As government transportation agencies continue to evolve from infrastructure builders to balanced operations organizations that increasingly focus on transportation systems management and operations (TSMO), the need has arisen not only to attract, retain, and evolve traditional positions such as traffic engineers but also to recruit a more technically diverse workforce. A more diverse workforce needs to have expertise in supporting emerging technologies such as connected and automated vehicles, big-data analytics, and sophisticated decision support systems. The TSMO activities of departments of transportation (DOTs) and other government agencies likely will need to change dramatically over the next 10 years because of the increasing speed of technology’s impacts on transportation.

Under the auspices of the National Operations Center of Excellence and funded by the National Cooperative Highway Research Program (NCHRP), several resources have been developed—skills requirements, position descriptions, and career pathways—to help government transportation agencies understand and address the challenges of securing and maintaining their TSMO capabilities.

In addition to providing organizations with usable materials for revamping their TSMO hiring and knowledge development, the project offers lessons to meet other workforce needs associated with new technologies. The following sections outline key project activities and outcomes for NCHRP Project 20-07(408).

**Highest-Priority Issues**

To determine key challenges faced by transportation agencies, researchers conducted a series of interviews with the staff of more than 30 DOTs, along with a comprehensive literature review related to TSMO workforce development. The highest-ranked issues were 1) the lack of existing training versus emerging needs and 2) the lack of a clear career path development for TSMO.
to develop a set of forward-looking roles and responsibilities for TSMO positions. Table 1 (page 34) provides suggestions for future incremental evolution in several traditional positions.

Other key findings include:

- Most agencies continue to operate with staffing restrictions.
- Although about one-half of new hires are civil engineers, trends suggest a growing recognition by DOTs of the need for other professions to deliver high-quality TSMO services.
- Most states appear to have some difficulty filling key technical positions, especially in systems engineering, information technology, and intelligent transportation systems (ITS) device maintenance; approximately one-half of the states depended significantly on consultants.
- Existing TSMO staff members tend to be experts in one or more subject areas; not many have broad, diverse expertise.
- Very few people coming into the TSMO profession are properly prepared to meet existing needs.
- Recruitment difficulties are related to salary competition, lack of required skills and certifications, or both (1).

Transitioning Existing Positions

Government transportation agencies, and especially DOTs, historically have been organized to expand and deliver infrastructure capacity. As society begins to place more value on system performance and reliability, however, the use of technology to manage infrastructure more effectively and share information quickly has become more appealing.

Over the past decade, transportation agencies have advanced different approaches to organizing and creating a program structure for TSMO in order to manage and operate the transportation system effectively. For example, reliability-related research under the second Strategic Highway Research Program played a pivotal role in the concept of TSMO program planning by examining both the technical and organizational support needed to enhance highway operations and travel time reliability at state DOTs and metropolitan planning organizations.

NCHRP Project 20-07(408) research developed a capability maturity model (CMM) consisting of six key dimensions to help transportation agencies improve the effectiveness of their TSMO activities, which specifically included organization and workforce in terms of organizational structure, staff development, and recruitment and retention. This and other efforts have enabled DOTs to slowly adopt and transition more positions related to management and operations of the transportation system (2).

Before thinking about new TSMO positions, over the next 5 years it is critical to evolve technical capabilities of the existing workforce. NCHRP Project 20-07(408) built upon the framework established from previous efforts, as well as a literature review from relevant fields, to develop a set of forward-looking roles and responsibilities for TSMO positions. Table 1 (page 34) provides suggestions for future incremental evolution in several traditional positions.

Recruiting New and Emerging Positions

As part of NCHRP Project 20-07(408), interviews with many DOTs and two virtual workshops helped identify 19 new and emerging positions. Researchers then developed initial motivations, or triggers; position descriptions, including how each can improve CMM maturity (see Figure 1, page 35); and associated knowledge, skills, and abilities (KSAs) for each position. A brief description of the positions considered under this project and the rationale for including each position follows.

- **Traffic Data Scientist/Statistician.** An added emphasis on data science is required as very large amounts of data become more important.
- **TSMO Manager/Chief/Bureau Director.** As TSMO is elevated in government agencies, the roles and responsibilities of higher-level executive management are necessary.
- **TSMO Program Manager.** Several early adopters of TSMO have created program manager positions to coordinate across the wide array of functional areas and to implement activities that call for a broad range of internal and external stakeholders.
is used to make better operational decisions and to demonstrate the benefits of TSMO.

• **Computer Engineer.** Specialized computer engineering is required as processing becomes more distributed and as more and more operational decisions are made through edge computing in the field as opposed to a centralized model.

