# Traffic Incident Management System

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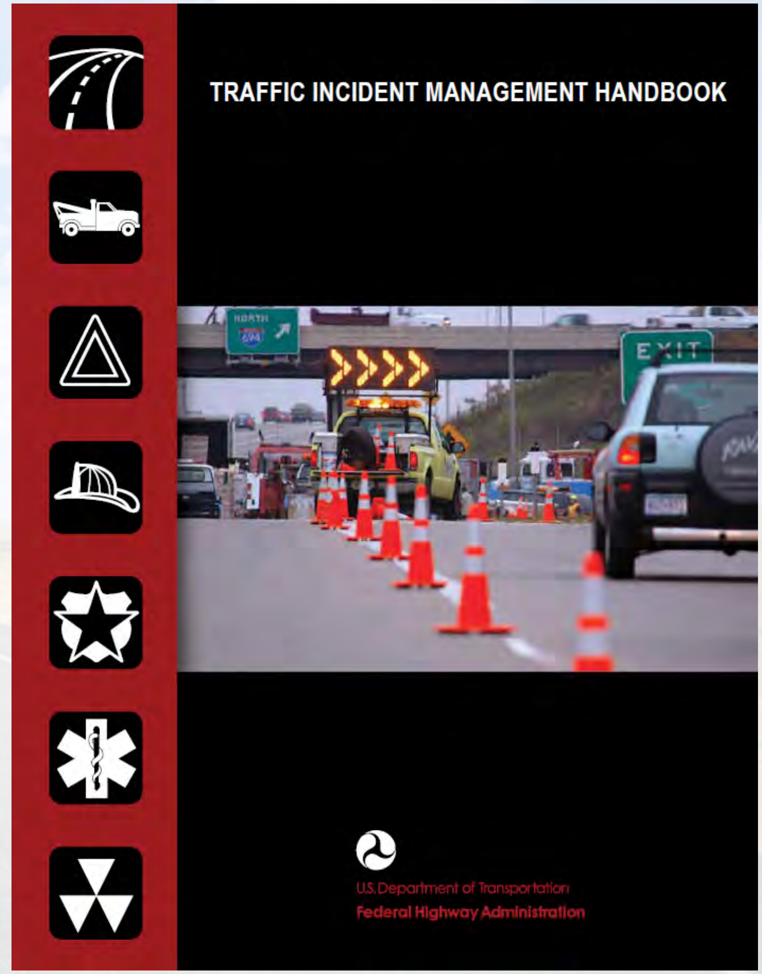
# Introduction, Mission, and Need

- Why this System?
  - Personal experience in traffic.
- The TIMS will provide an incident management and resolution capability that quickly documents incidents, commands all stakeholders, clears the roadway, and directs passing traffic in order to reduce the impact traffic incidents have on society.
- Impacts
  - Reduce Travel Times (Commuters)
  - Improve Safety (Reduce Secondary Incidents)
  - Reduce Environmental Impact (Less fuel usage)
  - Reduce Costs (Transportation and Logistics Industry)

# Requirements Development

- Stakeholders
  - Department of Transportation Personnel
  - Incident Responders
  - Transportation Industry Personnel
- Process
  - Identify user needs and CONOPs
  - Identify operational requirements
  - Derive performance requirements
  - Derive functional requirements
  - Derive constraint requirements



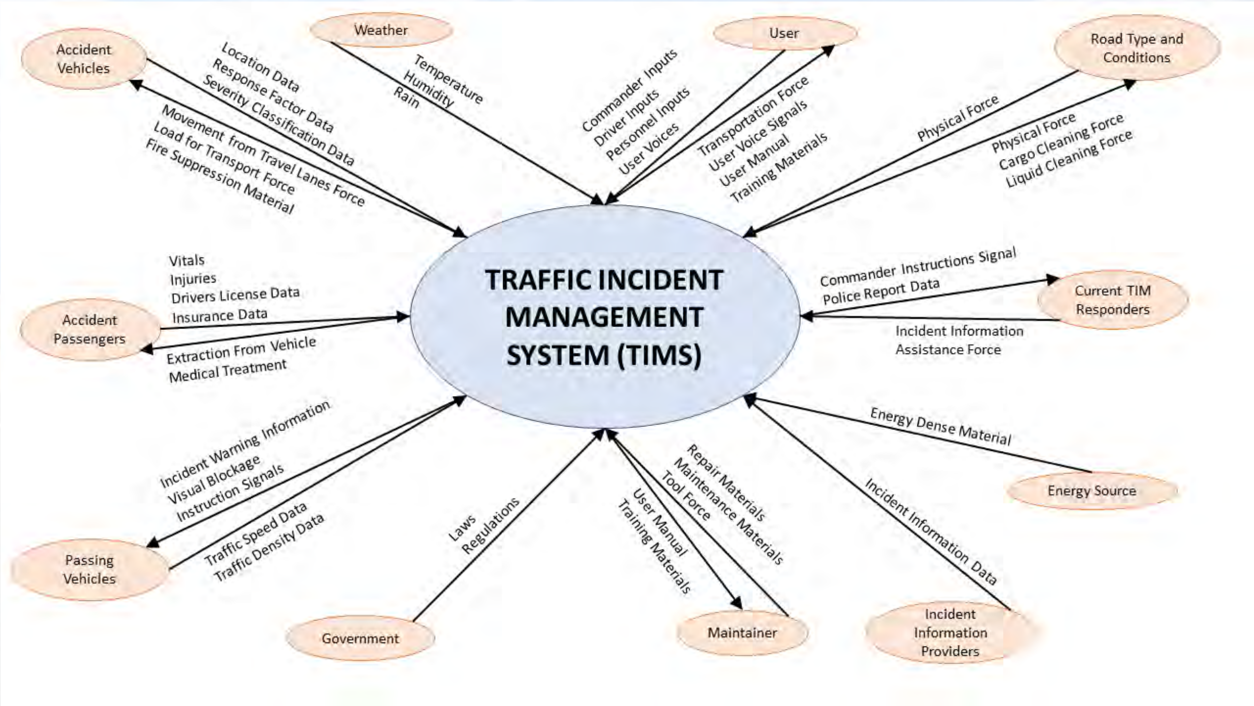

Traffic Incident Management Handbook. Federal Highway Administration, 2010, https://ops.fhwa.dot.gov/eto_tim_pse/publications/timhandbook/tim_handbook.pdf.

# CONOPS

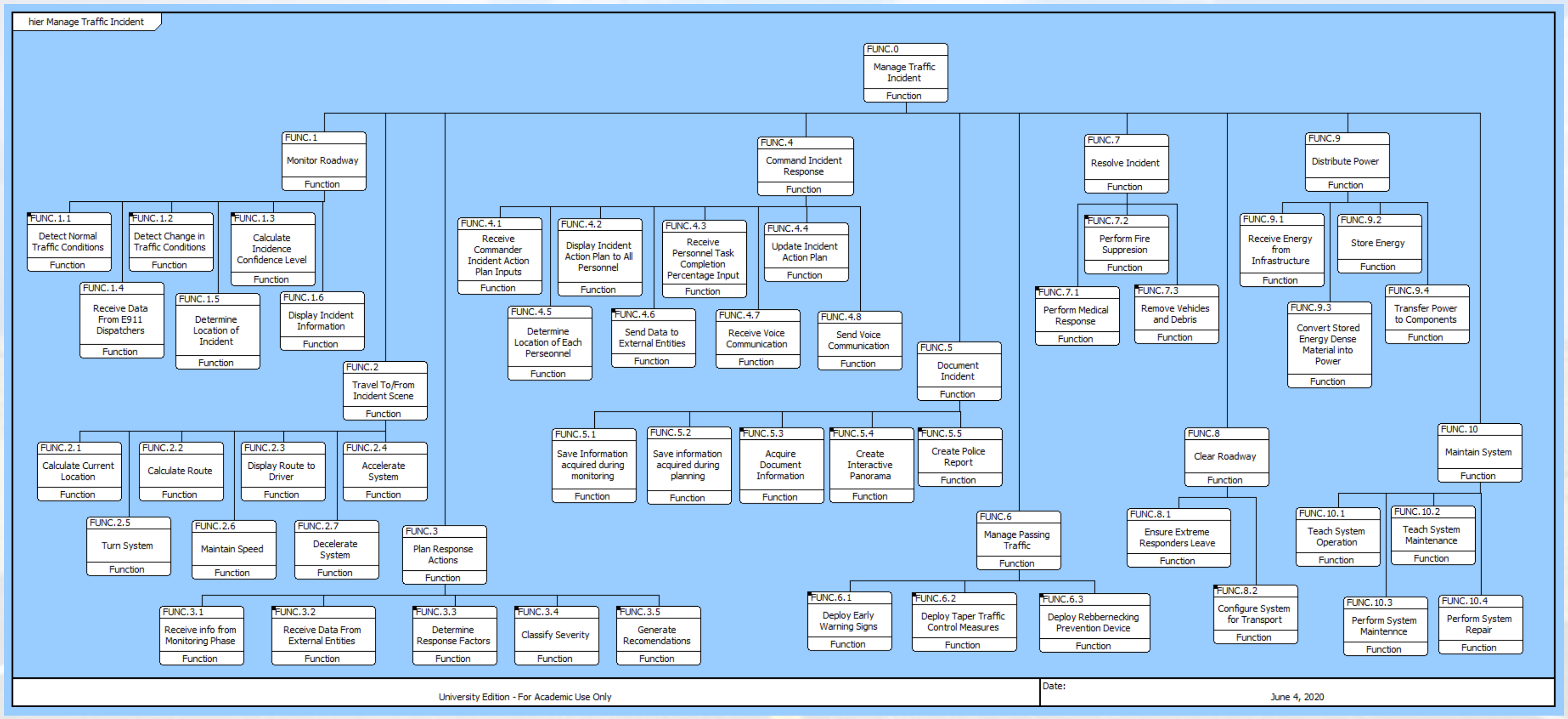
- Detect Incident
- Travel to Incident
- Plan Response
- Document the Scene
- Clear the Roadway

