Artificial Intelligence (AI)-Enabled Intelligent Transportation Systems (ITS) Capability Maturity Model (CMM) and Readiness Checklists

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Final Report – May 2024
FHWA-JPO-24-136

U.S. Department of Transportation

Produced by Leidos
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Notice

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-24-136		

4. Title and Subtitle	5. Report Date
Artificial Intelligence (AI)-Enabled Intelligent Transportation Systems (ITS) Capability Maturity Model (CMM) and Readiness Checklists	May 2024
	6. Performing Organization Code
7. Author(s) Brandon Freeman, Mohammed Hadi, David Hale	8. Performing Organization Report No.
9. Performing Organization Name and Address Leidos, Inc. 1750 Presidents Street Reston, VA 20190	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. 693JJ322F00456N
12. Sponsoring Organization Name and Address U.S. Department of Transportation Intelligent Transportation Systems Joint Program Office 1200 New Jersey Ave SE Washington, DC 20590	13. Type of Report and Period Covered Final Report (Jan 2023 – May 2024)
	14. Sponsoring Organization Code ITS-JPO

15. Supplementary Notes

The TOCOR was Robert Sheehan. The original TOCOR was Murat Omay.

16. Abstract

The United States Department of Transportation (USDOT) recognizes that artificial intelligence (AI) offers benefits in intelligent transportation systems (ITS), such as improving safety, mobility, equity, efficiency, accessibility, productivity, resilience. Several industries use capability maturity models (CMM) to objectively assess an organization's processes and ability to execute activities in the scope of the CMM topic area. This document provides an AI-enabled ITS CMM as an approach for organizations to self-assess their strengths and weaknesses for incorporating and mainstreaming AI into their ITS programs and operational processes. The AI-enabled ITS CMM fills a gap for transportation professionals by providing a more rigorous assessment (via comprehensive readiness checklists) compared to existing AI CMMs developed by commercial technology companies. Importantly, stakeholders helped to define capability maturity levels within the AI-enabled ITS CMM, which helped to inform the resulting readiness checklist items developed by the research team. Specifically, stakeholders noted the importance of a Level 2 (out of 4) maturity to denote organizations that have made the proper steps to achieve AI-enabled ITS readiness but have not yet deployed AI-enabled ITS solutions. Stakeholders recommended explicit recognition of a level zero maturity, because a large proportion of organizations have no awareness or capability within certain AI dimensions or subdimensions at this time of this writing.

17. Keywords	18. Distribution Statement
Intelligent Transportation Systems, capability maturity framework, capability maturity model, artificial intelligence, machine learning.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161. http://www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	67	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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List of Abbreviations

AI	artificial intelligence
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
CMF	capability maturity framework
CMM	capability maturity model
DOT	department of transportation
FHWA	Federal Highway Administration
GSA	General Services Administration
IMSS	integrated management support system
IT	information technology
ITS	intelligent transportation system
ITS-JPO	Intelligent Transportation System Joint Program Office
KSA	knowledge, skills, and abilities
ML	machine learning
NCHRP	National Cooperative Highway Research Program
NIST	National Institute of Standards and Measures
RDaF	Research Data Framework
RMF	Risk Management Framework
SHRP 2	second Strategic Highway Research Program
SME	subject matter expert
TSMO	transportation systems management and operations
USDOT	United States Department of Transportation
UX	user experience

Chapter 1. Introduction

The U.S. Department of Transportation (USDOT) Intelligent Transportation Systems Joint Program Office (ITS-JPO) recognizes the "promise artificial intelligence (AI) offers for achieving considerable benefits in intelligent transportation systems, such as improving safety, mobility, equity, efficiency, accessibility, productivity, resilience, and reducing individual and societal costs, emissions, and other negative environmental impacts." ITS-JPO envisions "advancing next generation transportation systems and services by leveraging trustworthy, ethical AI (including machine learning) for safer, more efficient, and accessible movement of people and goods" (Intelligent Transportation Systems Joint Program Office, n.d.).

Infrastructure owner-operators face several challenges that can impede successfully adopting AI for ITS. The foundation of modern AI applications lies in the quantity and quality of data used to train AI and machine learning (ML) models. For example, AI-enabled ITS applications involve handling, processing, and storing massive video feeds for object detection and real-time decision support. Agencies must contend with infrastructure readiness in terms of hardware, software, and specialized equipment and technology needed to support AI-enabled ITS applications. They must also contend with data issues in terms of bias, privacy, and ownership concerns; issues with ethics, equity and liability; and other technical, operational, and institutional issues. For widescale adaptability of AI-enabled ITS applications, agencies may likely need to assess their systems' current capabilities and make improvements to support AI technologies and realize the full benefits of AI. ITS-JPO funded and managed the work described in this report.

The past decade has seen an upshift in the deployment of ITS across the United States. Contributing factors to this upshift include the advancement of associated strategies, tactics, and operations, and the introduction of advanced vehicles and infrastructure technologies, such as those associated with connected and automated vehicles and infrastructure sensing, control, and management. During this period, transportation organizations and State and local governments have deployed enabling digital infrastructure that allows modern ITS applications to function.

As the data from ITS applications and other sources become available, and as implemented ITS solutions increase in sophistication, organizations have an increasing need to evolve their engineering processes and tools from existing, well-understood heuristic approaches to AI-enabled solutions. These solutions have the potential to provide more automated and granular outputs to support better system monitoring; diagnosis of underperformance; prediction; and prescription leading to better selection and implementation of strategies, tactics, operations, and management. The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) Version 9.2 (U.S. Department of Transportation, n.d.) showed that AI-enabled ITS will enhance a range of capabilities associated with ITS service packages, including transportation management, traveler information systems, emergency management and public safety, advanced public transportation, commercial vehicle operations, maintenance and construction, weather management, sustainable travel, and vehicle safety. AI-enabled systems will support offline and real-time processes associated with the ITS service packages and applications. However, stakeholders interested in AI-enabled ITS may need additional capabilities and resources. These capabilities cover several institutional and technical dimensions, with multiple subdimension levels for each dimension. The required maturity level of each capability increases with the complexity of the AI utilization and associated applications. At the same time, not all stakeholders desire, require, or can achieve the same levels of capabilities. Organizations face potential limitations in their available budgets, data science talent pool, and State/local policy that prohibits public deployment of certain AI-enabled applications. The different types and complexities of applications that various stakeholders plan to apply may not all require achieving the same capability levels. The above discussion indicates an increasing motivation for assessing existing stakeholder capabilities for AI-enabled ITS, identifying target maturity levels, and identifying actions to improve the capabilities to achieve the target levels of maturity based on an organization's needs, current capabilities, and available resources.

The Capability Maturity Model (CMM) Concept

Several industries use CMMs to objectively assess an organization's processes and ability to execute activities in the CMM topic area. The second Strategic Highway Research Program (SHRP 2) Reliability Program developed the *Business Process Frameworks for Transportation System Management and Operations (TSMO) Program Areas* (Gopalakrishna et al. 2019) based on a concept that is widely used for various information technology (IT) applications (American Association of State Highway and Transportation Officials, n.d.). Building on the identified TSMO CMM in that effort, the Federal Highway Administration (FHWA) has developed capability maturity frameworks (CMF) that focus on organizations' capabilities in specific program areas, including Road Weather Management, Planned Special Events, Traffic Incident Management, Traffic Management, Transportation Performance Management, Traffic Signal Management, Work Zone Management, Integrated Corridor Management, Connected and Automated Vehicles, Traffic Analysis, and Active Demand Management.[1] FHWA has developed these frameworks for organizations and regions to self-assess their current strengths and weaknesses and to develop targeted action plans for program area improvements. Government and industry have developed CMMs in the AI field (e.g., chapter 6 of *AI Guide for Government*) that focus on data science, data engineering, security, data governance, and data analytics/AI (General Services Administration 2023). This AI-enabled ITS CMM framework document leverages this previous work to provide a framework for transportation industry stakeholders to assess their level of readiness for undertaking AI-enabled ITS activities.

Document Purpose

This document provides an AI-enabled ITS CMM for organizations to self-assess their strengths and weaknesses for incorporating and mainstreaming AI into their ITS programs and operational processes. The CMM can help organizations assess their capability maturity across several dimensions and help them determine their current capabilities in the use of AI. Organizations can use this CMM in coordination

[1] "Welcome to Business Process Frameworks for Transportation Operations," Federal Highway Administration, Office of Operations, accessed April 12, 2024, https://ops.fhwa.dot.gov/tsmoframeworktool/index.htm.

with other related CMFs and CMMs to evaluate their capability maturity in areas that support AI-enabled ITS development. Capability assessments of TSMO, data management, and cybersecurity may be useful for organizations to undertake prior to assessing their AI-enabled ITS maturity, as their capabilities are often related to successful AI-enabled ITS implementation. If an organization has a high/low maturity score in an overlapping capability area from a previous CMM, it may inform the respective maturity level in this CMM (e.g., the culture dimension from the TSMO CMM is similar to the culture dimension in this CMM). If an organization undertakes actions to improve a capability area in this CMM, or these related CMMs, the capability score will likely rise in the respective capability area across multiple CMMs.

The target audience can consider using the AI-enabled ITS CMM in this document (and the resulting action plan from) as an important part of an overall integrated process to enhance organizational capabilities in ITS and TSMO. The SHRP 2 Reliability Program and FHWA's CMFs have data analytics, performance measurements, and performance management dimensions and subdimensions. Organizations from around the Nation have used these CMFs. Agencies can consider the AI-enabled CMM as part of an overall process to use other CMFs applicable to high-priority use cases within the organization. This can result in an action plan for advancing ITS and TSMO in a State or region including AI applications to ITS and TSMO. When considering the ITS/TSMO use cases for AI applications in their action plans, it is important for an organization to determine its maturity and target maturity in the focus area of the use cases (e.g., incident management, signal control, active demand management) and select use cases with acceptable levels of existing or target maturity in the overall ITS/TSMO action plan for the organization or region.

Agencies can also consider applying the AI-enabled ITS CMM and action plan in the context of national and regional ITS architectures, and as part of an overall ITS system engineering process for ITS projects, when such process is implemented. A system engineering process is required for all ITS projects that use highway trust funds (Federal Highway Administration 2002). ITS agencies have generally used the systems engineering approach to plan and implement ITS projects. A key aspect of the systems engineering process is compliance with statewide or regional ITS architectures that reflect the national ITS architecture. The latest national version, ARC-IT Version 9.2[2] has 156 service packages (originally called market packages) in 12 areas. One of these areas is Data Management, which includes two service packages: DM01: ITS Data Warehouse and DM02: Performance Monitoring. The Performance Monitoring service package involves the use of the collected and archived data for various research, planning, and operations tasks. Although this service package may be the core of where AI is supposed to reside, AI is applicable to most other service packages. Thus, organizations can examine their data management service packages as well as the service packages of high-priority use cases in their statewide or regional ITS architecture to determine any need to update these service packages based on action plans developed as a result of the AI-enabled ITS CMM.

Organizations can perform a readiness assessment through this CMM using a high-level approach or a detailed approach that includes readiness checklists. The CMM can also enable users to prioritize dimensions of capability to reach a level of readiness required for specific ITS use cases that an organization seeks to undertake. This CMM can support organizations in producing roadmaps and action

[2] Architecture Reference for Cooperative and Intelligent Transportation, ARC-IT Version 9.2 (U.S. Department of Transportation, https://www.arc-it.net/.

plans to build their AI-enabled ITS capabilities as an input to their existing planning processes. This CMM does not provide a primer or introductory overview of AI and assumes that users understand basic AI concepts. Organizations without exposure to AI technology and processes may consider providing introductory AI training to CMM participants prior to undertaking this process.

Key Terminology

AI and ML are key terminologies in this report. According to Vasudevan et al. 2020, “AI enables systems to: (1) sense and perceive the environment, (2) reason and analyze information, (3) learn from experience and adapt to new situations, potentially without human interaction, and (4) make decisions, communicate, and take actions. Examples of AI include ML, natural language processing, and object recognition. ML is a broad subfield of AI in which computers learn from data, discover patterns, and make decisions without human intervention. The ML field is broadly categorized into supervised, semi-supervised, unsupervised and reinforcement learning. In ITS, AI can be used to replace or augment actions of field, handheld and remote sensing devices, connected and automated vehicles, TMC operators, transit and freight operators, decision-makers, and travelers.”

In this report the term “use case” refers to a common category of AI-enabled ITS applications, such that many different applications can fall within a single use case. By contrast, case studies demonstrate how to apply a model (such as a CMM) to real-world conditions. Real-world case studies may someday demonstrate how the CMM could provide customized information for specific use cases. Table 1 provides an example of grouping AI-enabled ITS applications into use cases. Table 1 comes from an ITS-JPO publication (Vasudevan et al. 2020) that uses the term “scenarios” instead of “use cases.” This report uses the term “use cases” instead of “scenarios” when describing categories of AI-enabled ITS opportunities.

Target Audience

The CMM in this document is applicable to State, regional, and local transportation organizations that plan, design, manage, and operate ITS solutions. Individual organizations or departments or offices within an organization can use the CMM to self-assess their current capabilities and formulate actions to improve those capabilities.

