12 December 2018: Transportation Working Group
A Project Showcase of the Systems Engineering Efforts
and
Minnesota Statewide Regional ITS Architecture Update

Rashmi Brewer
MnDOT

Ming-Shiun Lee
AECOM
Webinar Plan:

- Regular webinars at fixed, predictable days & time
- Organized by the following INCOSE Working Groups (alphabetical order):
  - Automotive Working Group (AWG)
  - Critical Infrastructure Protection and Recovery (CIPR)
  - Infrastructure Working Group (IWG)
  - **Transportation Working Group (TWG)**
- Round robin approach
- Monthly basis, usually second Wednesday @ 11AM ET / 8AM PT
- One hour duration: ca. 45 min presentation, 10-15 min Q/A
- Webinars recorded and uploaded to INCOSE CONNECT & INCOSE TWG YouTube
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2019 International Workshop

2019 Annual INCOSE International Workshop
Torrance, CA, USA
January 26 - 29, 2019

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To (Presenter): Your Question
A Project Showcase of the Systems Engineering Efforts and Minnesota Statewide Regional ITS Architecture Update
• Introduction to ITS and ITS Architecture
• Systems Engineering Efforts in Minnesota
• Minnesota Statewide ITS Architecture
• Systems Engineering Practices
• Implementation Process and Tools
• Next Steps and Enhancements
Intelligent Transportation Systems (ITS) include electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of a surface transportation system.

ITS facilitates stakeholder communications, collaboration, coordination and data sharing.

- Cost-Effective
- Typical Measures of Effectiveness
  - Capacity / throughput
  - Safety
  - Delay / time savings
  - Cost savings
  - Energy and environment
  - Customer satisfaction → Minimizing driver frustration
What is an ITS Architecture?

• An ITS Architecture is like a city plan

• A city plan sets building codes and plans common services such as roads and water

• An ITS Architecture does the same for ITS technology. It describes:
  • The region, participating agencies & stakeholders
  • How agencies, modes, and systems interact and operate
  • A framework for planning, defining, and integrating ITS

An ITS Architecture Facilitates Stakeholder Communication and System Integration
Why Do We Need an ITS Architecture?

• Ensure Compliance with Federal Requirements (23 CFR 940) & Eligibility for Federal Funds
  • 23 CFR 940 – Systems Engineering Analysis and ITS Architecture Requirements

• Foster Integration of ITS Deployment
  • Help planning and procurements of connected and interoperable systems

• Promote Proper Considerations of Technology Interoperability and Future Expansion

• Enhance Financial Effectiveness
• MnDOT has been a leader in ITS research, development, and deployment

• Needs for systematic planning and engineering analysis to facilitate integration, interoperability, and future expansion were recognized

• Systems Engineering Guidance for ITS
  • Federal regulatory requirements (23 CFR 940)
  • FHWA ITS Implementation Memo to MnDOT

• Systems Engineering analysis has been performed and documented for ITS deployments
  • Standard Systems Engineering framework and resource documents developed for common ITS applications (freeway traffic management, arterial traffic management, traffic signals, RWIS, HRI, WIM)
  • Continue developing Systems Engineering analysis resource documents for additional ITS applications (DMS, CCTV, vehicle detection, ramp meters, communications, MnPASS, etc.)
ITS Systems Engineering Efforts in Minnesota (Cont.)

- Use ITS Architecture as a starting point
  - Initial Architecture was developed in late 1990 with an update on a 4- to 5-year cycle
  - Latest update will be published by the end of 2018

- Highway Project Development Process (HPDP) – ITS Systems Engineering Requirement
  - Builds upon guidance from FHWA ITS Implementation Memo
  - Defines Systems Engineering requirements for ITS projects and/or projects with an ITS component(s)

- ITS Systems Engineering Implementation Process
  - Facilitates the implementation of HPDP – ITS Systems Engineering Requirement
ITS Architecture and Systems Engineering

*ITS Architecture*

*Systems Engineering*
Minnesota Statewide ITS Architecture

• A singular architecture covering the entire state, including all 8 MPO areas

• Covers all service package areas identified in the National ITS Architecture (ARC-IT)

• Includes a strategic ITS implementation plan (Implementation Volume) listing ITS initiatives and project concepts for short, medium and long terms