# Functional Context Diagram

- Defines the interfaces between the system and external entities
- Shows what is passed between them.

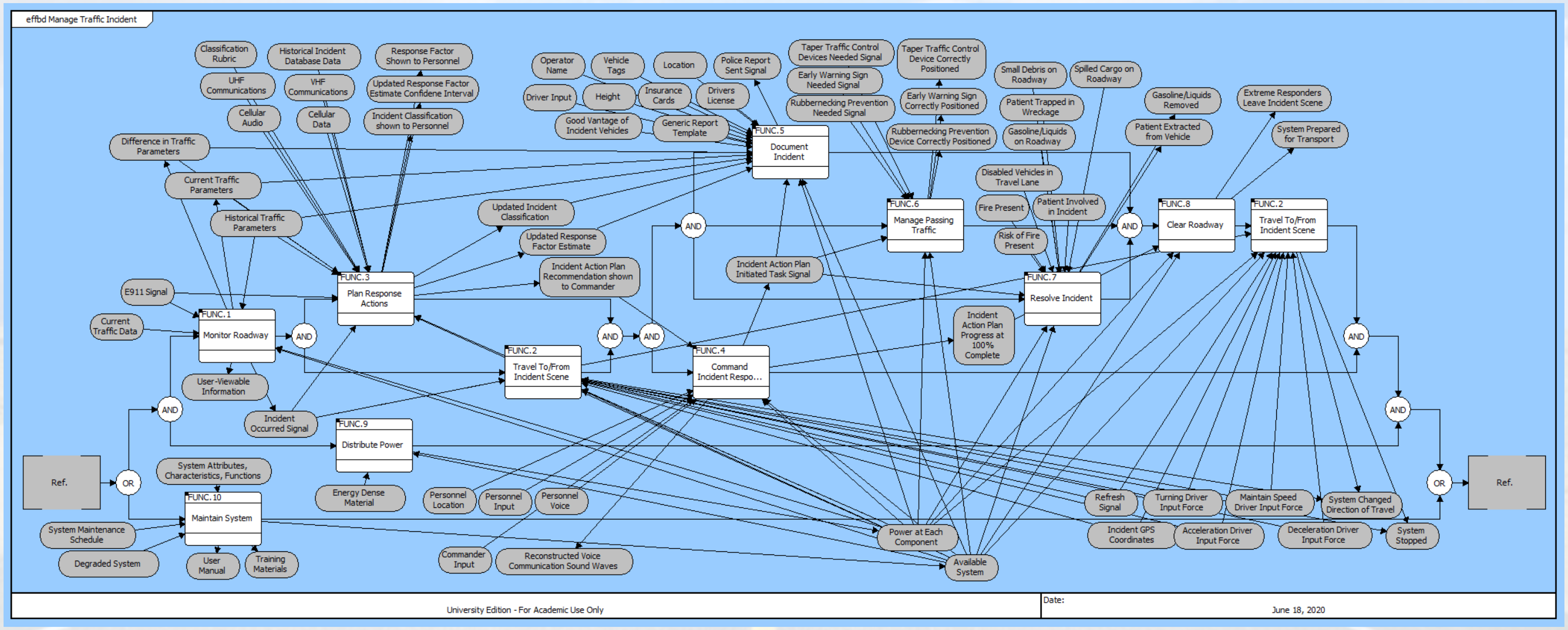


# Functional Tree




- Shows the Level 1 and 2 functions.
- Level 3 and Level 4 functions decomposed for critical functions.

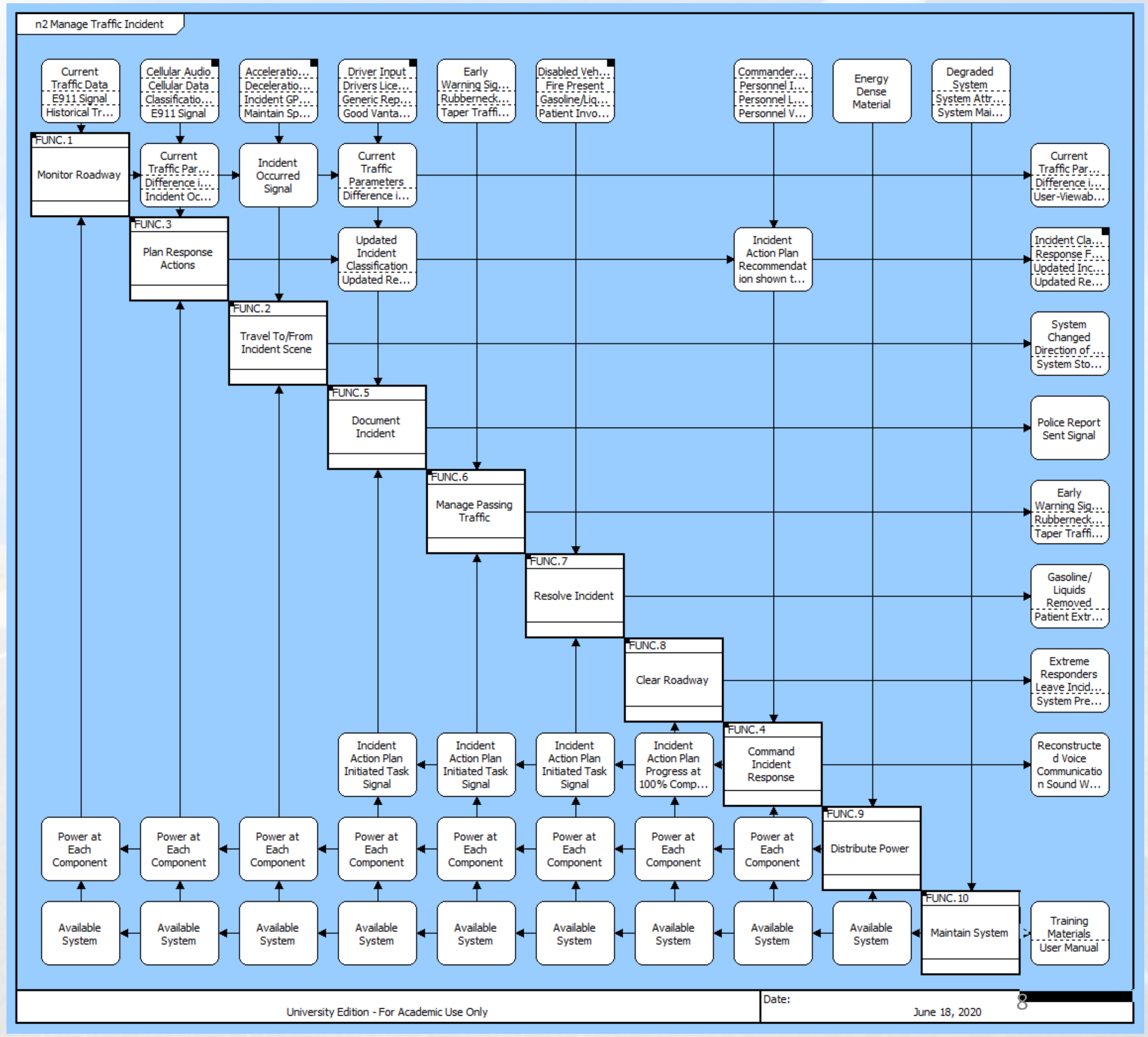
# Enhanced Functional Flow Diagram




- Level 1 functions shown with logical operators.
- Inputs and outputs trace through the logical operators.

