ROAD USER COST ANALYSIS FOR WORK ZONE APPLICATIONS

Jawad Paracha
Work Zone Safety & Mobility Team
FHWA Office of Transportation Operations

Jagannath Mallela
Principal Engineer
ARA, Inc.

November 15, 2011

U.S. Department of Transportation
Federal Highway Administration

CAMBRIDGE SYSTEMATICS
Transportation leadership you can trust.

APPLIED RESEARCH ASSOCIATES, INC.
An Employee Owned Company

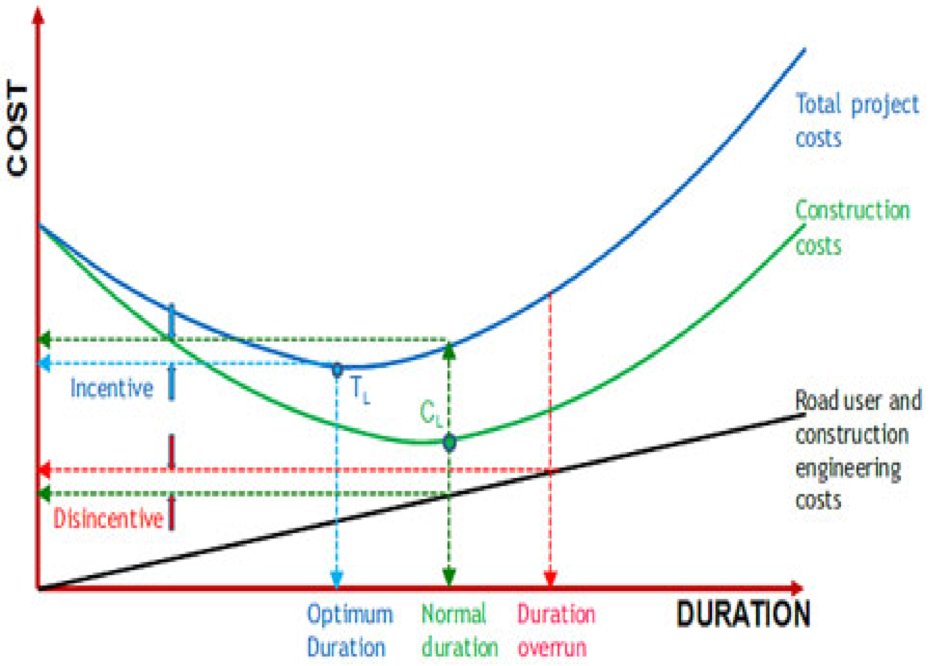
WZ Road User Costs (RUC)

- **Overview**
  - Road work has been on rise
  - FHWA Rule on Work Zone Safety & Mobility (23 CFR 630 Subpart J)
  - RUC provide economic basis for quantifying adverse impacts and effective decision-making

- **Base document:**
  - Work Zone Road User Costs: Concepts and Applications, FHWA-HOP-12-005, To be Released December 2011

Work Zone Road User Costs

- **Project Objectives:**
  - Synthesis of current RUC practices and tools
  - Establish a framework for WZ RUC analysis
  - Guidance on RUC applications:
    - MOT strategy related decision-making
    - Project delivery methods and contracting strategy selection
    - WZ impacts and B/C analysis



Presentation Outline

- **WZ RUC: Definition, Applications, Components and Computation**

Q&A

- **Application of WZ RUC in MOT Alternate Analysis**
  - Illustrative Example

Q&A

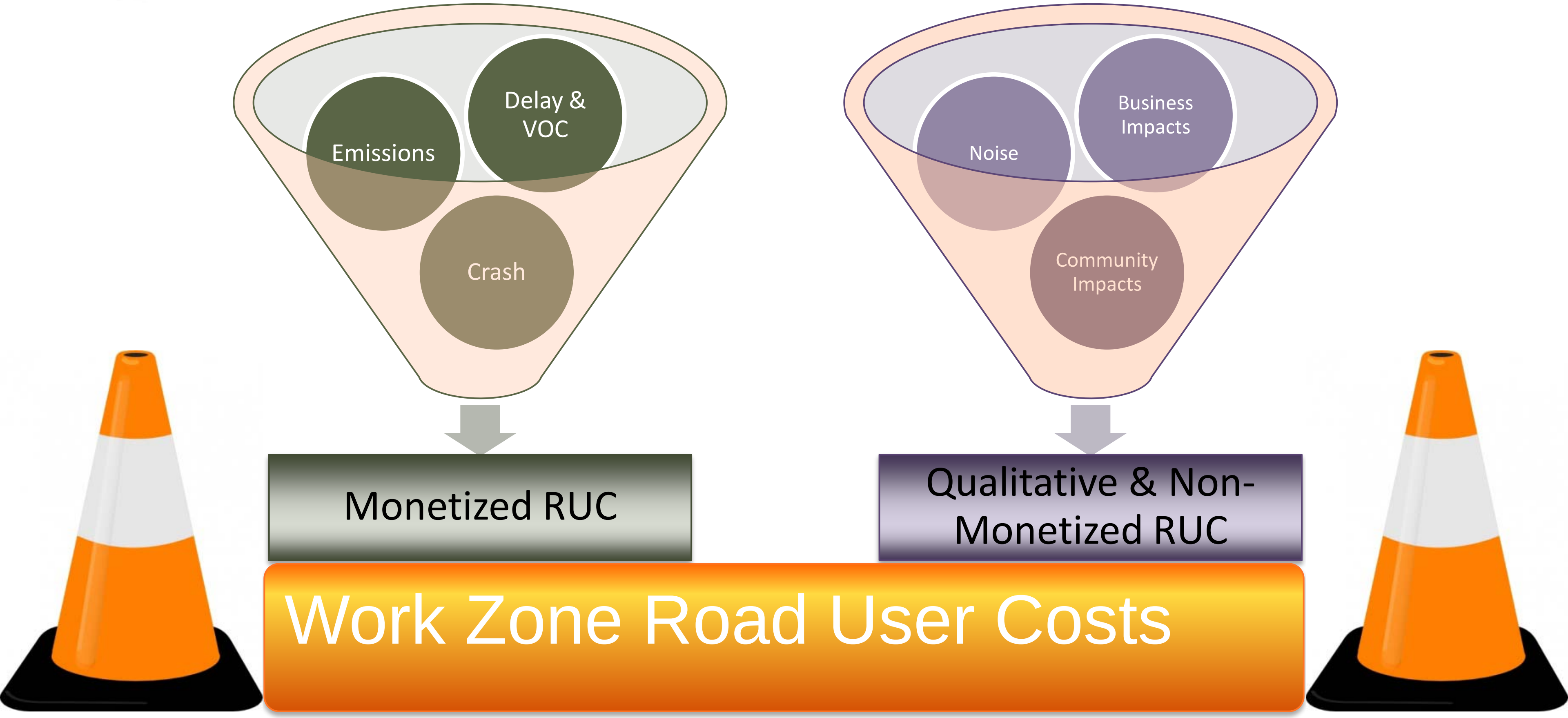
- **Application of WZ RUC in Contracting/ Project Delivery Methods**
  - Illustrative Example
- **Application of WZ RUC in Benefit-Cost Analysis**
  - Illustrative Example

