Electronic Engineers (IEEE) 1512 family of emergency management standards, Transit Communications Interface Profiles (TCIP), and the Society of Automotive Engineers (SAE) J2354 message sets for Advanced Traveler Information System (ATIS).

TMDD's Relationship to NTCIP C2C Standards

TMDD is a language, not an interface itself or a communication protocol. As a high-level information-level standard, the TMDD is used to develop a system interface, a software entity. As shown in Figure 4, as an information level data dictionary standard, the TMDD standard defines the content, syntax, and semantics of messages exchanges between center-based systems, but it does not define the mechanism of encoding and transporting a message between centers.

[Users should also note that there are separate dictionaries standards for other functional areas such as IEEE 1512 (emergency management), ATIS (traveler information), and TCIP (transit).]

NTCIP is a communication application level protocol designed to transport a message to the other end independent of the content. The NTCIP family of standards has developed two common protocols:

- NTCIP 2306 C2C-XML is based on the XML data representation and rules of message encoding and transport of the W3C (World Wide Web Consortium) Web Services Architecture, and also provides a way to define dialogs, based on the Web Services Definition Language (WSDL). (This is currently a preferred protocol).
- The NTCIP 2304 C2C-DATEX application profile takes the ASN.1 data representation, encodes it with a companion encoding standard (BER), and moves the information from center to center. (This was an earlier protocol, not much in use).

As shown in Figure 10, for the traffic management system interface implementation the following standards are required:

1. As a Language-Dictionary: TMDD Standard v3.0
2. As an Application Profile: NTCIP C2C (One of the two protocols available)

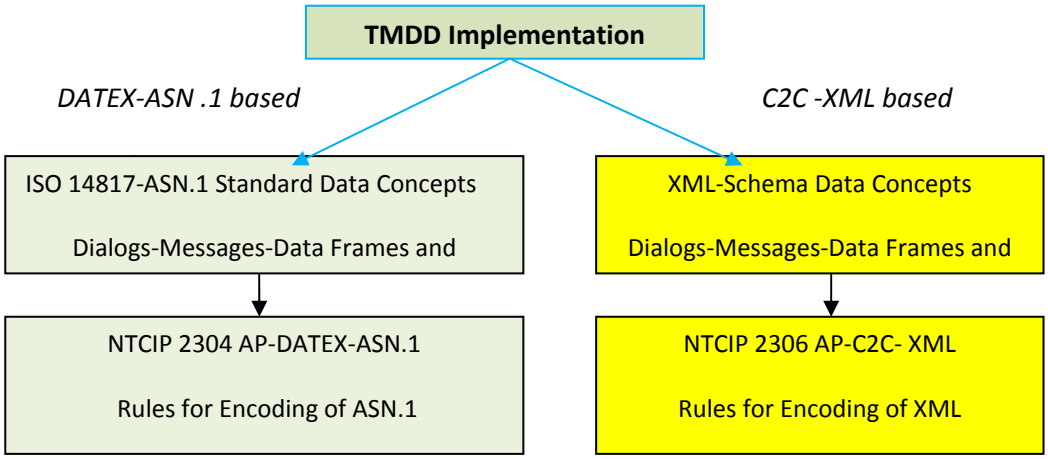


Figure 10: TMDD Implementations

TMDD Standard v3.0 Development

As shown in Figure 11 the development of the TMDD v3.0 was driven by the application of the systems engineering process, committee consensus, and discussion with working focus groups and peer evaluations, including deployments efforts. Two key objectives of the development were to correct deficiencies identified with the earlier version and to incorporate lessons learned from deployments that utilized previous TMDD Version 2.1. The lessons learned and

feedback received from C2C deployments are incorporated, including additional areas of scope and unresolved issues from the earlier version.

The standard includes data elements and message sets from the *Clarus* initiative (*Clarus* is Latin for "clear") to develop and demonstrate an integrated surface transportation weather observing, forecasting, and data management system. In addition the Archived Data User Service (ADUS) to enable transportation agencies to retain ITS-generated data and make them available for analysis is also supported. A large number of agencies provided significant feedback and participated in development work and reported defects in the previous version of the TMDD standard and had expressed new needs arising from their implementations. The TMDD v3.0 considered this feedback and incorporated modifications to the extent possible.

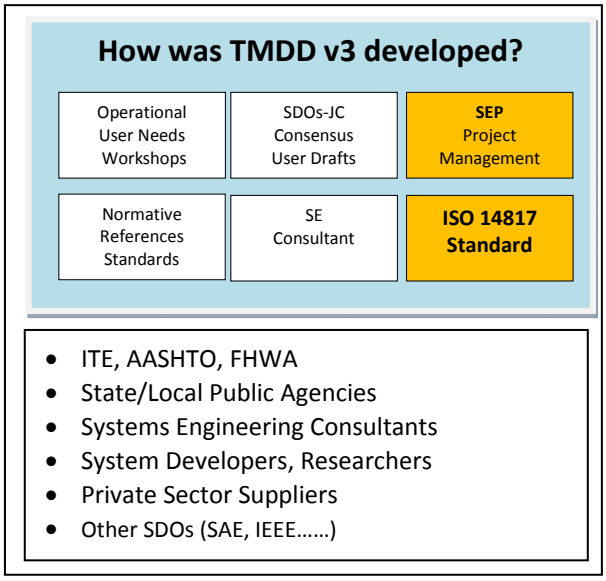


Figure 11: TMDD Development

In addition, the TMDD effort utilized the ISO 14817 standard (to replace the previously use of IEEE 1488 and 1489 standards) for data concepts and the development process was conducted as per the systems engineering guidelines.

Backward Compatibility

IEEE Standard Glossary of Software Engineering Terminology defines compatibility as an ability of two or more systems or components to perform their required functions while sharing the same hardware or software environment.

The reader should note that there are sufficient reasons to state that the TMDD v3.0 is not backward compatible with the previous version. The developers also determined that there were not many v2 based implementation in the field that would require backward compatibility and opted to improve the content of the new standard, a number of changes to the messages have been made. The revisions included some general redefinitions of elements that caused significant differences between two versions. Some of the changes with the greatest impact (from a backward compatibility standpoint) are:

- The development of generic device messages that are then configured for individual devices.
- The creation of a general device objects identifier, which replaced numerous identical (but uniquely named) ID data concepts in TMDD v 2.1.