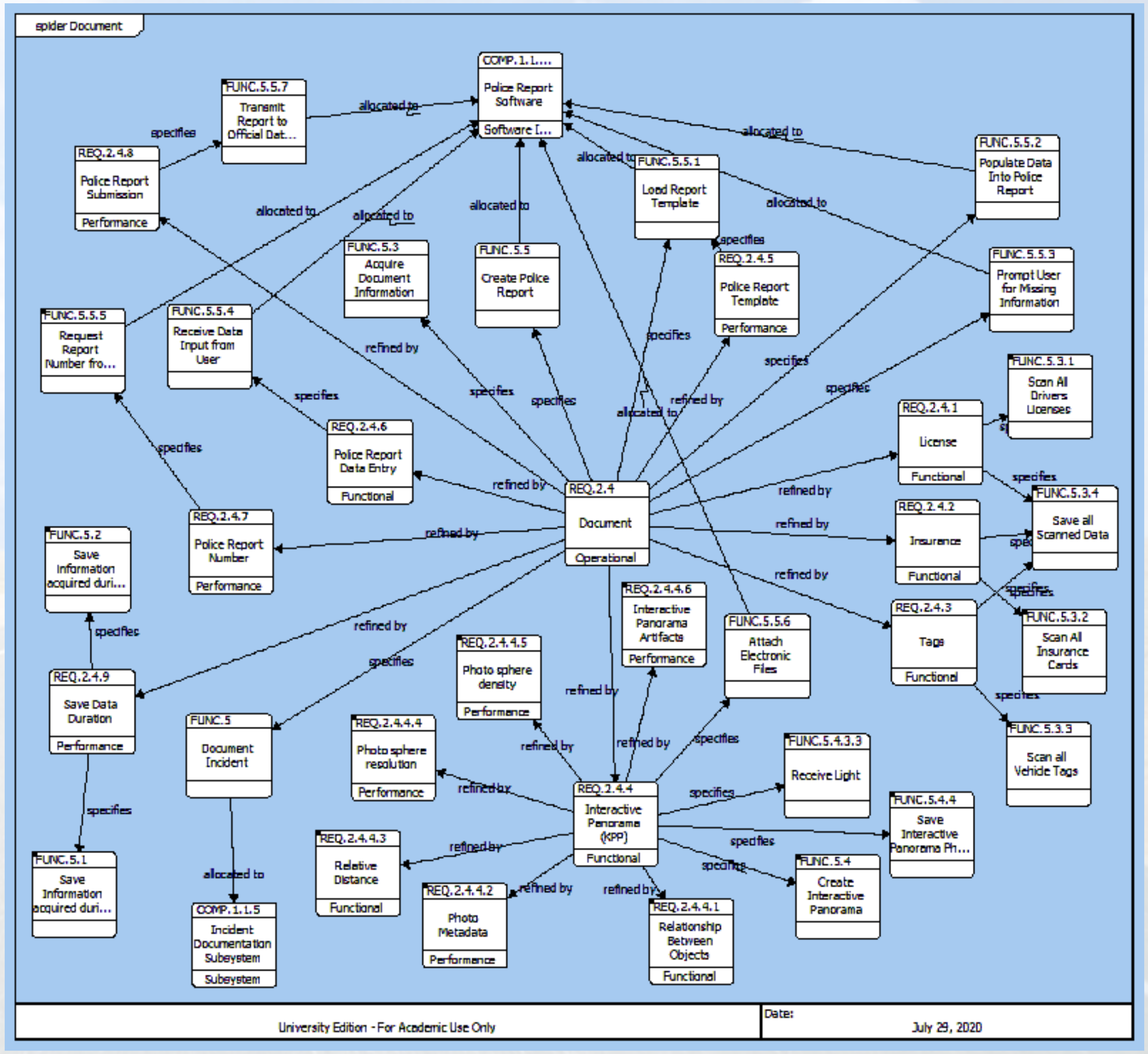
# Functional N2 Diagram

- Functions listed along the diagonal.
- FEDS-M elements shown as inputs and outputs.
- External elements located in top row and right column.



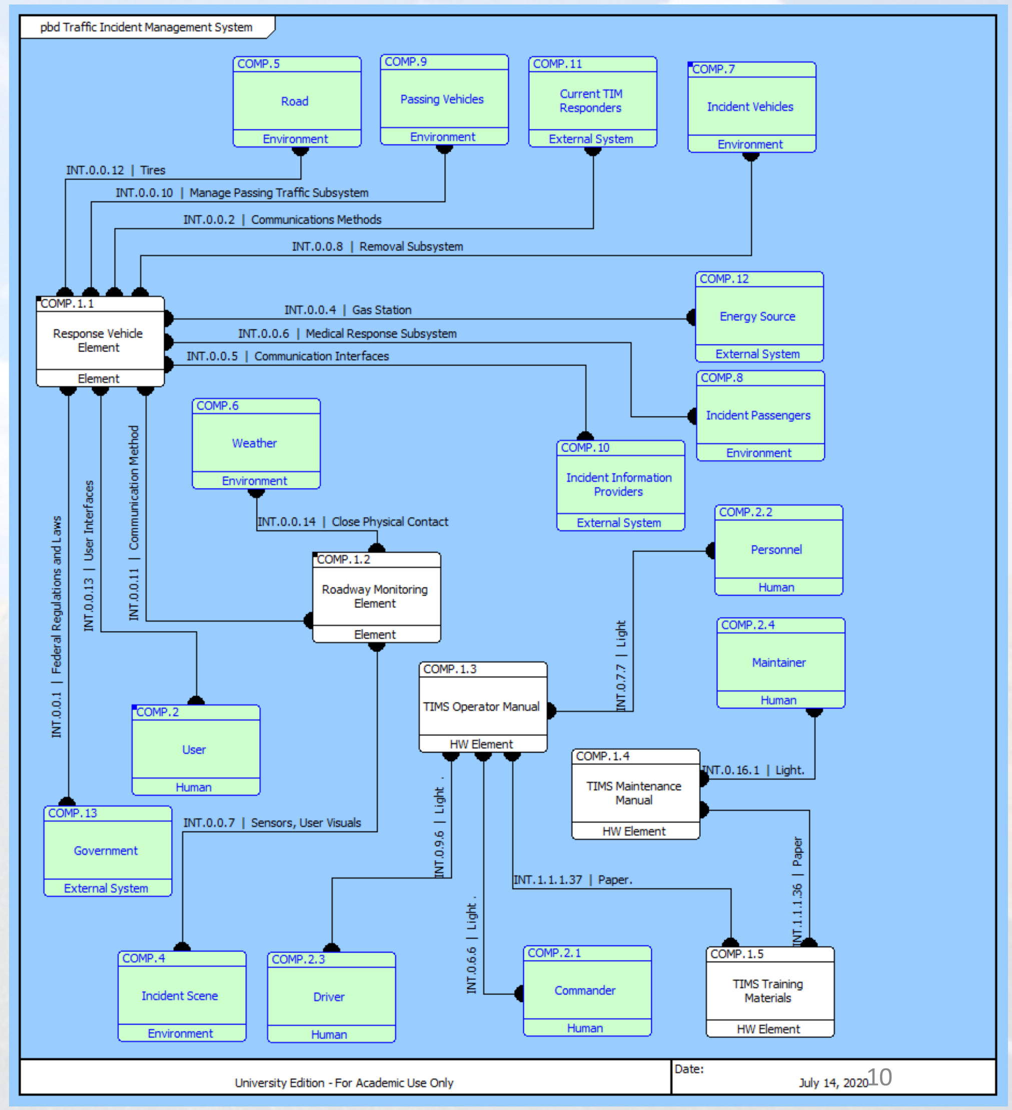
# Traceability

- Most useful form is in a matrix.
- Establishes relationships.
- Determines completeness and over/under allocation.
- REQ.2.4
  - Refined by sub-REQs
  - Specifies FUNCs
  - Allocated to COMPs



