



U.S. Department
of Transportation
Federal Highway
Administration

December 20, 2012



ADAPTIVE SIGNAL CONTROL TECHNOLOGY MODEL SYSTEMS ENGINEERING DOCUMENTS



What Do Motorists Want?

- *“Why do I have to wait when there’s nobody else moving”*
 - Translation: Equitable distribution of green time
- *“Can’t I just drive down the street?”*
 - Translation: Progression—driving through successive greens



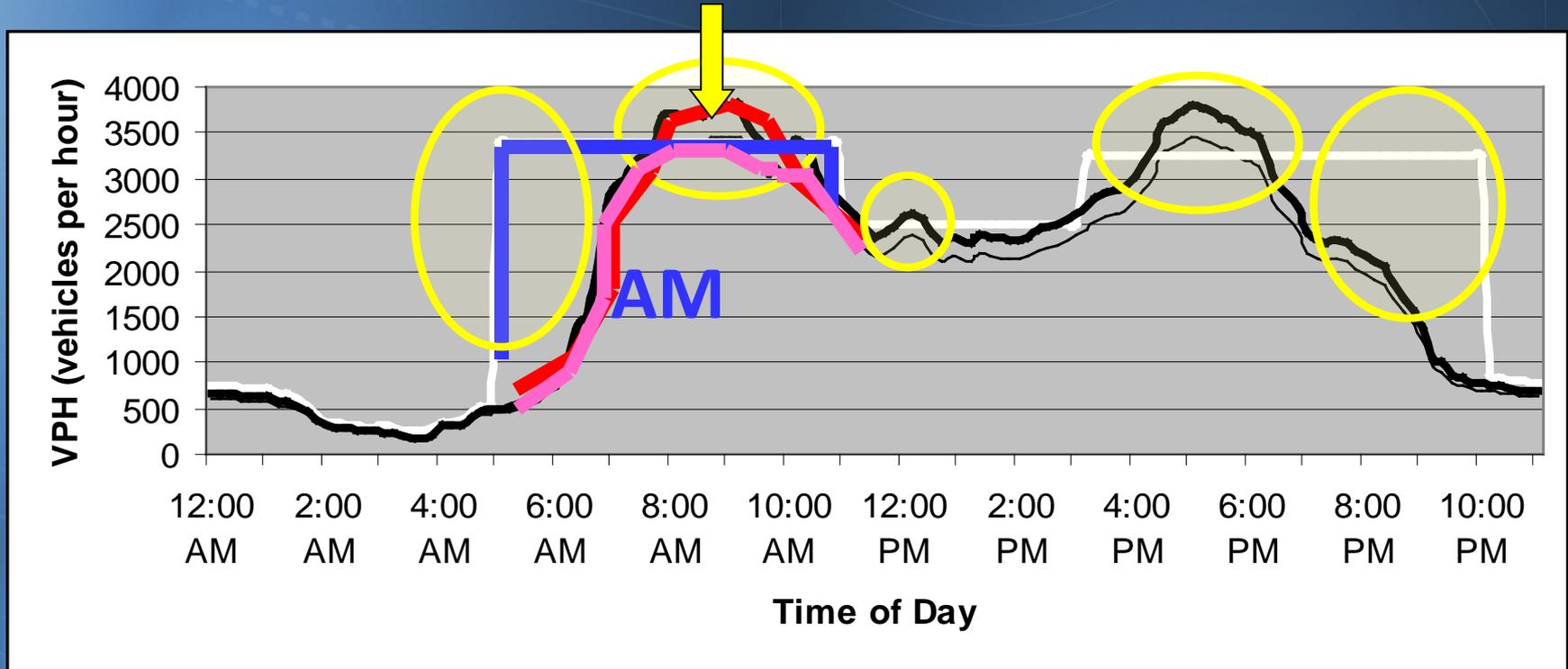
The Big Box Scenario – Year 1





TYPICAL Traffic Signal Timing

PEAK 15 Min





Year 9



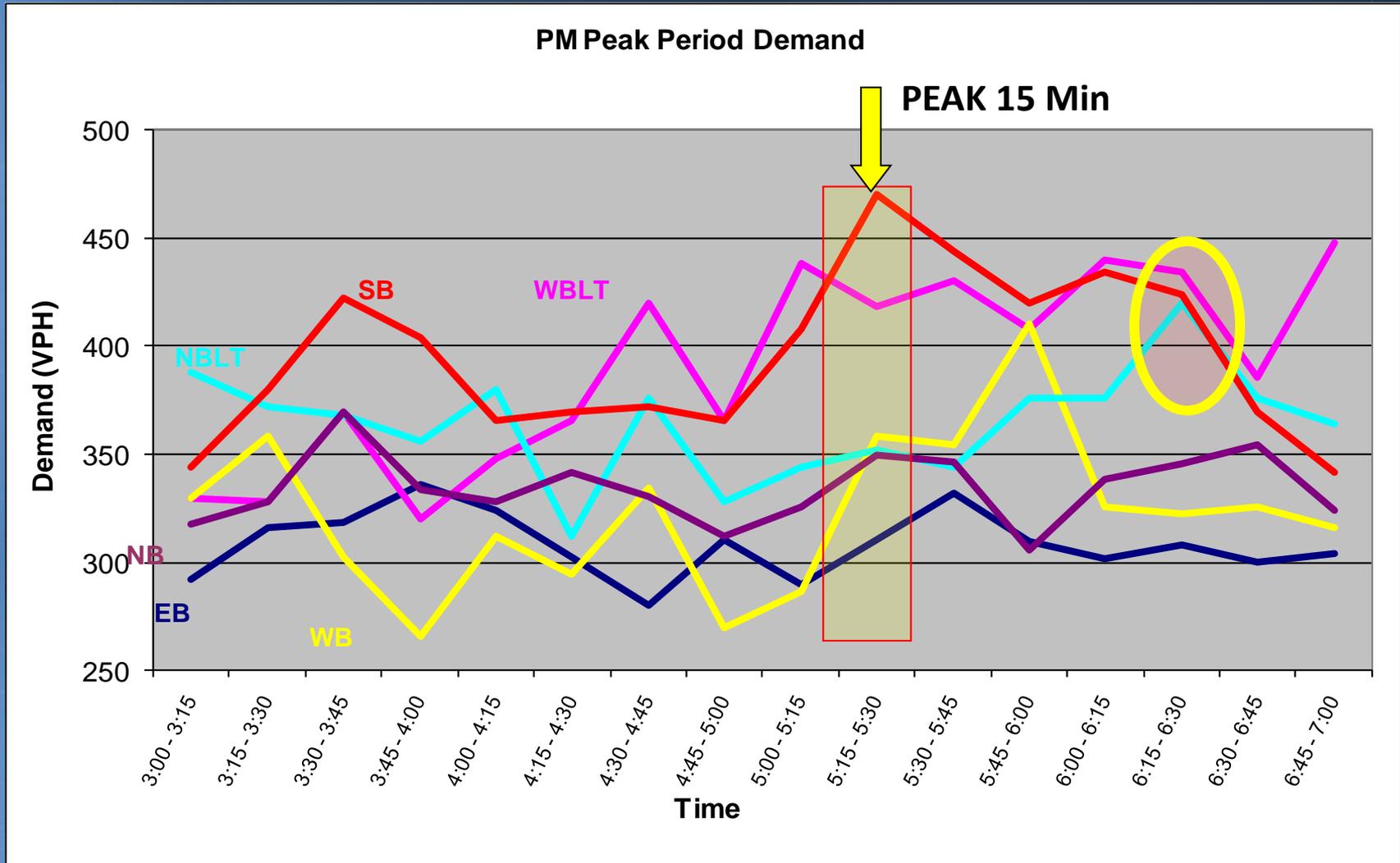


Year 10





Variability is Normal—And the Problem



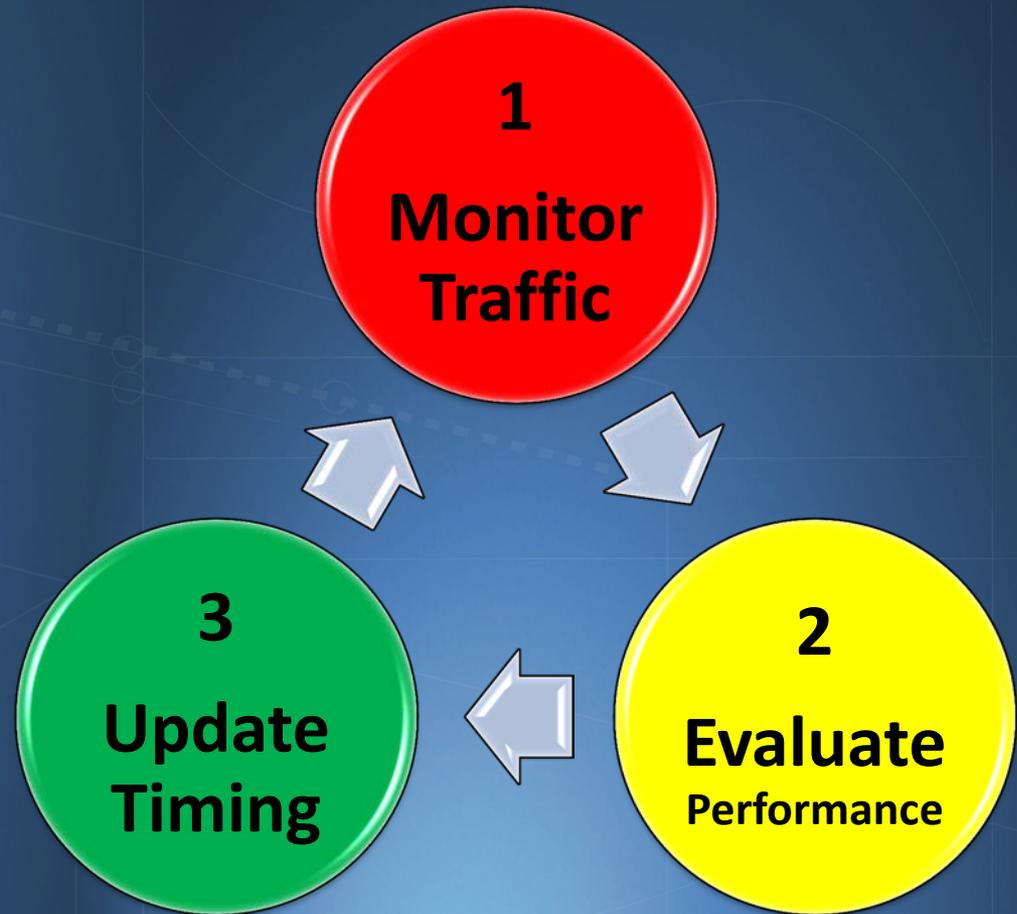
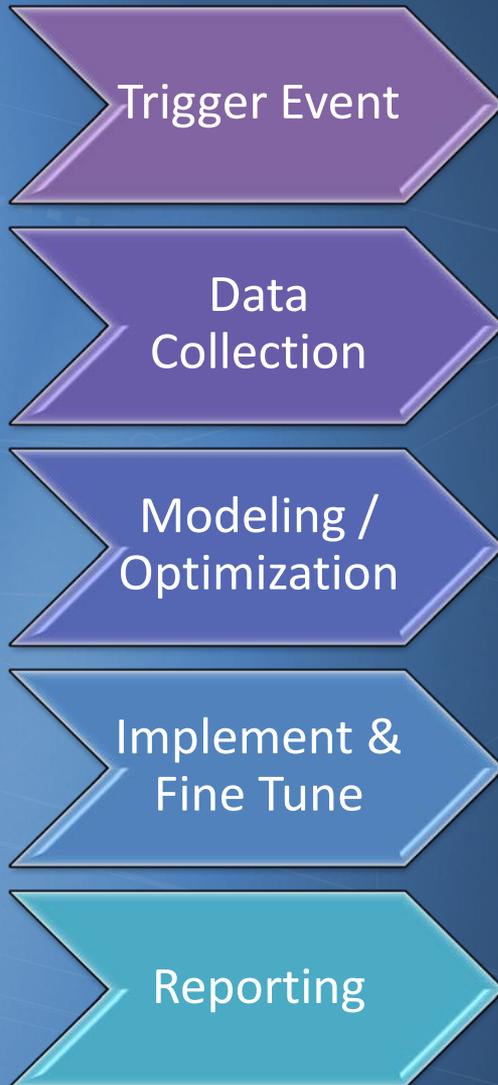


Year 13





Adaptive Signal Control Technology





Getting It Right is Important

- New focus on traffic systems means
 - New opportunities for success
 - New consequences of failures
 - Greater interest from industry
 - More visibility and scrutiny
- Federal regulations governing ITS projects
- Federal regulations governing procurements



23 CFR 940.11 Requirements

- **All** ITS projects must be developed using a *Systems Engineering (SE) analysis*
- The analysis shall be on a scale commensurate with the project scope
- SE analysis shall address (7) requirements
- The purpose is to ensure that agencies get what they (and their stakeholders) need



Seven Requirements of SE Analysis

1. Identify portions of the regional ITS architecture being implemented
2. Identification of participating agencies roles and responsibilities
3. Requirements definitions
4. Analysis of technology options to meet requirements
5. Procurement options
6. Identification of applicable ITS standards and testing procedures
7. Procedures and resources necessary for operations and management of the system



Procurement Regulations

- Proprietary Materials (23 CFR 635.411)
 - **Certification** of no available competitive product
 - Uniquely fulfills the *requirements* imposed on the product
 - Achieves *synchronization* with existing systems
 - **Public Interest Finding** for proprietary purchase despite *alternative* available competitive products
 - Limited **experimental** application
- Systems Engineering provides justification