- TMDD v3.0 dialogs that are based on the ISO 14827 (TMDD v 2.1 used IEEE standards).

TMDD and Interoperability

The TMDD standard plays a constructive role in providing standardized definitions of data concepts to facilitate design of a common system interface to serve C2C operational needs. This system interface design based on user needs replaces costly proprietary solutions. With TMDD-based system interface, centers can now compose consistent messages to carry out dialogs in a prescribed way. If two or more centers implement the same subset of user needs and requirements in a common specification, the resulting system interface can provide interoperability.

Centers from different functional areas desiring interoperability with TMCs must have a TMDD-based system interface specification and a common application level protocol. In addition, for messages to arrive at the destination as intended ("bits and bytes on the wire"), common transport level and sub-network level protocols must be deployed at both ends to complete the communication process. For additional information readers are directed to the TMDD v3.0 Guide.

Pre-conditions for Achieving Interoperability: To ensure interoperability, the parties involved in the sharing of information shall participate in the development of the system interface specification. Interoperability is attained only if multiple networked systems implement the same protocols, dialogs, messages, and data content definitions, i.e., they implement the same system interface specification (including user needs/requirements). For example, at the application level, AP-DATEX and AP-C2C XML are not interoperable. Therefore, only one application level standard can be chosen.

Interoperability

The ability of two or more systems or components to exchange information and use the information that has been exchanged

(IEEE Std. 610.12-1990: IEEE Standard Glossary of Software Engineering Terminology).

[The transport level contains the TCP/IP standard. The TCP/IP has been described as the "Swiss Army Knife" of communications. It is the glue between systems on a network and the network infrastructure. In the subnetwork and plant levels, hardware and electronics may exist for connecting disparate communications media. For example, 700 MHz and 800 MHz systems will not communicate with each other, nor will PCS communicate with cellular telephones. Therefore, for a connection between any two units, one subnetwork standard must be chosen for each communication link, and that subnetwork standard must provide capabilities to interface with the plant level used.]

What if a need is not found in the TMDD standard?

The following is a hypothetical situation that has created a new ConOps that was not addressed by the TMDD and necessitated a definition of a new user need, as well as corresponding requirements and data concepts.

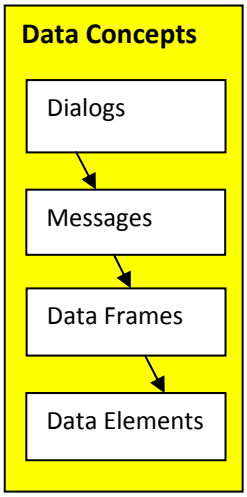
"We have a concept of operations that is unfolding in our region. We are thinking about introducing variable congestion pricing on our High Occupancy Vehicle (HOV) facilities and if that happens, a TMC may manage the facilities with a variable pricing scheme imposed by yet another regional center, and they may need to "talk" to each other in real time to communicate pricing schemes. This need is not included in the current standard. What should we do?"

The response to such a situation can be to extend the standard if needed by the following rules stated in Exhibit 2-11 in TMDD v3.0 Guide.

However, in general, "*Extensions*" to a TMDD conformant implementation are discouraged because they break interoperability (the reason why the TMDD standard was created). However, it is recognized that the TMDD standard does not satisfy every possible user need that can exist between two centers. Therefore, it allows for specific project implementations to "extend" or add new needs, requirements, and data concepts (dialogs, messages, etc.) to the implementation. To support these additional requirements, project implementations are allowed to "extend" the standard by defining new data elements, data frames, or data messages outside the TMDD standard. (Please consult TMDD v3 Guide for full discussion on this topic).

TMDD Standardized Data Concepts

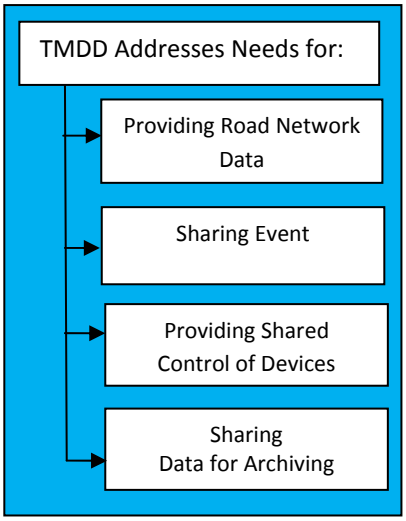
Data *is a representation of facts, concept, or instructions in a formalized manner suitable for communication, interpretation, or processing by human or by automatic means. Various Data concepts are shown the side figure. (see TMDD v3 Guide for details).*



As shown in the box, TMDD data concepts includes dialogs that start a conversation, messages pertain to a function or information and data frames and data elements are used to construct fixed messages. These data concepts support the four areas discussed below. Data concepts in the TMDD v3 standards are developed in two formats: ASN.1 and XML. Users need to choose only one format and both cannot be mixed. Also for interoperability, centers must choose same format-based data concepts in system interface design.

Support for User Needs Areas

TMDD enables *interoperability* (the ability of two or more systems or components to exchange information and use the information that has been exchanged). TMDD accomplishes this task by supplying raw materials (data concepts) from which a system interface can emerge to perform information exchange tasks shown in the box. Thus with TMDD-based solutions, one can also expect to achieve the full potential of the ITS capabilities and assets located across boundaries in an interoperable manner. For example, a seamless data exchange would make it possible for an emergency services vehicle to notify a traffic management center to trigger a change in the timing of the traffic signals on the path to a hospital, in order to assist the responding ambulance.



The TMDD standard's contribution to strengthen interoperability achievements can be summarized in the following three ways:

- TMDD standard accounts for typical needs of neighboring centers related to ITS devices, event management, and other functions performed by the TMC.
- TMDD data concepts are reusable by other functional areas to support domain specific-needs. Thus TMDD effort has avoided confusion among application areas.
- TMDD standard can be integrated with other ITS standards such as NTCIP and IEEE 1512 families.