The potential stakeholders of the CMM include:

- Workshop facilitators: One or more professionals who help attendees identify their agencies’ maturity levels and action plans in each subdimension. The professionals could be from one or more of the units/organizations participating in the workshop or from consultants who are contracted to perform this effort.
- State departments of transportation (DOTs) and local transportation organizations divisions/departments, including the following:
    - Planning
    - Demand forecasting and simulation modeling

- Design
  - TSMO
  - Performance measurements and trend tracking
  - IT
  - Data management
  - Innovation, research, and/or strategic management
- State DOTs and local transportation organizations multimodal functions, including the following:
  - Public transit
  - Freight
  - Pedestrians and bicycles
  - Micromobility
  - Shared mobility
  - Accessible transportation
- Traffic management centers
- Regional agencies such as transportation coalitions
- Transportation authorities (e.g., toll facilities, bridges, tunnels)
- State and local first responders and emergency services entities, including the following:
  - Offices of emergency services
  - Fire and rescue
  - Police
- State and local asset management, maintenance, and construction organizations
- Metropolitan planning organizations
- Academic and research institutions
- Transportation consultants

Document Organization

To introduce key concepts and approaches to the AI-enabled ITS CMM, chapter 2 provides a review of current AI practices and prior experience with relevant CMMs. Chapter 3 provides details of the AI-enabled ITS CMM dimensions, subdimensions, and maturity levels. Chapter 4 discusses the CMM implementation process and how users can begin the CMM self-assessment. Chapter 5 discusses summary conclusions and provides recommendations for future efforts in this area.

Chapter 2. Review of Current Practices

This chapter provides an overview of findings from documents that addressed AI applications in ITS, based on a literature review within the transportation industry. The chapter also provides an overview of current CMM/CMF practices in the transportation industry and other industries, based on literature reviews and discussions with selected professionals. The information obtained from the discussions and literature reviews helped to inform the overall CMM development effort.

Transportation Industry Literature Review

The objectives of the transportation industry literature review are to: 1) identify high-priority use cases of AI applications in ITS and 2) identify needs, issues, constraints, and risks associated with AI-enabled ITS the developed CMM should address when identifying the required capabilities to advance AI.

USDOT Research, Development, and Technology Strategic Plan for Fiscal Year 2022–2026 (USDOT 2022)

The USDOT Research, Development, and Technology (RD&T) Strategic Plan for Fiscal Year 2022–2026 lists priorities and objectives of transformation research in three research areas. One of these areas is data-driven insight including data science and foresight. As explained in the plan, data science focuses on harnessing advanced data collection and data processing capabilities to create timely, accurate, credible, and accessible information to support transportation operations and decision-making. Strategic foresight involves the assessment, anticipation, and planning for changes to the transportation system. Some of the research priorities mentioned that are related to AI-enabled ITS include conducting exploratory research on transformational mobility data analytics; developing and making accessible data sources, data analysis, and visualization tools to support transportation stakeholders and researchers; developing a USDOT data analysis framework guide; developing computer-aided decision modeling systems to assess the implications of emerging technologies, forecast travel demand, and assess potential scenarios; supporting scenario planning and robust decision-making around policy decisions and investments to address future opportunities and disruptions; exchanging information on emerging trends with private, public and academic sector peers, domestically and internationally; and supporting research and engagement activities designed to anticipate, respond to, and recover from disruptions

Identifying Real-World Transportation Applications Using Artificial Intelligence (AI): Summary of Potential Application of AI in Transportation (Vasudevan et al. 2020), Identifying Real-World Transportation Applications Using Artificial Intelligence (AI) Plan for Artificial Intelligence for Intelligent Transportation Systems (Vasudevan, Townsend, and Schweikert 2020).

These ITS-JPO documents describe an AI plan for ITS to identify key challenges and barriers. Although the documents focus on the Federal program, the findings can be useful in identifying the required maturity capabilities of AI in ITS in general. These findings point to the need for CMM subdimensions that address prioritizing and protecting investment, fostering interagency and intra-agency coordination, ITS community outreach, data, infrastructure, legacy systems, generalizability of the developed models, model bias, privacy, ethics and equity, liability, stakeholder acceptance, workforce availability, and culture. The documents identified potential AI-enabled ITS applications categorized into application areas such as advanced driver assistance systems and automated driving systems, cybersecurity, accessible transportation, traveler decision support tools, TSMO, commercial vehicle and freight operations, transit operations and management, emergency management, air traffic management, remote sensing, and asset management and roadway construction and maintenance.

The documents identified 11 scenario categories of AI-enabled applications that can map to the service packages of the ARC-IT. The effort identified 49 potential applications in these categories. Later, with input from experts from USDOT and other agencies, the project identified a subset of 40 priority AI applications categorized into five real-world transportation scenarios that can motivate and inform stakeholders; accelerate the impact of AI deployment; and form the basis of potential proof-of-concept tests, prototype demonstrations, and deployments illustrating the power of AI. The prioritization accounted for risks, rewards, and possible inclusion in the 5-year plan roadmap. Table 1 shows these five top-priority scenarios. The AI-enabled ITS applications in table 1 are those that transportation agencies and stakeholder organizations are likely to undertake now and in the future.

Table 1. Identified Real-World Scenarios and Applications in Vasudevan, Townsend, and Schweikert (2020)

Scenario	Application
Urban arterial network	1. Traffic signal coordination plan optimization 2. Real-time traffic signal optimization 3. Traffic signal decision support subsystem 4. Misbehavior detection system 5. Comprehensive traffic modeling 6. Crash and incident detection 7. Pedestrian, cyclist, and micromobility detection 8. Safety metrics assessment 9. Transit signal priority optimization 10. Demand response transit network optimization 11. Identification of unauthorized bus lane usage
Urban multimodal corridor	1. Interagency collaboration 2. Detection of multimodal failures and incidents 3. Prediction of multimodal corridor delays 4. Personalized dissemination of multimodal travel information 5. Multimodal corridor demand management 6. Integrated payment for multimodal corridor 7. Real-time demand responsive traffic management and control
Regional system management	1. AI for asset condition monitoring 2. AI for weather prediction and response 3. AI for incident detection and response 4. AI for work zone safety and information dissemination 5. AI for data fusion in transportation management centers 6. AI for port operations and planning
Rural freeway corridor	1. AI for crash and emergency detection 2. AI for wildlife detection 3. AI for emergency planning 4. AI for road weather management 5. AI for safe asset health inspections 6. AI for predictive asset maintenance 7. AI for work zone management 8. AI for smart truck parking information systems 9. AI for distracted driver behavior detection 10. AI for freight traveler information 11. AI for decision support system
Underserved communities	1. AI-enabled routing and wayfinding tools for pedestrians 2. Navigation applications with augmented reality and localized points of interest 3. AI interpretation of user input 4. Environmental mapping and guidance 5. AI-enabled payment assistance 6. AI-powered safety monitoring and alerts 7. Virtual reality for testing 8. AI-powered assistive robotics

Raising Awareness of Artificial Intelligence for Transportation Systems Management and Operations (Gettman 2019)

This report introduces the fundamentals of AI technologies and potential areas of AI applications in TSMO. It documents successful AI applications and lessons learned in traffic management center operations and identifies needs for future studies. The report points to several case studies of using AI in TSMO. The report emphasizes that improvements in using AI are based on supporting institutional frameworks, policies, culture, processes, staff, technology, and implementation of the system. The findings from reviewing the report point to the need for CMM subdimensions that address the required infrastructure, integration with legacy systems, policy and legal requirements, staffing needs, application and tool selection, process development and adjustment, application prioritization, required funding, collaboration and agreements, AI performance assessment, and organizational framework.

An Integrated Management Support System Combining Business Intelligence and Decision Support Systems[3]

This FHWA effort involved the development and application of an integrated management support system (IMSS) framework that addresses and supports all levels of decisions, including strategic, tactical, and operational decisions. The IMSS framework recognizes the importance of linking strategies, performance measurement, people, processes, platforms, and data to support decision-making processes in an integrated manner. AI is an important component of the data analytics processes, identified to support the decisions. The IMSS research team interviewed several transportation agencies to assess their use of data and analytics in decision-making. The findings point to the need for CMM subdimensions that address data availability; archiving the needed information for AI, data governance; data and performance measure visualization, alignment of performance measures between different levels of decision-making; alignment of performance measures between partner agencies, methods for information delivery to stakeholders; methods for performance target setting; prediction of performance; and needed changes to culture, collaboration, and organization. Existing use cases include ITS planning, crash prediction, ITS maintenance, and winter maintenance.

Emerging Data Science for Transit: Market Scan and Feasibility Analysis (Perlman et al. 2022)

This report describes the state of the practice in emerging data science tools and methodologies among U.S. transit agencies. The report summarizes common challenges, opportunities, issues, and potential solutions through a literature review. The report outlines key factors and considerations for further adoption of emerging data science practices and tools within the U.S. domestic transit industry. The authors identify examples of advanced and emerging and data science, including applications to support asset health monitoring and predictive maintenance; occupant counting and monitoring; improving operational efficiency and information availability; and planning, scheduling, and performance management. The review of the report points to the need for CMM subdimensions that address data

[3] Hadi, M., D. Hale, P. Noyes, H. Mata, T. Wang, S. Ercisli, and F. Abdulkadir, *An Integrated Management Support System: Combining Business Intelligence and Decision Support Systems* (Washington, DC: USDOT, forthcoming).

quality, interoperability of system and data, data integration and exchange, data use, staffing, need for proof-of concept applications, integration with legacy systems, learning margining data and tools, and organizational structure.

Leveraging Big Data to Improve Traffic Incident Management (Pecheux, Pecheux, and Carrick 2019)

This National Cooperative Highway Research Program (NCHRP) project report focuses on big data concepts, sources, applications, and analyses for traffic incident management. The project report describes potential opportunities for TIM agencies to leverage big data, identify potential challenges associated with the use of big data, and develop guidelines to help advance the state of practice for TIM agencies. The report describes potential applications to improve scene management practice, improve resource utilization and management, improve safety, enable predictive TIM, support performance measurement and management, and support TIM justification and funding. The description includes the current practice, the potential for a big data approach, the differences in data needs and analytical approaches, and the possibilities and benefits afforded by big data. Key findings of this study point to the need for CMM subdimensions that address the required data sources, data cost, data openness, data standards and policies, data sharing, data processing, and data archiving.

Guide to Establishing Monitoring Programs for Travel Time Reliability (List et al. 2014)

This is the final report of SHRP 2 Project L02, which focused on creating a suite of methods by which transportation agencies could monitor and evaluate travel time reliability. Although the L02 guide focuses on reliability, some of its findings are relevant to other analytical applications to traffic operations. The findings point to the need for CMM subdimensions that address data availability, emerging data sources, performance measure identification, quality control and management of data and tools, public-private sector partnership, underperformance diagnostic tools, analysis result communication, collaboration and data sharing, need for area-wide measures, culture, and human user interface.

The Role of Artificial Intelligence and Machine Learning in Federally Supported Surface Transportation 2022 Updates (Federal Highway Administration 2022)

This report points to the potential of using AI to improve traffic flows at signalized intersections along specific routes or as part of integrated corridor management, aiding traffic management centers with improving crash detection, predicting traffic slowdowns, recommending detours, facilitating traffic safety by warning vehicles of pedestrians obscured by parked vehicles, discerning and anticipating how drivers might react in certain traffic situations, providing information to travelers with disabilities to assist in their trip planning and increase their situational awareness, allowing traffic engineers and urban planners to better understand what variables may reduce the potential for traffic crashes or injuries, and reducing highway infrastructure repair and reconstruction costs by augmenting data from structural health monitoring of highway. The report emphasizes the needs to maintain trustworthiness, avoid bias or tracking and mitigating bias, and transparency of AI applications.

Federal AI and Risk Literature Review

The Federal Government has also released guidance and support materials for use by government organizations that are exploring the adoption and integration of AI into their processes and technology applications. The research team identified three documents as pertinent to the adoption of AI-enabled ITS applications and focus respectively on risk management, data management, and capability maturity in this domain.

Artificial Intelligence Risk Management Framework (AI RMF 1.0) (National Institute of Standards and Technology [NIST] 2023)

NIST published the AI risk management framework to assist organizations in better assuring the trustworthiness of AI-enabled applications. Part 1 of this document outlines the different forms of risk inherent in the development and operation of AI-enabled applications. Part 2 provides a four-dimension framework for managing risk across organizational and technical aspects of an organization's AI programs.

NIST Research Data Framework (RDaF) (Hanisch et al. 2023)

The NIST RDaF is a tool intended to assist organizations in developing a research data management strategy and plan for data management and open data access. The document outlines six lifecycle stages in an organization's data management journey and provides key themes for consideration and action during each lifecycle phase.

AI Guide for Government (General Services Administration [GSA] 2023)

The GSA published a guide for government organizations on exploring and implementing AI in its processes and technical infrastructure. This document contains a CMM that is similar in structural composition (e.g., organizational and technical dimensions using five levels of maturity); however, it is focused on the use of AI more broadly, rather than specifically for ITS applications as this CMM is intended. The GSA AI CMM also utilizes a set of questions similar to the readiness checklists of this CMM to assist organizations in their self-assessments.

External Industries Literature Review

A survey of literature across government and commercial sectors outside of transportation resulted in the identification of the following AI CMM approaches and related materials:

- *Artificial Intelligence Maturity Model* (Gartner 2020)
- *AI Maturity Framework for Enterprise Applications* (IBM AI Applications 2021)
- *AI Maturity and Organizations* (Charran and Sweetman 2018)
- *Trust and Artificial Intelligence* (Stanton and Jensen 2020)
- *How to Achieve AI Maturity and Why It Matters* (Ovum 2018)

The currently existing AI CMMs developed by the commercial sector generally target audiences in the beginning or early stages of exploring AI implementation. Accordingly, the model structures themselves stay at a high level of detail with non-rigorous and non-evidence-based assessment methodologies. The AI CMM found in *AI Guide for Government* also intends to be non-rigorous. The guide states, “The AI CMM is not meant to normatively assess capabilities, but to highlight milestones that indicate maturity levels throughout the AI journey” (General Services Administration 2023, chap 6). The above discussion points to the fact that the scope and intent of these existing AI CMMs differ from that of the AI-enabled ITS CMM. However, the findings from the external industry CMM approaches have informed the organization of the CMM developed in this study.