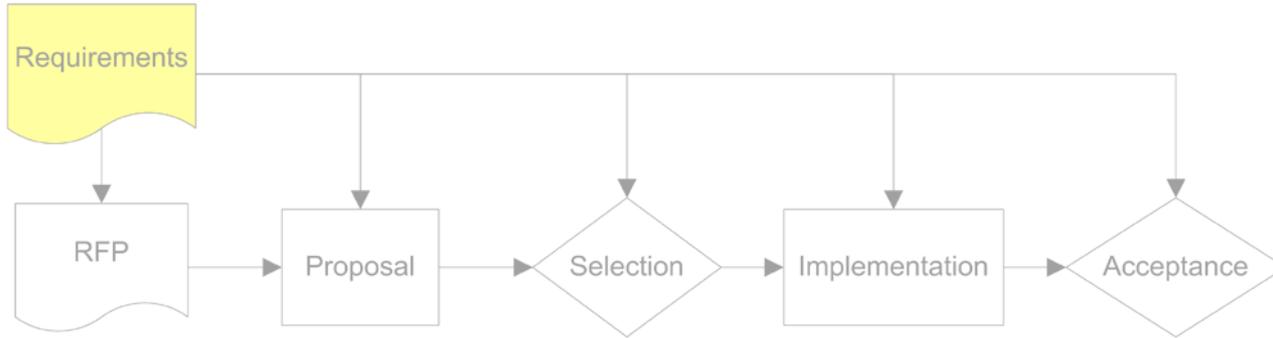
What is Commercial-Off-The-Shelf?

- FAR definition of COTS:
 - *a non-developmental item of supply that is both commercial and sold in substantial quantities in the commercial marketplace, and that can be procured or utilized under government contract in the same precise form as available to the general public.*
- No ASCT meets this requirement
- ASCT is an operational concept, not just equipment

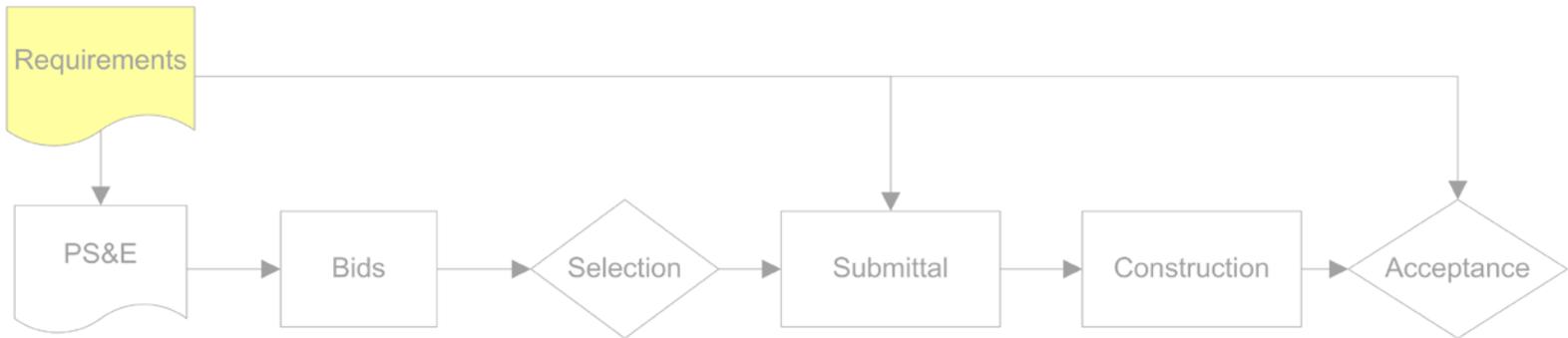


Typical Procurement

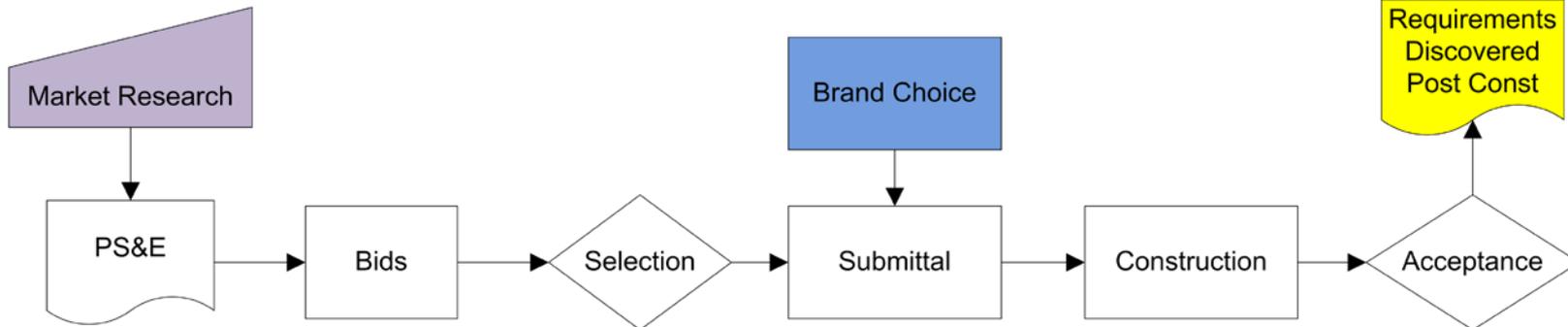
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Analysis