Structure of the TMDD v3.0 Standard

The TMDD v3.0 Standard Organization

As shown in Figure 12, Volume I and Volume II together make up the TMDD v3.0 standard. The standard documentation organization follows this sequence—*User Needs-Requirements-Data Concept*—and guides the reader through specification preparation for the system interface consistent with the systems engineering approach. In this layout, Volume I deals with addressing a known C2C problem, and Volume II provides for solution content that a separate design phase of the project will use.

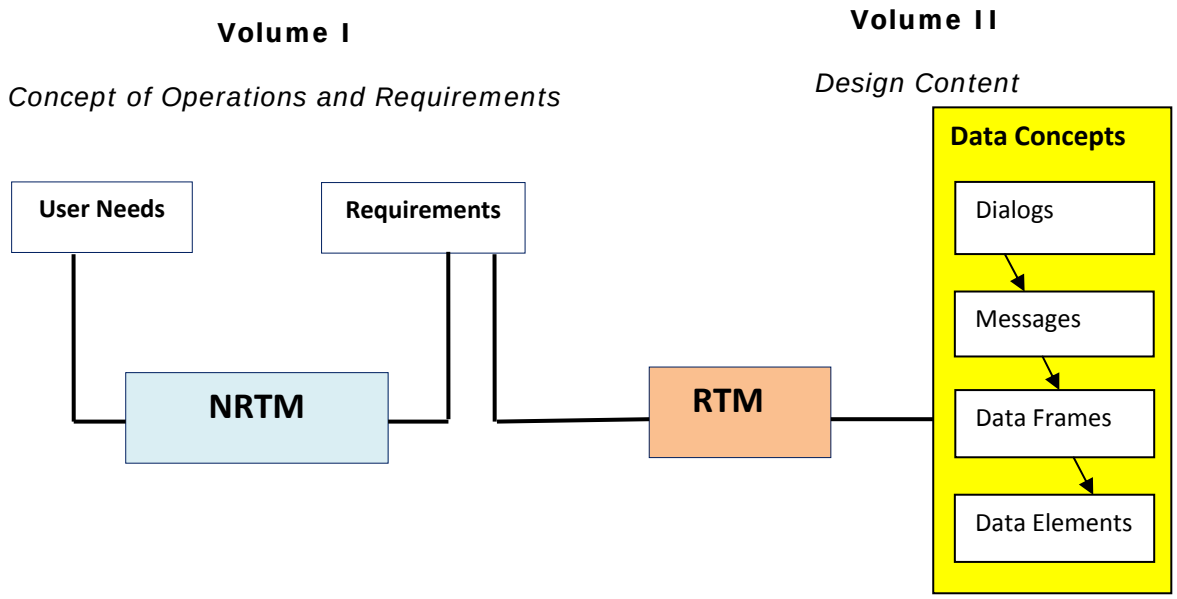


Figure 12: TMDD Standard Organization

The readers should view the NRTM and RTM as tools in preparation for a project specification that is requirements-centric to system interface design. As shown in Figure 4, NRTM is the only way to select standard-supplied user needs and tailoring requirements that satisfy the selected user needs. Similarly only through RTM necessary specific-design concepts (solutions) that fulfill the requirements are selected. As shown in Figure 4, there are no direct links between user needs and requirements. Thus, the TMDD standard has ensured traceability in both forward and backward direction of development process, in addition to providing for standardized definitions of user needs, requirements and design concepts.

Prior to the NRTM review, users should have already firmly established their ConOps directed operational needs in consultation with the concerned stakeholders using the SEP. The resulting operational needs of the local project will be mapped to those in the standard through the NRTM. This step ensures that the TMDD-based specification work begins with the local project-centric approach to user needs and not necessarily dictated by the broadly-based standard.

TMDD v3.0 Standard Sections

Figure 13 shows how various sections are organized for each of the two volumes of the TMDD v3.0 standard. Users are advised to refer to each Volume with a section number as a pair (e.g. Volume I, Section 3) for clarity and to avoid using page numbers altogether in the specification. Also be advised that each *User Need* has been provided with a unique ID number and each *requirement(s)* has an ID number, both listed in the NRTM. Each data concept is referred to by the standard clause and relates to requirements in the RTM. Users must adhere to columns provided in the standard while preparing their project-specific NRTM and RTM.

Volume I

Concept of Operations and

Section	***Section Title (Purpose)***
Section 1	*Documentation Introduction (General Information, Organization)*
Section 2	*Concept of Operations for TMC to Center Communications (Listing of User Needs: event sharing, sharing of devices, control and status, sharing data for archiving)*
Section 3	*Requirements (Listing of Requirements to match with the above needs, from which the users will prepare their local project specification)*
Section 4	*Traceability to National ITS Architecture (Mapping to ITS Architecture Flows)*
Section 5	*Needs to Requirements Traceability Matrix (**NRTM**) (Checklist to verify needs/requirement combination)*

Volume II

Design Content

Section	***Section Title (Purpose)***
Section 1	*Documentation Introduction (shows relationship between Volume I and II)*
Section 2	*TMDD Interface Dialogs and Messages (Basic information on dialogs and lists Generic TMDD Dialogs, information on ASN.1, Object Identifiers, and XML)*
Section 3	*TMDD ISO 14817 ASN.1 and XML Data Concept Definitions (Lists related Data Concepts: Dialogs, Messages, Data Frames, Data Elements)*
Section 4	*Requirements Traceability Matrix (**RTM**)* *The RTM traces* Requirements *defined in Volume I to each* Data Concept *defined in Volume II. Also note that data concepts fulfill intended function of each requirement in Volume I.*

Figure 13: TMDD Standard Sections

User Needs

[User needs describe one or more system features and the intent of the said need in addressing a user problem or responsibility. Requirements describe what information is and how these operations are exchanged with external center (EC) subsystems through a communications interface. The requirements also describe what functionality is supported across the interface. (TMDD v3 Standard)

As shown in the table Volume-I, Section 2 of the TMDD standard describes 126 user needs to support the operational environment. Project-specific operational needs must be mapped to these user needs in the standard. To aid in this process, users can read high level definitions of the standard user needs, and align them with project's operational need. For example, an external center may be only interested in sharing information about an *event* such as a road crash should examine 11 user needs outlined in the standard to decide which of them satisfy project's operational needs. Centers that desire to exchange information with each other must select same subset of user needs.