Q&A

WZ RUC DEFINITION COMPONENTS AND COMPUTATION

WZ RUC Definition

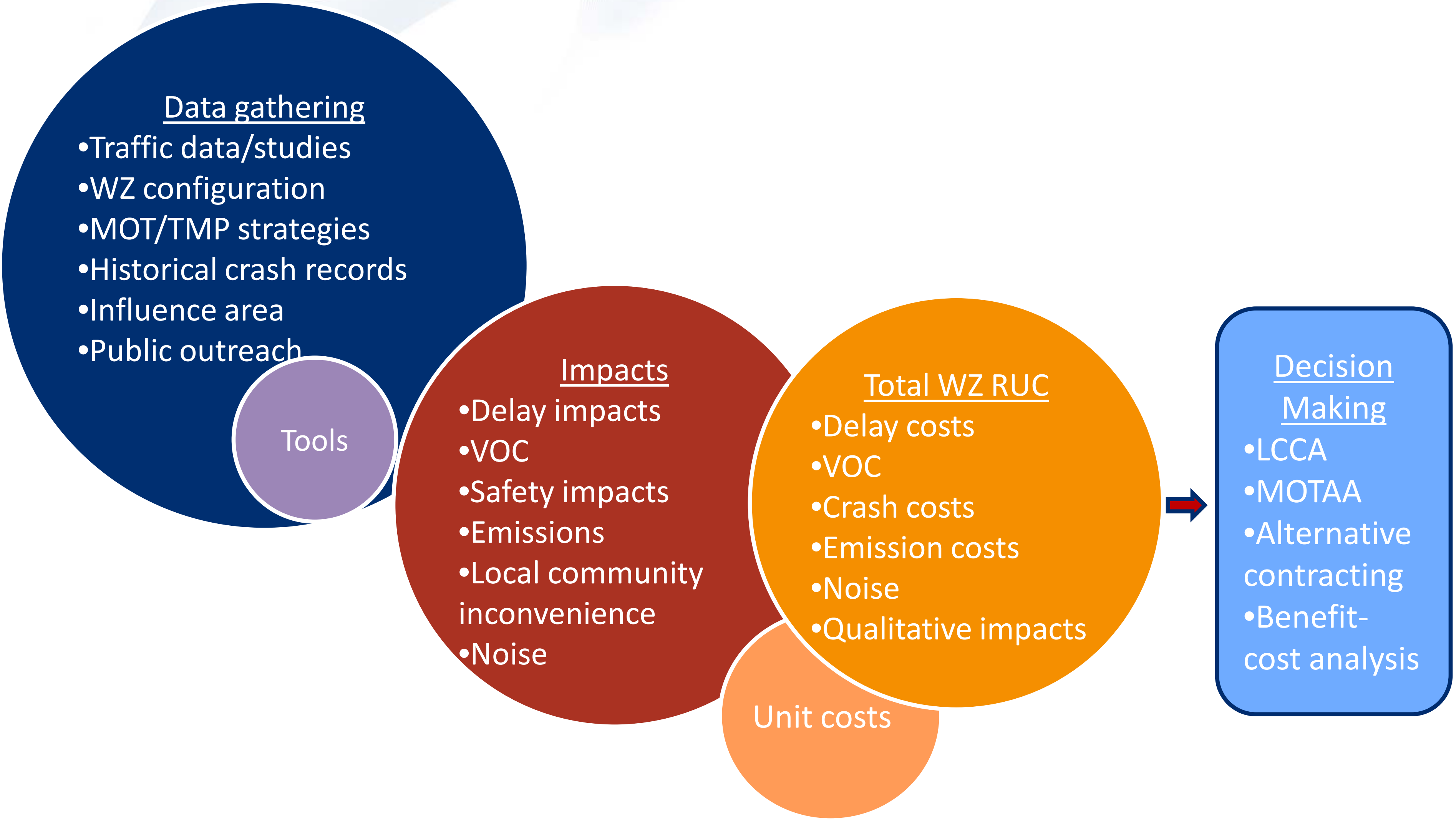
- **"WZ RUC is the additional cost borne by the motorists and local communities due to work zone activity."**



Applications of WZ RUC

- **System preservation and improvements**
  - e.g. life cycle cost analysis of pavements, bridges and pavement markings
- **Contract administration**
  - e.g. determination of incentives and disincentives
- **MOT strategy selection**
  - e.g. selection of work zone MOT strategies
- **Benefit-cost analysis of capital investments**
  - e.g. economic efficiency of construction innovations
- **Operational efficiency of work zones**
  - e.g. post-construction mobility and safety performance review

WZ RUC Computation Process



Tools for WZ RUC Computation

- **Work Zone Traffic Impact Analysis Tools**
  - Sketch-planning tools
    - State-specific tools (e.g. Michigan's CO3, Colorado's WorkZone-RUC)
    - QUEWZ-98
    - Quick Zone
    - CA4PRS
  - Simulation tools
    - Macroscopic (e.g. PASSER)
    - Mesoscopic (e.g. DYNASMART)
    - Microscopic (e.g. CORSIM)
- **Economic analysis tools**
  - Life cycle cost analysis (RealCost)
  - Benefit cost analysis (HERS-ST, MicroBENCOST, Cal B-C, BCA.Net)

3 Steps to Estimate Monetary Components

1. **Estimate work zone impacts**
   - Mobility impacts (e.g., delay, VOC) → traffic/economic analysis tools
   - Crash rates/frequency → project-specific historical records
   - Emission rates → static or dynamic emission factor models
2. **Derive unit costs for each impact (use the Bureau of Labor Statistics economic indices for unit cost adjustments)**
   - Mobility → monetary value of travel time & vehicle operating costs
   - Crash → human & comprehensive costs by crash severity
   - Emissions → air pollutant damage costs ($/ton)
3. **Monetize impacts**

Estimating Travel Delay Costs

Work zone delay time

*

Unit cost data (updated to current year $)

- $/hr value of personal travel (passenger cars only)
- $/hr value of business travel (passenger cars only)
- $/hr value of truck travel (trucks only)
- $/hr value of time-related depreciation by vehicle type (all vehicles)
- $/hr value of freight inventory (loaded trucks only)

*

Number of vehicles

- Number of passenger cars on personal travel
- Number of passenger cars on business travel
- Number of trucks
- Number of vehicles by vehicle type
- Number of loaded trucks

=

Work zone travel delay costs

Estimating Personal Travel Delay Costs (Autos)

1. **Determine the proportion of passenger cars on personal travel**
   - National averages may vary with local or intercity travel
2. **Establish the average vehicle occupancy (AVO) of cars**
   - National averages from National Household Travel Survey (NHTS)
3. **Estimate per person-hr value of personal travel time**
   - Uses median annual income reported by the U.S. Census Bureau (OST guidelines)
4. **Compute per vehicle-hr value of travel time (=Step 2*Step 3)**
5. **Compute travel delay costs for passenger cars (=Step 4*total delay time estimated from traffic studies/modeling)**

Estimating Vehicle Operating Costs

- **VOC components**
  - Fuel and engine oil consumption
  - Tire-wear
  - Repair and maintenance
  - Mileage-related depreciation

Estimating Vehicle Operating Costs

- **Work zone through traffic (includes forced flow condition)**
  - Speed change, stopping and idling conditions
  - VOC models
    - NCHRP Report 133 (implemented in RealCost)
    - Texas R&D Foundation – Zaniewski et al (e.g. MicroBENCOST)
    - HERS-ST – modified Zaniewski equations
- **Detour traffic (assuming no forced flow on detour routes)**
  - Per-mile costs
    - VOC models (at constant speed conditions)
    - AAA Your Driving Costs
    - American Transportation Research Institute - ATRI (for trucks)