• Provides agencies with a useful planning tool for
  • ITS project identification and planning
  • Design, deployment, integration and expansion
  • Operations, management and maintenance
  • Investment decisions
ITS Architecture Implementation Volume

- Includes 115 ITS project concepts
  - Covering all potential ITS projects, from traffic management, traveler information, transit to emerging transportation technology such as connected automated vehicles and smart city technology

- Offers information on functionalities and user interfaces → Establish foundation for developing concept of operations and requirements

- Showcase Project: Centralized Traffic Control Software Procurement
• Centralized Traffic Signal Control Software (CTSCS) Procurement

• Project Needs:
  • MnDOT Metro District utilized Siemens i2 Central Traffic Signal Control Software
  • i2 Software is no longer supported.
  • Metro District plans to continue to expand central system and migrate signals off of Aries.
CTSCS Project Goals

• Performing the Systems Engineering analysis to identify the needs and features of a new CTSCS.

• Fostering integration of the deployment with regional ITS systems and components while complying with federal regulations.

• Enhancing MnDOT’s financial effectiveness while taking proper consideration of systems interoperability and future expansion compatibility.

• Working cooperatively with **agency partners** to achieve greater safety, mobility, and efficiency on the signalized arterial system.

• Developing procurement specification that meets the operating needs of MnDOT and its agency partners.
Proposed CTSCS

On-going Enhancements
• A need for desktop/tablet secured Internet access and credentialing to CTSCS
• An additional access via VPN to RTMC field network
Systems Engineering Analysis for CTSCS

- Concept of Operations
- Systems Requirements
- Detailed Design – Procurement Specification
- Plans for System Testing, Verification, Acceptance, and Validation
CTSCS Concept of Operations

- Stakeholders
- Needs
- Operational Concept
- Proposed System
- Roles and Responsibilities
- Operational Scenarios

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Role / Responsibility</th>
</tr>
</thead>
</table>
| MnDOT Metro District Traffic Staff | • Use CTSCS to monitor and maintain traffic signal operations on MnDOT operated roadways within the Metro District boundaries.  
• Use CTSCS to troubleshoot hardware issues with traffic signals.  
• Provide administrator for CTSCS to manage operator access and user rights.  
• Serve as in-house technical expert for MnDOT.  
• Serve as primary MnDOT contact with CTSCS vendor for training, technical support and warranty services. |
| Other MnDOT District Traffic Staff | • Use CTSCS to monitor and maintain traffic signal operations on MnDOT operated roadways within the District boundaries.  
• Use CTSCS to troubleshoot hardware issues with traffic signals. |
| MnDOT Office of Traffic, Safety and Technology-Electrical Services Section Staff | • Review CTSCS operational performance logs, identified by District traffic staff, to troubleshoot and repair (as needed) hardware issues with traffic signals. |
| MN.IT | • Maintain communication, server and computer infrastructure used by MnDOT to operate the CTSCS with traffic signals throughout the state. |
| Local Partners | • Use CTCS, as per agreement with MnDOT, to monitor and maintain traffic signal operations on roadways with shared jurisdictional control and interests. |
| CTSCS Vendor | • Provide training, technical support and warranty services as negotiated by MnDOT. |
• Met with stakeholders and operators to discuss project
• Identified 17 Needs to be addressed
• Needs were mapped to the Operational Concept and Requirements

Examples of Needs from ConOps

Need 1: MnDOT needs to control any department-operated traffic signal controller that is equipped with continuous communications (e.g. Ethernet) capabilities and also supports NTCIP 1202 Actuated Signal Controller (ASC) management information base (MIB) codes, from one central system.

Need 2: MnDOT needs central control software to be easy to use and convenient, supporting both regular operators who will work with it daily and occasional operators.

Need 3: MnDOT needs central control software to be compatible with MnDOT hardware and software environments, as well as the Minnesota Statewide Regional ITS Architecture.