Stakeholder Outreach

As a part of the iterative development process for this project, the research team frontloaded the outreach phase with heavy literature review, followed by direct stakeholder outreach throughout the course of the CMM development. This enabled the team to test and solicit feedback on more mature iterations of the CMM and readiness checklist with stakeholders and make these sessions more valuable to both parties. The team has incorporated stakeholder feedback in such areas as the composition of dimensions and subdimensions, as well as the content and structure of the self-assessments, into the current version of the CMM contained in this report. Chapter 5 of this report contains a summary of this stakeholder feedback, as well as suggestions regarding implementation of the CMM.

Chapter 3. AI-Enabled ITS CMM Mechanics

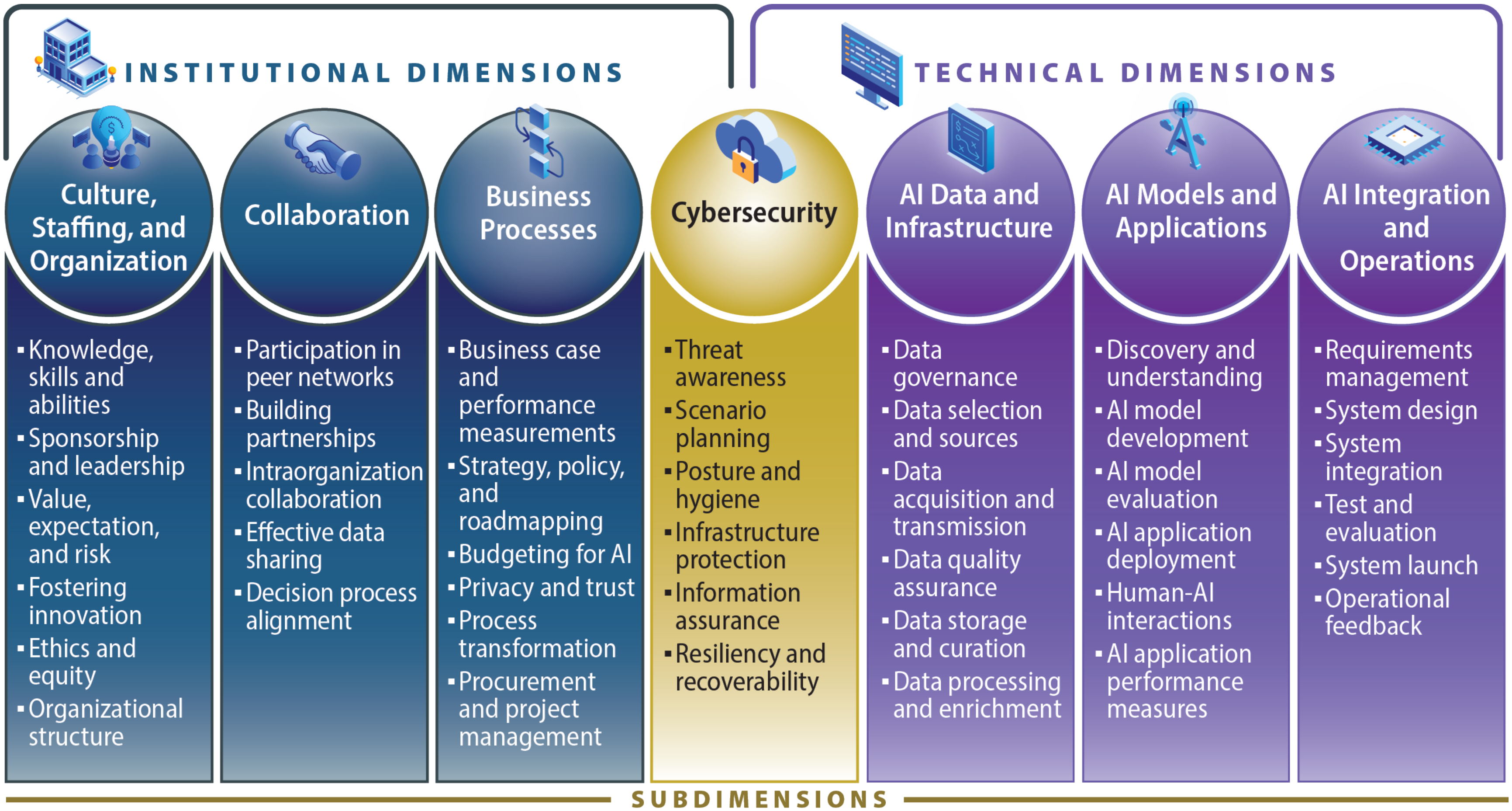
The AI-enabled ITS CMM can help organizations identify their current capability levels, identify opportunities for improvement, and create an action plan for incorporating AI in ITS to meet their target operational goals. The CMM allows for a common understanding of current and target institutional and technical capabilities. Since the field of AI is evolving, and still emerging within the ITS community, organizations can review their current CMM level and goals on an annual basis if possible. By using this CMM, organizations can:

- Determine their current AI capability maturity level in each dimension and subdimension of the CMM.
- Determine priority capability maturity dimensions that are in line with AI-enabled ITS projects that organizations are looking to undertake.
- Develop consensus around needed organization improvements, identify priorities for improvements, identify resources, and identify an action and monitoring plan for AI-enabled ITS.
- Compare AI-enabled ITS needs and benefits against other priorities and how AI investments may compliment and/or reduce the resource needs of other transportation activities.

Users of this AI-enabled ITS CMM should consider the two points mentioned in chapter 1 regarding the linkages to other TSMO CMM/CMFs and the systems engineering process/ITS architecture. The organization can make these linkages within various steps of the AI-enabled ITS CMM implementation.

Dimensions and Subdimensions

This AI-enabled ITS CMM is comprised of seven dimensions spanning institutional and technical capability areas. With six subdimensions apiece, the seven major dimensions contain 42 total subdimensions to provide a greater level of specificity. Figure 1 illustrates this composition.



Source: ITS-JPO.

Figure 1. Diagram. AI-Enabled ITS CMM Dimensions and Subdimensions

Dimension 1: Culture, Staffing, and Organization

This dimension involves building the organization and workforce needed for developing, deploying, and operating an AI-enabled ITS. This capability involves identifying, developing or hiring, and retaining qualified staff to perform these tasks, as well as continuous education to increase the capability of different levels and types of staff. This dimension also includes the organizational ability to ensure effective structure to plan, design, procure, implement, and use AI in ITS. This can involve the need for adding new roles or modifying existing roles. The culture subdimensions involve capabilities such as leadership/championship, understanding, fostering of innovation, and building a culture that values ethics and equity. The culture, staffing, and organization dimension includes the following subdimensions.

Knowledge, Skills, and Abilities

The knowledge, skills, and abilities (KSAs) subdimension addresses the need for the organization's technical capability to align with the needs of building AI solutions. This subdimension involves identifying and building KSAs required for planning, designing, implementing, operating, managing, and evaluating AI-enabled ITS, in addition to those required for the associated data management and governance. Identifying KSAs can inform related efforts at the national level and in other States. Based on identifying KSAs, the organization will implement programs for recruitment, retention, and training and methods to acquire, maintain, and expand their capabilities as required for specific applications and use cases. The identified KSAs can help produce needed job specifications to support their programs and a well-defined career path/ladder. The organization can recognize that taking advantage of peer resources utilization may address needs for these jobs. Depending on the organization's needs and resources, the organization can implement a process to assess the trade-offs for in-house core staff capacity building versus outsourcing. Based on this assessment, the organization can use mechanisms for outsourcing, partnership, and/or academia/industry collaboration for using AI in ITS. The organization can also establish a career development program building on national and statewide opportunities for training and a program for retention of staff, including professional development, advancement opportunities, and rewards. The organization will benefit from facilitating staff participation in national technical and professional organizations and committees.

Sponsorship and Leadership

This subdimension involves identifying and supporting staff champions for AI utilization. An established mechanism can encourage and reward championship by providing the needed authority, budgets, and staff to build the required AI research, development, and proof-of-concept deployments. As AI utilization matures, the organization will aim at promoting and extending championship throughout the organization. This subdimension is to build strategic, tactical, and operational leadership to generate the best vision, road map, and day-to-day tactical and operational decisions for AI. These leaders must have a good understanding of the implications of AI, data management, and data governance for their business through training, job support, and inclusion in the process of designing and deploying AI solutions.

Value, Expectation, and Risk

This subdimension involves the understanding of the business case and potential risks of using AI in ITS. This understanding should be across the decision makers, policymakers, stakeholders, organization staff, partner organizations, and the public. The understanding will involve managed people's perceptions of the usefulness, ease of use, trust/certainty, and impact on job security of AI. This subdimension also addresses the need to understand the importance of investing in data governance to ensure the availability, usability, consistency, privacy, integrity, and security of the data associated with AI-enabled ITS applications.

Fostering Innovation

This subdimension involves evaluating and implementing potential needed changes in organization values, priorities, and culture to foster innovation and acceptance of experimentation, additional costs and risks, and emerging technology. Fostering innovation may require changes to objectives/performance measures, policy, staff empowerment, and reduction in obstacles. Organizations can review their risk management efforts to determine if they create barriers to innovation and experimentation in new ideas, technologies, and processes. The culture of innovation within organizations can also support recruitment and retention of staff in data analytics, data engineering, and data science including AI.

Ethics and Equity

This subdimension involves building a culture that understands, appreciates, and accounts for ethics and equity in using data, establishing data governance, developing and using the AI systems, and the impact of these systems on public value. Organization staff should understand the importance of ethics and equity in AI planning, design, development, acquisition, and use to foster public trust and confidence while protecting privacy, civil rights, civil liberties, and values, and being consistent with legal and regulatory requirements. In addition to efficacy and effectiveness, the organization should have other measures of AI solutions such as understandability, accountability, ethics, transparency, fairness, privacy, mitigation of bias, and inclusion. Policies and governance frameworks should reinforce these principles. Organization staff should receive training on the importance of these measures and policies.

Organization Structure

This subdimension involves identifying organizational structure issues that require attention to advance AI-enabled ITS capabilities and the required data management and governance. This identification can leverage experience using AI in the transportation field and in other disciplines and the initial AI deployment effort by the organization. Based on the identification, the organization will update its organizational structure as needed, including the hierarchy layers and the roles, responsibilities, relationships, and coordination among organization units responsible for development, operation, maintenance, and end use of AI applications. The reorganization should reduce stove-piping and authority conflicts. The organization should use data governance principles to strengthen the overall data management process by defining roles and responsibilities for all players involved in the AI planning, development, and utilization in the organizational structure. Organizations can also establish a data governance board, council, or committee that oversees the data governance. Organizations can update the roles and responsibilities based on additional experience from implementing pilot projects and adding new applications and use cases of AI in ITS.

Dimension 2: Collaboration

The Collaboration dimension involves collaborating with peers, building partnerships, identifying roles and responsibilities of the partners, collaborating within the organization, ensuring effective data sharing, and aligning AI use at different levels of the organization. The collaboration dimension includes the following subdimensions.

Peer Network Participation

This subdimension involves participating in peer and national dialogues regarding policy, planning, technical, privacy, security, trust, and legal issues. The needed capability involves identifying and building multijurisdictional peer cooperation, including multiregional and multistate cooperation regarding various required capabilities to build the AI-enabled ITS. This can include identifying opportunities for information sharing, resource sharing, and workforce training among agencies. The peer cooperation can consider common priority applications, use cases, standards, and other capabilities. At the mature levels, the peer organizations can establish resource sharing agreements regarding technical, financial, and staff resources to generate required outcomes and minimize duplication.

Building Partnerships

This subdimension involves identifying key regional public and private partnerships and stakeholders to implement and operate AI-enabled ITS in the region. Once identified, the organizations work on identifying, and in some cases aligning, the strategic, tactical, and operational objectives and performance measures for the success of AI applications in ITS in the region. Based on this effort, organizations can implement—and at higher maturity levels, institutionalize—a collaborative approach for AI use in ITS. This collaborative approach can further consider regulating and harmonizing the collaboration process to maximize the benefits for all organizations. The mature collaborative effort also involves maintaining clear relationships among all collaborative partners. The partnership will incrementally expand to other partners based on experiences with the implementation.

Intra-organization Collaboration

This subdimension addresses whether there is strong collaboration among different units within the same department and among different departments in an organization. Strong collaboration would be across the entire organization with clearly defined and integrated roles and responsibilities. The collaboration can include information sharing, resource sharing, workforce training, and developing AI solutions to accommodate different units and functions within the organization.

Effective Data Sharing

This subdimension involves establishing agreements, methods, and tools for sharing data between multi-organizations and multijurisdictions public and private sector organizations. This capability includes understanding the value of various data items to share from different sources. Based on this understanding, organizations can establish appropriate data-sharing agreements and models with the involvement of stakeholders. The organizations can adopt and use available information for sustainable data sharing. Data-sharing practices, models, and methods should align with organization and AI utilization goals and objectives, and in accordance with the wider data strategy of the organization and AI-enabled ITS, such as data governance and risk assessments.

Design Process Alignment

This subdimension involves developing an integrated management AI-enabled ITS that addresses and supports all levels of decisions in the organization (i.e., strategic, tactical, and operational) in an integrated manner. This integrated implementation can support additional functions within the organization or the region. The application will ensure that the agency aligns objectives, measures, targets, and initiatives at all levels (i.e., strategic, tactical, and operational) to achieve strategic objectives.

Dimension 3: Business Processes

This dimension involves building the business case for using AI-enabled ITS. This includes assessing AI impacts before and after deployment; establishing an AI strategy, policy, and road map; transforming current organizational processes to take full advantage of AI; ensuring privacy and trust in using AI in organizational processes; and establishing methods for procuring AI solutions. The business processes dimension includes the following subdimensions.