#	Need	Total	Volume I Section
1	*Need for Connection Management*	4	2.3.1
2	*Need for Authentication and Restrictions*	4	2.3.2
3	*Need to Provide Information on organization, Centers and Contacts*	1	2.3.3
4	*Need to Share Event Information*	11	2.3.4
5	*Need to Provide Roadway Network Data, includes sub-needs*	11	2.3.5
6	*Need to Share Control of Devices (Inventory, Status and Control of Detectors, CCTV, Video Switch, DMS, ESS, Gate Control, HAR, Lane Control, Ramp Meters, Traffic Signal Control*	87	2.3.6
7	*Need to Share Data for Archiving*	7	2.3.7
8	*Need to Accept Null Values*	1	2.3.8

Mandatory User Needs (M)

- ✓ Verify Connection Active (UN ID 2.3.1.1)
- ✓ Request Need to Support (UN ID 2.3.1.2)
- ✓ Need to Support Error Handling (UN ID 2.3.1.4)
- ✓ Need for Node Inventory (UN ID 2.3.5.1.1)
- ✓ Need for Link Inventory (UN ID 2.3.5.1.2)
- ✓ Need to Accept Null Values (UN ID 2.3.8)

Additionally, user is required to select six mandatory user needs listed above as stipulated by the standard. A specification that does not include mandatory needs will be considered non-conformant and may result in breaking interoperability (agencies desiring interoperability among centers must select a common set of user needs to drive the development of a common system interface).

A full list of user needs defined by the TMDD v3 standard is provided in the following section.

User Needs Defined by the TMDD v3.0 Standard

(Source: Based on TMDD v3.0 standard, Volume I, Table of Contents)

2.3 Needs 12
2.3.1 Need for Connection Management 12
2.3.1.1 Verify Connection Active 12
2.3.1.2 Need to Support Requests 12
2.3.1.3 Need to Support Subscriptions 12
2.3.1.4 Need to Support Error Handling 12
2.3.2 Need to Support Authentication and Restrictions 13
2.3.2.1 Need to Specify Restrictions 13
2.3.2.2 Need to Authenticate the Source of Messages 13
2.3.3 Need to Provide Information on Organizations, Centers, and Contacts 13
2.3.4 Need to Share Event Information 13
2.3.4.1 Need For An Index of Events 14
2.3.4.2 Need to Correlate an Event with Another Event 14
2.3.4.3 Need to Provide Free Form Event Descriptions 14
2.3.4.4 Need to Provide Free Form Event Names 14
2.3.4.5 Need to Provide Multilingual Event Descriptions 14
2.3.4.6 Need for Current Event Information 14
2.3.4.7 Need for Planned Event Information 14
2.3.4.8 Need for Forecast Event Information 15
2.3.4.9 Need to Share the Log of a Current Event 15
2.3.4.10 Need to Reference a URL 15
2.3.4.11 Need to Filter Events 15
2.3.4.11.1 Need to Filter Event Recaps 15
2.3.4.11.2 Need to Filter Event Updates 15
2.3.5 Need to Provide Roadway Network Data 15
2.3.5.1 Need for Roadway Network Inventory 16
2.3.5.1.1 Need for Node Inventory 16
2.3.5.1.2 Need for Link Inventory 16
2.3.5.1.3 Need for Route Inventory 16
2.3.5.2 Need to Share Node, Link and Route Status 16
2.3.5.2.1 Need to Share Node State 16
2.3.5.2.2 Need to Share Link State 16
2.3.5.2.3 Need to Share Route State 16
2.3.5.3 Need to Share Link Data 16
2.3.5.4 Need to Share Route Data 16
2.3.5.5 Need to Maintain English Units 17

2.3.6 Need to Provide Control of Devices 17
2.3.6.1.1 Need to Share Detector Inventory 18
2.3.6.1.2 Need Updated Detector Inventory 18
2.3.6.1.3 Need to Share Detector Status 18
2.3.6.1.4 Need for Detector Metadata 18
2.3.6.1.5 Need for Detector Data Correlation 18
2.3.6.1.6 Need for Detector Data Sharing 18
2.3.6.1.7 Need for Detector History 18
2.3.6.2 Need to Share CCTV Camera Status and Control 19
2.3.6.2.1 Need to Share CCTV Device Inventory 19
2.3.6.2.2 Need to Share Updated CCTV Device Inventory 19
2.3.6.2.3 Need to Share CCTV Device Status 19
2.3.6.2.4 Need to Control a Remote CCTV Device 19
2.3.6.2.5 Need to Verify CCTV Control Status 20
2.3.6.2.6 Need to Cancel CCTV Control Requests 20
2.3.6.3 Need to Share Video Switch Status and Control 20
2.3.6.3.1 Need to Share Video Switch Inventory 20
2.3.6.3.2 Need to Share Updated Video Switch Inventory 20
2.3.6.3.3 Need to Share Video Switch Status 20
2.3.6.3.4 Need to Control a Remote Video Switch 21
2.3.6.3.5 Need to Verify Video Switch Control Status 21
2.3.6.3.6 Need to Cancel Video Switch Control Requests 21
2.3.6.4 Need to Share DMS Status and Control 21
2.3.6.4.1 Need to Share DMS Inventory 21
2.3.6.4.2 Need to Share Updated DMS Inventory 21
2.3.6.4.3 Need to Share DMS Status 21
2.3.6.4.4 Need to Display a Message on a Remote DMS 22
2.3.6.4.5 Need to Verify DMS Control Status 22
2.3.6.4.6 Need to View DMS Message Queue 22
2.3.6.4.7 Need to Cancel DMS Message Requests 22
2.3.6.4.8 Need to Share DMS Message Appearance 22
2.3.6.4.9 Need to Share DMS Message Inventory 22
2.3.6.4.10 Need to Share DMS Font Table 23
2.3.6.5 Need to Share Environment Sensor Data 23
2.3.6.5.1 Need to Share ESS Inventory 23
2.3.6.5.2 Need to Share Updated ESS Inventory 23
2.3.6.5.3 Need to Share ESS Device Status 23
2.3.6.5.4 Need to Share ESS Environmental Observations 24
2.3.6.5.5 Need to Share ESS Environmental Observation Metadata 24
2.3.6.5.6 Need to Receive a Qualified ESS Report 24
2.3.6.5.7 Need to Share ESS Organizational Metadata 24
2.3.6.6 Need to Share Lane Closure Gate Control 24
2.3.6.6.1 Need to Share Gate Inventory 24

