ROAD USER COST ANALYSIS FOR WORK ZONE APPLICATIONS

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November 15, 2011
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
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

Data gathering
• Traffic data/studies
• WZ configuration
• MOT/TMP strategies
• Historical crash records
• Influence area
• Public outreach

Impacts
• Delay impacts
• VOC
• Safety impacts
• Emissions
• Local community inconvenience
• Noise

Total WZ RUC
• Delay costs
• VOC
• Crash costs
• Emission costs
• Noise
• Qualitative impacts

Unit costs

Decision Making
• LCCA
• MOTAA
• Alternative contracting
• Benefit-cost analysis
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**

<table>
<thead>
<tr>
<th>Unit cost data (updated to current year $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/hr value of personal travel (passenger cars only)</td>
</tr>
<tr>
<td>$/hr value of business travel (passenger cars only)</td>
</tr>
<tr>
<td>$/hr value of truck travel (trucks only)</td>
</tr>
<tr>
<td>$/hr value of time-related depreciation by vehicle type (all vehicles)</td>
</tr>
<tr>
<td>$/hr value of freight inventory (loaded trucks only)</td>
</tr>
</tbody>
</table>

**Number of vehicles by vehicle type**

- Number of passenger cars on personal travel
- Number of passenger cars on business travel
- Number of trucks
- Number of vehicles
- 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
   \[ = \sum (VMT \times \text{Emissions Rate} \times \text{Cost/ton}) \text{ by Emissions Type} \]
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 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**

- **WZRUC - Monetary Factors**
  - Mobility costs
  - Crash costs
  - Construction duration
  - Alternate detour routes

- **WZRUC - Qualitative Factors**
  - Inconvenience to local residents
  - Emergency response and school transportation
  - Pedestrian access

- **MUST & WANT Objectives**
  - Constructability
  - Traffic control costs

- **Project Factors**
Kepner-Tregoe Decision Analysis

Step 2: Define Objectives

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

- WZ travel speed
- Queue length
- Number of open lanes
- Average delay time
- Delay costs
- Daily WZ RUC
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

<table>
<thead>
<tr>
<th>Kenilworth Avenue Project</th>
<th>WANT Objective</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility costs</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Spillback on nearby roadways</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Crash costs</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Inconvenience to local residents</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Emergency response and school transportation</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Pedestrian access</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Construction duration</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Traffic control costs</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>MUST Objective</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kenilworth Avenue Project</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does an MOT option satisfy constructability requirements?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Are there any alternate detour routes to accommodate full diversion of Kenilworth Avenue traffic?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
</tr>
</tbody>
</table>
Step 7: Evaluate against WANT objectives

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

<table>
<thead>
<tr>
<th>WANT Objective</th>
<th>MOT Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility costs</td>
<td>2 10 4</td>
</tr>
<tr>
<td>Spillback on nearby roadways</td>
<td>2 10 4</td>
</tr>
<tr>
<td>Crash costs</td>
<td>4 8 6</td>
</tr>
<tr>
<td>Inconvenience to local residents</td>
<td>10 3 3</td>
</tr>
<tr>
<td>Emergency response and school transportation</td>
<td>5 7 5</td>
</tr>
<tr>
<td>Pedestrian access</td>
<td>8 4 4</td>
</tr>
<tr>
<td>Construction duration</td>
<td>- - -</td>
</tr>
<tr>
<td>Traffic control costs</td>
<td>- - -</td>
</tr>
</tbody>
</table>

Kenilworth Avenue Project

Not considered for further analysis since they did not meet MUST objectives
### 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

<table>
<thead>
<tr>
<th>WANT Objective</th>
<th>Weight</th>
<th>MOT Options</th>
<th>Total weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility costs</td>
<td>10</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Spillback on nearby roadways</td>
<td>10</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Crash costs</td>
<td>10</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>Inconvenience to local residents</td>
<td>5</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>Emergency response and school transportation</td>
<td>4</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>Pedestrian access</td>
<td>5</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Construction duration</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Traffic control costs</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total weighted score</td>
<td>190</td>
<td>343</td>
<td>195</td>
</tr>
</tbody>
</table>

**Tentative choice**: Option 2
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.

<table>
<thead>
<tr>
<th>Adverse Consequence</th>
<th>Kenilworth Avenue Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MOT Option 1</td>
</tr>
<tr>
<td></td>
<td>Probability</td>
</tr>
<tr>
<td>Emergency Evacuation</td>
<td>LM</td>
</tr>
<tr>
<td>H=High</td>
<td>M=Medium</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
<th>Total Weighted Score</th>
<th>Total Adverse Consequence Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>Close one of three lanes in each direction on mainline Kenilworth</td>
<td>182</td>
<td>Low-risk</td>
<td>3</td>
</tr>
<tr>
<td>Option 2</td>
<td>Close one of three lanes in each direction on mainline Kenilworth and supplement with two-lane service roads per direction</td>
<td>327</td>
<td>Low-risk</td>
<td>1</td>
</tr>
<tr>
<td>Option 3</td>
<td>Close 2 of 3 lanes in each direction on mainline Kenilworth and supplement with two-lane service roads per direction</td>
<td>183</td>
<td>Low-risk</td>
<td>2</td>
</tr>
<tr>
<td>Option 4</td>
<td>Full closure of this segment of Kenilworth and divert traffic through detour</td>
<td>Eliminated</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Option 5</td>
<td>Close one of three lanes in each direction during nighttime only.</td>
<td>Eliminated</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
Questions
APPLICATION OF WZ RUC IN CONTRACTING/PROJECT DELIVERY
WZ RUC vs Project Completion Time