Business Case and Performance Measurements

This subdimension involves building the business case for using AI in ITS (utilizing quantitative measures if possible) and using the business case to prioritize investment decisions. The business case can reflect evaluations and lessons learned and can report out according to the user type: public organization, private organizations, and the public. This capability also includes developing a strategy to communicate the business case within the organization and to partner and peer organizations. This subdimension also includes developing a plan for implementing pilot projects to confirm the business case of AI-enabled ITS and to identify implementation issues. The organization should also establish policies, procedures, and protocols to track the performance and evaluate the cost effectiveness of AI solutions.

Strategy, Policy, and Roadmapping

This subdimension involves establishing and implementing a vision, strategy, and road map of staged actions for achieving the desired level of AI-enabled ITS maturity. The developed AI strategy and road map should align with other organizational road maps and should address coordinating AI efforts across functions for greater impact. The plan will need to balance short-term and long-term goals with regard to implementation, operation, and management of AI. Key activities to address are setting the direction, translating strategy into action, aligning the organization and the people with the developed strategy, developing strategic capabilities, and determining the effective intervention points. This subdimension also involves developing or modifying policies, standards, procedures, and compliance requirements to ensure effectiveness and reduce the risks of AI implementations.

Budgeting for AI

This subdimension involves identifying the costs and resources required to implement specific AI-enabled ITS applications and use cases. These costs and resources include capital, operating, maintenance, and upgrade costs of AI development and use, and the required data management and governance. This dimension also involves the budget and resources needed to continuously refine, manage, and sustain AI elements and technologies. This involves creating line items and budget for AI utilization. Budgeting for AI also involves identifying funding sources, investment partnerships, investment protocols, and risk mitigation strategies. At the mature level, this capability involves developing a sustainable program with sustainable funding for existing and future AI implementations.

Privacy and Trust

This subdimension involves developing frameworks, principles, procedures, and training for privacy, trust, equity, and ethics in AI-enabled ITS planning, design, development, acquisition, and use—in a manner that fosters public trust and confidence, and in accordance with an implemented data governance process. At high levels of maturity this includes organizationwide integration, training, and monitoring of ethical aspects of AI-enabled ITS applications in accordance with legal and regulatory requirements. The capability requires protecting privacy in the data and helping to ensure the developed AI-enabled ITS applications do not create privacy concerns. The design, development, acquisition, and use of AI—as well as relevant inputs and outputs of particular AI-enabled ITS applications—should be well documented and traceable. Organizations should also ensure they regularly test their AI-enabled ITS applications against ethics and equity principles. Organizations should maintain mechanisms to address AI-enabled ITS applications that are inconsistent with their intended use. Organizations may also need to implement and enforce appropriate safeguards for the proper use and functioning of their AI-enabled ITS applications. They should monitor, audit, and document compliance with those safeguards. Organizations should ensure application of AI is consistent with use cases they had used for training AI, and that such uses are accurate, reliable, and effective. Organizations should be transparent in disclosing relevant information regarding use of AI to appropriate stakeholders, including the protection of privacy.

Process Transformation

This subdimension involves using AI to transform organizational processes to automate how the organization can monitor, diagnose, predict, optimize, and evaluate performance. This subdimension involves infusing AI in ITS by updating ITS planning, design, operations, and management processes to take advantage of AI in supporting strategic, tactical, and operational processes and associated analysis and decisions. This can involve updating systems engineering process documents, standards, and procedures for incorporating AI in ITS projects. At the highest maturity levels, organizations will institutionalize and mainstream the process transformation.

Procurement and Project Management

This subdimension involves identifying and addressing issues and options related to procuring and managing AI platforms and AI-enabled solutions for ITS projects. In many industries, including transportation, organizations are having to further evaluate how they procure AI-enabled systems in areas of procurement contracting including legal, policy, privacy, and liability. Organizations are additionally having to determine whether or not they have the technical expertise available to correctly write project technical requirements into requests for proposals. This subdimension also considers adopting methods for identifying and managing costs and resources for AI projects and establishing funding for the AI projects to cover the estimated initial and recurrent costs. The process includes a decision analysis and resolution process for determining if the organization should perform or outsource the work. The organization will also implement a procedure for identifying vendors or consultants that can provide AI platforms and AI-enabled solutions that meet technical and institutional requirements and expectations, including product elimination and new product introduction. In addition, the organization will establish a procedure to evaluate and select among potential analysts based on identified criteria such as qualifications, cost, project management, and technical approach. At the highest capability levels, the organization will maintain procedures and templates for procuring platforms and solutions that are customizable for specific AI-enabled ITS use cases.

Dimension 4: Cybersecurity

Cybersecurity is a hybrid dimension that addresses the organizational and technical capabilities necessary to protect AI-enabled ITS applications from cyberattack, as well as processes for disclosing and recovering from cyber incidents. AI-enabled ITS have a large attack surface, due to their public/private composition, where bad actors may attempt to penetrate the system. AI-enabled ITS applications include a mix of government, commercial, and open-source data; a mix of government and commercial infrastructure; and a mix of government and public end users. Each area presents opportunities for vulnerabilities to occur, which organizations can mitigate through a combination of organizational and technical approaches. The cybersecurity dimension also includes certain physical security capabilities necessary to protect connected assets in the field from exposure to cyber threats. The cybersecurity dimension includes the following subdimensions.

Threat Awareness

This subdimension addresses the level of awareness an organization maintains regarding current and future cyber threats to AI-enabled systems, including aspects of an organization's workforce, processes, and technology infrastructure. Cyber threats are continuously evolving, and state and non-state actors are both targeting transportation infrastructure within the United States. A threat awareness capability is important to ensure that organizations can protect their technology systems as the types and quantity of cyber threats increase.

Scenario Modeling and Planning

This subdimension addresses the level of preparation an organization undertakes to proactively understand and plan for different cyberattack scenarios. Cyberattacks often occur without warning and can cause ongoing damage to technology systems in a short duration of time. Planning and preparing for cyber incidents (including in specific scenarios that involve AI-enabled systems) are key in enabling an organization to appropriately respond to cyber threats when these events occur.

Posture and Hygiene

This subdimension addresses the level of proactivity an organization maintains in practicing cybersecure processes, maintaining cybersecurity investments, and mitigating potential cyber vulnerabilities whenever staff identify them. Cyberattacks are often damaging and expensive to mitigate once an attack has occurred. Maintaining a proactive cybersecurity readiness posture and hygiene (specifically regarding AI platforms and AI-enabled ITS applications) are key in enabling an organization to appropriately react to cyber threats and defend against cyberattacks.

Infrastructure Protection

This subdimension addresses the level of effort and investment an organization has made to protect technology and operational infrastructure from physical and cyber threats. AI-enabled ITS infrastructure is particularly vulnerable to cyberattack as equipment is often located in publicly accessible locations and has a significant operational lifetime. As cyber threats quickly evolve, an organization's ability to adapt its infrastructure protection measures accordingly will reduce the likelihood of cyber incidents in this area.

Information Assurance

This subdimension addresses the level of capability necessary for an organization to protect AI and ITS data by ensuring data integrity, authenticity, confidentiality, and non-repudiation through cybersecurity measures. AI models rely on accurate and trusted information to train and operate correctly. As cyber threats focus attacks on these data directly, an organization's ability to protect its data and detect anomalous information helps ensure its AI-enabled ITS applications function properly.

Resiliency and Recoverability

This subdimension addresses the capability of an organization to respond and adapt to cyber incidents. Organizations face numerous cyber threats that are impossible to completely mitigate, due to internal IT budget constraints and the evolving nature of cyber threats to AI-enabled systems. As a part of a cyber defense-in-depth approach, resiliency and recoverability capabilities allow an organization to operate in conjunction with cybersecurity risk.

Dimension 5: AI Data and Infrastructure

AI-enabled ITS applications often require unique data and technology infrastructure, beyond what organizations have collected or deployed to support current ITS applications. AI models rely on carefully curated data to accurately train against. New data pipelines and processes are often necessary to meet these new requirements. Once analysts train these models, the AI-enabled applications that contain them often require upgraded infrastructure that enables additional data, computing, and sensors to support operation in the field. This dimension addresses the technology and data that support training, operation, and ongoing refinement of AI models and applications. In the AI-enabled ITS CMM, this dimension will address the specific capabilities related to AI and ML data engineering. The AI data and infrastructure dimension includes the following subdimensions.

Data Governance

This subdimension addresses the breadth and maturity of an organization's processes to manage how it gathers, stores, processes, and retires data. The large datasets that organizations manage today have significant value in benefiting—also potentially harming—individuals and the public at large. AI-enabled ITS applications can add a layer of impact, in that they use these data for planning and automation applications that impact the operations of transportation systems. Having a mature data governance capability enables an organization to proactively manage its data so that staff can use the data correctly and beneficially in these scenarios.

Data Selection and Sources

This subdimension addresses the maturity of an organization's processes to identify and manage an appropriate breadth of data types and sources, such that they are of sufficient quality, conformity, and accuracy for use in AI application development and operations. AI and ML models typically require training against large datasets from a variety of operational scenarios to achieve a level of fit and accuracy for an intended application, considering the different scenarios anticipated in real-world applications. A mature capability in managing data selection considering data from multiple sources will increase the success rate of AI model development and AI application operations.

Data Acquisition and Transmission

This subdimension addresses the capability and robustness of an organization's processes and technology systems used to acquire and transmit data from their sources into data repositories and out to AI-enabled ITS applications both in the cloud and in the field. Networking infrastructure used in ITS applications today is often a mix of legacy, third-party, and modern technology, which impacts the speed, accuracy, and integrity of the acquired data. The maturity of an organization's data acquisition processes and technical architecture of these hybrid networks determines the ability to enable data to correctly support AI-enabled ITS applications.

Data Quality Assurance

This subdimension addresses the maturity of an organization's quality assurance processes in maintaining data quality and integrity. Due to the diverse data sources used in ITS applications, an organization's aggregated datasets often contain overlapping and conflicting information that impacts data quality and can potentially make the data unsuitable for use in AI model development. A mature data quality assurance process, which has the ability to find data errors and conflicts, leads to a higher quality and quantity of data that organizations can use to support AI model development and AI-enabled ITS application operation.

Data Storage and Curation

This subdimension addresses the maturity and robustness of an organization's data curation processes and data storage systems used to organize and maintain dataset access by users who are looking for specific information. Having a consistent methodology for storing this information is a key part of building data pipelines for training and use by AI models and applications. A mature data storage and curation capability can allow for a more efficient and accurate data pipeline development for AI model training and AI-enabled ITS application operation.

Data Processing and Enrichment

This subdimension addresses the maturity of an organization's data processing, integration, and enrichment capability used in its data pipelines to transform datasets for use in AI model training and application development. The diverse data sources used in ITS applications again lead to raw datasets that are often comprised of different formats and units, which impacts the ability to build cohesive and coherent training datasets for use in AI model development. A mature data processing, integration, and enrichment capability enables the creation of larger and higher quality data that analysts can use to train AI models more effectively.

Dimension 6: AI Models and Applications

AI-enabled ITS applications have a wide breadth of use cases and functionality. These applications also vary in level of autonomy, from decision support to fully autonomous control. This dimension includes the capabilities necessary to implement the AI development lifecycle, including design, development, testing, deployment, and measurement of AI models in AI-enabled ITS.

Discovery and Understanding

This subdimension addresses the capability of an organization to understand business, operational, and policy needs and translate these into requirements for AI model development. AI models require the ability to learn from datasets that mirror the real-world operational environment. AI application architectures similarly need to provide outputs that are useful for ITS. Developing an AI-enabled ITS application requires transportation subject matter experts (SMEs) and data scientists to help ensure an AI model architecture and training closely reflect the intended application use cases and operational environments.

AI Model Development

This subdimension addresses the capability of an organization to translate an understanding of the operational use cases, identified requirements, and available data to determine the optimal type of AI model and learning approach (e.g., deep learning, ML, fuzzy logic) for development. Once AI model development is underway, modelers should also transform the utilized datasets through feature engineering in an iterative manner to optimize the model. An organization's ability to iteratively collaborate and leverage a depth of knowledge of different AI model development technical approaches can enable more robust AI-enabled ITS applications.

AI Model Evaluation

This subdimension addresses the capability of an organization to understand the predictive accuracy and effectiveness of AI models and identify areas of strength and weakness (e.g., precision, sensitivity, specificity) to better understand how a model will perform when deployed into an operational ITS environment. An organization's level of capability maturity in statistically evaluating AI models prior to deployment into ITS applications will accelerate the model development process and help ensure that AI-enabled ITS applications function within required parameters.

AI Application Deployment

This subdimension addresses the capability of an organization to deploy new AI tools into preexisting production environments. Preexisting ITS application environments are often incompatible with newer AI development platforms, data exchange, user interface, and software languages. This requires coordination across technical teams to adapt AI models to integrate with an organization's data pipelines and reliably operate in an organization's production environment. This multidisciplinary capability maturity helps ensure successful deployment of AI-enabled ITS applications from the lab into actual operational environments.

Human/AI Interactions

This subdimension addresses the capability of an organization to develop and operate AI-enabled ITS applications of differing levels of autonomy and human-AI interaction. These applications can act as decision support aids, prescriptive tools that recommend an action, or autonomous command-and-control systems. Depending on the level of autonomy, technical staff should design, deploy, and operate the interaction between the application and humans in differing manners to suit the use case (e.g., operational planning, operational control, passenger safety). An organization's capability to understand how humans and AI applications bidirectionally communicate and perceive each other will enable development of AI-enabled ITS applications that best execute their intended operation.