2.3.6.6.2 Need to Share Updated Gate Inventory 24
2.3.6.6.3 Need to Share Gate Status 25
2.3.6.6.4 Need to Control a Remote Gate Control Device 25
2.3.6.6.5 Need to Verify Gate Control Request Status 25
2.3.6.6.6 Need to Cancel Gate Control Device Requests 25
2.3.6.6.7 Need to Share Gate Control Schedule 25
2.3.6.7 Need to Share Highway Advisory Radio (HAR) Status and Control 25
2.3.6.7.1 Need to Share HAR Inventory 25
2.3.6.7.2 Need to Share Updated HAR Inventory 26
2.3.6.7.3 Need to Share HAR Device Status 26
2.3.6.7.4 Need to Control a Remote HAR Device 26
2.3.6.7.5 Need to Verify HAR Control Request Status 26
2.3.6.7.6 Need to View HAR Message Queue 26
2.3.6.7.7 Need to Cancel HAR Control Requests 26
2.3.6.7.8 Need to Share HAR Schedule 26
2.3.6.7.9 Need to Share HAR Messages 27
2.3.6.8 Need to Share Lane Control and Status 27
2.3.6.8.1 Need to Share Controllable Lanes Inventory 27
2.3.6.8.2 Need to Share Updated Controllable Lanes Inventory 27
2.3.6.8.3 Need to Share Controllable Lanes Status 27
2.3.6.8.4 Need to Control a Remote Lane Control Device 27
2.3.6.8.5 Need to Verify Lane Control Device Control Status 27
2.3.6.8.6 Need to Cancel Lane Control Device Control Requests 28
2.3.6.8.7 Need to Share Controllable Lanes Schedule 28
2.3.6.9 Need to Share Ramp Meter Status and Control 28
2.3.6.9.1 Need to Share Ramp Meter Inventory 28
2.3.6.9.2 Need to Share Updated Ramp Meter Inventory 28
2.3.6.9.3 Need to Share Ramp Meter Status 28
2.3.6.9.4 Need to Control a Remote Ramp Meter Device 28
2.3.6.9.5 Need to Verify Ramp Meter Control Request Status 29
2.3.6.9.6 Need to Cancel Ramp Meter Control Requests 29
2.3.6.9.7 Need to View Ramp Metering Plan Queue 29
2.3.6.9.8 Need to Share Ramp Metering Schedule 29
2.3.6.9.9 Need to Share Ramp Metering Plans 29

2.3.6.10 Need to Share Traffic Signal Control and Status 29
2.3.6.10.1 Need to Share Signal System Inventory....29
2.3.6.10.2 Need to Share Updated Signal System Inventory 30
2.3.6.10.3 Need to Share Intersection Status....30
2.3.6.10.4 Need to Control a Remote Traffic Signal Controller 30
2.3.6.10.5 Need to Verify Traffic Signal Controller Control Request Status 30
2.3.6.10.6 Need to View Traffic Signal Controller Plan Queue....30
2.3.6.10.7 Need to Cancel Traffic Signal Controller Control Requests....30
2.3.6.10.8 Need to Share Controller Timing Patterns....30
2.3.6.10.9 Need to Filter Controller Timing Patterns 31
2.3.6.10.10 Need to Share Controller Schedule....31
2.3.6.10.11 Need to Share Turning Movement and Intersection Data 31
2.3.6.10.12 Need to Share Time Synchronization Information....31
2.3.6.10.13 Need to Monitor Signal Operations 31
2.3.6.10.14 Need to Share Section Status....31
2.3.6.10.15 Need to Control a Section 31
2.3.6.10.16 Need to Verify Section Plan Status 32

2.3.6.10.17 Need to View Section Plan Queue 32
2.3.6.10.18 Need to Cancel Traffic Signal Section Control Requests....32
2.3.6.10.19 Need to Share Section Timing Pattern Schedule 32

2.3.7 Need to Share Data for Archiving 32
2.3.7.1 Need for Traffic Monitoring Data 32
2.3.7.1.1 Need for Direct Measurements of Traffic Flow and Conditions 32
2.3.7.1.2 Need for Original Source Data for Traffic Monitoring Measurements32
2.3.7.1.3 Need for Processed Traffic Monitoring Data....33
2.3.7.1.4 Need for Data Collection System Metadata 33
2.3.7.1.5 Need for Processing Documentation Metadata....33
2.3.7.1.6 Need for Roadway Characteristics Data....33
2.3.7.1.7 Need for Event Data 33
2.3.8 Need to Accept Null Values 33

Note: each of the above listed user needs is listed in the table format called NRTM discussed in the following section. All user needs are described in Section 2, Volume I.

Needs to Requirements Traceability Matrix (NRTM)

An operational need arises from a project ConOps, as illustrated in the box: *Need to Verify CCTV Control Status (Section 2.3.6.2.5) as an example*. The need states a desire of the external centers to know if the camera images are currently available or not and its justification.

> ***Need to Verify CCTV Control Status***
> *The center that sends a control request for a CCTV device operated by another center needs to verify the status of the control request. The status may be that the request was implemented, was queued, or was rejected.*

As shown in the table below, using the NRTM (Volume I, Section 5) will enable the user to match the operational need to the first column and select UN ID 2.3.6.2.5 with YES in the second column. (This completes the **N** part of the NRTM).

At this point, the NRTM traces to 10 requirements, displaying the Requirement ID in the third column with the tile in the fourth column. (This is the **R** part of the NRTM). The TMDD standard states at least six are mandatory.