Steps for Estimating VOC

- **Traffic flowing through work zone**
  1. Estimate speed change cycles and idling time using traffic analysis tools
  2. Update the unit cost data used in the VOC models
  3. Estimate cost impact of speed change and idling time using VOC models
  4. Estimate the total VOC
- **Detour traffic**
  1. Determine additional distance traveled due to detour
  2. Use VOC models to consider speed differential for detour conditions
     - For simpler calculations, use AAA/ATRI or equivalent estimates
  3. Estimate the detour VOC

Steps for Estimating Crash Costs

1. **Determine the pre-construction crash rate for "influence area"**
   - Sort by crash severity—3-year to 5-year averages
2. **Estimate WZ crash rate using a Crash Modification Factor (CMF)**
   - Typical WZ CMFs can be found at *CMF Clearinghouse* website
   - Use of agency-derived CMFs reflecting local trends is strongly recommended
3. **Estimate the measure of WZ exposure (typically in MVMT)**
   - Defined by the WZ influence area, vehicle miles traveled and the WZ duration
4. **Compute unit cost for crashes**
   - Human capital & comprehensive costs (by crash severity)
     - Crash cost estimates presented in the report FHWA-HRT-05-051
     - Use of agency-derived unit costs are recommended
5. **Compute aggregated WZ crash cost estimates for the project**

Steps for Estimating Emission Costs

1. **Estimate emissions rates (by emission type)**
   - Static emission factor OR Dynamic instantaneous emission models
2. **Determine Unit Costs for Emissions**
   - No consensus on emission costs
   - Available unit cost estimates: HERS-ST & Caltrans – typically based on the economic analysis of health impacts caused by emissions
3. **Determine emission costs**

   = ∑ (VMT x Emissions Rate x Cost/ton) by Emissions Type

Non-monetary & Qualitative Impacts

- **Predict construction noise levels**
  - Estimate noise levels for various construction operations, e.g., FHWA Roadway Construction Noise Model
- **Impacts of local communities and business**
  - Impact studies, surveys, public outreach and community awareness programs to identify needs and concerns

Questions

APPLICATION OF WZ RUC IN MOT ALTERNATE ANALYSIS

Overview of MOT Alternative Analysis

- **WHAT – Process for identifying the best MOT strategy**
- **WHEN – Recommended when the agency-set performance thresholds are exceeded**
- **HOW – Comparative evaluation of potential benefits, costs, and constraints**
  - Requires consideration of both quantitative and qualitative impacts
  - Use of decision analysis tools

Kepner-Tregoe Decision Analysis

- **Decision analysis tool to make informed choices**
- **Considers quantitative and qualitative WZ RUC components**
- **Provides flexibility to make project-specific choices**
- **Involves the following broad set of actions:**
  - Identify evaluation criteria and prioritize them
  - Identify candidate alternatives
  - Evaluate MOT alternatives against set-criteria
  - Select the preferred strategy

10-step process illustrated using an example project – Reconstruction of Eastern Avenue Bridge over Kenilworth Avenue in Washington, DC

Kepner-Tregoe Decision Analysis

Step 1: Prepare a Decision Statement

- Clearly state of the purpose of decision analysis
- Provides the focus for all other steps that follow
- Sets limits on the range of alternatives considered in the analysis

Kenilworth Avenue Project – Decision Statement

To identify the most effective MOT strategy on mainline Kenilworth Avenue during the reconstruction of bridge piers of the Eastern Avenue bridge .

Kepner-Tregoe Decision Analysis

Step 2: Define Objectives

- Define required and desired attributes of the preferred choice
- Specify required attributes as MUST objectives
  - GO or NO GO options
  - All attributes must be satisfied; otherwise alternative is eliminated
- Specify desired attributes as WANT objectives
  - Numerical weights to indicate relative importance
  - Screen for interdependence (high correlation) among objectives (e.g. average delay time vs delay costs)

"the MUSTS decide who gets to play, but the WANTS decide who wins."

Kepner-Tregoe Decision Analysis

Kenilworth Avenue Project – MUST objectives

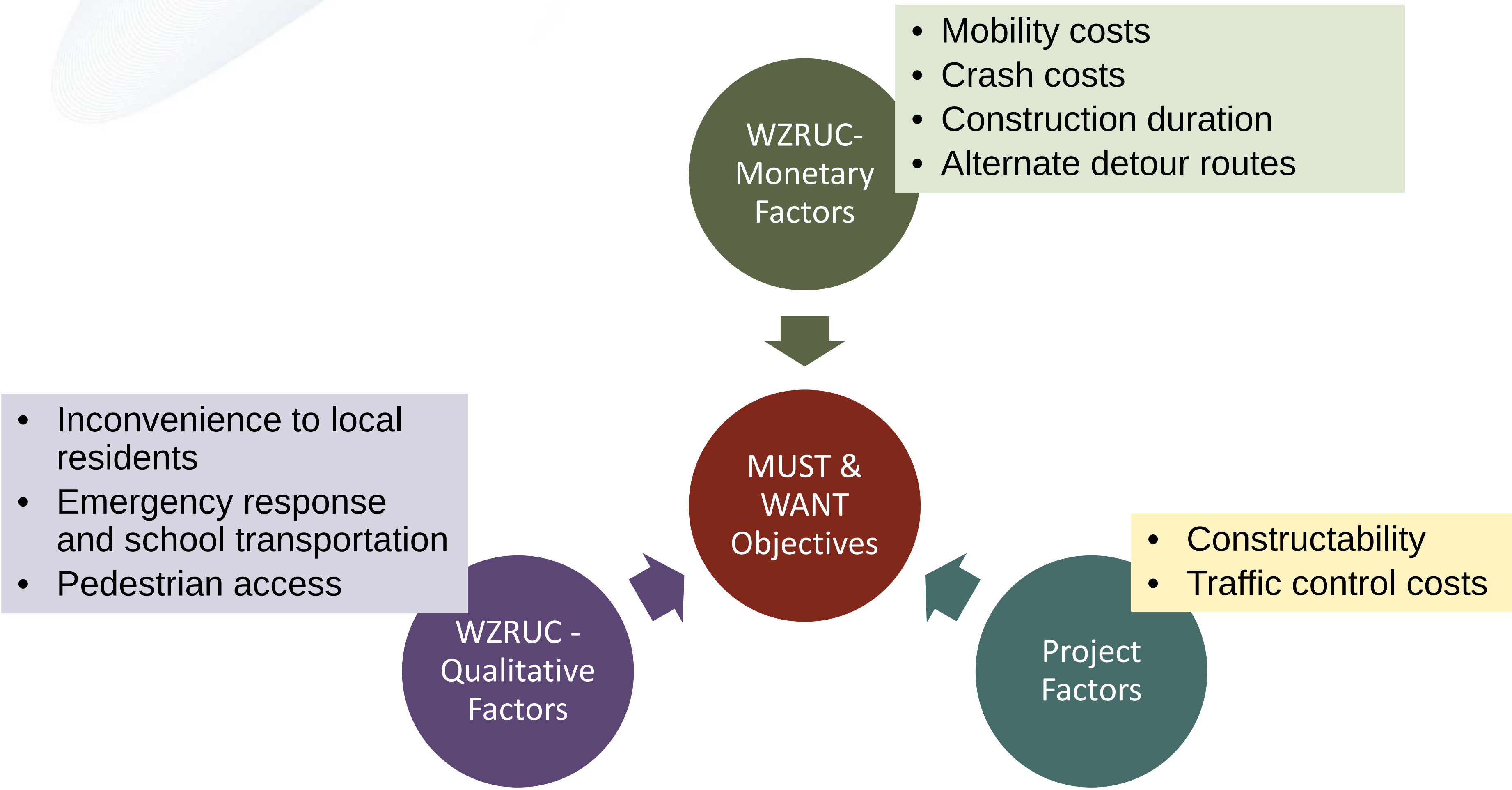
- *Does an MOT option satisfy constructability requirements? Limited work zone space on mainline Kenilworth Avenue - a key constraint*
- *Are there any alternate routes available to accommodate full diversion?*