Application Performance Measures

This subdimension address the capability of an organization to benchmark and understand the operational performance of ITS applications that include AI. These benchmarks focus on the technical performance of the individual applications themselves versus the overall performance of agency processes and systems that may utilize these applications (process and system performance is covered under the Business Case and Performance Measurement subdimension). Application benchmarking should evaluate performance using tests and metrics that measure the AI-enabled ITS application performance on its specific operational tasks. Some of the benchmarks used in the assessment will be standard metrics from the AI field. Others should be based on transportation system operational benchmarks and performance indicators. Application performance measures should also attempt to identify operational areas of strength and weakness (e.g., edge cases when the application performs differently than under normal operating conditions). An organization's capability maturity in application performance benchmarking helps build measures that maintain the consistent operation of AI-enabled ITS applications.

Dimension 7: AI Integration and Operations

AI-enabled ITS applications are often more complex to design, build, deploy, and operate than standard transportation systems, due to inclusion of AI models that require training, validation, and then maintenance through an operational feedback loop. Many of these systems encounter an additional complexity because they are retrofit upgrades to existing ITS applications that may not be optimized for AI-enabled application requirements (such as edge computing and modified sensors). All these complexities drive the need for a comprehensive approach to AI-enabled ITS system integration and operations. This dimension addresses each of the system integration and operations areas in detail in the following subdimensions.

Requirements Management

This subdimension addresses an organization's capability to identify, organize, and maintain the many business, operational, and policy requirements necessary to define the scope and features of an AI-enabled ITS system. By managing these system requirements, an organization can ensure the system operates as intended and provides the intended public benefits while mitigating negative impacts determined prior to system deployment and operation.

System Design

This subdimension addresses the maturity of an organization's processes and the resources it has invested to procure and design AI-enabled ITS applications and systems. Depending on its size and internal capabilities, an organization will decide whether to internally develop, outsource development, or externally procure a specific AI-enabled ITS application. The design process translates requirements into either a system architecture (in the case of development), or into the design of a procurement solicitation and contract. A mature system design capability helps ensure that all requirements correctly transition into these design patterns.

System Integration

This subdimension addresses the maturity of an organization's processes to integrate both new and retrofit AI-enabled ITS applications into the broader transportation system infrastructure. AI-enabled systems often have unique systems requirements that necessitate additional steps in the system integration process (e.g., integration of a development, security, and operations loop to keep AI models up to date). Depending on the complexity of the AI-enabled ITS application, varying levels of system integration capability will help ensure these applications correctly interoperate within the broader transportation system.

Test and Evaluation

This subdimension addresses the capability of an organization to test AI-enabled ITS applications to ensure proper functionality upon integration, and to evaluate the underlying AI model itself to validate that it functions as expected once deployed in the field. The black-box nature of AI models requires that analysts evaluate the models against a ground truth dataset and measures prior to deployment. It is also important after deployment to evaluate the model again against the real-world data and measures of its operational environment (e.g., object recognition in snowy environments) to validate that it performs within the same parameters. An organization's—or often its contractor's—capability maturity in this area can help ensure that AI-enabled ITS applications appropriately function in the operational environments of their deployments.

System Launch

This subdimension addresses the maturity of an organization's processes to introduce new systems. AI-enabled ITS applications often have elements of autonomy or predictivity that function differently than traditional systems. A mature system launch process can help ensure that all organizational users and public end users understand these differences and know how to operate and maintain the application. A mature launch capability also helps validate that new applications are still correctly functioning and integrating with other ITS applications after a broader set of users, objects, and systems has been interacting with the application.

Operational Feedback

This subdimension addresses the maturity of an organization's technical infrastructure and operational processes that provide operational feedback in various forms from the field to the AI-enabled ITS application and the team managing the application. The transportation operational environment constantly changes over the lifetime of deployed ITS assets. AI models can be sensitive to certain changes and require recalibration or retraining at appropriate intervals to maintain performance. Some AI-enabled ITS applications have this functionality built into the system and others require implementing periodic model performance evaluations. An organization's capability maturity in operationalizing this feedback will help ensure that applications perform optimally throughout their lifecycle.

Maturity Levels

The AI-enabled ITS CMM uses four levels of capability maturity to assess each dimension and subdimension. There is also a level of maturity where an organization has not yet obtained any information or knowledge within a specific dimension or subdimension of AI-enabled ITS. CMM users can consider this as level zero. For brevity, chapter 4 of the report does not reference level zero.

The AI-enabled ITS CMM defines the levels as follows:

- **Level 0 – No Information or Knowledge:** The organization has not yet obtained any information or knowledge regarding a specific dimension or subdimension of AI-enabled ITS.
- **Level 1 – Exploration:** The organization is familiar with the basic concepts of this dimension or subdimension. These organizations are interested in knowing more and may be informally exploring the dimension or subdimension. They potentially exchange ideas related to the

dimension or subdimension both internally and amongst stakeholder communities, but do not have formal strategies or plans for developing improved capability.

- **Level 2 – Prepared:** The organization has begun the process of planning to develop improved capability within the dimension or subdimension. These organizations have a basic understanding of their requirements, along with an awareness of their capability strengths and where capability gaps may reside.
- **Level 3 – Operational:** The organization has successfully adopted AI to support one or more operational processes. They invested in workforce capabilities to support AI and some aspects of the needed infrastructure, data science, data management, and cybersecurity. These organizations have not yet organized these projects into a formal institutionalized program.
- **Level 4 – Systematic:** The organization has institutionalized the use of AI across departments. The AI implementations and adoptions are sustainable and include a continuous improvement process based on a feedback loop and lessons learned. These organizations have an integrated team to support all aspects of the needed infrastructure, data science, data management, and cybersecurity. The utilization of AI has established values to support different decision-making processes.

Chapter 4. AI-Enabled ITS CMM Implementation

This chapter describes how organizations can use the CMM to self-assess their strengths and weaknesses and identify actions to improve their capabilities in different dimensions of AI-enabled ITS. Organizations should apply a collaborative process when using the CMM and consider including a broad set of regional stakeholders in this process. The CMM dimensions span a wide breadth of domain areas, so including regional stakeholders in this process may help to ensure the appropriate SMEs are available.

The CMM assessment process allows the users to achieve the following results:

- **Current capability assessment:** Participants can first determine the organization's current high-level capability maturity and associated limitations. Participants can then choose to formally compute a quantitative CMM level score in a detailed approach to the assessment based on detailed criteria for each dimension and subdimension.
- **Capability prioritization:** Participants can discuss and identify what AI-enabled ITS activities to pursue, based on the organization's operational requirements (and potentially from other ITS CMM workshops). The prioritization tables in this chapter can help the organization prioritize CMM dimensions and subdimensions based upon the organization's unique regional attributes and AI-enabled ITS use cases of interest.
- **Action plan:** Participants can use their CMM maturity level scores in each dimension and subdimension, along with their CMM dimension prioritizations, to develop an action plan. The action plan can be specific to the organization and adhere to its existing processes. An action plan will enable participants to identify, filter, and compile a set of actions and monitoring plans appropriate to the region. The organization can then regularly update the action plan based upon its strategic planning timeline. This will further advance its AI-enabled ITS capabilities in line with its operational goals.

High-Level Capability Assessment

Organizations can first conduct a high-level assessment, using the capability matrices in appendix A. The high-level assessment will help organizations decide if they want to proceed to the next step of utilizing the detailed approach of the CMM and to determine the appropriate stakeholders and SMEs to engage the next steps of the CMM process. Before undertaking the CMM process, organizations may also consider holding a separate introductory AI session to familiarize CMM users with basic AI and ML concepts.[4]

The purpose of the high-level assessment is to provide organizations with a basic understanding of their capability maturity level in each dimension and subdimension. This process is ideal for organizations that have limited resources for this effort, and for organizations that are just beginning to explore AI-enabled ITS opportunities. It can also support other organizations' use of the detailed approach. Participants should be able to complete this assessment in less than 60 minutes in order to quickly derive a high-level understanding of the organization's maturity levels.

The high-level assessment is useful as a gap assessment tool for organizations that intend to conduct a detailed self-assessment to determine which professionals and SMEs should participate, in order to provide coverage and knowledge of each dimension. Once the high-level assessment is complete, an organization can review the results and decide if it wishes to summarize its evaluation based on this high-level approach or continue with an additional detailed evaluation, to better understand specific areas of operational relevance to the CMM subdimensions.

Detailed Capability Assessment

For organizations that seek to undertake a more rigorous process in determining their capability maturity levels, the detailed assessment utilizes a set of readiness checklist items, included in appendix B, that drive the determination of maturity levels for each CMM dimension and subdimension. For each maturity level of each subdimension, the readiness checklist presents evaluation criteria that CMM users can review to determine the checklist fulfillment status.

An ideal mechanism for the detailed assessment is a one-day workshop, where participants review the AI-enabled ITS CMM and conduct the assessment to determine the agency's maturity levels. A local lead organization can organize the workshop, which can include a broad set of stakeholders and SMEs. The lead organization can identify participants based on their contribution and potential use of the AI-enabled ITS. Organizations may consider including contractors as participants, while being mindful of bias or conflicts of interest that this may introduce. This broad inclusion will expedite the CMM implementation process and reduce the time required to conduct the appropriate level of diligence.

Prior to convening the one-day workshop and initiating the assessment, the lead organization and partners may identify the SMEs best positioned to address each dimension of the CMM and the various steps in CMM implementation. This will allow participants to efficiently conduct the detailed assessment of maturity levels and accurately determine the CMM level scores at the workshop. Organizations can estimate the resource cost associated with the CMM effort by calculating the time and travel for stakeholders to participate in the 1-day workshop, plus a suggested 2 additional hours of preparation for those who did not participate in the high-level assessment.

[4] Organizations can pursue this introductory session at the stakeholders' discretion; however, such sessions are outside the scope of this CMM.

Readiness Checklist Items

In order for participants to undertake the detailed capability maturity assessment, appendix B references a readiness checklists tool (in a spreadsheet format) that contains a set of evaluation criteria, which drive the determination of maturity level for each CMM subdimension. This readiness checklist tool contains detailed readiness checklists for each subdimension. Participants can use these checklists to conduct the detailed agency assessment. To maintain process efficiency given the large number of readiness checklist items, the checklists provide a means of converting the checklist results into quantitative CMM scores for each dimension and subdimension.

Detailed Assessment Scoring

In the AI-enabled ITS CMM, the calculation of maturity scores reflects the number of completed readiness checklist items for each subdimension. The CMM readiness checklist tool includes a mechanism to automate this scoring process. Table 2 illustrates an example of this process. After completing the readiness checklist and the detailed assessment process, participants will have a quantitative understanding of the organization’s maturity levels across the CMM dimensions and subdimensions.

Table 2. Example Methodology for CMM Subdimension Maturity Level Score Determination.

Subdimension	Readiness Checklist Items	Complete (YES/NO)	Maturity Level	Percentage	Subdimension Score
Value, Expectation, and Risk	1. Awareness of AI applications across industries	YES	1	1.00	2.27
	2. Awareness of AI applications in transportation	YES	1	1.00	2.27
	3. Understanding of ITS needs that can be enabled by AI	YES	1	1.00	2.27
	4. Champion-driven understanding of the value of AI in some units based on reviewing national documents, and experience by peers and other disciplines	YES	2	0.67	2.27
	5. Champion-driven understanding of the required budget of AI in some units	NO	2	0.67	2.27
	6. Organization's leaders are well versed in AI, allowing them to integrate AI capabilities directly into organizational strategy	YES	2	0.67	2.27
	7. Organizationwide understanding of the value of AI with formal effort to increase this understanding	YES	3	0.60	2.27
	8. Organizationwide understanding of the required budget of AI with formal effort to increase this understanding	NO	3	0.60	2.27
	9. Organizationwide understanding of the limitations and constraints of AI with formal effort to increase this understanding	YES	3	0.60	2.27
	10. Organizationwide understanding of the risks of AI with formal effort to increase this understanding	NO	3	0.60	2.27
	11. Understanding of the importance of investing in data governance to increase the benefits and reduce the risks	YES	3	0.60	2.27
	12. Documented process for collecting and sharing information to establish a culture of understanding of AI	NO	4	0.00	2.27
	13. An outreach/communications plan fosters understanding of the role, value, limitations, risks, and required budget associated with AI within the organization and partners	NO	4	0.00	2.27

CMM Dimension Prioritization

Once the capability maturity assessment process is complete, participants can develop an action plan for the organization. This involves discussing and identifying what AI-enabled ITS activities the organization should pursue based on operational requirements (and potentially from other ITS CMM workshops). Throughout the stakeholder engagement process used to develop and refine this CMM, stakeholders have noted the need to be able to tailor the CMM assessment process to the regional uniqueness and specific use case focuses of an individual organization that is undertaking the CMM process. CMM users can apply the dimension prioritization tables in this section to prioritize specific dimensions and subdimensions within the action plan, based on the organization's unique regional attributes and AI-enabled ITS use cases of interest.

This CMM dimension prioritization approach consists of a series of questions that identify specific circumstances that may impact the organization's prioritization of future activities. These questions can help CMM users prioritize the respective CMM dimensions for their organization's future needs. The questions can stimulate group discussion and allow participants to assign either a high, medium, or low priority to each of the CMM dimensions. Tables 3–9 contain these prioritization questions for each of the seven dimensions.

Table 3. Dimension Prioritization Questions – Workforce, Culture, and Organization

Questions – Workforce, Culture, and Organization	
1.	Do you have a formal effort for staff development, training, recruitment, and retention for ITS that can extend to AI-enabled ITS?
2.	Are you planning to use your staff for or outsource the development, evaluation, and application of the AI-enabled ITS?
3.	How important is it for your AI-enabled ITS to have the support of different levels of organization from upper managers to operation staff?
4.	Can your organization facilitate change in order to implement and advance AI-enabled ITS? Do you think such change management will be useful for your AI-enabled ITS application?

Table 4. Dimension Prioritization Questions – Collaboration

Dimension Prioritization Questions – Collaboration	
1.	What is the level needed for interorganizational collaboration for your AI-enabled ITS applications?
2.	Are there organizations that you need and can share data with for AI-enabled ITS?