Low Bid
Supported by SE
Analysis



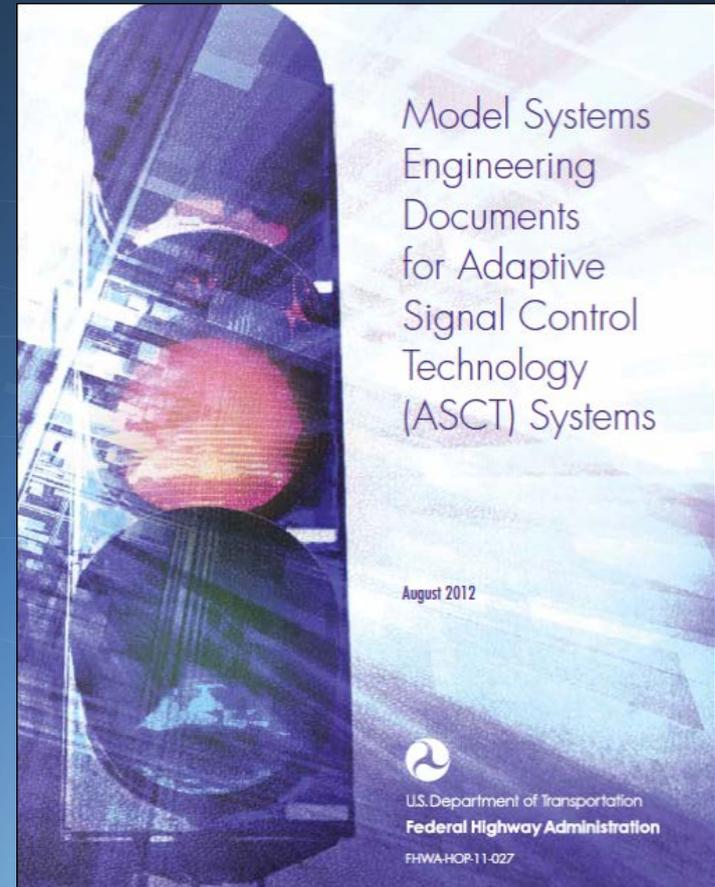
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Model Systems Engineering Document for ASCT Systems

- Purpose of the Document
- How to use the Document
- Document Organization





Purpose of SE Model Documents

- Evaluate need for Adaptive Control
- Help agencies identify verifiable, needs-driven requirements for evaluating design and implementation choices
- Model documents greatly reduce systems engineering effort by providing wording and documentation...
- ...but agencies still must identify their needs



Model Document Process

Build Requirements

- Answer questions
 - About the situation
 - About you
- Select and tailor ConOps statements
- Select and tailor requirements

Evaluate Alternatives

- Evaluate proposed approaches/products against requirements
- Solution feasible given constraints?

Continue Tailoring Until Solutions...

- Fulfill requirements
- Are feasible



Model Document *Products*

Concept of Operations: What You Need

- Basis for creating and defending requirements
- Basis for validating system

Well-Formed, Testable Requirements Driven by Needs

- Basis for product choices
- Basis for procurement documents
- Basis for verification of design and installation: testing and acceptance

Sample project architecture

- Basis for achieving integrated traffic management systems



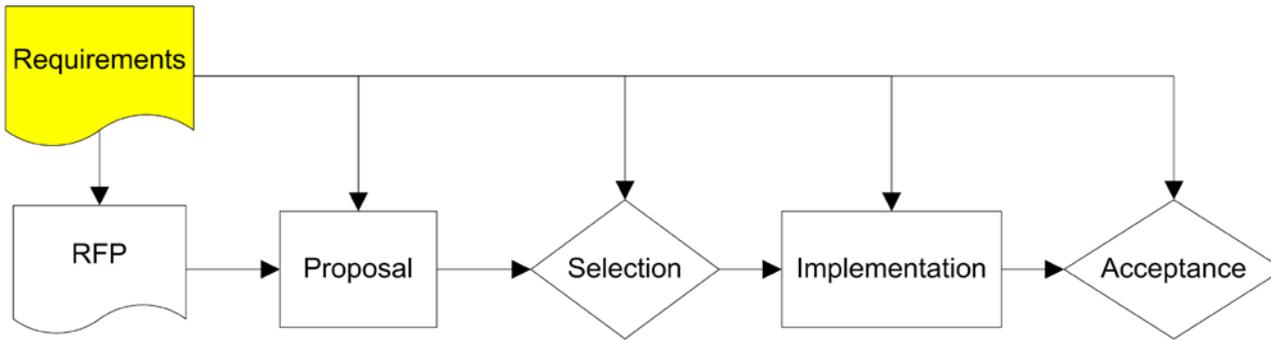
Outcome of the Process

- Inform Technology Selection
 - Agency Needs & Objectives
 - Agency Policies
 - Operations and Maintenance Capability
 - Resources
 - Expansion
 - Equipment Life Cycle
 - Procurement Options
- Meet Federal Rule 940 and Rule 635 requirements for Federal Funding