Sample Needs to Requirements Traceability Matrix (NRTM)

UN ID User Need	*UN Selected*	*Requirement ID*	*Requirement*	*Conformance*	Support	*Other Requirements*
2.3.6.2.5	***Yes / ~~No~~***	***3.3.6.1.4.2***	***Contents of Device Control Request Response***	***M***	**Yes**	
		3.3.6.1.4.2.1	***Required Device Control Response Content***	***M***	**Yes**	
		3.3.6.1.4.2.2.1	*Operator Identifier*	*O*	Yes / No	
Need to Verify CCTV Control Status		*3.3.6.1.4.2.2.2*	*Operator Lock Identifier*	*O*	Yes / No	
		3.3.6.1.4.2.2.3	*Owner Center Organization*	*O*	Yes / No	
		3.3.6.1.4.2.2.4	*Operator Last Revised Date and Time*	*O*	Yes / No	
		3.3.6.1.5.1	***Send Device Control Status Upon Request***	***M***	**Yes**	
		3.3.6.1.5.2	***Contents of the Device Control Status Request***	***M***	**Yes**	
		3.3.6.1.5.3	***Contents of Device Control Status Response***	***M***	Yes	
		3.3.6.3.4	***Request CCTV Control Status***	***M***	Yes	

Note*: In this Exhibit, only one need is illustrated. When a user completes a project-specific NRTM, the user will select multiple user needs (UN IDs) from the first column, which maps to the allocated requirements: M-Mandatory O-Optional.*

The remaining four requirements are marked as **O** and are left to the local project to decide if they are to be selected and should be marked appropriately in the Support column of the NRTM; once these are selected, they are mandatory and form (along with the other six mandatory requirements) the project implementation specification relating to this particular user need (*Need to Verify CCTV Control Status* in this example*).* When all 10 requirements are

determined, the **R** part of the NRTM is completed. In the last column of the project NRTM, users may decide to place notes to further certify the specification.

From this illustration, we can see the critical use of the NRTM as intended by the TMDD standard consistent with the system engineering approach, where only user needs drive the requirements. The NRTM is provided by the TMDD standard to guide users at several levels:

- A specification writer uses the NRTM columns to ensure how requirements are to be implemented in a project-specific implementation.
- A protocol implementer uses the NRTM as a checklist to reduce the risk of failure to conform to the standard through oversight.
- An ITS project management uses the NRTM to ensure that the communication capabilities with associated centers are met.

Those who are concerned with the interoperability among agencies must also ensure that *User Needs* to support desired functions (and requirements that satisfy those user needs) are selected in their specification. For example, if a regional TMC of a state desires to share CCTV information with a city TMC in the region, both must select this user need to achieve interoperability. The NRTM helps both agencies to compare and select their needs. In general, by working together they should develop a "common" specification or exchange of each other's specifications.

Preparing System Interface Specification

Introduction

This chapter expands on the course discussion on how to prepare project specifications using the TMDD standard. The chapter outlines four key steps at the ConOps stage of the SEP and content of the two volumes of the TMDD standard needed to prepare a system interface specification. Please note that a system interface specification is a document that contains complete definitions of the data concepts (dialogs, messages, data frames, and data elements) for the system interface and mapping of the requirements (with the use of RTM).

Specification Considerations

Students may recall detailed discussion in modules A101 and A201 on the acquisition process to procure a system that is based on the ITS standards. Acquisition process documentation includes a complete, consistent, and correct statement on what is desired from the system being procured.

A project specification document (regardless of its title) achieves that purpose in which an agency outlines services desired from a TMDD v3.0 standard-based system interface. This information may be provided in a section in the procurement document.

While the nature of documentation may vary from project to project (based on type of system being procured) and perhaps agency to agency, in general, from the user needs stand point, following components should be considered and included in a specification document:

1. A general background of the project, problem definition, and ConOps/operational needs
2. A populated NRTM for the project: developed by mapping operational needs to those in TMDD

Additional considerations beyond these two are not discussed here but will be required in a full procurement document. An agency desiring to proceed with acquisition of a system interface must begin with the above steps in consultation with their system support consultant.

The “V” diagram shown in Figure 6 outlines four steps for preparing the TMDD-based, system interface specification. The “V” Model shows us where these steps are occurring in the SEP life cycle. Each step is explained in details followed by the “V” diagram.

Applicable TMDD standard sections are identified in each step and mapped to the stages SEP. Users should be guided by these steps to prepare a project specific specification. NRTM and RTM tools provided by the TMDD standard must be used.

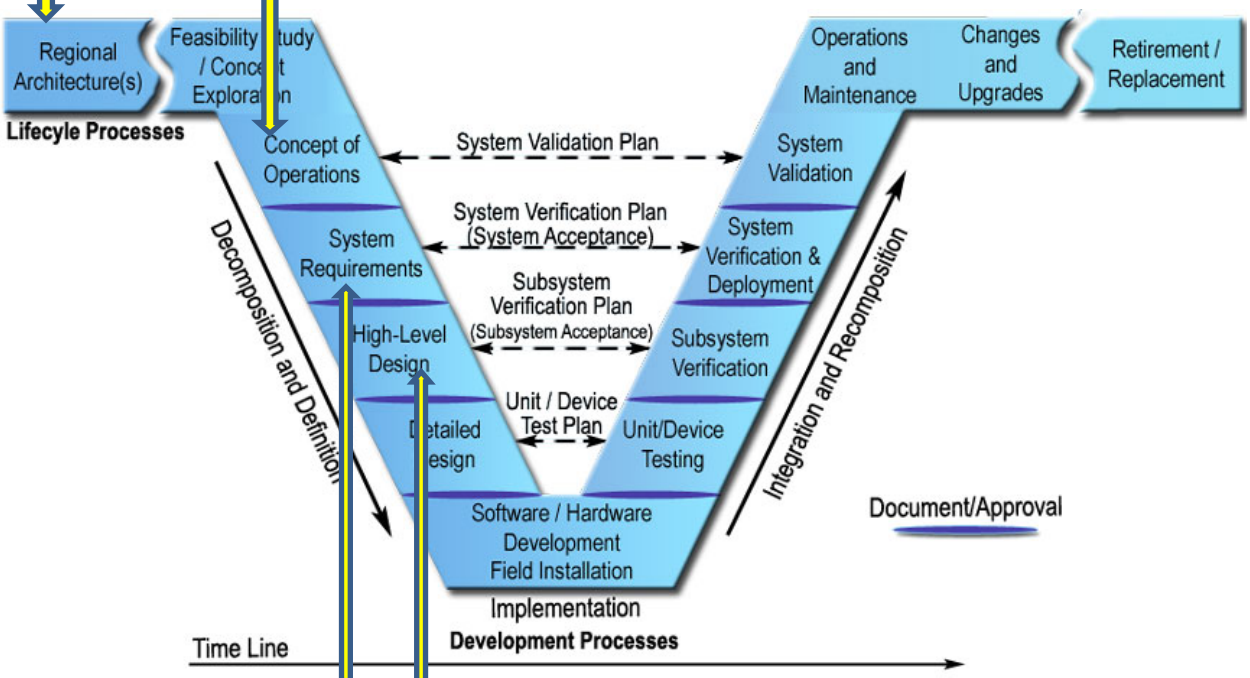
Mapping TMDD Standard to "V" Model Steps

Figure 14 shows four steps to guide the user in mapping project level user needs for specification preparation. Each step is linked to pertinent portion of the standard.