Table 5. Dimension Prioritization Questions – Business Process

Dimension Prioritization Questions – Business Process	
1.	Do you have a vision, strategic direction, action plan, or a road map for your current ITS deployment that can extend to AI-enabled ITS?
2.	Do you currently have budget separately identified and programmed for ITS that can extend to AI-enabled ITS?
3.	Do you currently have procurement processes separately identified for ITS projects that can extend to AI-enabled ITS?
4.	Are there ITS standards and policies, such as planning, programming, design, analysis, operations, evaluation, and testing, that you have developed and are currently maintaining for ITS that can extend to AI-enabled ITS?
5.	Do you anticipate that your application may have privacy, equity, and/or ethics issues?

Table 6. Dimension Prioritization Questions – Cybersecurity

Dimension Prioritization Questions – Cybersecurity	
1.	Does your organization have a high percentage of ITS and/or IT networking equipment that the organization has not yet updated to current cybersecurity standards?
2.	Does your organization currently have a cybersecurity monitoring solution in place?
3.	If so, has your organization detected a concerning level of cyberattack attempts on your organizational IT or ITS infrastructure?

Table 7. Dimension Prioritization Questions – AI Data and Infrastructure

Dimension Prioritization Questions – AI Data and Infrastructure	
1.	Does your organization utilize or intend to utilize high volumes of data and/or a large number of data sources in your AI-enabled ITS use cases?
2.	Do your organization's AI-enabled ITS use cases utilize a broad variety of data types?
3.	Are the datasets for your organization's AI-enabled ITS use cases aggregated and centrally stored, or are the datasets stored in multiple distributed locations?

Table 8. Dimension Prioritization Questions – AI Models and Applications

Dimension Prioritization Questions – AI Models and Applications	
1.	Are your organization's AI-enabled ITS applications that interact with underrepresented communities developed using representative datasets that reflect these communities?
2.	Do your organization's AI-enabled ITS use cases utilize a broad variety of AI and ML model types?
3.	Will your organization's AI-enabled ITS uses cases have a high level of human interaction?

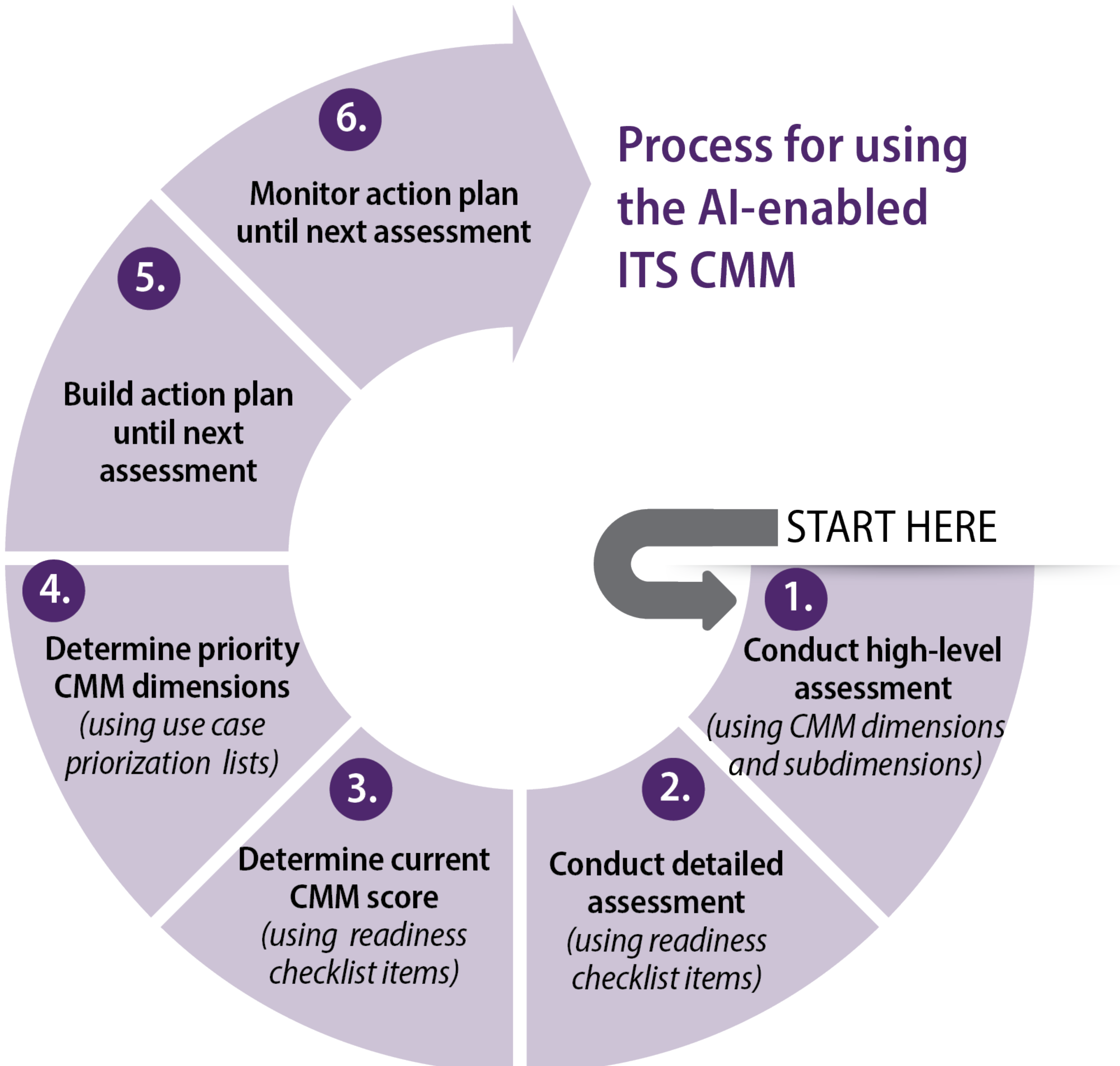
Table 9. Dimension Prioritization Questions – AI Integration and Operations

Dimension Prioritization Questions – AI Integration and Operations	
1.	Do your organization's AI-enabled ITS use cases operate across multiple jurisdictions and/or will multiple organizations operate these?
2.	Do your organization's AI-enabled ITS use cases have a high level of complexity and/or a large number of interfaces with other IT or transportation systems?
3.	Do your organization's AI-enabled ITS use cases have a high-level of direct impact and/or visibility to the public?

After reviewing the question tables and determining the priority level for each of the seven dimensions, CMM users can then compare these priority weightings against the current maturity scores to determine where gaps exist. This can then inform an organization's future areas of focus as they integrate the CMM outputs into their action planning process.

Determining Stakeholder Action Plans

After completing the readiness assessment and dimension prioritization processes, organizations can better understand areas of opportunity to focus on to take on the specific AI-enabled ITS applications of interest. Organizations can then optionally use this information as inputs to their existing planning processes in order to develop an action plan to achieve these priority CMM maturity levels. Organizations can also choose to leverage their existing processes to develop a plan to monitor and assess progress along this plan of action. Figure 2 summarizes the CMM implementation lifecycle process that participants can follow as described in this chapter.



Source: ITS-JPO.

Figure 2. Flowchart. Process for Using the AI-enabled ITS CMM

Chapter 5. Conclusions and Recommendations

This chapter summarizes the conclusions and recommendations of the research team. The chapter also summarizes stakeholder feedback and conclusions drawn from a case study exercise conducted by observing the implementation of this CMM process with various stakeholder organizations. The team gathered stakeholder input across a wide breadth of individuals from USDOT and the broader intended audience for this AI-enabled ITS CMM.

A fundamental finding was that nearly all stakeholders self-assessed low maturity levels (i.e., levels 1 and 2) for their agencies across the majority of subdimensions. They noted that this was logical as the industry is just beginning to explore and implement AI-enabled ITS applications. Many larger stakeholder organizations have an expectation that they will achieve higher levels (i.e., level 3 and in some subdimensions level 4) in future years as they progress in development of this domain. Stakeholders liked that they would be able to conduct this self-assessment in future years to evaluate their progress.

CMM Mechanics

The research team determined through observation and stakeholder feedback that the CMM is effective in assisting CMM users in achieving the goals laid out in the CMM approach. The CMM dimension and subdimension descriptions provide stakeholders with what they view as an appropriate level of depth and breadth for the seven dimensions and 42 subdimensions. The CMM dimension/subdimension structure and organization made intuitive sense and was easy to follow. Stakeholders and case study participants noted that this level of detail was appropriate for a transportation industry AI-enabled ITS CMM and is consistent with expectations based on using other transportation CMM/CMFs. Feedback on the maturity levels noted that these are logical steps in an organization’s maturity evolution and will maintain consistency as the industry matures in future years.

Specific stakeholder recommendations for AI-enabled ITS CMM mechanics included:

- **Dimensions and subdimensions:** These should capture unique AI needs such as bias, trust, equity, ethics, privacy, cybersecurity, and data science expertise. Across industries, advanced agencies usually have dedicated AI budgets, so one of the subdimensions should capture this.
- **Maturity levels:** It is more important to have a level zero in the AI-enabled ITS CMM than in other transportation CMMs because a large proportion of organizations have no awareness and/or capability within the associated dimensions and/or subdimensions. Level 2 should specifically indicate organizations that have made the proper steps to achieve AI-enabled ITS readiness but have not yet deployed AI-enabled ITS solutions.
- **Use cases:** Different organizations prioritize different AI-enabled ITS applications and use cases. It is therefore important to take these individual priorities into account and enable organizations to make prioritization adjustments without impacting the overall CMM maturity level scoring. Upon receiving this feedback, the research team adjusted the CMM to apply optional dimension

prioritizations that would only affect action plans, as opposed to use case weighting factors that would affect maturity level scoring.

The research team discussed the CMM dimension prioritization process with stakeholders to understand the effectiveness of the prioritization questions. While stakeholders did not undertake a formal action planning process as a part of these discussions (this is typically conducted at a later time as a part of their broader strategic planning), they were able to review the prioritization questions and provide feedback on their perceptions of this process.

A summary of the key observations of the CMM dimension prioritization process include:

- **Usefulness in prioritization:** Stakeholders noted that these questions were useful in stimulating group discussion regarding the importance of particular CMM dimensions for their organization. They were able to self-assess the priority level (i.e., low, medium, high) for each of the CMM dimensions using this process.
- **Question consistency across use cases:** Stakeholders noted that questions would maintain relevance across all AI-enabled ITS application categories and scenarios (refer to table 1 from chapter 2). They did not see a need for any use case-specific customization of the question tables.
- **Additional prioritization guidance:** Stakeholders noted that they would also need to incorporate AI into any new policy at the State or Federal level regarding their prioritization determinations. This applies to all the CMM dimensions and does not require an explicit form of question in this process.
- **Subdimension prioritization:** Stakeholders noted that the dimension prioritization question approach would also be useful at the subdimension level. The research team noted that reviewing 42 prioritization question tables would significantly increase the duration of the subdimension prioritization process and that there is a sensitivity to ensuring that agencies can complete the overall CMM process in an efficient time manner. The team has thus kept prioritization at the CMM dimension level (as opposed to the subdimension level) to ensure the optimal approach for value and efficiency.

CMM Implementation

Stakeholders found the readiness assessment approaches provide flexibility for organizations with differing levels of focus and resources to derive value from the CMM process. Stakeholders noted that the high-level self-assessment was effective in both individual and group environments, depending on the preference of an organization. Organizations were able to complete the high-level self-assessment in roughly 1 hour using either approach. The detailed self-assessment provided a comprehensive overview of an organization’s capabilities for those organizations that are interested in this level of detail. Based on the time durations observed during the case study, organizations anticipate that they can complete the detailed self-assessment in the 1-day workshop format and time period. Some organizations noted that they would select between approaches consistently based upon their current maturity and level of resources available. This is consistent with the goals of this CMM approach. The dimension priority questions were effective in assisting case study participants in prioritizing future CMM dimension focus areas, based on an organization’s respective demographics and specific use case interests.

The following is a summary of key observations of the CMM readiness self-assessment process:

- **High-level assessment organization and efficiency:** The high-level self-assessment process was effective in helping participants quickly evaluate the organization's maturity levels across the 42 subdimensions.
- **High-level assessment duration:** The total session time for the observed high-level self-assessment was approximately 60 minutes, which is generally consistent with stakeholder organizations' desire to conduct the high-level self-assessment in under 1 hour. Participants noted that the duration was efficient for achieving the goals of the high-level assessment.
- **Detailed self-assessment preparation:** The high-level assessment process was helpful as an aid in preparation for conducting a detailed self-assessment, specifically because it helped the group identify where they had gaps in subject matter expertise. Organizations could then address these gaps by including additional individual SMEs in the detailed self-assessment. A broad group of individual participants appears key to effectively review all the CMM subdimensions. Stakeholders thought that this would be appropriate, as they typically have had broad organizational participation in their previous work with other CMM assessments.
- **Detailed self-assessment operationalization:** Participants were able to read through and comprehend the CMM process. Participants noted that as an effective practice it would be useful to conduct the CMM review as a group to stimulate discussion and a common understanding. Furthermore, it would be beneficial to have a facilitator who is familiar with the CMM process lead the group review session.
- **Detailed self-assessment efficiency:** Participants provided suggestions for potential CMM users to consider toward conserving their time and resources. The following are general suggestions from stakeholders and from the research team for streamlining the CMM process:

    1. **Planning logistics:** Before using the CMM, organizations can determine whether a group and/or individual review process is most appropriate. Some organizations may prefer participants to complete the review and assessments individually and then discuss these in a group setting. Other organizations may prefer to conduct the review and assessments as a team. The case study determined that either approach utilizes roughly that same amount of time and resources, so it is primarily a preference based on an organization's particular dynamics.
    2. **Leveraging outside resources:** Organizations exploring AI adoption can leverage outside resources to provide CMM users with a primer or overview of basic AI concepts prior to undertaking the AI-enabled ITS CMM process. This will ensure that participants have a basic understanding of the CMM subdimensions and are in a better position to answer the self-assessment questions. Use of CMMs on overlapping transportation topics (e.g., TSMO, transportation data management, traffic analysis) may also improve agencies' AI readiness.
    3. **Reviewing AI-enabled ITS opportunities:** Before using the CMM, stakeholders and SMEs should review table 1 of this report to estimate which AI-enabled ITS applications and use cases may be of interest. Knowledge of the organization's priority applications and use cases may help to inform the CMM process to identify which capabilities the organization should develop.
    4. **Selecting participants:** Review subdimensions or take the high-level assessment in advance to determine which participants can cover the breadth and depth of the CMM. This prevents the need to bring in additional participants once the detailed assessment has begun.
    5. **Stopping after high-level assessment:** A key benefit of the high-level assessment is for organizations to quickly estimate their strengths and weaknesses.