• **Artificial Intelligence (AI) Scientist.** Government agencies currently have very little experience with AI, but this will rapidly change as cooperative automated transportation becomes more broadly deployed.

• **Telecommunications Engineer.** As private and public communication networks become ubiquitous and more bandwidth is required for emerging technologies, staff who can design the best ways to communicate with fixed and mobile assets will become more critical.

• **Data Management Specialist.** As a complement to computer engineers and data scientists, data management specialists are responsible for curating data in a way that ensures a high level of reliability and accuracy.

• **Visualization Specialist.** Along with analysis performed by data scientists, visualization of large amounts of data in an easy-to-understand way becomes important. The information is used to make better operational decisions and to demonstrate the benefits of TSMO.

• **Connected and Automated Vehicle (CAV) Program Manager.** Many government agencies have hired program managers to work on issues related to developing the capacity to support CAV technologies through research, testing, and partnerships with industry.

• **Traffic Incident Management Program Manager.** Working with partners to improve responses to traffic incidents is crucial to driving down clearance times and secondary

### Table 1: Evolution of Existing Positions

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<th>JOB TITLE</th>
<th>FUTURE ROLES AND RESPONSIBILITIES</th>
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| Traffic Engineer       | • Use spatial data, such as GIS and relevant spatial analyses and statistics, for data-driven decision-making.  
                          | • Advocate for the appropriate TSMO countermeasures during the planning, design, and construction of highway projects as appropriate.  
                          | • Consider CAV impacts on traffic operations.                                                     |
| Traffic Signal Engineer| • Incorporate ICM techniques into the operations of traffic signals.                             
                          | • Consider CAV impacts on traffic signal operations.                                             
                          | • Effectively use GIS and other analytical tools such as SPSS/STATA and traffic simulation and signal timing software (e.g., VISSIM, CORSIM, and Synchro) to create information that enhances operational decision-making. |
| Freeway Operations Engineer | • Incorporate ICM and other demand-management techniques into the operations of freeway facilities.  
                                 | • Consider CAV impacts on freeway operations. Consider and manage new techniques such as automated vehicle–only lanes.  
                                 | • Take a multimodal approach to freeway operations.                                               
                                 | • Use real-time data to make real-time operational decisions. Implement and use prediction software to make operational decisions. |
| Arterial Operations Engineer | • Incorporate ICM techniques into the operations of arterial facilities.                        
                                 | • Consider CAV impacts on arterial operations.                                                    
                                 | • Take a multimodal approach to arterial operations.                                              
                                 | • Use real-time data to make real-time operational decisions. Implement and use prediction software to make operational decisions.  
                                 | • Identify, analyze, and interpret trends or patterns in complex data sets.                      |
| ITS Design Engineer    | • Integrate connected vehicles into ITS design. For example, add DRSC or 5G connectivity as needed.  
                          | • Use modern technology in ITS design including CIM.                                              |
| ITS Planner            | • Use big data to analyze benefits of TSMO strategies and implement if feasible.                 
                          | • Mainstream TSMO into the project-planning process.                                             
                          | • Implement modeling for analysis, visualization, planning, and training related to TSMO programs. |
| Transportation Planner | • Mainstream TSMO into the project planning process.                                             
                          | • Integrate management and operations strategies into the metropolitan transportation planning process to maximize the performance of the existing and planned transportation system.  
                          | • Implement modeling for analysis, visualization, planning, and training related to TSMO programs. |
                          | • Take a multimodal approach to transportation planning.                                           |

**NOTE:** GIS = geographic information systems; TSMO = transportation systems management and operations; CAV = connected and automated vehicles; ICM = integrated corridor management; DRSC = dedicated short-range communications; CIM = civil information modeling.
Several organizations have identified a need for an industry liaison to facilitate collaboration among local private-sector technology companies and government agencies, recognizing the direct benefits of new approaches to solving problems and a less-direct economic development impact.

- **Emerging Technologies Industry Liaison.** The new positions described, such as cybersecurity engineer and AI scientist, may be extended to fit into a transportation organization’s overall information system and technology strategy and would thereby further strengthen the case for the position.
Organizations also need to recognize that new, specialized positions may require relying on the private sector and university partners, which tend to have more flexibility with new types of contracting and working with nontraditional disciplines.

Conclusion
The work of the NCHRP Project 20-07(408) has culminated in a guidebook that provides human resource staff and others tasked with defining new positions a comprehensive resource to begin rethinking TSMO positions, evaluate potential impact on the agency, identify training resources, and provide guidance needed to take the initial steps in recruiting a capable TSMO workforce.

REFERENCES