Need 4: Operators need easy access to real-time signalized intersection information.
• 18 functional areas were identified
• Operational scenarios were identified to describe how the system would be used by stakeholders
• Requirements were developed and mapped to the operational concept and needs
• Requirements were used to develop detailed specifications for the procurement document
CTSCS Procurement Documents

- References – Proven Systems
- Request for Proposal – Process for Selection
- System Requirements, Testing, and Validation – Proof of Concept
- Cost Proposal
  - Base Bid
  - Alternates

### Sample of Requirements to be addressed by Proposer

<table>
<thead>
<tr>
<th>No.</th>
<th>Requirement</th>
<th>Meets and Will Comply with Requirement</th>
<th>Describe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5.4.1</td>
<td>Select the timing plan that is best suited to the existing traffic conditions from a list of optional timing plans authorized for the given time period.</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.5.4.2</td>
<td>Allow operators to assign time periods for timing plans (e.g. timing plan 111 might be assigned to only be selected during the AM peak).</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.5.4.3</td>
<td>Command the Signal Timing Plan number to the intersections on a continuous basis until the traffic-responsive process recognizes a change in the traffic condition.</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.5.4.4</td>
<td>Include logic to avoid ‘loops’ (hysteresis) where the CTSCS implements several consecutive timing plan changes in rapid manner.</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.5.4.5</td>
<td>Provide detailed description of the traffic-responsive algorithm.</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
Lessons Learned

• Project team meetings and stakeholder input → key decision points

• Full compatibility with signal controller features (proprietary Management Information Base Data) → may be needed by the operating agency, NTCIP compatibility isn’t always enough

• Check with legal / administrative staff early on → what’s allowed during evaluation and procurement

• Procurements involving multiple agencies can be difficult → increased complexity caused by:
  • interagency agreements,
  • schedule, competing needs,
  • funding, and
  • differences in the ranking of evaluation criteria
More Lessons Learned

• Build off previous systems engineering documents and specifications whenever possible
  → Collectively, using other agencies procurement documents as a resource saved us a significant effort on this project

• Maintain focus on your goals
  → Adaptive Signal Control requirements and a new signal controller procurement were discussed, but excluded & pursued separately to maintain the focus on the CTSCS features
• Further use of the Systems Engineering for Centralized Traffic Signal Control Software greatly enhanced the:
  • CTSCS product
  • Stakeholder teams overall understanding to support regional ITS integration (in this case regional signal operations) for:
    • Counties: Dakota, Hennepin
    • City of Bloomington

• Enhancements for the Development of the MnDOT ITS Implementation Process
ITS Implementation Process

• A Process Developed by MnDOT to Govern ITS Project Planning, Design and Implementation

• It Builds Upon the Statewide ITS Architecture and Systems Engineering Principles
Purpose of ITS Implementation Process

• Promote Consistent Use of Systems Engineering

• Ensure Compliance with Federal Requirements & Eligibility for Federal Funds

• Foster Integration of ITS Deployment

• Promote Proper Considerations of
  • Interoperability
  • Operations and Management
  • Future Expansion

• Enhance Financial Effectiveness
Key Process Components

- Systems Engineering Requirements
- ITS Architecture & Consistency Check
- Project Planning & Scoping Assistance
- Implementation Process Guidance
- Tools & Training
  - Quick Reference Guide
  - Decision Tree
  - Checklists
  - Website

Traffic Engineering

Systems Engineering

FHWA Implementation Memo
- Implementation of 23 CFR 4060 Regulations - ITS Architecture and Systems Engineering for ITS Projects (PDF)

Highway Project Development Process (HPDP) - ITS

Resource Documents
- Does Your Project Contain ITS Components? (PDF)
- ITS Implementation Tools & Resources (PDF)
- ITS Implementation - Project Classification and Systems Engineering (ISE) Requirements Decision Tree (PDF)
- Procedures for Implementing HPDP ITS Systems Engineering Requirement in a Quick Reference Guide (PDF)

Checklists (Complete and sign the appropriate checklist below for the class of your project.)
Class A (Standard ITS Applications)
- MnDOT System Engineering for Standard ITS Applications - Concept of Operations and Functional Requirements for Class A Projects
- Class A Checklist (Traffic Signal) (Word)
- Class A Checklist (Road Weather Information System) (Word)
- Class A Checklist (Railroad Grade Crossing) (Word)
- Class A Checklist (Wrecks in Motion System) (Word)
Tools – A Decision Tree with Color Codes

Decision Tree with Project Classification Charts
https://www.dot.state.mn.us/its/docs/decisiontree.pdf
### Tools – Project Classification Charts