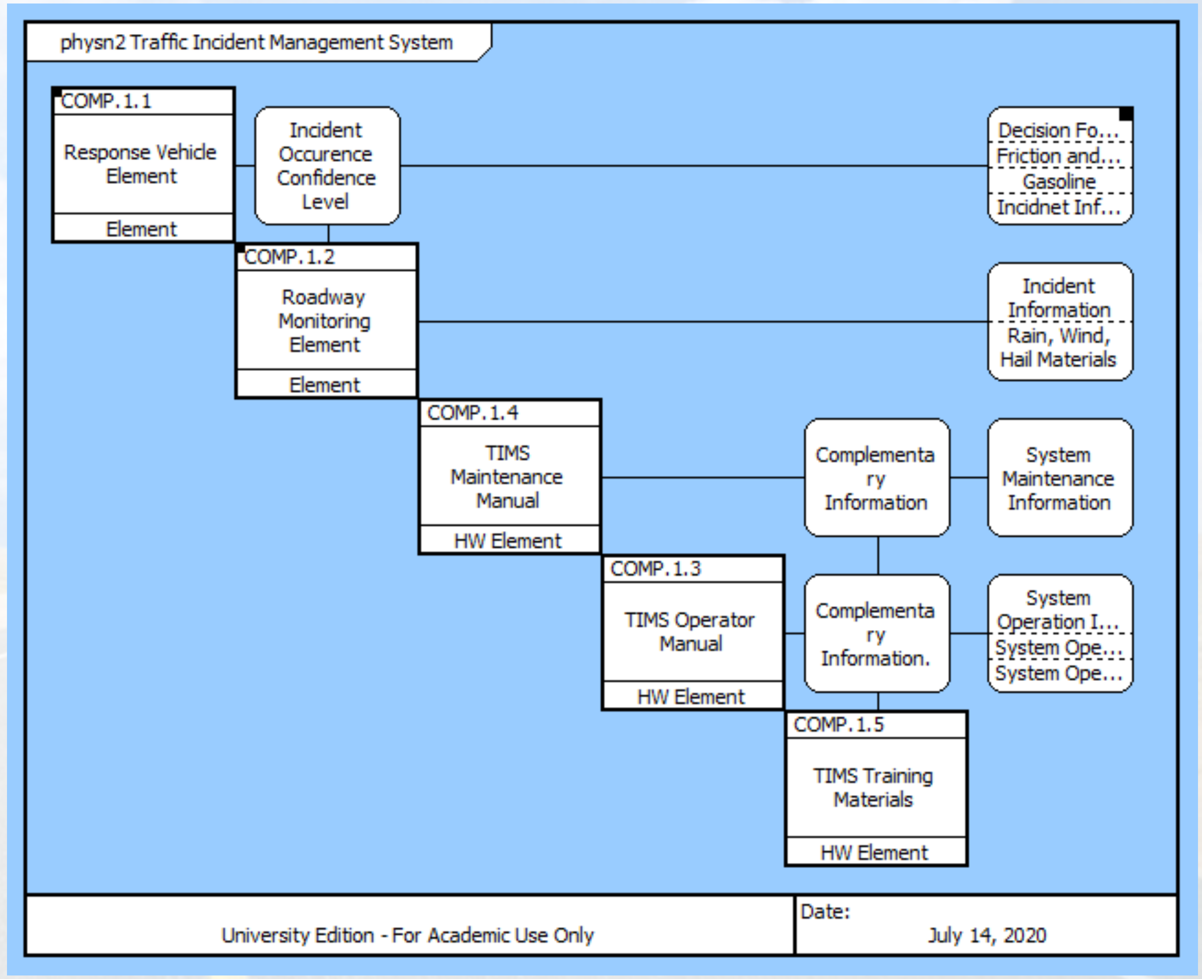
# Physical Block Diagram – Level 1

- COMP.1 TIMS
- Shows implementation of external interfaces between components and external entities.
- Organizes internal components.



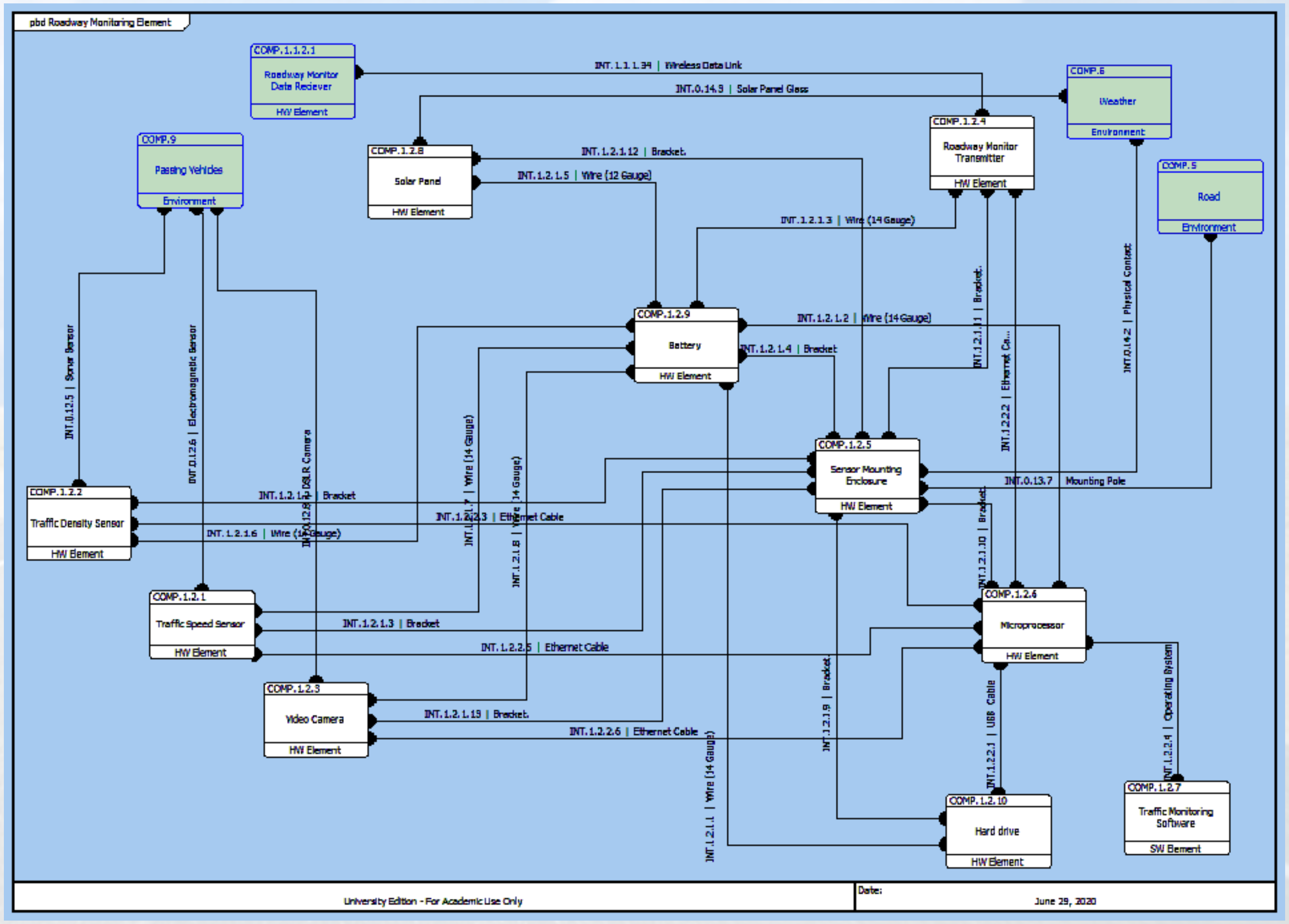
# Physical N2 Diagram - Level 1

- COMP.1 TIMS
- Shows what is passed over each interface.
- Interfaces are not directional (all are located above/right of the diagonal.)