Kenilworth Avenue Project – WANT objectives

- *Mobility costs– the goal is to minimize travel delay costs, VOC and WZ exposure*
- *Spillback congestion – traffic backups may cause spillback on nearby routes*
- *Crash costs– larger influence area and longer exposure periods*
- *Inconvenience to local residents – Bus access and parking along service roads*
- *Emergency response and school transportation*
- *Pedestrian access - Eastern Avenue used by many pedestrians*
- *Construction duration – calendar days required for project completion*
- *Traffic control costs - expenditure for traffic control devices, related roadway improvements (to maintain traffic), and public information strategies*

Kepner-Tregoe Decision Analysis

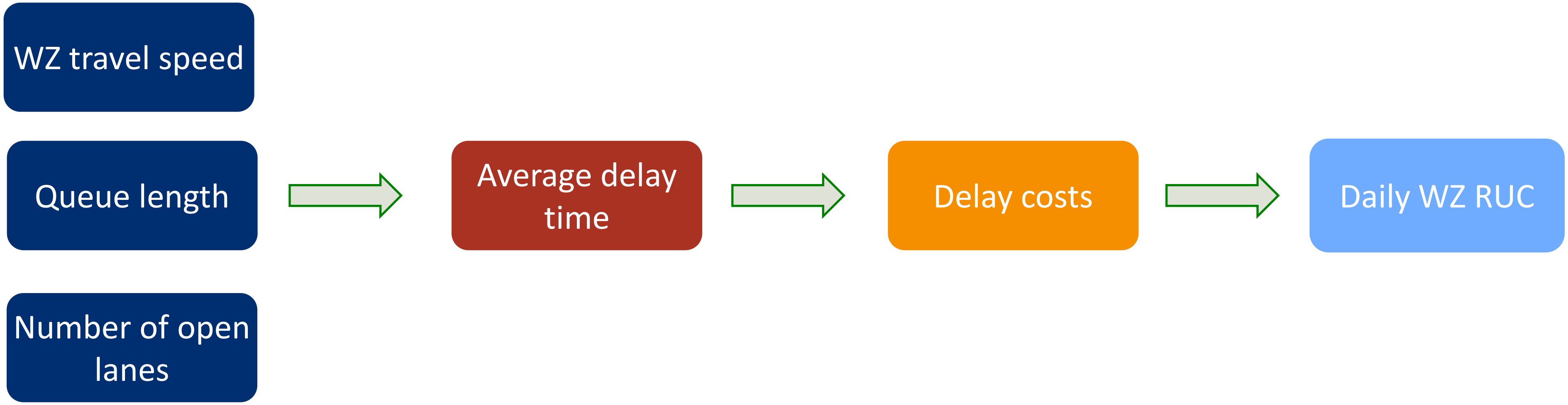
Step 2: Define Objectives – Focus on WZ RUC



Kepner-Tregoe Decision Analysis

Step 2: Define Objectives

- High correlation among objectives may lead to biased analysis
- Minimize interdependency



Kepner-Tregoe Decision Analysis

Step 3: Assign Weights to WANT Objectives

- Assign weights to WANT objectives
  - Use a scale of 1 (least preferable) to 10 (most preferable)
  - Weighting should reflect agency policies and project needs
- Common weighting mistakes to avoid:
  - Too many high weights
  - Too many low weights
  - Biased weighting

Kenilworth Avenue Project	
WANT Objective	Weights
Mobility costs	10
Spillback on nearby roadways	10
Crash costs	10
Inconvenience to local residents	5
Emergency response and school transportation	4
Pedestrian access	5
Construction duration	8
Traffic control costs	6

Kepner-Tregoe Decision Analysis

- **Step 4: Identify and list all potential MOT alternatives**

Kenilworth Avenue Project – Potential Alternatives

- *MOT Option 1 – close one of three lanes in each direction on mainline Kenilworth Avenue*
- *MOT Option 2 – close one of three lanes in each direction on mainline Kenilworth Avenue and supplement with two-lane service roads in each direction*
- *MOT Option 3 - close two of three lanes in each direction on mainline Kenilworth Avenue and supplement with two-lane service roads in each direction*
- *MOT Option 4 - full closure of this segment of Kenilworth Ave and divert traffic through detour*
- *MOT Option 5 - close one of three lanes in each direction during nighttime only*

Kepner-Tregoe Decision Analysis

- **Step 5: Summarize the findings of work zone impact assessment:**
  - Constructability
  - Detour Alternatives
  - Service Roads
  - Pedestrian Access
  - Emergency Response and School Transportation
  - Construction Duration
  - Traffic Control and Improvement Costs
  - Mobility Impacts
  - Crash Risks

Kepner-Tregoe Decision Analysis

- **Step 6: Evaluate potential alternatives against each MUST objective**
  - Eliminate an alternative that fail to satisfy at least objectives – only those satisfy all objectives are considered as feasible ones

Kenilworth Avenue Project					
MUST Objective	MOT Options				
	1	2	3	4	5
Does an MOT option satisfy constructability requirements?	✓	✓	✓	✓	✗
Are there any alternate detour routes to accommodate full diversion of Kenilworth Avenue traffic?	✓	✓	✓	✗	✓

Kepner-Tregoe Decision Analysis

Step 7: Evaluate against WANT objectives

- Assign a score on a scale of 1 to 10 for each alternative against each WANT objective

Kenilworth Avenue Project					
WANT Objective	MOT Options				
	1	2	3	4	5
Mobility costs	2	10	4	Not considered for further analysis since they did not meet MUST objectives	
Spillback on nearby roadways	2	10	4		
Crash costs	4	8	6		
Inconvenience to local residents	10	3	3		
Emergency response and school transportation	5	7	5		
Pedestrian access	8	4	4		
Construction duration	-	-	-		
Traffic control costs	-	-	-		

Kepner-Tregoe Decision Analysis

- **Step 8: Calculate the weighted scores**
  - Multiply the weight of an objective with the alternative score
  - Compute the total weighted score for each alternative
  - Select the alternative with the highest weighted score as the tentative choice

Tentative choice
Option 2

Kenilworth Avenue Project				
WANT Objective	Weight	MOT Options		
		1	**2**	3
Mobility costs	10	20	**100**	40
Spillback on nearby roadways	10	20	**100**	40
Crash costs	10	40	**80**	60
Inconvenience to local residents	5	50	**15**	15
Emergency response and school transportation	4	20	**28**	20
Pedestrian access	5	40	**20**	20
Construction duration	8	-	**-**	-
Traffic control costs	6	-	**-**	-
Total weighted score		190	**343**	195

Kepner-Tregoe Decision Analysis

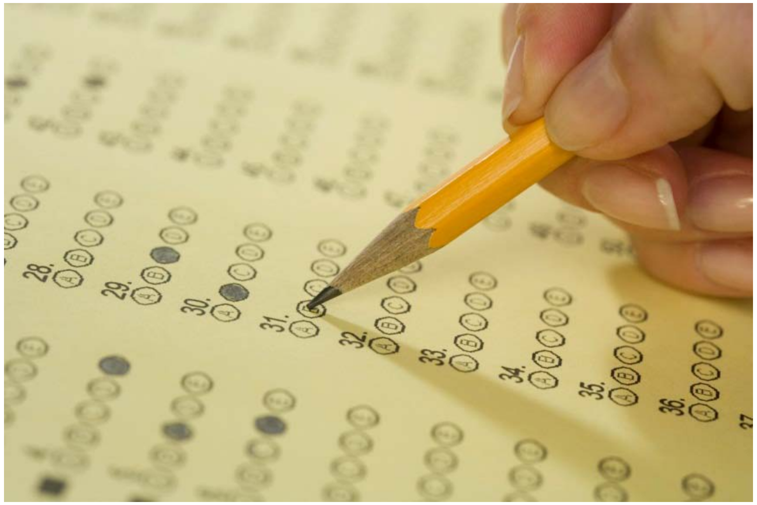
- **Step 9: Evaluate adverse consequences separately for each alternative**
  - Identify potential risks
  - Determine the probability of occurrence
  - Determine the severity of impacts
  - Evaluate the adverse consequences of selecting an alternative
  - Identify low-risk and high-risk choices.