- Early completion
- Savings
- Baseline duration
- Additional costs
- Delays

WZ RUC ($)
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**
- Design-bid-build
- Design-build (DB)
- Construction manager/general contractor (CMGC)

**Construction techniques**
- Cast in-place
- Accelerated technique

**Contracting methods**
- 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

<table>
<thead>
<tr>
<th>Project size</th>
<th>Is project routine or innovative?</th>
<th>Certain over design scope?</th>
<th>In-house design?</th>
<th>Early cost certainty?</th>
<th>Certain over constructability?</th>
<th>Suggested strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small-medium</td>
<td>Routine</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>DBB</td>
</tr>
<tr>
<td>Small-medium</td>
<td>Innovative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-large</td>
<td>Routine</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>DBB/DB/CMGC</td>
</tr>
<tr>
<td>Medium-large</td>
<td>Innovative</td>
<td>Yes</td>
<td></td>
<td>No</td>
<td></td>
<td>DBB</td>
</tr>
<tr>
<td>Medium-large</td>
<td>Innovative</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td>DB</td>
</tr>
<tr>
<td>Medium-large</td>
<td>Innovative</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
<td>CMGC</td>
</tr>
<tr>
<td>Medium-large</td>
<td>Innovative</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td>CMGC</td>
</tr>
<tr>
<td>Medium-large</td>
<td>Innovative</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
<td>CMGC</td>
</tr>
</tbody>
</table>

**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

**Note:**

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

- Decision matrix focuses only on shortening completion time
- Actual selection may require more comprehensive evaluation
### Step 3: Select a Contracting Method

<table>
<thead>
<tr>
<th>Baseline Project duration</th>
<th>Time sensitivity</th>
<th>Complete Early</th>
<th>Intermediate Phases</th>
<th>Detours impractical/long, Urban commuter traffic</th>
<th>Owner’s confidence on estimated duration</th>
<th>Suggested Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>Yes</td>
<td>Yes</td>
<td>Critical</td>
<td>Yes - Full closure required</td>
<td>High</td>
<td>(A+B) / No Excuse Incentives/ (I/D) + Accelerated Construction</td>
</tr>
<tr>
<td>Long</td>
<td>No</td>
<td>No</td>
<td>Not critical</td>
<td>Yes-full closure not required</td>
<td>Low</td>
<td>(I/D) + LR</td>
</tr>
</tbody>
</table>

#### 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

\[
\text{Cost of Acceleration (CA)} \leq I/D \leq \text{WZ RUC}
\]

\[
I/D = \text{Discount Factor} \times \text{WZ RUC}
\]
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

<table>
<thead>
<tr>
<th>Actual days to complete the project (normal = 60 days)</th>
<th>Discount Factors</th>
<th>0.1</th>
<th>0.2</th>
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#### Agency’s savings and losses

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<th>Actual days to complete the project (normal = 60 days)</th>
<th>Discount Factors</th>
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<td>-47</td>
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<td>-54</td>
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</tbody>
</table>

**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.**

**Incentive to complete early goes up with increasing discount factor.**

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

**Green ➔ profits**

**Red ➔ losses**
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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Closed</th>
<th>Opened</th>
<th>Daily WZ RUC for the given closure period</th>
<th>Difference in daily WZ RUC between actual and allowable closure periods</th>
<th>Estimated maximum queue length (miles)</th>
<th>Estimated maximum delay time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early Closure</strong></td>
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<td></td>
<td></td>
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<tr>
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<td>$1,518,188</td>
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<td>$637,237</td>
<td>$564,946</td>
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<tr>
<td>10 pm</td>
<td>5 am</td>
<td></td>
<td>$72,291</td>
<td>$0</td>
<td>2.2</td>
<td>35.6</td>
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<tr>
<td><strong>Failure to Open</strong></td>
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<tr>
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<td>$72,511</td>
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<tr>
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<td>$169,696</td>
<td>$97,405</td>
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<td>10 pm</td>
<td>9 am</td>
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<td>$350,813</td>
<td>$278,522</td>
<td>13.1</td>
<td>138.8</td>
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</table>
### I-66 Pavement Rehabilitation

#### Lane Rental Fee Computation – Three lane Closure

<table>
<thead>
<tr>
<th>Condition</th>
<th>Lane Closure Timings</th>
<th>Difference in daily WZ RUC between actual and allowable closure periods</th>
<th>VDOT Lane Rental Fee</th>
<th>Lane Rental Fee</th>
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<tr>
<td></td>
<td>Closed</td>
<td>Opened</td>
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<td>DF=0.25</td>
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<tr>
<td>Allowable Closure (baseline)</td>
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<td>5 am</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td>Failure to Open</td>
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<td>6 am</td>
<td>$220</td>
<td>$9,000</td>
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<td>7 am</td>
<td>$17,537</td>
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<td>8 am</td>
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<td>10 pm</td>
<td>9 am</td>
<td>$278,522</td>
<td>$68,000</td>
</tr>
</tbody>
</table>

整改原因：
- 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

<table>
<thead>
<tr>
<th>Case</th>
<th>Project Completed in (days)</th>
<th>Days saved/delayed</th>
<th>I/D</th>
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<tbody>
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<tr>
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<td>$90,364</td>
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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
- Preliminary design and engineering
- Construction costs
- Mobilization
- Construction engineering
- Traffic control
- Law enforcement

### WZ RUC
- 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

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Cast In-place Scenario</th>
<th>Accelerated Construction Scenario</th>
<th>Savings</th>
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<td>Net Savings</td>
<td>$3,480,756</td>
<td>$1,087,147</td>
<td>$1,016,211</td>
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</table>

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

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Principal Engineer  
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THANK YOU!