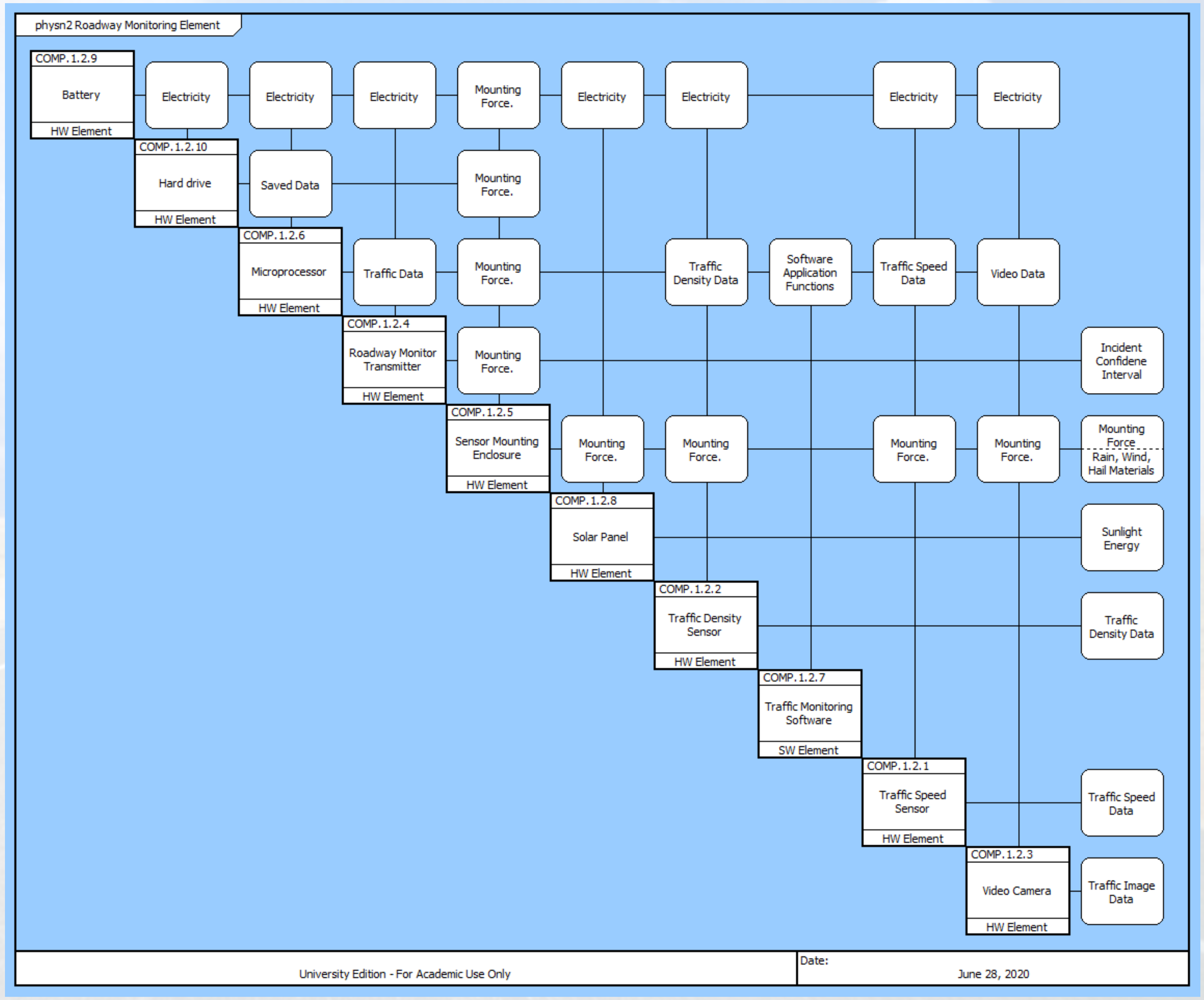
# Physical Block Diagram – Level 2

- COMP.1.2 Roadway Monitoring Element
- Components and interfaces trace back to functions.
- Implementation of each interface is shown.



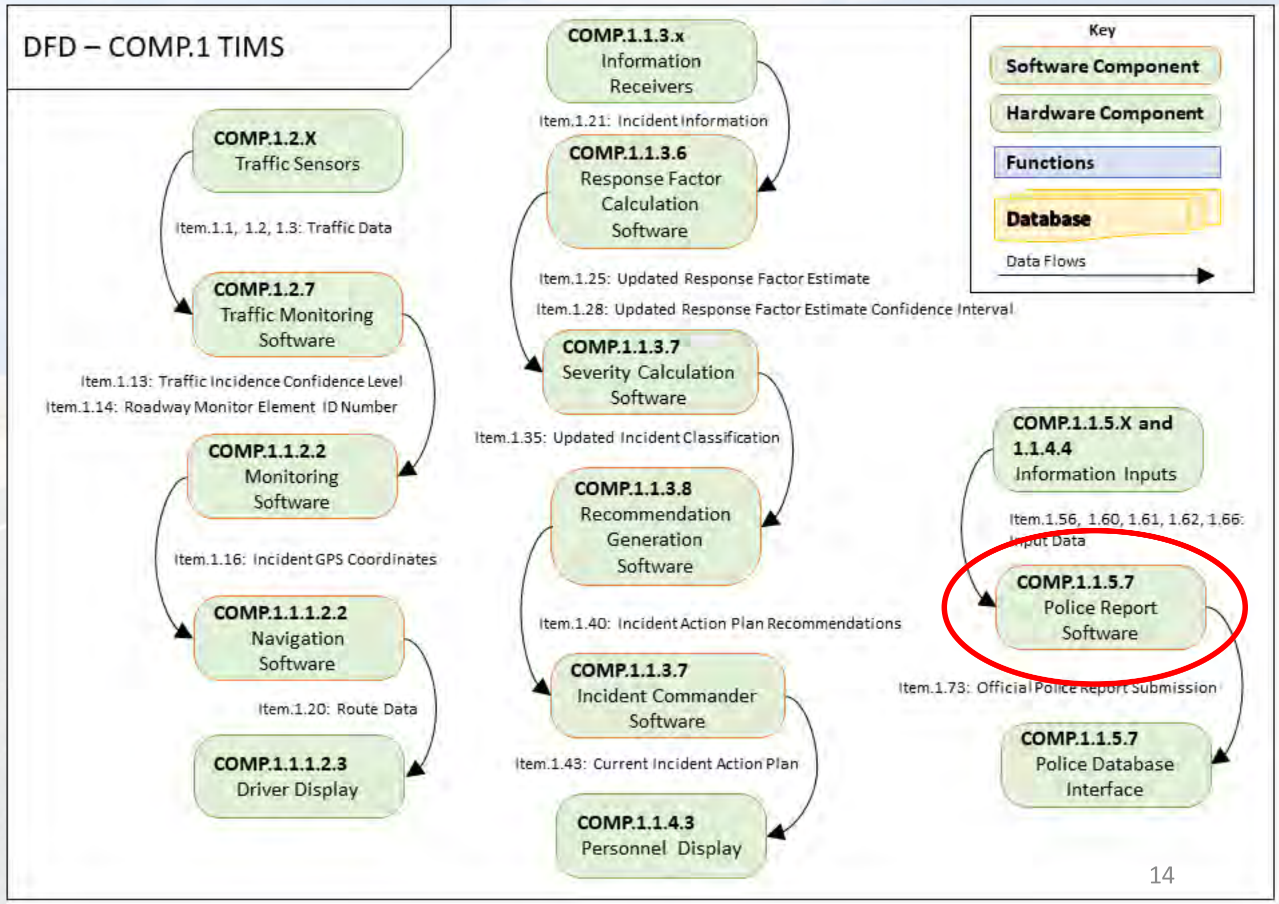
# Physical N2 Diagram - Level 2

- COMP.1.2 Roadway Monitoring Element
- Shows what is passed over each interface.
- Interfaces are not directional (all are located above/right of the diagonal.)