Kenilworth Avenue Project						
Adverse	MOT Option 1		MOT Option 2		MOT Option 3	
Consequence	Probability	Severity	Probability	Severity	Probability	Severity
Emergency Evacuation	LM	HM	LM	HM	LM	M
H=High	M=Medium	L=Low	HM=High-medium	LM=Low-medium		

No high-risk options were identified.

Kepner-Tregoe Decision Analysis

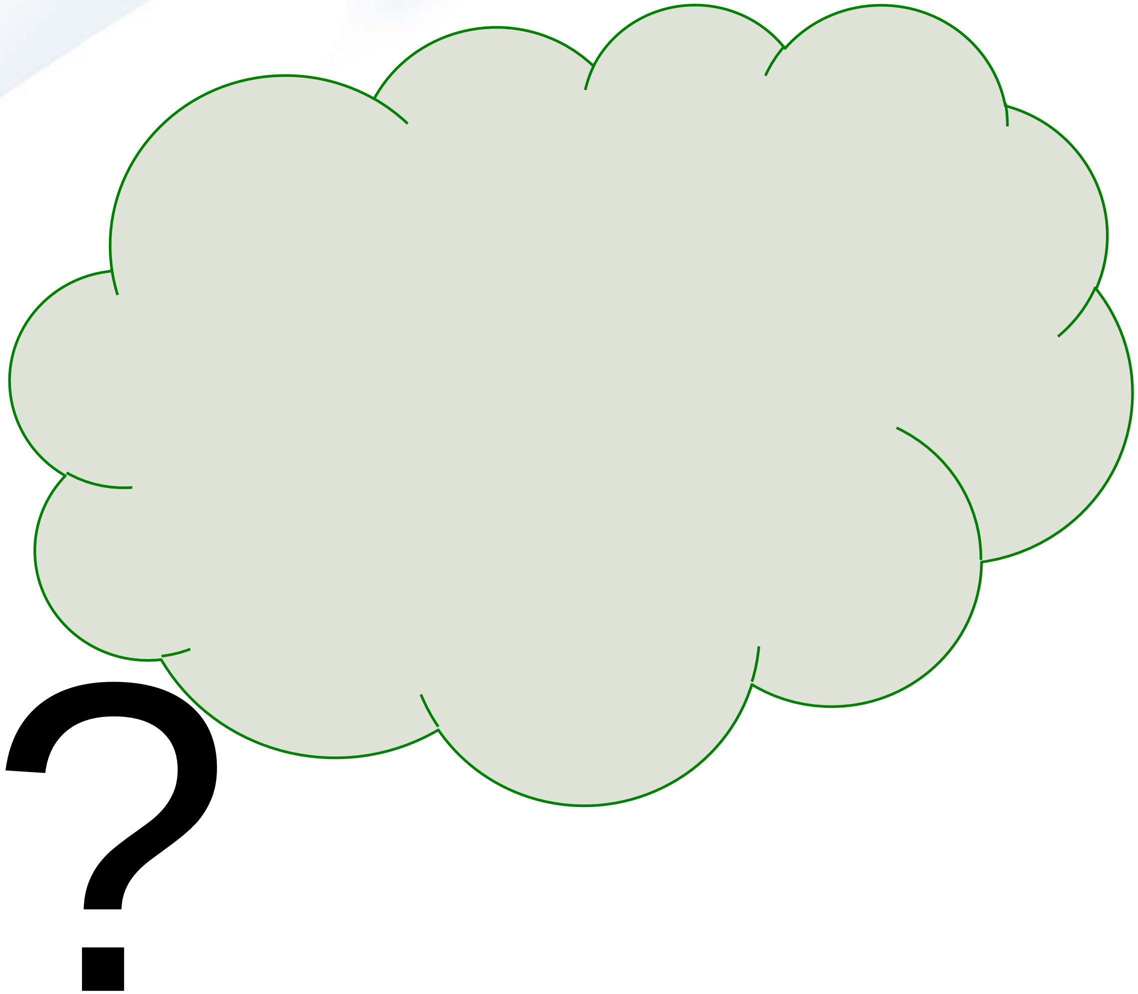
- **Step 10: Select the Preferred MOT Strategy**
  - List and rank the total weighted score of each alternative
  - Summarize the results of risk evaluation
  - Evaluate the high-risk choices for elimination or possible modifications
  - Re-evaluate modified alternatives, if required
  - Select the preferred choice



Kepner-Tregoe Decision Analysis

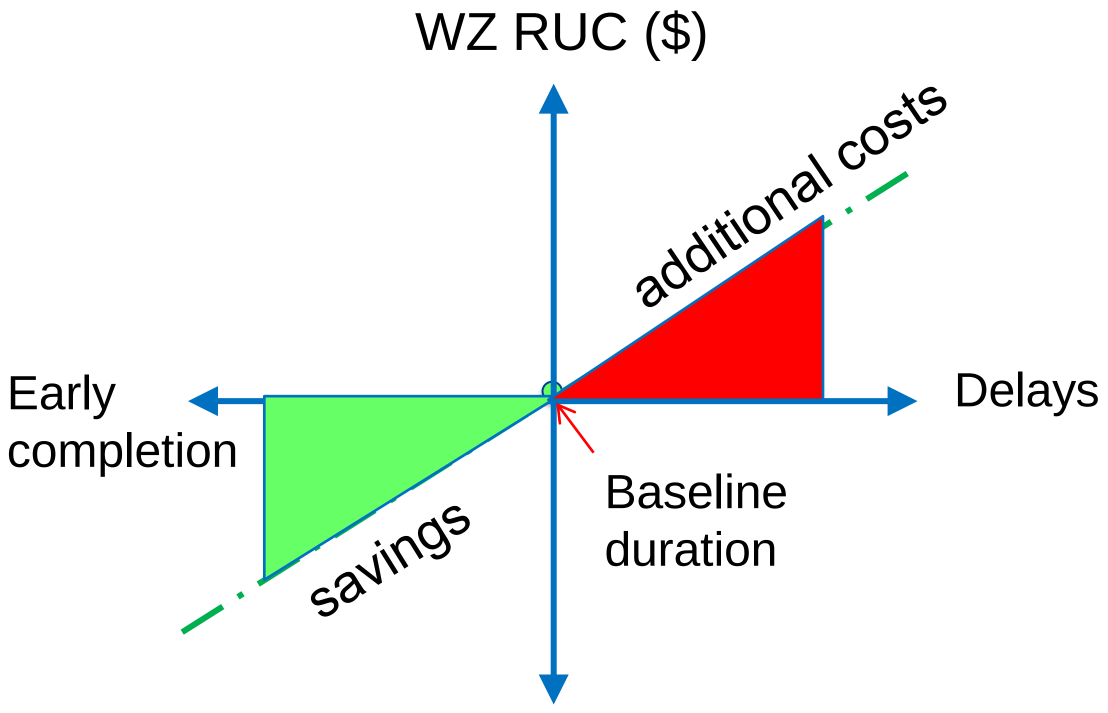
Alternative	Description	Total Weighted Score	Total Adverse Consequence Score	Rank
Option 1	Close one of three lanes in each direction on mainline Kenilworth	182	Low-risk	3
Option 2	Close one of three lanes in each direction on mainline Kenilworth and supplement with two-lane service roads per direction	327	Low-risk	1
Option 3	Close 2 of 3 lanes in each direction on mainline Kenilworth and supplement with two-lane service roads per direction	183	Low-risk	2
Option 4	Full closure of this segment of Kenilworth and divert traffic through detour	Eliminated	–	–
Option 5	Close one of three lanes in each direction during nighttime only.	Eliminated	–	–