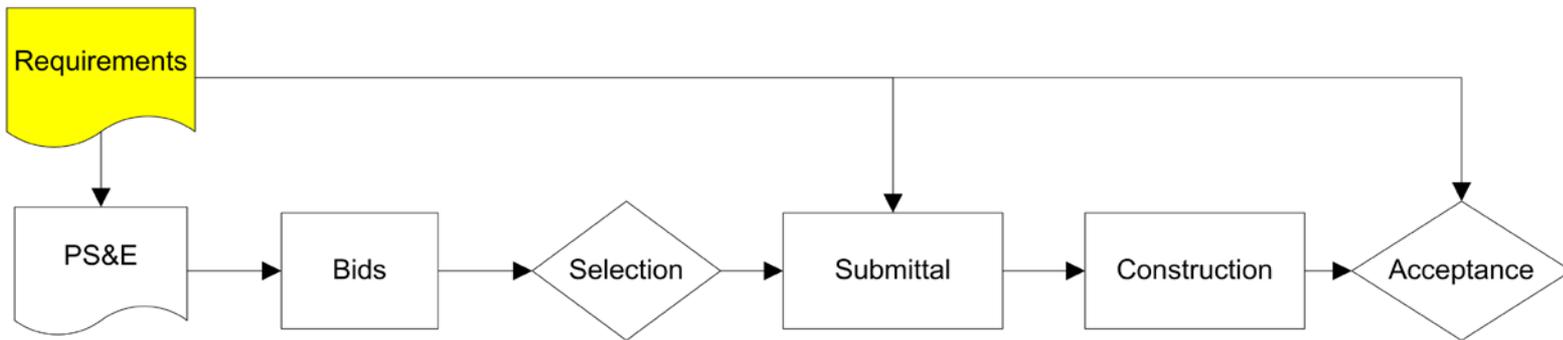
SE-Informed Procurement



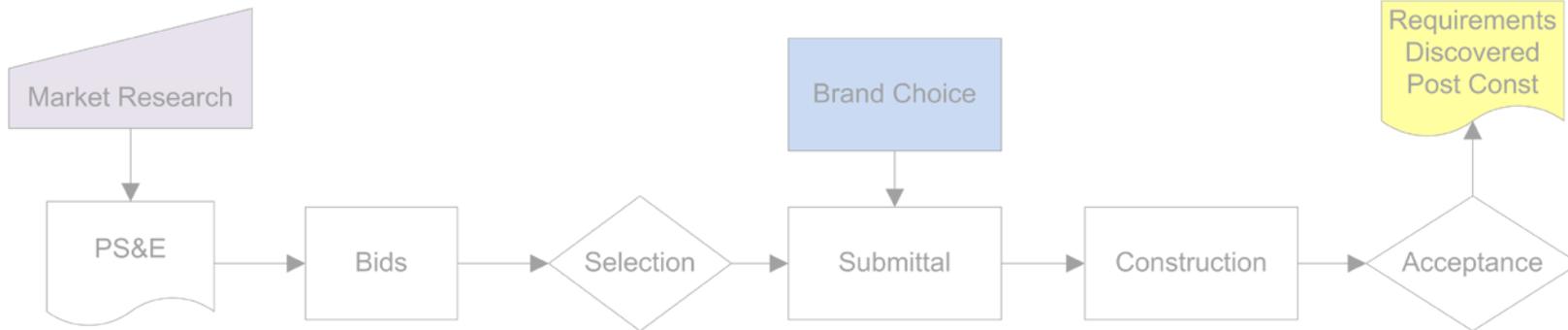
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Guidance Document Organization

- Role and components of systems engineering
 - A. Preamble
 - B. Overview of the Process
 - C. Systems Engineering Documents
- Guidance
 - D. Concept of Operations Guidance
 - E. System Requirements Guidance
 - F. Verification Plan Guidance
 - G. Validation Plan Guidance
- Templates and Tables



Concept of Operations Organization

1. Scope
2. Referenced Documents
3. *User-Oriented Operational Description*
4. *Operational Needs*
5. Envisioned Adaptive Operation
6. Adaptive Operational Environment
7. Adaptive Support Environment
8. Proposed Operational Scenarios