#### Class A Standard ITS Applications

<table>
<thead>
<tr>
<th>Standard ITS Applications</th>
<th>Freeway Traffic Management Applications</th>
<th>Arterial Traffic Management Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Signals:</td>
<td>Observation and Detection</td>
<td>Observation and Detection</td>
</tr>
<tr>
<td>- Basic traffic signals</td>
<td>- Visual surveillance (e.g. CCTV)</td>
<td>- Visual surveillance (e.g. CCTV)</td>
</tr>
<tr>
<td>- Traffic signal interconnect (closed loop)</td>
<td>- Traffic detectors</td>
<td>- Traffic detectors</td>
</tr>
<tr>
<td>- Flashing yellow arrows</td>
<td>- Condition reporting system</td>
<td>- Condition reporting system</td>
</tr>
<tr>
<td>- Advanced warning flashers</td>
<td>- Weather sensors and provision of current and forecast weather conditions</td>
<td>- Weather sensors and provision of current and forecast weather conditions</td>
</tr>
<tr>
<td>- Railroad preemption</td>
<td>- Automatic vehicle location (AVL) for FIRST, maintenance, and State Patrol vehicles</td>
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</tr>
<tr>
<td>- Emergency vehicle preemption (localized without control center oversight)</td>
<td>- Information Sharing</td>
<td>- Information Sharing</td>
</tr>
<tr>
<td>- Transit signal priority (localized without control center oversight)</td>
<td>- Dynamic message signs (DMS)</td>
<td>- Dynamic message signs (DMS)</td>
</tr>
<tr>
<td>- Enforcement lights</td>
<td>- Radio broadcast</td>
<td>- Radio broadcast</td>
</tr>
<tr>
<td>- Road Weather Information Systems (RWIS):</td>
<td>- Web pages for construction and traveler information</td>
<td>- Web pages for construction and traveler information</td>
</tr>
<tr>
<td>- Environmental sensor stations</td>
<td>- 511 phone</td>
<td>- 511 phone</td>
</tr>
<tr>
<td>- Communication system for data transfer</td>
<td>- Computer aided dispatch (CAD) for FIRST, maintenance, and State Patrol vehicles, including CAD-CARS integration</td>
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</tr>
<tr>
<td>- RailRoad-Highway Grade Crossings:</td>
<td>- Traffic Control</td>
<td>- Traffic Control</td>
</tr>
<tr>
<td>- Railroad flashing-light signals</td>
<td>- Lane control signs</td>
<td>- Lane control signs</td>
</tr>
<tr>
<td>- Railroad cantilever flashing-light signals</td>
<td>- Ramp meters</td>
<td>- Ramp meters</td>
</tr>
<tr>
<td>- Standard railroad gates</td>
<td>- Electronic toll collection</td>
<td>- Electronic toll collection</td>
</tr>
<tr>
<td>- Four quadrant railroad gates</td>
<td>- Automated gate closure systems</td>
<td>- Automated gate closure systems</td>
</tr>
<tr>
<td>- Traffic signal preemption</td>
<td>- Data Processing and Response Formulation</td>
<td>- Data Processing and Response Formulation</td>
</tr>
<tr>
<td>- Weigh-in-Motion (WIM) Systems:</td>
<td>- TMC software</td>
<td>- TMC software</td>
</tr>
<tr>
<td>- WIM for CVO inspection</td>
<td>- Data extract tool</td>
<td>- Data extract tool</td>
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<tr>
<td></td>
<td></td>
<td><strong>Infrastructure Support Tools</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Landline communication (fiber, copper, telephone lines, DSL lines)</td>
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<tr>
<td></td>
<td></td>
<td>- Wireless communication (point-to-point and cellular)</td>
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<tr>
<td></td>
<td></td>
<td><strong>Power</strong></td>
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<tr>
<td></td>
<td></td>
<td><strong>Data Processing and Response Formulation</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- TMC software (for example, central traffic signal control software)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Data extract tool</td>
</tr>
</tbody>
</table>