Questions



APPLICATION OF WZ RUC IN CONTRACTING/PROJECT DELIVERY

WZ RUC vs Project Completion Time



Role of WZ RUC in Contracting/Project Delivery

- **Use of Liquidated Damages clause in traditional contracting:**
  - Partially effective in enforcing project completion time
  - No incentives to contractor for early completion
- **Significance of Milton vs State of Alabama case**
  - Relating daily incentive/disincentive (I/D) rate to daily WZ RUC
- **Applications of WZ RUC**
  - Justifying the need for schedule acceleration
  - Selecting the most appropriate project delivery strategy
  - Establishing time-related contract provisions (e.g. I/D)

Justifying the Need for Schedule Acceleration & Selection of Appropriate Project Delivery Strategies

Accelerating Project Schedule

1. **Establish the need for schedule acceleration**
   - Expediting project completion costs money
   - Not required for every project
   - Identify the need based on project conditions and work zone road user impacts
2. **Select a project delivery method**
3. **Select a schedule-focused contracting method**

Step 1: Need for Schedule Acceleration Typical Questions

- Heavy traffic volume?
- Located in urban area?
- Commuter route?
- Network level impacts?
- Early completion required?
- Time-sensitive project?
- Located in tourist or economically sensitive area?
- Lacks viable detour alternatives?
- Political interests?
- Affects local community and business?
- Safety issues for construction workers?
- Safety issues for motorists?

Available Strategies

Project delivery	Construction techniques	Contracting methods
• Design-bid-build • Design-build (DB) • Construction manager/general contractor (CMGC)	• Cast in-place • Accelerated technique	• Liquidated damages • Incentive/disincentive (I/D) for early completion • A+B bidding (with I/D) • Lane rental • No-excuse incentives • Interim completion dates (with or without I/D) • Liquidated savings

Step 2: Select a Project Delivery Method

Project size	Is project routine or innovative?	Certain over design scope?	In-house design?	Early cost certainty?	Certain over constructability?	Suggested strategy	
Small-medium							Select schedule related strategies.
Small-medium							
Medium-large							
Medium-large							
Medium-large							
Medium-large							
Medium-large							
Medium-large							
Medium-large							
Medium-large							
Medium-large							

++May hire consultants or seek constructability advice from local contractors or trade associations.

EXAMPLE	
Project size?	Large
Routine or innovative project?	Innovative
Agency certain over design scope?	Yes
design performed in-house?	Yes
agency certain over constructability	No
agency confident on its early cost estimates?	Assumed to be YES
Suggested Strategy	Design-bid-build. May hire consultants or consult local contractors/trade associations

- Decision matrix focuses only on shortening completion time
- Actual selection may require more comprehensive evaluation

Step 3: Select a Contracting Method

Baseline Project duration		Time sensitivity		Complete Early		Intermediate Phases		Detours impractical/long, Urban commuter traffic			Owner's confidence on estimated duration		Suggested Strategy
Short	Long	Yes	No	Yes	No	Critical	Not critical	Yes - Full closure required	Yes-full closure not required	No	High	Low	
✓													EB/(I/D) + ACT
✓													(I/D) +ACT
✓													EB/(I/D) + LR/ACT
✓													(I/D) +LR/ACT
✓													EB/(I/D) + LR
✓													(I/D) +LR
✓													EB + (I/D)
✓													(I/D)
✓													EB/(I/D) + LR
✓													(I/D) +LR
✓													EB/(I/D) + LR
✓													(I/D) +LR
✓													
✓													
✓													D)
✓													D)
✓			✓		✓		✓			✓	✓		(L/D)
✓			✓		✓		✓			✓		✓	(L/D)
	✓	✓		✓		✓		✓			✓		(A+B)/NEB/IMS/(I/D) + ACT
	✓	✓		✓		✓		✓				✓	(A+B)/IMS/(I/D) + ACT
	✓	✓		✓		✓			✓		✓		(A+B)/NEB/IMS /(I/D) + LR
	✓	✓		✓		✓			✓			✓	(A+B)/IMS/(I/D) + LR
	✓	✓		✓		✓				✓	✓		(A+B)/NEB/IMS /(I/D)
	✓	✓		✓		✓				✓		✓	(A+B)/IMS/(I/D)

EXAMPLE	
Baseline project duration	Long
Time sensitivity	No
Complete early	Yes
Intermediate phases	Not critical
Detours impractical/long, Urban commuter traffic	Yes - Full closure required
Owner's confidence on estimated duration	High
Suggested Strategy	(A+B)/ No Excuse Incentives/ (I/D) + Accelerated Construction

Establishing Time-related Contract Provisions

WZ RUC and Contract Provisions

- **Incentive/Disincentives**
  - Daily I/D = Discount Factor * Daily WZ RUC
  - (include agency construction oversight costs)
- **A+B bidding**
  - Bid value = (A) + (B x Daily WZ RUC)
- **Lane Rental**
  - Rental fee = WZ RUC for actual closure period – WZ RUC for allowable closure period

Applying WZ RUC in I/D Computation

- **Combine "Time-Cost Tradeoff" & "Time is Money" concepts**
- **Schedule acceleration incurs additional costs to contractor**
  - Labor, materials and equipment
- **If incentive < contractor cost of acceleration?**
- **If incentive > WZ RUC?**
  - Incentive < acceleration costs?
- **I/D Equations**

Cost of Acceleration (CA) ≤ I/D ≤ WZ RUC

I/D = Discount Factor * WZ RUC

Discount Factors in I/D Computation

- **Portion of WZ RUC savings shared or recovered**
- **Range of discount factors:**
  - 0.1 to 1.0 ; 0.2 to 0.5 (typically used)
- **How to determine the discount factor?**
  - Market conditions
  - Confidence on the accuracy of WZ RUC estimates
  - Level of project acceleration required
  - Agency costs - WZ RUC – Total incentives cannot exceed 5% of project cost.
- **Is there an appropriate discount factor?**
  - Adequate to stimulate schedule acceleration?
  - Adequate to cover additional contractor costs?