6. **Facilitating detailed assessment:** Consider who will facilitate the CMM process and ensure that they have a sufficient understanding of the CMM contents and approach prior to beginning the process. Some organizations may prefer to have an outside consultant facilitate the workshop, while others may have this capability within their organization.
7. **Conducting detailed assessment only for high-priority dimensions:** Once an organization decides to conduct the detailed assessment for a given dimension, they should respond to each readiness checklist item within that dimension to obtain accurate maturity assessment scores.

Future Efforts

Stakeholders involved in the CMM development process noted the following observations and suggestions for USDOT to consider in future efforts to support the transportation industry:

- **AI-enabled ITS application and regulatory guidelines:** Stakeholders noted that it would be helpful for USDOT to begin providing guidance on how Federal regulatory requirements and processes can incorporate AI-enabled ITS applications. For example, one public agency representative noted current regulatory guidelines that require a 100-day study for a new highway interchange. Organizations could potentially gather these same data over a 10-day period by augmenting observations through AI. Participants suggested that an open-source directory of approved use cases would be helpful.
- **National data source acquisition:** Stakeholders noted the high costs of commercial datasets (e.g., probe vehicle data products) as a key barrier to AI-enabled ITS development. Stakeholders suggested that USDOT pursue national contracts on behalf of all government organizations to provide equal access to these datasets.

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Appendix A. High-Level Assessment Tables

Tables 10–50 contain the high-level evaluation criteria for each AI-enabled ITS CMM subdimension.

Table 10. High-Level CMM Assessment – Workforce, Culture, and Organization: Value, Expectation, and Risk

Level	High-Level Assessment Criteria
1	Some awareness that AI in ITS can have benefits, which generates interest. However, there is little understanding of the actual value, limitations, risks, and required budget associated with AI-enabled ITS.
2	Units within the organization start a process for understanding and sharing (on a limited basis) the value and budget of AI-enabled ITS.
3	Establishes full understanding of the role, value, limitations, risks, and required budget of AI in ITS.
4	Establishes a process for building culture that understands AI. Creates stakeholder/decision maker outreach/communications plan to foster understanding of the role, value, limitations, risks, and budget associated with of AI, data management, and data governance in ITS.

Table 11. High-Level CMM Assessment – Workforce, Culture, and Organization: Sponsorship and Leadership

Level	High-Level Assessment Criteria
1	AI-enabled ITS activities are ad hoc and champion driven.
2	Has a process to identify and support staff champions for development and utilization of AI-enabled ITS.
3	Extends the championship and leadership building process to increase the number of champions for AI-enabled ITS. This includes providing support and rewards for champions with leadership positions and resources to expand implementations.
4	Expands the championship and leadership building process for AI-enabled ITS to involve more agency functions and partner agencies.

Table 12. High-Level CMM Assessment – Workforce, Culture, and Organization: Value, Expectation, and Risk

Level	High-Level Assessment Criteria
1	Some awareness that AI in ITS can have benefits, which generates interest. However, there is little understanding of the actual value, limitations, risks, and required budget associated with AI-enabled ITS.
2	Units within the agency start a process for understanding and sharing (on a limited basis) the value and required budget of AI-enabled ITS.
3	Establishes full understanding of the role, value, limitations, risks, and required budget of AI in ITS.
4	Establishes a process for building culture that understands AI. Creates stakeholder/decision maker outreach/communications plan to foster understanding of the role, value, limitations, risks, and required budget associated with of AI, data management, and data governance in ITS.

Table 13. High-Level CMM Assessment – Workforce, Culture, and Organization: Fostering Innovation

Level	High-Level Assessment Criteria
1	Assesses current culture and organization issues that limit potential for fostering innovation and embracing technology in AI-enabled ITS.
2	Identifies changes in organization, priorities, and culture to foster innovation and embracing technology in AI-enabled ITS. Develops a plan for implementing these changes.
3	Implements changes that foster innovation and embrace technology of AI-enabled ITS.
4	Revises and updates the approaches to fostering innovation based on experience with implementing changes for fostering innovation in AI-enabled ITS.

Table 14. High-Level CMM Assessment – Workforce, Culture, and Organization: Ethics and Equity

Level	High-Level Assessment Criteria
1	Assesses current workforce, culture, and organization issues that limit consideration of ethics and equity in AI development and use in ITS.
2	Identifies workforce, culture, organization, and policy/procedural changes to ensure consideration of ethics and equity in AI development and use in ITS.
3	Implements workforce, culture, organization, and policy/procedural changes to ensure consideration of ethics and equity in AI development and use in ITS.
4	Revises and updates workforce, culture, organization, and policy/procedural approaches to ensure consideration of ethics and equity in AI development and use in ITS.

Table 15. High-Level CMM Assessment – Workforce, Culture, and Organization: Organizational Structure

Level	High-Level Assessment Criteria
1	Recognizes and reviews potential reorganization options for AI in ITS but still considers AI using existing organizational structure.
2	Starts a process for identifying AI-enabled ITS-specific organizational concepts and structures within and among jurisdictions.
3	Implements reorganization for AI-enabled ITS and the required data management and governance.
4	Continues evolving and updating its organizational structure for AI-enabled ITS, based on the assessment of the implemented reorganization.

Table 16. High-Level CMM Assessment – Collaboration: Peer Network Participation

Level	High-Level Assessment Criteria
1	Starts participating in peer and national dialogues on AI-enabled ITS.
2	Contributes to building peer cooperation on AI-enabled ITS among peer organizations.
3	Uses peer cooperation to advance policies, standards, processes, and applications of AI-enabled ITS.
4	Peer organizations share information about needed updates to policies, standards, processes, and applications based on their experiences with implementations related to AI-enabled ITS.

Table 17. High-Level CMM Assessment – Collaboration: Building Partnerships

Level	High-Level Assessment Criteria
1	Works in isolation but has started identifying key regional public and private partnerships and stakeholders of AI-enabled ITS based on a systems engineering process that involves developed concept of operations.
2	Starts collaborating with partners and involving stakeholders on AI-enabled ITS on some projects on a case-by-case basis.
3	Has processes and memorandums of understanding on AI-enabled ITS. Has agreements with all partners to be included in the agreement as identified in the systems engineering process for regional collaboration with roles and responsibilities identified. Shares information, data, resources, training, and models.
4	Institutionalizes a regional collaborative approach for AI use in ITS with resource sharing. Updates roles and responsibilities among all collaborative partners based on lessons learned.

Table 18. High-Level CMM Assessment – Collaboration: Intra-organization Collaboration

Level	High-Level Assessment Criteria
1	Units within the organization work in isolation but limited ad hoc collaboration occurs on AI-enabled ITS.
2	There is collaboration on AI-enabled ITS among the units within the same program or department (e.g., transportation system operations and management, planning, design, etc.) but limited collaboration across programs or departments.
3	Different departments and programs within the organization have strong collaboration on AI-enabled ITS with the support of management.
4	The collaboration among different departments AI-enabled ITS is institutionalized and documented.

Table 19. High-Level CMM Assessment – Collaboration: Effective Data Sharing

Level	High-Level Assessment Criteria
1	Data sharing is ad hoc when one unit or partner organization requests available data items.
2	Has tools and a formal process for units to identify, request, and obtain available data.
3	Established procedures, applications, and agreements with public sector partners and private sector data providers, considering the needs of different units across the programs and departments of the organization and partner organizations.
4	Adopted and funded sustainable data-sharing practices of the organization and partner organizations, considering the value of data items for different applications in accordance with the wider data strategy, including data governance and risk assessment.

Table 20. High-Level CMM Assessment – Collaboration: Decision Process Alignment

Level	High-Level Assessment Criteria
1	ITS performance measures assessed but not aligned. AI-enabled ITS use case selection considers individual unit and program needs.
2	Performance measures align with strategic organizational goals. AI-enabled ITS use case selection considers supporting additional functions within organization or region.
3	AI-enabled ITS use cases selected with consideration of objectives, performance measures, performance targets, and initiatives of all units and at all levels (strategic, tactical, and operational).
4	ITS-enabled performance measures and use cases selected with consideration of objectives, performance measures, performance targets, and initiatives of all units and at all levels (strategic, tactical, and operational).

Table 21. High-Level CMM Assessment – Business Processes: Business Case and Performance Measurement

Level	High-Level Assessment Criteria
1	No process to identify the business case or (pre-deployment and post-deployment) performance estimation for AI-enabled ITS.
2	Starts collecting information about how to assess the business case and the performance of AI-enabled ITS.
3	Has documented process to assess and communicate business case, pre-deployment, and post-deployment methods for AI-enabled ITS.
4	Has documented process for use of the business case to prioritize investment decisions in AI-enabled ITS, plus established and documented policies, procedures, and protocols to track the performance and evaluate the cost effectiveness of AI solutions.

Table 22. High-Level CMM Assessment – Business Processes: Strategy, Policy, and Roadmapping

Level	High-Level Assessment Criteria
1	AI implementations are not based on developed vision, strategic direction, action plan, or roadmap.
2	Starts utilizing a systems engineering approach for AI development and utilization.
3	Develops and implements AI strategic plan, action plan, and roadmap based on the systems engineering process and CMM results.
4	Refines AI policy, strategy, and roadmap based on continued assessment of the evaluation of AI implementations.

Table 23. High-Level CMM Assessment – Business Processes: Budgeting for AI

Level	High-Level Assessment Criteria
1	No separate budget programmed for AI-enabled ITS, and any AI effort is funded using current program and/or project resources.
2	Starts identifying general estimates of the lifecycle costs for budget allocation for specific AI-enabled ITS applications and use cases.
3	Allocates annual budget based on the creation of line items for AI utilization in ITS according to developed action plan and roadmap for AI, data management, and data governance.
4	Develops a program with sustainable and optimized funding allocation for existing and future AI implementations in ITS according to the action plan and roadmap.

Table 24. High-Level CMM Assessment – Business Processes: Privacy and Trust

Level	High-Level Assessment Criteria
1	Has an understanding of the needs to maintain privacy and trust in AI and starts related internal and external discussions.
2	Starts the process of developing a framework and procedures related to privacy, trust, equity, and ethics in AI and in accordance with data governance, legal requirements, and regulatory requirements.
3	Implements the framework and procedures related to privacy, trust, equity, and ethics in AI in accordance with data governance, legal requirements, and regulatory requirements.
4	Institutionalizes and implements sustainable and organizationwide integration, training, and monitoring of privacy, trust, equity, and ethics in AI and in accordance with data governance, legal requirements, and regulatory requirements.

Table 25. High-Level CMM Assessment – Business Processes: Process Transformation

Level	High-Level Assessment Criteria
1	Processes are not reorganized to take advantage of AI in ITS.
2	Starts examining and implementing potential updates to processes and procedures with the utilization of AI in ITS.
3	Establishes a roadmap for infusing AI in ITS planning, design, operations, management, and evaluation processes to fully leverage AI-enabled ITS.
4	Implements, monitors, and updates a roadmap for process transformation of AI-enabled ITS.

Table 26. High-Level CMM Assessment – Business Processes: Procurement

Level	High-Level Assessment Criteria
1	Implements traditional procurement practices for AI development and utilization in ITS efforts.
2	Adopts methods for identifying and managing costs and resources for AI-enabled ITS projects. Implements a decision analysis and resolution process for determining if the work should be done by the organization or be contracted out.
3	Adopts a process for identifying potential vendors or consultants to provide the AI-enabled ITS solutions that meet technical and institutional requirements and expectations.
4	Maintains procedures and templates for procuring AI-enabled ITS that are customizable for specific use cases.

Table 27. High-Level CMM Assessment – Cybersecurity: Threat Assessment

Level	High-Level Assessment Criteria
1	General awareness of current cyber threats pertinent to AI-enabled ITS systems and an understanding of where some sources of cyber threat intelligence exist, in order to stay informed as these threats evolve.
2	Understanding of the AI-ITS cyber threat environment and developing internal processes for maintaining ongoing cyber threat awareness.
3	Operationalized cyber threat awareness by forming connections with government and/or commercial cybersecurity organizations, as well as creating processes to ensure cybersecurity technology infrastructure is updated with information on the latest cyber threats.
4	Transformed workforce with inclusion of cybersecurity professionals who actively engage with the cyber research community, as well as transformed processes and infrastructure investments to proactively identify and adapt to emerging cyber threats in the AI-ITS domain.

Table 28. High-Level CMM Assessment – Cybersecurity: Scenario Planning

Level	High-Level Assessment Criteria
1	Awareness of specific cyberattack scenarios that pertain to AI and ITS systems and their possible points of vulnerability.
2	Sufficient understanding of AI and ITS cyberattack scenarios, as well as the potential attack surface of the organization’s own systems. The organization has begun developing planning processes to prepare for cyberattacks.
3	Detailed procedures for each identified cyberattack scenario. High level of workforce awareness regarding these protocols.
4	Consults experts to analyze potential ongoing and emerging vulnerabilities and identify most likely scenarios to prepare for.