#### Class B-1 Applications: Freeway Traffic Management

<table>
<thead>
<tr>
<th>Freeway Traffic Management Applications</th>
<th>Class B-2 Applications: Arterial Traffic Management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Information Sharing</strong></td>
<td><strong>Infrastructure Support Tools</strong></td>
</tr>
<tr>
<td>- Dynamic message signs (DMS)</td>
<td>- Landline communication (fiber, copper, telephone lines, DSL lines)</td>
</tr>
<tr>
<td>- Radio broadcast</td>
<td>- Wireless communication (point-to-point and cellular)</td>
</tr>
<tr>
<td>- Web pages for construction and traveler information</td>
<td>- <strong>Infrastructure Support Tools</strong></td>
</tr>
<tr>
<td>- 511 phone</td>
<td>- Landline communication (fiber, copper, telephone lines, DSL lines)</td>
</tr>
<tr>
<td>- Computer aided dispatch (CAD) for FIRST, maintenance, and State Patrol vehicles, including CAD-CARS integration</td>
<td>- Wireless communication (point-to-point and cellular)</td>
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<td>- 511 phone</td>
<td><strong>Class C Applications: Large/Complex Projects</strong></td>
</tr>
<tr>
<td>- Computer aided dispatch (CAD) for FIRST, maintenance, and State Patrol vehicles, including CAD-CARS integration</td>
<td><strong>Class C Applications: Large/Complex Projects</strong></td>
</tr>
</tbody>
</table>

#### Class B-2 Applications: Arterial Traffic Management

<table>
<thead>
<tr>
<th>Arterial Traffic Management Applications</th>
<th>Class C Applications: Large/Complex Projects</th>
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<tr>
<td><strong>Information Sharing</strong></td>
<td><strong>Class C Applications</strong></td>
</tr>
<tr>
<td>- Dynamic message signs (DMS)</td>
<td>- Integrated Corridor Management (ICM)</td>
</tr>
<tr>
<td>- Radio broadcast</td>
<td>- Bus Rapid Transit (BRT)</td>
</tr>
<tr>
<td>- Web pages for construction and traveler information</td>
<td>- Communications (for example, fiber network)</td>
</tr>
<tr>
<td>- 511 phone</td>
<td>- Transportation management center (TMC)</td>
</tr>
<tr>
<td>- Computer aided dispatch (CAD) for FIRST, maintenance, and State Patrol vehicles, including CAD-CARS integration</td>
<td>- Incident management systems</td>
</tr>
<tr>
<td>- Information Sharing</td>
<td>- Intersection conflict warning systems</td>
</tr>
<tr>
<td>- Dynamic message signs (DMS)</td>
<td>- Infrastructure-based safety systems</td>
</tr>
<tr>
<td>- Web pages for construction and traveler information</td>
<td>- Truck priority</td>
</tr>
<tr>
<td>- 511 phone</td>
<td>- Smart work zone</td>
</tr>
<tr>
<td>- Computer aided dispatch (CAD) for FIRST, maintenance, and State Patrol vehicles, including CAD-CARS integration</td>
<td>- Other complex applications not listed above and not listed in Class B-1 or B-2</td>
</tr>
</tbody>
</table>

#### Class C Applications: Large/Complex Projects

<table>
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<tr>
<td>- Integrated Corridor Management (ICM)</td>
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<td>- Other complex applications not listed above and not listed in Class B-1 or B-2</td>
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</tbody>
</table>

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Next Steps and Enhancements

• Systems Engineering Analysis for ITS and Connected and Automated Vehicle Readiness for:
  • DMS, CCTV, Vehicle Detection, Communications (Fiber, Wireless), Ramp Meters

• Connected and Automated Vehicle Projects

• Continued Enhancements of the SE ITS Implementation Process
- MnDOT Systems Engineering Web Page
  - [www.dot.state.mn.us/its/systemsengineering.html](http://www.dot.state.mn.us/its/systemsengineering.html)

- Minnesota Statewide Regional ITS Architecture Web Page
Thank you!
Questions?

Rashmi Brewer, PE
MnDOT
Rashmi.Brewer@state.mn.us
651-234-7063

Ming-Shiun Lee, PhD, PE
AECOM
ming.shiun.lee@aecom.com
612-376-2048
Please post your questions under the “Public Chat” box

To (Presenter): Your Question
Q&A

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- Increase volume *4
- Decrease volume *7
- Increase microphone *5
- Decrease microphone *8

Rashmi Brewer  
MnDOT

Ming-Shiun Lee  
AECOM