Sensitivity of Discount Factors

Contractor Profits & Losses

Actual days to complete the project (normal = 60 days)	Discount Factors 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
70	-43	-47	-51	-55	-59	-63	-67	-71	-75	-79
69	-35	-39	-42	-46	-49	-53	-57	-60	-64	-67
68	-28	-31	-34	-38	-41	-44	-47	-50	-54	-57
67	-22	-25	-27	-30	-33	-36	-39	-41	-44	-47
66	-16	-19	-21	-24	-26	-28	-31	-33	-36	-38
65	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30
64	-8	-9	-11	-13	-14	-16	-17	-19	-21	-22
63	-5	-6	-7	-8	-9	-11	-12	-13	-14	-15
62	-2	-3	-4	-5	-6	-6	-7	-8	-9	-10
61	-1	-1	-2	-2	-2	-3	-3	-4	-4	-4
60	0	0	0	0	0	0	0	0	0	0
59	0	0	1	1	2	2	2	3	3	4
58	-1	0	1	2	2	3	4	5	6	6
57	-2	-1	0	1	3	4	5	6	7	9
56	-5	-3	-1	0	2	3	5	7	8	10
55	-8	-6	-4	-2	0	2	4	6	8	10
54	-12	-9	-7	-4	-2	0	3	5	8	10
53	-16	-13	-11	-8	-5	-2	1	3	6	9
52	-22	-18	-15	-12	-9	-6	-2	1	4	7
51	-28	-24	-21	-17	-13	-10	-6	-3	1	5
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-11	-7	[illegible]	1

Delay

Early

Incentive to complete early goes up with increasing discount factor

At discount factor of 1.0, the agency takes no savings/ losses

Agency's savings and losses

Actual days to complete the project (normal = 60 days)	Discount Factors 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
70	-4.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
69	-4.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
68	-3.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
67	-3.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
66	-2.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
65	-2.25	-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
64	-1.8	-1.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63	-1.35	-1.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62	-0.9	-0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
61	-0.45	-0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
59	0.45	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
58	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
57	1.35	1.2	1.05	0.9	0.75	0.6	0.45	0.3	0.15	0
56	1.8	1.6	1.4	1.2	1	0.8	0.6	0.4	0.2	0
55	2.25	2	1.75	1.5	1.25	1	0.75	0.5	0.25	0
54	2.7	2.4	2.1	1.8	1.5	1.2	0.9	0.6	0.3	0
53	3.15	2.8	2.45	2.1	1.75	1.4	1.05	0.7	0.35	0
52	3.6	3.2	2.8	2.4	2	1.6	1.2	0.8	0.4	0
51	4.05	3.6	3.15	2.7	2.25	1.8	1.35	0.9	0.45	0
50	[illegible]	4	3.5	3	2.5	2	1.5	1	0.5	0

At discount factor of 0.1, the agency shares only a portion of savings as incentives for early completion

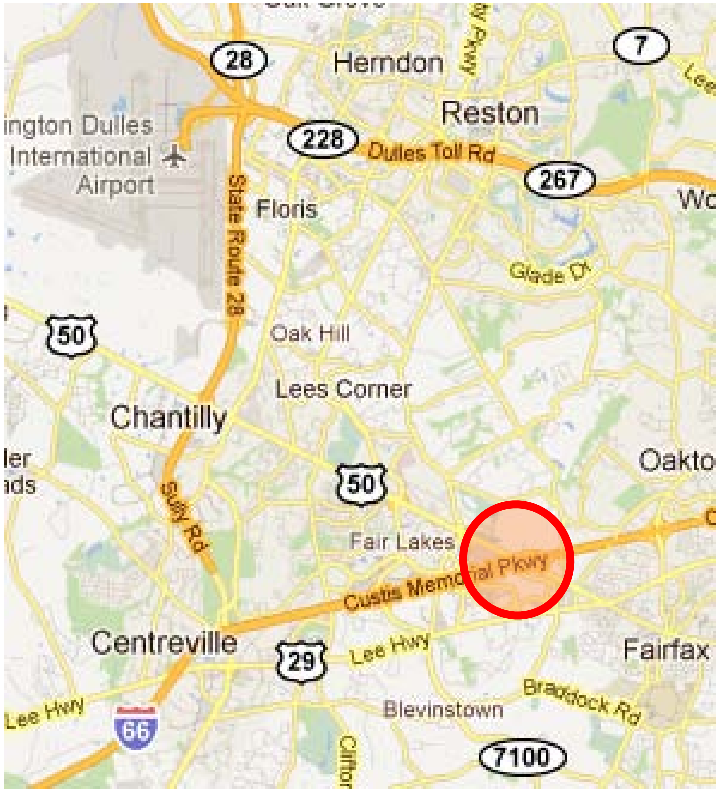
At discount factor of 0.1, the agency recovers only a portion of additional costs as disincentives for late completion

Red →losses

Green→ profits

Illustrative Example: Concrete Pavement Rehabilitation on Interstate-66, Fairfax County, Virginia

- **Highways for Life demonstration project**
- **Urban interstate**
  - heavy commuter traffic
  - ~ 90,000 vpd (one-way)
- **Three lanes + auxiliary lane for peak hours**
- **Allowable lane closure:**
  - Three lane closure: 10pm-5am
  - Two lane closure: 9pm-5am (not considered for illustration)
- **Used RealCost for illustration**



Lane Rental Computation

- **Lane rental fee for a given closure period**
  - daily WZ RUC (***actual closure period***)

    MINUS daily WZ RUC (***allowable closure period***)
- **Negative differences indicate no adverse effect (no fee)**
- **Include construction engineering costs**
- **Adjusted using a discount factor**

I-66 Pavement Rehabilitation
Lane Rental Fee Computation – Three lane Closure

Condition	Lane Closure Timings: Closed	Lane Closure Timings: Opened	Daily WZ RUC for the given closure period	Difference in daily WZ RUC between actual and allowable closure periods	Estimated maximum queue length (miles)	Estimated maximum delay time (minutes)
Early Closure	7 pm	5 am	$1,590,479	$1,518,188	16.7	246.5
	8 pm	5 am	$637,237	$564,946	9.4	140.3
	9 pm	5 am	$264,196	$191,904	5.4	81.3
Allowable Closure (baseline)	10 pm	5 am	$72,291	$0	2.2	35.6
Failure to Open	10 pm	6 am	$72,511	$220	2.2	35.6
	10 pm	7 am	$89,828	$17,537	2.2	35.6
	10 pm	8 am	$169,696	$97,405	5.7	65.2
	10 pm	9 am	$350,813	$278,522	13.1	138.8

I-66 Pavement Rehabilitation
Lane Rental Fee Computation – Three lane Closure

	Lane Closure Timings		Difference in daily WZ RUC between actual and allowable closure periods	VDOT Lane Rental Fee	Lane Rental Fee		
Condition	Closed	Opened			DF=0.25	DF=0.5	DF=1.0
Allowable Closure (baseline)	10 pm	5 am	$0	$0	$0	$0	$0
Failure to Open	10 pm	6 am	$220	$9,000	$55	$110	$220
	10 pm	7 am	$17,537	$28,000	$4,384	$8,769	$17,537
	10 pm	8 am	$97,405	$48,000	$24,351	$48,703	$97,405
	10 pm	9 am	$278,522	$68,000	$69,631	$139,261	$278,522

- **No one-to-one comparison is made.**
  - Computation tools were different.
  - Unit costs were not the same.
  - Construction engineering costs were not included.
  - No information available on VDOT's discount factors.

I-66 Pavement Rehabilitation
If this project were to use A+B bidding?