Table 29. High-Level CMM Assessment – Cybersecurity: Posture and Hygiene

Level	High-Level Assessment Criteria
1	Researched potential cyberattacks of vulnerable AI-ITS systems and cybersecurity practices to prepare for and prevent cyberattacks.
2	Good understanding of the potential cyberattacks that AI and ITS systems may encounter and has begun developing and implementing internal processes for maintaining an ongoing defensive posture against these threats.
3	Aware of the specific potential cyberattack vectors. Developed defense, response, and mitigation protocols based on these threats.
4	Established a select group of individuals responsible for monitoring potential cyberattack vectors, as well as for management and implementation of internal cybersecurity infrastructure and processes as cyber threats evolve.

Table 30. High-Level CMM Assessment – Cybersecurity: Infrastructure Protection

Level	High-Level Assessment Criteria
1	Up-to-date inventory of AI and ITS infrastructure and aware of specific potential points of vulnerability in these assets.
2	Conducting a cyber vulnerability assessment and remediation plan for AI-ITS infrastructure. Integrating cybersecurity processes (e.g., software update checks) into its asset maintenance activities.
3	Routine AI-ITS asset inventory maintenance. Implementing IT/operational technology architecture to protect infrastructure assets.
4	Implemented processes and tools to preemptively respond to cyber threats against its infrastructure. Invests resources to ensure that infrastructure management workforce is kept up to date with evolving cyber threats and resulting vulnerabilities in infrastructures.

Table 31. High-Level CMM Assessment – Cybersecurity: Information Assurance

Level	High-Level Assessment Criteria
1	Conducting research into the security, trust, and authenticity of the datasets it uses to train AI models.
2	Verified security, trust, and authenticity of datasets to train AI models and ready to begin model training with these data.
3	Secured datasets while at rest and in motion with its learning models. Begun use of obfuscation to protect sensitive attributes.
4	Established open channels of communication with researchers and data scientists who curate and develop datasets used in the AI learning models. A deeper understanding of datasets and sensitivity of attributes allows for more focused AI protocols.

Table 32. High-Level CMM Assessment – Cybersecurity: Resiliency and Recoverability

Level	High-Level Assessment Criteria
1	Familiar with cyber resiliency and recoverability practices to protect system operations in the event of a cyberattack.
2	Conducted a cyber resiliency/recoverability review of AI and ITS systems against industry practices to determine areas of concern that should be addressed with future resource investments.
3	Architected/rearchitected systems with redundancy and recovery components as determined in its review. Implemented data and system recovery procedures to enable rapid system recoverability in the event a cyber threat cannot be completely mitigated.
4	Invested resources in a cyber response capability focused on mitigating cyberattacks when they arise and restoring regular system operations as efficiently as possible.

Table 33. High-Level CMM Assessment – AI Data and Infrastructure: Data Governance

Level	High-Level Assessment Criteria
1	Building an inventory of data. Exploring what processes are needed to adequately manage collection and management of datasets.
2	Sufficient understanding of sensitivity/impact of datasets plus interaction with learning models used to train AI-enabled ITS applications.
3	Developed minimally invasive data management policies and procedures that create value for AI and ITS use cases.
4	Common data governance policy across the organization. Invests resources to familiarize workforce with effective practices. Integrates industry standards into data management practices.

Table 34. High-Level CMM Assessment – AI Data and Infrastructure: Data Selection and Sources

Level	High-Level Assessment Criteria
1	Exploring and cataloging ITS datasets that may support the development of learning models for AI-enabled ITS use cases of interest.
2	Experimenting with ITS and related data sources. Developing process to blend useful datasets into the data governance framework.
3	Has inventory of actively managed data sources. Implemented robust method of dataset and source selection.
4	Able to reach across internal and external data silos to access datasets that may not be directly owned. Established a peer ecosystem from which to source new datasets and effective practices as industry trends and technologies evolve.

Table 35. High-Level CMM Assessment – AI Data and Infrastructure: Data Acquisition and Transmission

Level	High-Level Assessment Criteria
1	Sufficient understanding of networking infrastructure and outlining goals the data acquisition processes are trying to achieve.
2	Implementing data acquisition pipelines and understanding various data extraction techniques that are required, based on the types and usage of the various datasets the organization plans to collect.
3	Developed data acquisition pipelines and processes that can be tailored to the types of data being acquired. Both the transport and data layers of pipelines are mature and incorporate the organization’s data management and cybersecurity requirements.
4	Invests in modern networking and data management infrastructure to support and optimize ongoing data acquisition processes. Invests in consultants or staff development to stay up to date with effective practices.

Table 36. High-Level CMM Assessment – AI Data and Infrastructure: Data Quality Assurance

Level	High-Level Assessment Criteria
1	Understands key factors that comprise data quality and considers their importance while maintaining datasets.
2	Assessing and measuring the quality of existing AI and ITS datasets and developing standards for datasets to be managed against.
3	Established procedures to ensure data quality is routinely assessed throughout the process of AI model development and deployment. Developed quality standards (that include AI-specific trust concerns), which are kept in consideration during these assessments.
4	Dedicated workforce resources to quality assurance, especially to assess and maintain datasets used in AI model development.

Table 37. High-Level CMM Assessment – AI Data and Infrastructure: Data Storage and Curation

Level	High-Level Assessment Criteria
1	Exploring data curation concepts related to AI development, and has infrastructure in place to store data securely.
2	Deploying additional data pipeline infrastructure and processes to load and curate datasets for use in AI model training and development.
3	Established data storage systems and data pipeline systems optimized for data science. Developed standards for its workforce to follow when organizing and maintaining datasets.
4	Established data storage and curation capabilities that enable internal access to datasets across the organization and external access as appropriate. Invested in ongoing development of the data engineering capabilities of its workforce.

Table 38. High-Level CMM Assessment – AI Data and Infrastructure: Data Processing and Enrichment

Level	High-Level Assessment Criteria
1	Researched methods to use in the enrichment of datasets.
2	Access to a workforce with an appropriate data engineering skillset. Begun transforming datasets for use in AI model development.
3	Established a stage in the data pipeline process that focuses on transforming and enriching data, in order to optimize the training of AI models.
4	Developed enrichment methodologies specifically related to ITS data types that allow a deeper understanding of datasets and their behavior within AI models.

Table 39. High-Level CMM Assessment – AI Models and Applications: Discovery and Understanding

Level	High-Level Assessment Criteria
1	General awareness of how AI can impact and automate ITS applications. Exploring ramifications of introducing such capabilities.
2	Familiar with AI-ITS use cases and understands how transportation SMEs and data scientists interact in AI application development.
3	Devised application development procedures that reinforce collaboration among SMEs and data scientists to help ensure AI models and applications are optimized to correctly enhance ITS operational functionality.
4	Provides and/or leverages third-party open platforms for consistent communication for its transportation workforce and the data scientists the workforce collaborates with, in order to promote greater understanding of growing technologies and standards.

Table 40. High-Level CMM Assessment – AI Models and Applications: Model Development

Level	High-Level Assessment Criteria
1	Aware of basic AI development process. Identified internal or external data science team for AI-enabled ITS application development.
2	Knowledge of learning approaches applicable to AI model development. Ready to try model feature selection for ITS use cases.
3	Established an AI model development workforce and model training infrastructure that prioritizes model trust and transparency to the extent possible. Identified data science team and is comfortable working with datasets and algorithms associated with AI-enabled ITS use cases of interest.
4	Development environment well adapted to selecting features from diverse spectrum of datasets and optimally trained models. Established strategy for data science workforce and AI capability anticipates workforce/contractor turnover and continuous learning.

Table 41. High-Level CMM Assessment – AI Models and Applications: Model Evaluation

Level	AI Models and Applications: Model Evaluation
1	Aware of methods to test/validate AI models to minimize change in model behavior when deployed to operational ITS environments.
2	Developed AI model validation and test processes and has sufficient (and separate) datasets to train, validate, and test models.
3	Established an AI model development workforce and model evaluation infrastructure that includes checks for bias in evaluation criteria.
4	Established strategy to maintain data science workforce and AI capability that anticipates turnover and continuous learning.

Table 42. High-Level CMM Assessment – AI Models and Applications: Application Deployment

Level	AI Models and Applications: Application Deployment
1	Understands ITS systems and operational environments to deploy AI models. Exploring tools/processes for AI application deployment.
2	Has a series of development, test, and production environments with tools for AI application development, validation, and deployment. Sufficient understanding of tools and environments it works with to begin experimenting with AI application production.
3	Familiar with limitations and requirements associated with AI application deployment across various ITS systems. Has processes for routine communication across transportation and data science teams to streamline application deployment.
4	Integrated AI model development processes and tools with application development and operations (DevOps) tools and processes for continuous integration, deployment, and monitoring loop for AI applications.

Table 43. High-Level CMM Assessment – AI Models and Applications: Human-AI Interactions

Level	High-Level Assessment Criteria
1	Aware of the need to design human-AI interfaces that establish trust between the application and end user and support the specific purpose of AI application function (e.g., decision support, automation).
2	Ready to experiment designing user interfaces for AI ITS applications that human users will interact with.
3	Successfully deployed and measured human-AI interfaces. User experience design ensures accessible, safe, and intuitive AI applications.
4	Operational processes implement end-user feedback in AI application development, in order to optimize AI-ITS application performance. Deeply understand the interaction between humans and AI-ITS applications.

Table 44. High-Level CMM Assessment – AI Models and Applications: Application Performance Measures

Level	High-Level Assessment Criteria
1	Understands implications of AI application performance metrics vis-a-vis how AI applications perform in operational ITS environments.
2	Developed measurement criteria to evaluate operational performance of AI applications once deployed into operational ITS environments. Ready to deploy and evaluate AI-enabled ITS applications.
3	Has logging procedures to monitor performance of the AI-enabled application and underlying AI model. Uses logs to identify data trends and update AI models to maintain consistent performance over time.
4	Governance process monitors AI application performance against a baseline as operational ITS environment changes and other environmental factors come into play. Refactors AI-ITS applications and AI models based on conclusions from performance metrics.

Table 45. High-Level CMM Assessment – AI Integration and Operations: Requirements Management

Level	High-Level Assessment Criteria
1	General understanding of business, operational, and policy requirements for AI-enabled ITS applications.
2	AI-ITS applications integrate the above requirements into the model and application development process to begin experimentation.
3	Operational and end-user requirements inform design process for AI-ITS application and are validated prior to operational deployment.
4	Requirement management system, along with checkpoints in its lifecycle management process, ensures requirements are met at all stages. Routinely ensures requirements and use cases represent correct populations with privacy/trust dictated by policy and regulation.

Table 46. High-Level CMM Assessment – AI Integration and Operations: System Design

Level	High-Level Assessment Criteria
1	Understanding of its own ITS systems architecture and exploring how AI models can be integrated into these system designs.
2	Created reference system architecture for AI-ITS systems based on use cases of interest and ready to develop its initial applications.
3	Created repeatable system design process that leverages open-source datasets, model libraries, and application code from the open-source community as appropriate, in order to optimize resource allocation.
4	Developed a system design and code repository and makes it available to the open-source community as appropriate. Dedicates resources to maintenance of its architectures, models, and code bases as its AI-ITS systems continue to grow.

Table 47. High-Level CMM Assessment – AI Integration and Operations: System Integration

Level	High-Level Assessment Criteria
1	Understands transportation and third-party IT/operational technology infrastructure that will support AI-ITS application deployment and data acquisition.
2	Conducted research to understand system integration capability requirements needed to fit with its AI-ITS applications.
3	Established system integration protocols that account for unique systems requirements and support legacy integration with older system infrastructures.
4	Established open channels of communication with transportation system infrastructure teams to understand changing integration requirements as systems evolve.

Table 48. High-Level CMM Assessment – AI Integration and Operations: Test and Evaluation

Level	High-Level Assessment Criteria
1	Identified relevant ground truth and real-world datasets to implement in its AI-ITS application testing.
2	Developed test and evaluation methodology for AI-ITS applications once deployed in the field before operational system launch approval.
3	Developed a process that returns accurate findings when pairing AI models with ground truth datasets. Takes steps to reevaluate the model against real-world data to validate its performance in its operational environment.
4	Dedicated resources to testing AI models with new datasets and monitoring functionality and performance as the scopes of the operational environments change.

Table 49. High-Level CMM Assessment – AI Integration and Operations: System Launch

Level	High-Level Assessment Criteria
1	Knowledge of legacy systems allows articulation of functionality differences provided by new autonomous and predictive elements.
2	Developed commissioning and launch process that validates operational functionality and supports end-user education and onboarding.
3	Created documentation of new functionality and operation instructions for its AI models. Prioritizes onboarding public end users alongside organizational users.
4	Invested in consultation from and communication with ITS application developers to streamline application interactions.

Table 50. High-Level CMM Assessment – AI Integration and Operations: Operational Feedback

Level	High-Level Assessment Criteria
1	Aware of basic principles of how to incorporate operational feedback into the development process. Understands which internal/external individuals should be incorporated into this process.
2	Established operational feedback system. Made the system available to the AI application development team and those operating the application in the field.
3	Developed operational feedback analysis process that reports relevant findings to ITS operations, data science, and software development teams. Routinely conducts AI model maintenance and application performance optimization based on these findings.
4	Integrated routine collaboration among AI application development team and internal/external end users into the application lifecycle. Uses public relations apparatuses to solicit feedback from a representative set of target end-user population.

Appendix B. Detailed Assessment Tool

Accompanying this document is the companion detailed self-assessment tool (Microsoft® Excel™ file format) that CMM users can apply during the detailed assessment process.

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