3. User-Oriented Operational Description

3	3 Chapter 3: User-Oriented Operational Description
3.1	3.1 The Existing Situation
3.1.1	3.1.1 Network Characteristics
3.1.1.1	3.1.1.1 Arterial
3.1.1.1.0-1	The arterial has regularly spaced signalized intersections. The spacing between major intersections is approximately XX, with less important intersections spaced at XX. The locations at which ASCT is being considered are illustrated in FIGURE XX.
3.1.1.1.0-2	The free-flow travel time between major intersections is approximately XX seconds. (Expand this description as appropriate to cover additional arterials or networks.)
3.1.1.1.0-3	The travel time between key intersections allows two-way progression when cycle lengths of XX seconds (CL=travel time) or YY (CL= 2x travel time) seconds can be used. (Add descriptions of additional cycle lengths if appropriate.)
3.1.1.1.0-4	The arterial has irregularly spaced signalized intersections, and there is no “natural” cycle length that allows two-way progression.
3.1.1.1.0-5	During the peak periods, the cycle length is generally determined by the needs of one or more critical intersections.
3.1.1.1.0-6	The cycle length required to service traffic at the critical intersection(s) is generally close to a “natural” cycle length.
3.1.1.1.0-7	The capacity of the arterial changes during the day, with parking restrictions providing higher capacity during peak periods.
	AND SO ON...



4. User Needs

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4	4 Chapter 4: Operational Needs		
4.0-1	<p>This chapter describes the operational needs of the users that should be satisfied by the proposed ASCT system. Each of these statements describes something that the system operators need to be able to achieve. Each of these needs will be satisfied by compliance with one or more system requirements. In the attached list of requirements, each one is linked to one or more of these needs statements.</p>		

4.1	4.1 Adaptive Strategies		
4.1.0-1	The system operator needs the ability to implement different strategies individually or in combination to suit different prevailing traffic conditions. These strategies include:		3.4 3.5
4.1.0-1.0-1	<p>* Maximize the throughput on coordinated routes</p> <p>Note to user when selecting these requirements:</p> <p>Select from requirements in the 2.2 group when sequence-based systems are allowed (sequence-based systems explicitly calculate cycle, offset, and split).</p> <p>Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset, and split).</p> <p>(Select requirements from both groups when the vendor is given the choice of supplying one type of adaptive operation or the other.)</p>	<p>2.2.0-4</p> <p>(Sequence-based only) The ASCT shall calculate offsets to suit the current coordination strategy for the user-specified reference point for each signal controller along a coordinated route within a group.</p> <p>2.2.0-4.0-1</p> <p>(Sequence-based only) The ASCT shall apply offsets for the user-specified reference point of each signal controller along a coordinated route.</p> <p>2.1.1.0-7.0-1</p> <p>When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of the signal controllers, maximizing the throughput of the coordinated route.</p>	3.4 3.5

4.1.0-5

The system operator needs to minimize the chance that a queue forms at a specified location.

Note to user when selecting these requirements:

Select from requirements in the 2.2 group when sequence-based systems are allowed (sequence-based systems explicitly calculate cycle, offset, and split).

Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset, and split).

Select from requirements in the 2.5 group when phase-based systems are allowed (phase-based systems do not explicitly calculate cycle, offset and split at all intersections).

(Select requirements from two or all three groups when the vendor is given the choice of supplying the type of adaptive operation.)

2.3.0-5

(Non-sequence-based only) The ASCT shall adjust signal timing so that vehicles approaching a signal that have been served during a user-specified phase at an upstream signal do not stop.

2.5.0-7

(Phase-based only) The ASCT shall adjust the state of the signal controller so that vehicles approaching a signal that have been served during a user-specified phase at an upstream signal do not stop.

2.2.0-5.0-5

(Sequence-based only) The ASCT shall adjust offsets to minimize the chance of stopping vehicles approaching a signal that have been served by a user-specified phase at an upstream signal.

3.4

3.5

4.14.0-1

The system operator needs to fall back to TOD or isolated free operation, as specified by the operator, without causing disruption to traffic flow, in the event of equipment, communications and software failure.

13.1.0-2

The ASCT shall use the following alternate data sources for operations in the absence of the real-time data from a detector:

13.1.0-2.0-3

The ASCT shall switch to the alternate source in real time without operator intervention.

13.1.0-1

The ASCT shall take user-specified action in the absence of valid detector data from XX vehicle detectors within a group. (SELECT THE APPROPRIATE ACTION.)

13.1.0-1.0-1

The ASCT shall release control to central system control.

13.2-1

The ASCT shall execute user-specified actions when communications to one or more signal controllers fails within a group. (SELECT THE APPROPRIATE ACTION)

...(snippage)...

13.3-4

During adaptive processor failure, the ASCT shall provide all local detector inputs to the local controller.