STEP-1: Go to TMDD standard Volume I, Section 4, pages 156-170 on TMDD support to your ITS Architecture market Packages, architecture flows.

STEP-2: Using the NRTM (pages 174-295 in the TMDD Standard Volume I, Section 5), select the user needs that address your operational needs. The user need description provided in the ConOps (pages 9-33 in TMDD Standard Volume 1) will help to better understand the intent and capability of the user needs.

User Needs are located at ConOps stages of the V diagram; Requirements follow



STEP-3: Using the NRTM (pages 174-295 in the TMDD Standard Volume I), select from the list of associated requirements those that will satisfy the selected user needs.

STEP-4: Go to RTM (pages 580-635 in the TMDD Standard Volume II. Section 4), select data concepts for design elected requirements. This step is often undertaken by a system consultant.

Figure 14: System Life Cycle Process

Step-1: Regional ITS Architecture

Readers may recall that the market packages developed by the ITS Architecture collect several different subsystems (including equipment packages, terminators) and architecture flows (information flows between subsystems) to provide the desired service. To implement architecture flows between subsystems (centers), the TMDD standard has provided traceability to the National ITS Architecture selected number of relevant market packages to C2C needs.

As a first step towards preparation for the *system interface* specification, the reader is advised to also review the work done by the TMDD standard to support communications needs arising from regional ITS architecture *market packages,* and *architecture flows. Architecture flows* originating from the traffic management center to other centers and the corresponding user needs and requirements are discussed in the Volume I, Section 4.

The specification writing process should first check with local regional architecture market package C2C needs and then select appropriate architecture flows and related user needs as per Section 4, Volume I. The market packages (partial list) supported by the TMDD standard include: *Network Surveillance, Traffic Information Dissemination, Regional Traffic Operations, Traffic Incident Management, Road Weather Data Collection, Roadway Maintenance and Construction, ITS Data Mart, Emergency Call-Taking and Dispatch, Emergency Routing, Disaster Response and Recovery and Broadcast Traveler Information.* In all cases, the TMDD standard supports not the entire market package but a subset of the interfaces.

Step-2: Selecting User Needs with NRTM

Begin with Operational Needs: Users should be able to identify potential user needs by observing the C2C operational scenarios. Operational scenarios define the sequence of activities to be performed to satisfy user needs as well as the information flows between entities, both during normal operations and in emergency situations. For example, the operational scenario may include the procedures on how public safety agencies make requests for event information, road network data, device status and inventory, etc. from a TMC. In a C2C context, the need to communicate with others and/or request and receive information also varies. For example, at some agencies the C2C context may only have a need for sharing DMS messages and/or CCTV control while operating within the freeway environment. At another place, local agencies may be only interested or need the C2C system interface for traffic signals operations.

The TMDD standard lists a broad range of user needs of which local agencies may need only a small subset based on their ConOps. At this step of the SEP, people who will use the intended system interface or will be affected by its use must be engaged in selecting user needs for their specific project. This is critical because user needs set the tone for the project by clearly defining “what will be needed to support an operational problem solution” and dictate “how” system requirements will emerge in the next phase with which a system interfaces design is done. Only clearly stated user needs using NRTM will ensure that; if users miss them, an “imperfect” system interface can result if these needs are not identified.

Step-3: Tailoring Requirements with NRTM

In the previous step, the first three columns of the NRTM identified and described a unique user need. By doing so, the user had in essence answered the question: "What needs to be done to address a problem in a ConOps?" This was done independent of the question: "How it will be done?"

In Step-3, the last four columns of the same NRTM associated requirements are traced to satisfy that unique need. In the SEP methodology, determination on requirements is critical for system interface design. All system requirements are therefore written in the form of **"shall"** language.

Users should be advised that the TMDD standard has traced (allocated) 134 requirements to 125 different user needs. This outcome was a result of a collaborative effort by the knowledgeable experts in the field. All requirements were carefully elicited, analyzed, validated, and documented. Most of these requirements are listed as "**optional**," allowing user to make the selection for a project. A small number of requirements are thus determined by the experts to be essential to satisfy certain user needs and are made "**mandatory**." To conform to the TMDD standard, **mandatory** requirements must be included in the specification.

Step-4: Selecting Data Concepts Using RTM

At the high level design stage in the SEP, we are faced with selecting data concepts, dialogs, messages, data frames, and data elements, to complete the **system interface** specification (analogues to selecting building materials for a construction work). The TMDD standard provides representation of data concepts in both ASN.1 based and XML based formats. At this stage, the user must elect one (if it not already done so) and using the RTM as shown in the box and select appropriate data concepts from Volume-II.

A sample RTM below illustrates the requirements related to display a DMS message remotely. The generic dialog (2.4.1) carries out a request/response message pattern for DMS control with two messages. Users should also note that in a given project certain requirements may also trace to other ITS standards for data concepts as shown in this example (to NTCIP 1203 standard supplied data element will be necessary for Beacon control). If such a capability is needed in an implementation, risk to interoperability could result. In general adding data concepts from other domain standards not already included in the TMDD could break interoperability. Users should take care in such issues and prepare accordingly during implementation process and testing phase.