# Data Flow Diagram

- COMP.1 TIMS
  - Shows flow of data through each component.
  - HW -> SW -> HW.
- COMP.1.1.5.6 Police Report Software
  - Shows flow of data through each function.



# Physical Interfaces

- Interfaces connect COMP-COMP or COMP-EXT.
- Interfaces are designed like components.
- Performs a function and traces back to a REQ.

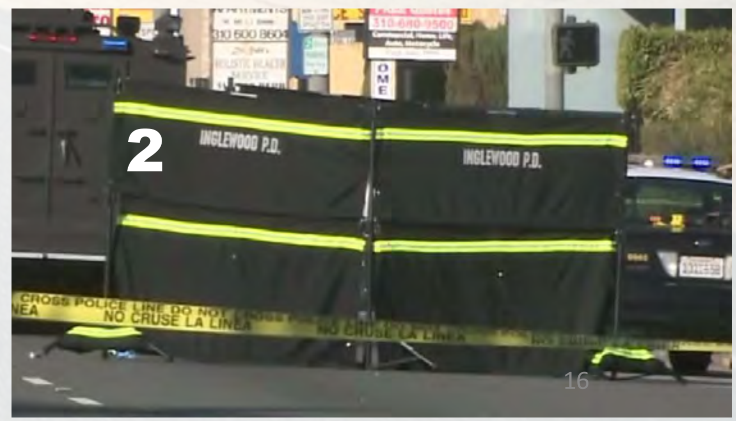
| Number | Name | Implementation | What is Passed | Source | Destination | Connects To | Function / Functional Interaction |
|---|---|---|---|---|---|---|---|
| INT.0.7.1 | GPS Satellite / Personnel GPS | GPS Signal | Timing Data | GPS | Personnel GPS | COMP.1.1.4.8 Personnel GPS COMP.14 GPS Satellite | FUNC.4.5 / GPS |
| INT.0.9.3 | Driver / Steering Wheel | Driver Hands | Turning Force | Driver | Steering Wheel | COMP.1.1.1.4.1 Steering Wheel COMP.2.3 Driver | FUNC.2.5 / Driver |
| INT.0.10.4 | Incident Vehicles / Interactive Panorama Assembly | DSLR Camera | Photograph Data | Incident Vehicles | Interactive Panorama Assembly | COMP.1.1.5.5 Interactive Panorama Assembly COMP.7 Incident Vehicles | FUNC.5.4 / Incident Vehicles |
| INT.1.1.1.11 | Engine / Gas Tank | Fuel Line | Gasoline Material | Gas Tank | Engine | COMP.1.1.1.3.2 Gas Tank COMP.1.1.1.3.3 Engine | FUNC.9.2 / FUNC.9.3 |
| INT.1.1.1.30 | Navigation Assembly / Vehicle Power Assembly | Wire (14 gauge) | Electricity Energy | Vehicle Power Assembly | Navigation Assembly | COMP.1.1.1.2 Navigation Assembly COMP.1.1.1.3 Vehicle Power Assembly | FUNC.9.4 Transfer Power to Components |

# Trade Study – Criterion and Alternatives

- Criterion
  - Height
  - Setup Time
  - # Setup Personnel
  - Ability to Handle Wind
  - Volumetric Storage





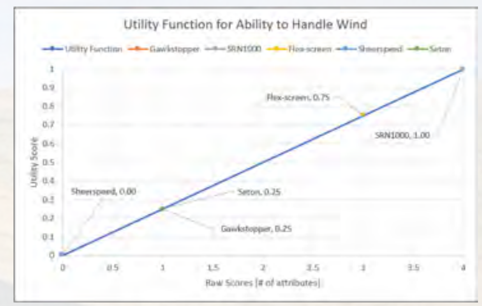


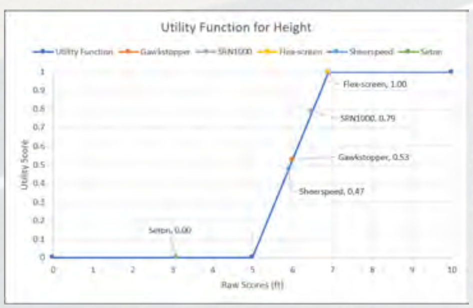
# Trade Study – Weights and Utility Functions

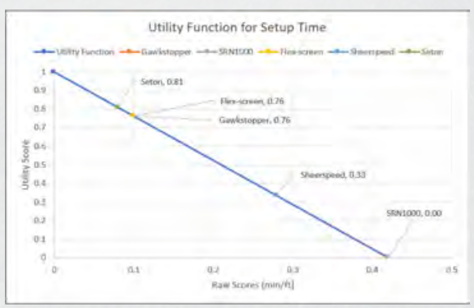
- Weighting
  - Pairwise comparison and Squared Matrix
- Utility Functions
  - All Linear
  - POS. or NEG. slope based on “max-ing” or “min-ing” the criterion.

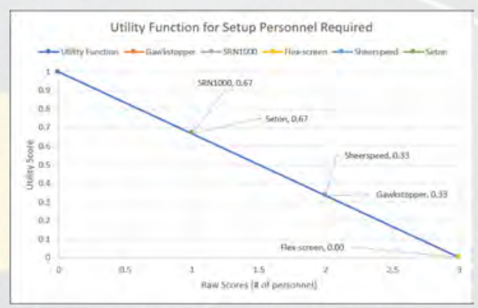
| | Height | Setup Time per Foot | Setup Personnel Required | Ability to Handle Wind | Volumetric Storage per Foot |
|---|---|---|---|---|---|
| Height | 1.00 | 5.00 | 0.33 | 0.14 | 1.00 |
| Setup Time per Foot | 0.20 | 1.00 | 1.00 | 0.33 | 4.00 |
| Setup Personnel Required | 3.00 | 1.00 | 1.00 | 3.00 | 5.00 |
| Ability to Handle Wind | 7.00 | 3.00 | 0.33 | 1.00 | 5.00 |
| Volumetric Storage per Foot | 1.00 | 0.25 | 0.20 | 0.20 | 1.00 |

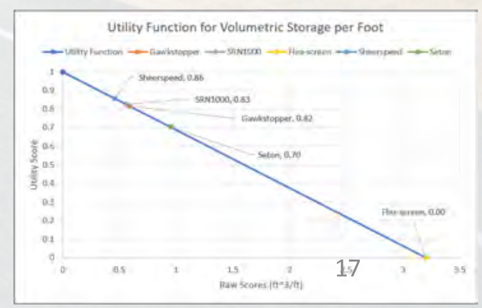
| | Height | Setup Time per Foot | Setup Personnel Required | Ability to Handle Wind | Volumetric Storage per Foot | Sum | Normalized Results |
|---|---|---|---|---|---|---|---|
| Height | 5.00 | 11.01 | 5.91 | 3.15 | 24.38 | 49.46 | 0.16 |
| Setup Time per Foot | 9.73 | 5.00 | 2.98 | 4.50 | 14.87 | 37.07 | 0.12 |
| Setup Personnel Required | 32.20 | 27.25 | 5.00 | 7.76 | 32.00 | 104.21 | 0.33 |
| Ability to Handle Wind | 20.60 | 42.58 | 7.00 | 5.00 | 30.67 | 105.85 | 0.34 |
| Volumetric Storage per Foot | 4.05 | 6.30 | 1.05 | 1.23 | 5.00 | 17.63 | 0.06 |
| | | | | | TOTAL: | 314.22 | 1.00 |