4.13



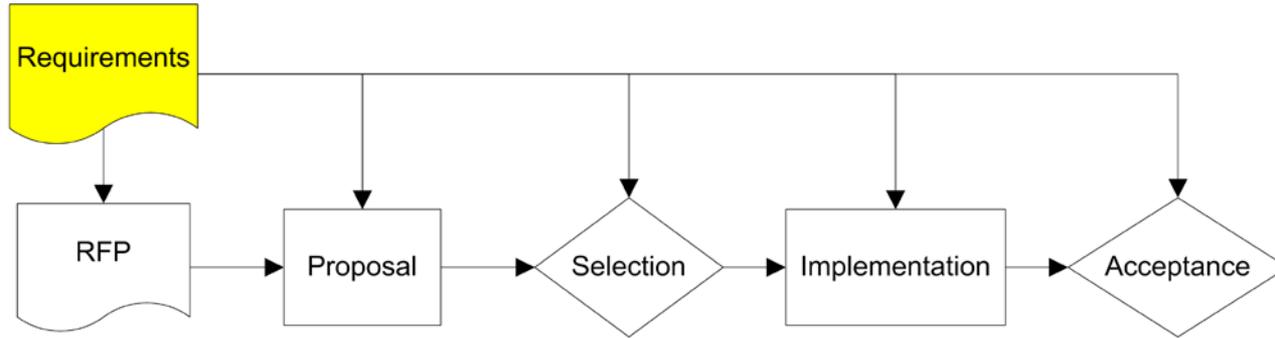
Basic Systems Engineering Deliverables

- Concept of Operations
- **Requirements**
 - before design
 - before implementation
 - before acquisition
 - before acceptance testing
- Verification Plan
- Validation Plan

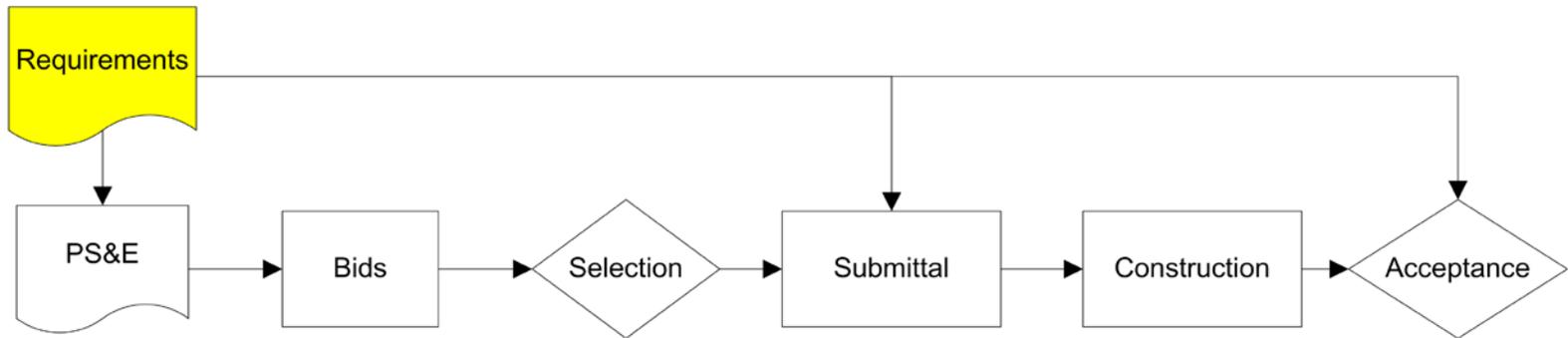


Requirements Before Design

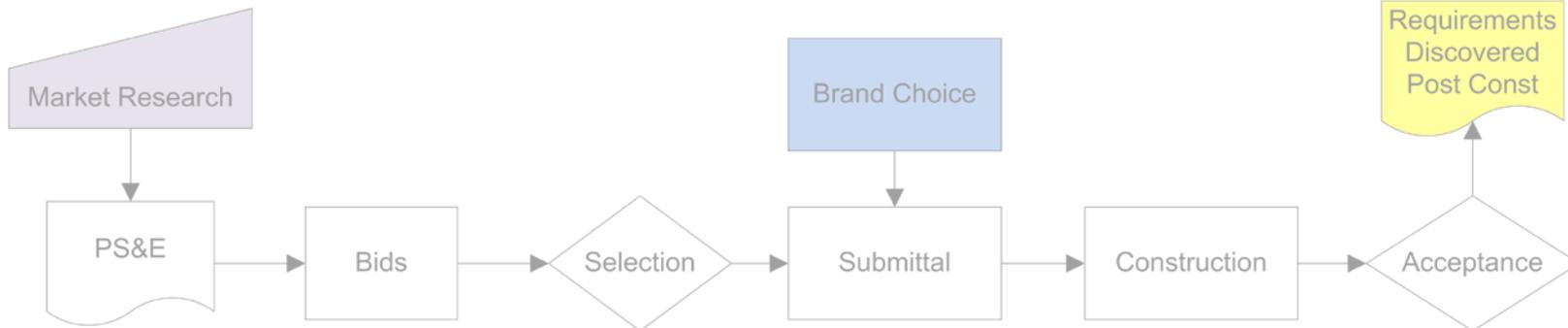
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Model SE Documents for ASCT (Final)—Now Online

<http://ops.fhwa.dot.gov/publications/fhwahop11027/index.htm>



Questions?

<http://www.fhwa.dot.gov/everydaycounts>



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