Selection of TMDD Data Concepts Using RTM: DMS Example

Requirement ID	*Requirement Title*	*Dialogue*	*Data Concept Name*	*Data Concept Type*	*Standard Clause*
3.3.6.1.4.1	***Contents of Device Control Request Header***		***DeviceControlRequestHeader***	***data-frame***	***3.3.5.2***
3.3.6.1.4.1.1	***Required Device Control Request Header Content***		***OrganizationInformation***	***data-frame***	***3.3.17.3***
3.3.6.5.3.1	***Send DMS Control Response Upon Request***	***2.4.1***	***dDMSControlRequest***	***dialog***	***3.1.6.1***
3.3.6.5.3.2	***Contents of DMS Control Request***		***dMSControlRequestMsg***	***message***	***3.2.6.1***
3.3.6.5.3.2.1	***Required DMS Control Request Content***		***DeviceControlRequestHeader***	***data-frame***	***3.3.5.2***
3.3.6.5.3.2.2.1	*Beacon Control*		*ntcip:DmsMessageBeacon*	*data-element*	*NTCIP 1203:5.6.8.6*
3.3.6.5.3.3	***Contents of DMS Control Response***		***deviceControlResponseMsg***	***message***	***3.2.5.2***

Example: Selecting a User Need

Why a user need should be selected: Example **- "Need to Share DMS Status Information"**

Operational Need*: In order to coordinate its own efforts in the region, a center may find it necessary to monitor the status of various traffic devices that are managed by another center to monitor traffic conditions and the state of the network, and to provide traveler information. In such a situation, data that should be accessible for each device include communications status, operational status (e.g., working, not available) and current operational state information, which results in user need shown below.*

2.3.6.4.3 Need to Share DMS Status

How User Need should be selected? Through use of NRTM **(Volume I, Section 5)**

UN ID	User Need	UN Selected	Requirement ID	Requirement	Conformance	Support	Other Requirements
2.3.6.4.3	Need to Share DMS Status	**Yes**					

Once the operational need is identified as the above need suggests, the user should go to the NRTM to identify the User Need ID in the first column, and select Yes in the second column. This User Need appears on page 222 in Volume I of the TMDD standard.

The other four columns (shown in pink) in the NRTM relate to the next steps, which are requirements-related. (Readers please note that the actual NRTM in the standard is not color coded).

Example of Potential User Needs for C2C Context

The following table provides a sample list of potential user needs to support a range of operational contexts. In any of these situations, users are very likely to combine various ITS devices and actions for their C2C information exchanges. For example, a freeway management system may include CCTV, HAR, ramp meters, and planned events. The NRTM will guide users in selecting user needs and ensuing requirements.

C2C Operational Context	UN ID	User Need Title
Need to Manage Assets		
*Provide **inventory sharing** for:* • *Traffic network* • *Closed circuit television cameras and switches* • *Dynamic message signs* • *Environmental sensor stations* • *Lane closure gates and swing bridges* • *Highway advisory radio and low power FM stations* • *Lane control signals* • *Ramp meters* • *Traffic detectors* • *Traffic signals* • *Provide information on agencies, centers, systems, and users*	2.3.3	*Need to Provide Information on Organization, Centers and Contacts*
	2.3.5	*Need to Provide Network Data*
	2.3.5.1	*Need for Roadway Network Inventory*
	2.3.5.2	*Need to share Nodes, Link and Route Status*
	2.3.5.3	*Need to share Link Data*
	2.3.5.4	*Need to share Route Data*
Need to Manage Information		
• *Events (planned, current, or forecast) and supporting network data* • *Traffic, weather and road conditions* • *Operational status of devices*	2.3.4	*Need to Share Information*
Need to Control Traffic Control Devices		
• *Closed circuit television (CCTV) cameras* • *Video switches* • *Dynamic message signs (DMS)* • *Environmental sensor stations (ESS)* • *Lane closure gates* • *Highway advisory radio (HAR)* • *Lane control signals* • *Ramp meters (RM)* • *Actuated Signal Controllers (ASC)*	2.3.6	*Need to Provide Control of Devices*
	2.3.6.1	*Need to Share Detector Data*
	2.3.6.2	*Need to Share CCTV Camera Status and Control*
	2.3.6.3	*Need to Share Video switch Status and Control*
	2.3.6.4	***Need to Share DMS Status and Control***
	2.3.6.5	*Need to Share Environmental Sensor Data*
	2.3.6.6	Need to Share Lane Closure Gate Control
	2.3.6.7	*Need to Share HAR Status and Control*
	2.3.6.8	*Need to Share Lane Control Status*
	2.3.6.9	*Need to Ramp Meter Status and Control*
	2.3.6.10	*Need to Share Traffic Signal Control and Status*
Need to Archive Data		
• Traffic monitoring data, traffic flow and conditions, data collection, roadway characteristics, and event data	2.3.7	*Need to Share Data for Archiving*

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13. USDOT, RITA, ITS-JPO, http://www.its.dot.gov/index.htm (Fact sheets)
14. USDOT, FHWA, Operations, http://ops.fhwa.dot.gov
15. USDOT Standards Program, http://www.standards.its.dot.gov/
16. USDOT, FHWA, Freeway Operations and Management
    http://ops.fhwa.dot.gov/freewaymgmt/frwy_ops.htm

Pre-Arrangement Information Sharing Agreements and MOUs by Centers

17. Memorandum of understanding for traffic incident management team within Florida department of transportation district four www.smartsunguide.com/pdf/**MOU**.doc
18. **STAERNET Stakeholders Cooperation Plan, Sacramento Area Council of Governments**
    http://www.fhwa.dot.gov/cadiv/segb/files/starnet/starnetstake.htm
19. Fontana/Ontario Advanced Traffic Management Information System(ATMIS) Concept of Operations, 2000
    tmcpfs.ops.fhwa.dot.gov/.../**Ontario**%20CA%20concept%20of%20ops.doc

Standards Development Organizations (SDOs) Web sites

Information Topic	Web link (ctrl+click to follow link)	Organization
C2C-TMDD	www.ite.org/standards/TMDD	ITE
C2C -NTCIP	www.ntcip.org/library/documents	NEMA
C2C DATEX-part 2	http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=41362	ISO
ITS (NTCIP) Field Devices	www.ntcip.org/library/documents	NEMA
ATC Controller	www.ite.org/standards/atc/	ITE