# Trade Study – Final Decision

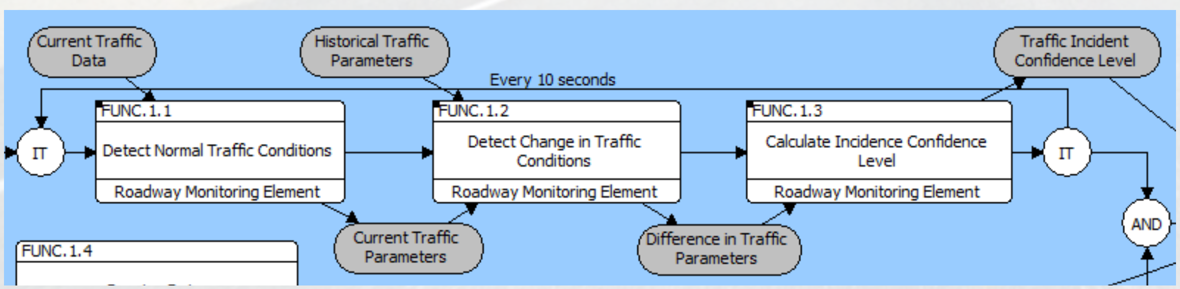
| Criteria | Criteria Weights | Gawkstopper | | SRN1000 | | Flex-screens | | Sheerspeed | | Seton | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unweighted Scores | Weighted Scores | Unweighted Scores | Weighted Scores | Unweighted Scores | Weighted Scores | Unweighted Scores | Weighted Scores | Unweighted Scores | Weighted Scores |
| Height | 0.16 | 0.53 | 0.08 | 0.79 | 0.12 | 1.00 | 0.16 | 0.47 | 0.07 | 0.00 | 0.00 |
| Setup Time per Foot | 0.12 | 0.76 | 0.09 | 0.00 | 0.00 | 0.76 | 0.09 | 0.33 | 0.04 | 0.81 | 0.07 |
| Setup Personnel Required | 0.33 | 0.33 | 0.11 | 0.67 | 0.22 | 0.00 | 0.00 | 0.33 | 0.11 | 0.67 | 0.07 |
| Ability to Handle Wind | 0.34 | 0.25 | 0.08 | 1.00 | 0.34 | 0.75 | 0.25 | 0.00 | 0.00 | 0.25 | 0.02 |
| Volumetric Storage per Foot | 0.06 | 0.82 | 0.05 | 0.83 | 0.05 | 0.00 | 0.00 | 0.86 | 0.05 | 0.70 | 0.03 |
| **Operational Utility Function (Weighted Sum)** | | 41.28 | | 73.00 | | 49.97 | | 27.06 | | 19.92 | |
| Cost ($) | | 240 | | 192 | | 114 | | 30 | | 18 | |
| **Cost-Effectiveness Selection Function (Weighted Sum / Cost)** | | 0.17 | | 0.38 | | 0.44 | | 0.90 | | 1.11 | |



- Final Selection Reasoning:
  - Are all requirements met?
  - Balance of Operational Utility and Cost Effectiveness?
  - Additional benefits?

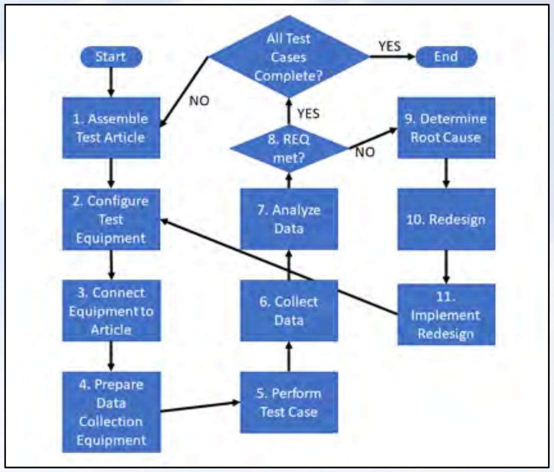
# Test Plan

- COMP.1.2 Roadway Monitoring Element
- Objectives
  - Verification of performance requirements specified by and functional requirements performed by this subsystem.
  - Reduction of risk (ID:06) in the network performance of the roadway monitoring element.
  - Demonstrate successful integration of subsystem components.




| Number | Name | Requirement |
|---|---|---|
| REQ.2.2 | Detect | The system shall detect when a traffic incident has occurred within 20 seconds (O) 30 seconds (T) of the occurrence. |
| REQ.2.2.2 | Compare Conditions | The roadway monitoring subsystem shall compare current traffic conditions to historic traffic conditions. |
| REQ.2.2.2.1 | Historic Traffic Conditions | The roadway monitoring subsystem shall maintain a database of 500 (O) 100 (T) historical traffic conditions on the roadways that are monitored. |
| REQ.2.2.2.2 | Confidence Level | The roadway monitoring subsystem shall calculate a confidence level that a traffic incident has occurred every 5 seconds (O), 10 seconds (T). |
| REQ.2.2.2.3 | Incident Confidence Calculation | The roadway monitoring system shall use change in traffic speed, density, and visual changes to determine a final level of confidence that a traffic incident occurred. |
| REQ.2.2.2.4 | Traffic Speed Magnitude | The roadway monitoring subsystem shall measure the speed of traffic passing to within 1 mph (O), 5 mph (T). |
| REQ.2.2.2.5 | Traffic Speed Update Frequency | The roadway monitoring subsystem shall measure the speed of passing traffic at least every 5 seconds (O), 10 seconds (T). |
| REQ.2.2.2.6 | Traffic Density Magnitude | The roadway monitoring subsystem shall measure the distance between each passing vehicle to a maximum of 5 ft (O), 25 ft (T). |
| REQ.2.2.2.7 | Traffic Density Update Frequency | The roadway monitoring subsystem shall measure the traffic density at least every 5 seconds (O), 10 seconds (T). |
| REQ.2.2.2.8 | Traffic Visual | The roadway monitoring subsystem shall capture images of the traffic conditions with a resolution of at least 1080p. |
| REQ.2.2.2.9 | Traffic Visual Update Frequency | The roadway monitoring subsystem shall record an image of traffic at least one every 5 seconds (O), 15 seconds (T). |
| REQ.2.2.2.10 | Night Time | The roadway monitoring subsystem shall have electrical storage to operate for 72 hours (O), 60 Hours (T) without sunlight. |
| REQ.2.2.2.11 | Power Generation | The roadway monitoring subsystem shall generate its daily power usage in a maximum 4 hour (O), 5 hour (T) period of sunlight. |
| REQ.2.2.3 | Element Interface | The interface between the Roadway Monitoring Element and the Response Vehicle Element shall transfer data with a latency of no more than 100 ms (O) 500 ms (T). |
| REQ.2.2.3.1 | Network of Nodes | The roadway monitoring element and response vehicle interface shall support up to 5000 (O) 1000 (T) network nodes. |

# Test Plan




- Environment: SIL with closed driving course.
- Equipment: Traffic simulators and real traffic.
- Units Under Test: 10 builds over 34 Test Cases.
- Integration, Qualification, and Field Test Cases.
- Process:
  - Build Article
  - Setup Equipment
  - Perform Test
  - Collect and Analyze Data
  - Determine if REQ was met

| # | Metric | Units | Requirement | Objective Value | Threshold Value |
|---|---|---|---|---|---|
| 1 | Structural | True/False | - | True | True |
| 2 | Interoperability | True/False | - | True | True |
| 3 | Detection Time | Seconds | REQ.2.2 | 20 sec | 30 sec |
| 4 | Comparison to Historic Functionality | True/False | REQ.2.2.2 | True | True |
| 5 | Entries in Database | Count | REQ.2.2.2.1 | 500 | 100 |
| 6 | CI Update Speed | Seconds | REQ.2.2.2.2 | 5 sec | 10 sec |
| 7 | CI Calculation Functionality | True/False | REQ.2.2.2.3 | True | True |
| 8 | Speed Sensor Accuracy | MPH | REQ.2.2.2.4 | 1 MPH | 5 MPH |
| 9 | Speed Sensory Update Frequency | Seconds | REQ.2.2.2.5 | 5 sec | 10 sec |
| 10 | Density Sensor Accuracy | Feet | REQ.2.2.2.6 | 5 feet | 25 feet |
| 11 | Density Sensor Update Frequency | Seconds | REQ.2.2.2.7 | 5 sec | 10 sec |
| 12 | Image Resolution | Pixels | REQ.2.2.2.8 | 1080p | 1080p |
| 13 | Image Capture Frequency | Seconds | REQ.2.2.2.9 | 5 sec | 15 sec |
| 14 | Electricity Usage Efficiency | Hours | REQ.2.2.2.10 | 72 hours | 60 hours |
| 15 | Power Generation Efficiency | Hours | REQ.2.2.2.11 | 4 hours | 5 hours |
| 16 | Data Transfer Latency | Millisecond | REQ.2.2.3 | 100 ms | 500 ms |
| 17 | Network Nodes | Count | REQ.2.2.3.1 | 5000 | 1000 |

# System Specification – Requirements Summary

- Focus changed throughout semester:
  - Capture all REQs.
  - Add REQs based on the current deliverable.
  - Add REQs based on new info.
  - Revise/modify REQs to improve maturity and be quantitative.

| Report | Total | Quantitative | Binary | Qualitative |
|---|---|---|---|---|
| Requirements Analysis Report | 105 | 27 (25.7%) | 57 (54.3%) | 21 (20.0%) |
| Functional Analysis Report | 123 | 36 (29.3%) | 65 (52.8%) | 22 (17.9%) |
| Trade Study | 128 | 39 (30.5%) | 67 (52.3%) | 22 (17.2%) |
| Conceptual Design Report | 130 | 39 (30%) | 69 (53.1%) | 22 (16.9%) |
| System Specifications | 133 | 89 (66.9%) | 37 (27.8%) | 7* (5.2%) |
| % Change from RAR | + 26.6% | +229.6% | -35.1% | -66.6% |

*Includes 7 User Need requirements.