- **Key assumptions:**
  - 3-lane closure
  - Bid days (B) = 44 days
  - Daily RUC = $72,291
  - Discount Factor = 0.25
- **I/D= 0.25 * daily RUC**

Case	Project Completed in (days)	Days saved/ delayed	I/D
Early Completion	39	5	$90,364
	40	4	$72,291
	41	3	$54,218
	42	2	$36,146
	43	1	$18,073
Baseline	44	0	$0
Delay	45	-1	-$18,073
	46	-2	-$36,146
	47	-3	-$54,218
	48	-4	-$72,291
	49	-5	-$90,364

APPLICATION OF WZ RUC IN BENEFIT-COST ANALYSIS

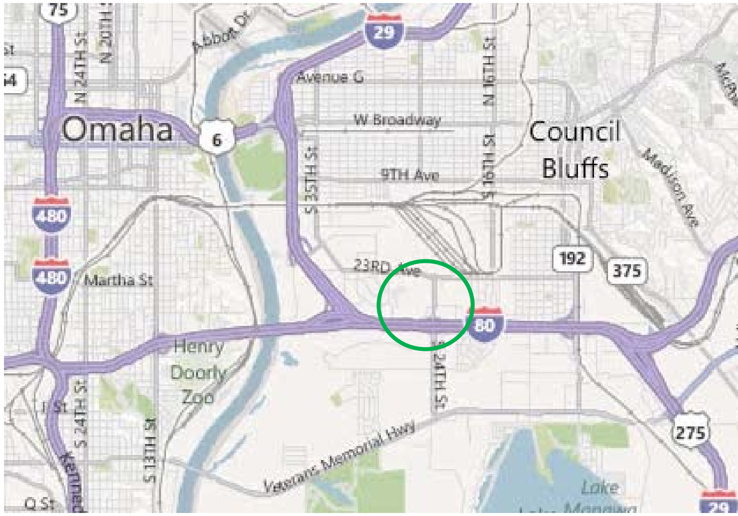
WZ RUC in Benefit-Cost Analysis

- **To evaluate the economic efficiency of a decision**
  - Compare costs & benefits, e.g. economic value of construction innovation
  - How an alternative compare with others, e.g. accelerated construction vs cast in-place techniques
  - Agency costs & WZ RUC

Agency Costs	WZ RUC
• Preliminary design and engineering • Construction costs • Mobilization • Construction engineering • Traffic control • Law enforcement	• Delay costs • Vehicle operating costs • Crash costs • Emission costs

Illustrative Example: Improvements to the 24th Street–I-29/80 Interchange in Council Bluffs, Iowa

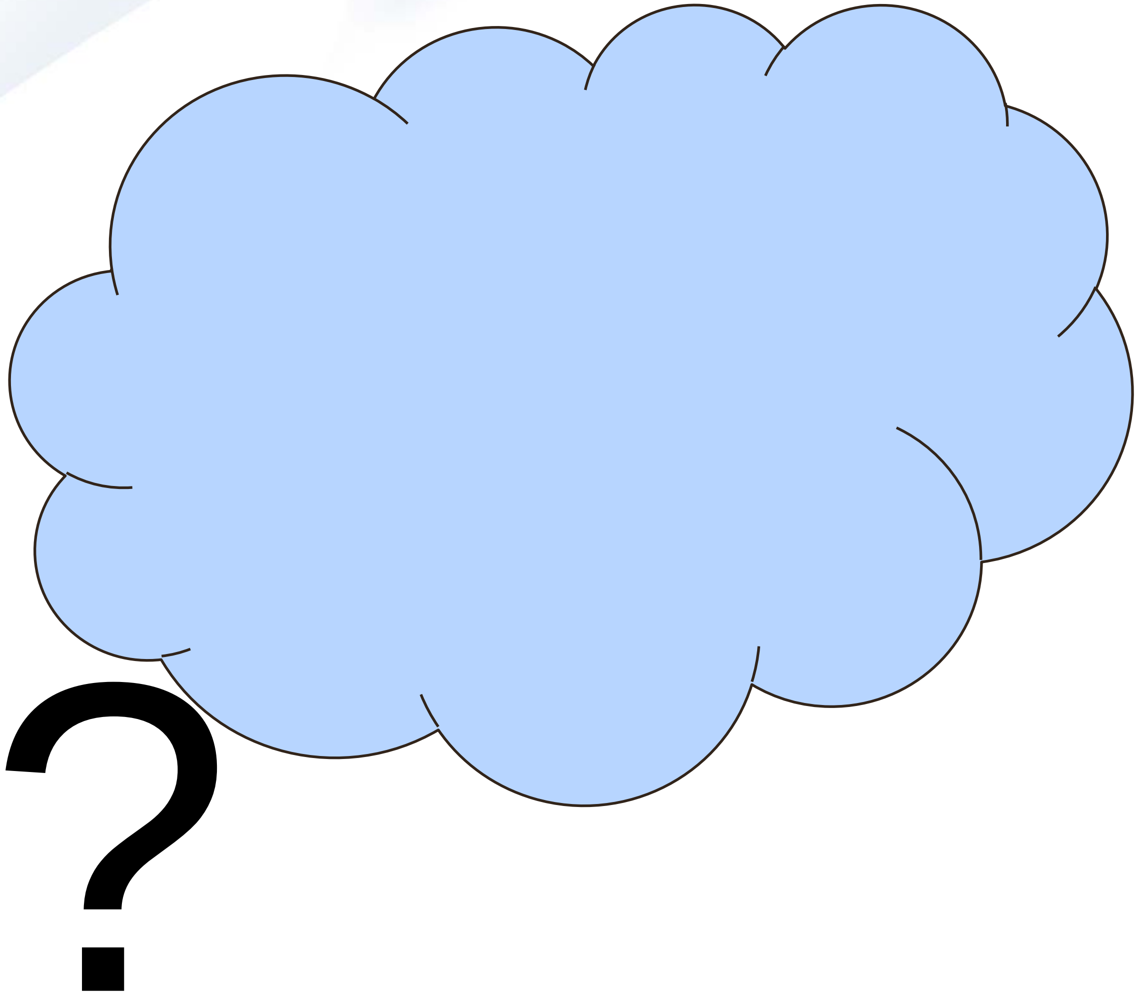
- **Accelerated vs cast-in place construction**
- **Estimated construction duration**
  - Cast in-place → 426 days (two seasons)
  - Accelerated → 175 days (less than one season)
- **Cost impacts of accelerated construction techniques**
  - Higher agency costs for design, construction and contractor incentives
  - Savings in WZ RUC



Cost Category	Cast In-place Scenario	Accelerated Construction Scenario	Savings
Agency costs	$11,128,864	$12,506,262	($1,377,398)
WZ RUC	$3,480,756	$1,087,147	$2,393,609
Net Savings			$1,016,211

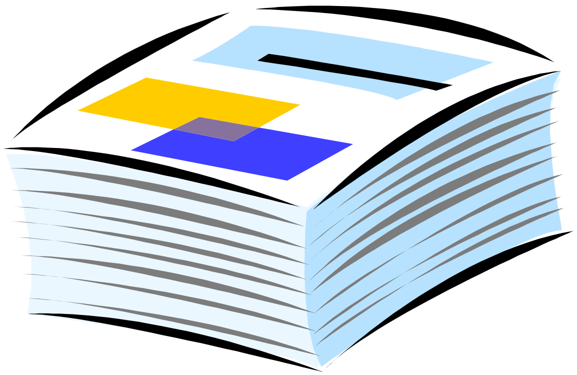
Use of accelerated construction techniques showed an 8 percent benefit (first cost basis) over traditional methods

Questions



WZ RUC Reference Documents

- **Important Upcoming Documents**
  - Work Zone Road User Costs: Concepts and Applications, FHWA-HOP-12-005
    - To be Released December 2011
  - TAT Vol. XII: Work Zone Traffic Impact Analysis – Applications and Decision Framework
    - To be Released December 2011



Contact Information:

Jawad Paracha
Work Zone Safety & Mobility Team
FHWA Office of Transportation Operations
jawad.paracha@dot.gov

Jagannath Mallela
Principal Engineer
ARA, Inc.
jmallela@ara.com

THANK YOU !