# System Specification - KPPs

- Set of requirements that must be met for customer to accept the system.
- Based on core/primary user needs.

| Number | Name | Description | Type | Rationale |
|---|---|---|---|---|
| REQ.1.2.2 | Speed (KPP) | The system shall achieve a forward speed of at least 80 mph (O), 70 mph (T). | Quantitative | https://en.wikipedia.org/wiki/Speed_limits_in_the_United_States Facilitates rapid incident response time and does not skew the performance based on the distance between the stand-by location and the incident. [1] |
| REQ.2.4.4 | Interactive Panorama (KPP) | The incident documentation subsystem shall create an interactive panorama of the entire incident scene within 5 minutes (O)(T) of arrival. | Quantitative | https://www.youtube.com/watch?v=BQ8HZd3psr0 Timestamp 23:45 [2] |
| REQ.3.1.2 | Trained Personnel (KPP) | The medical response subsystem shall facilitate trained personnel to attend to the injured within 15 seconds (O), 30 seconds (T) of arrival on scene. | Quantitative | Directly decreases the Incident Clearance Time, an important MOE for the system, through increased efficiency of a sub-step of the entire process. |
| REQ.4.1 | Commander (KPP) | The system shall be commanded by maximum one person. | Quantitative | TIMS Handbook paragraph 3.2.2 One incident commander is important to control the resolution activities and to be the final decision maker. [3] |
| REQ.5.1 | Removal (KPP) | The removal subsystem shall remove vehicles and debris from the travel lanes within 10 minutes (O), 20 minutes (T). Time starts once all medical needs have been attended to, and the scene is properly documented. | Quantitative | Directly decreases the Incident Clearance Time, an important MOE for the system, through increased efficiency of a sub-step of the entire process. |
| REQ.6.3 | Prevent Rubber-necking (KPP) | The manage passing traffic subsystem shall minimalize the line of sight between passing drivers and the incident scene to achieve less than one secondary incident out of every 30 primary incidents. (Compared to this study which found a secondary incident occurred once every 24.8 primary incidents. http://people.virginia.edu/~njg2q/secondary.pdf) [4] | Quantitative | https://rosap.ntl.bts.gov/view/dot/29634 "As far as the factor of barrier is concerned, the coefficient is negative. It implies that the presence of barriers on an accident scene decreased the likelihood of rubbernecking in the opposite direction. This may be due to blocking of the barriers for the motorists to view the accidents in the other direction." "Barriers are an effective way to reduce the likelihood of rubbernecking in the opposite direction and the delay caused by the rubbernecking. This conclusion is drawn upon the coefficients of the variable barrier in the models for the likelihood of rubbernecking occurrence and traffic delay." [5] |

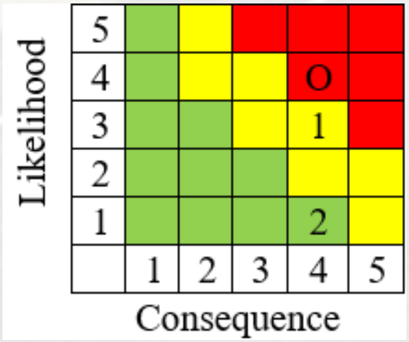
# Risk Management - Summary

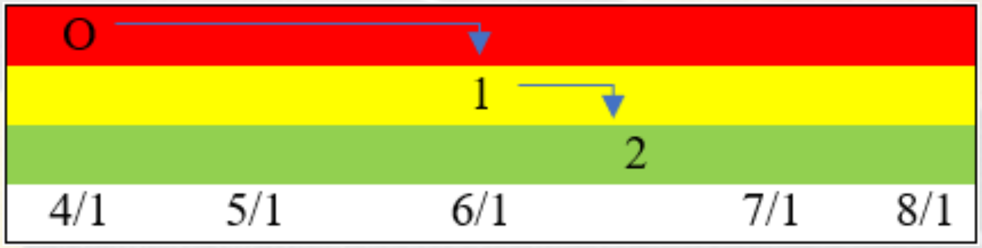
| ID | Title | Risk | Type | Original Score | Current Score |
|---|---|---|---|---|---|
| 1 | Deliverable Schedule | If the systems engineering process takes longer to complete than scheduled then the project will not finish during Summer 2020 semester. | Schedule | 3, 5 Red | 0, 0 Green |
| 2 | Incident Sensing and Documentation | If the incident sensing subsystem cannot quickly and accurately document the incident scene then the roadway clearance time will significantly increase in order to complete the incident investigation. | Technical | 3, 5 Red | 2, 5 Yellow |
| 3 | Emergency Medical Response | If the emergency medical response is not as good as current EMS standards then the clearance of the roadway will be delayed by the medical response function. | Technical | 3, 4 Yellow | 1, 4 Green |
| 4 | Traffic Management | If the manage traffic subsystem cannot reduce the amount of rubbernecking then the number of secondary incidents won’t decrease. | Technical | 4, 4 Red | 1, 4 Green |
| 5 | Implemented System Density | If the density of implemented TIMS is not large enough then response time will be increased. | Cost / Operational | 4, 5 Red | 4, 5 Red |
| 6 | Network of Roadway Monitoring Elements | If the bandwidth of the network is not sufficient to handle all of the data then the system will not identify when an incident occurred and it will not respond quickly. | Technical | 3, 5 Red | 2, 5 Yellow |
| 7 | Incident Action Plan Recommendations | If the incident action plan recommendation software does not utilize past incident data then the response efficiency will not improve. | Technical | 4, 5 Red | 3, 5 Red |

# Risk Management – Risk ID 04

- **Risk ID 04: Traffic Management**
- If the "manage traffic" subsystem cannot reduce the amount of rubbernecking then the number of secondary incidents won't decrease.
- *Type:* Technical
- *Original Score (O):* 4, 4
- L: 4 (No technology in US is widely used for this function)
- C: 4 (Significant degradation in performance)

| # | Mitigation Steps | ECD | ACD | L | C |
|---|---|---|---|---|---|
| 1 | Decompose functions that will facilitate achieving the MOE. | 5/31/20 | 6/5/20 | 3 | 4 |
| 2 | Complete the trade study on this subsystem to physically allocate a proven COTS item. | 6/12/20 | 6/12/20 | 1 | 4 |



# Summary and Next Steps

- System Engineering Process was used to develop this preliminary Traffic Incident Management System Architecture.
- Hold some SETRs
  - System Requirements Review, System Functional Review, Integrated Baseline Review
- Further iteration of the SE process needs to occur.
  - Derive requirements further
  - Decompose functions further
  - Allocate lower physical components
  - Perform more trade studies
  - Identify more interfaces

# Lessons Learned

- CORE is a great tool, but has some limitations
  - University Edition
  - Physical N2 diagram labels
- Stakeholders are very important
  - Can be consulted in all areas of the process.
- Questions to ask during requirements development
  - What criterion would I use in a Trade Study?
  - What objectives need to be tested?

# Recommendations

- Proposals being due before registration is good.
  - Find additional ways to engage students very early.
- 800 Capstone course should increase focus on cost.
  - Operations and Support costs are decided in the design.
  - No focus to decrease or determine them.
- Add “Logistics type” section in current deliverable.
  - FMECA to decrease risk?


Thanks Steve!