Transportation Decision-making – Principles of Project Evaluation and Programming

Safety Impacts of Transportation Interventions

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Introduction
**Introduction (1)**

**FATALITIES**
- 40,000 fatalities per year
- 95% are highway-related (BTS)
- For people < 65 yrs, transportation accidents is the 3rd leading cause of death (after cancer and heart disease)

**INJURIES**
- 3 Million injuries per year
- 98% are highway-related (USDOT)
Nationwide economic cost of transportation crashes

- Borne by individuals, insurance companies, and government

- Consists of Tangible and Intangible Costs
  - **Tangible costs:** market productivity, property damage, loss of household productivity and workplace costs
  - **Intangible costs:** pain and suffering, and loss of life

- **Total of $230 billion**
  - approximately $820 per person
  - 2% of the Gross Domestic Product
How did it get so bad?

- Most roads were designed & built decades ago
- Changed demand volumes, vehicle features, traffic flow patterns
- Standards used for original design now outdated
- Thus, inadequate road geometry, driver information deficiencies, lack of passing opportunities, traffic conflicts due to driveways, etc., etc.
- Many existing roads have these operational and safety deficiencies

Fortunately...

Transportation interventions can help improve safety
Transportation interventions can directly influence safety? How?

1. PHYSICAL IMPROVEMENTS

- Projects that increase capacity: these reduce congestion, reduce congestion-related crashes. E.g., highway lane addition for highways, airport runway expansions, transit line increase/extensions

- Localized interventions that reduce crash situations. E.g., signal operations improvement, channelization, turning lanes, passing lanes, and passing restrictions.

- Asset preservation projects improve condition and extend asset service life of assets, creating safer operating environments E.g., reconstruction, replacement, and rehabilitation of roadway, runways, docks, or guideways).
Transportation interventions that directly influence safety (continued)

2. OPERATIONAL IMPROVEMENTS

- Operational changes that reduce likelihood of crashes.
  E.g., roadway/runway/railtrack monitoring and response systems to identify and clear any obstructions (debris, animals, disabled vehicles) on these guideways.

- Policy-related interventions that are expected to affect traffic safety.
  E.g., for highway transportation, this could be a change in speed limits, traffic calming initiatives, lane restrictions by vehicle size, etc.
Operational Improvements that directly influence safety (continued)
Basic Definitions and Factors of Transportation Safety
Definition of a Crash

- Is the basic unit for measuring transportation safety
- Defined as a collision involving at least one moving “transportation vehicle” and another vehicle or object.
- Includes non-collision off the transportation path, such as a roll-over of a vehicle over an embankment
- “Transportation vehicle” includes car, truck, plane, boat, rail car, etc.
General Classification of Crash Severity

- **Fatal crash**: the highest casualty level is a fatality.

- **Injury crash**: the highest casualty level is a non-fatal injury.

- **Property-damage-only (PDO)**: involves a loss of all or part of the transporting vehicle and/or property but no injury or fatality.
Other Classifications of Crash Severity

**Abbreviated Injury Scale (AIS)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Severity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 6</td>
<td>Fatal</td>
<td>Loss of life due to decapitation, torso transaction, massively crushed chest, etc.</td>
</tr>
<tr>
<td>AIS 5</td>
<td>Critical</td>
<td>Spinal chord injury, excessive second or third degree burns, cerebral concussion (unconscious more than 24 hrs)</td>
</tr>
<tr>
<td>AIS 4</td>
<td>Severe</td>
<td>Partial spinal cord severance, spleen rupture, leg crush, chest wall perforation, cerebral concussion (unconscious less than 24 hours).</td>
</tr>
<tr>
<td>AIS 3</td>
<td>Serious</td>
<td>Major nerve laceration; multiple rib fracture, abdominal organ contusion; hand, foot or arm crush/amputation</td>
</tr>
<tr>
<td>AIS 2</td>
<td>Moderate</td>
<td>Major abrasion or laceration of skin, cerebral concussion finger or toe crush/amputation, close pelvic fracture</td>
</tr>
<tr>
<td>AIS 1</td>
<td>Minor</td>
<td>Superficial abrasion or laceration of skin, digit sprain, first-degree burn, head trauma with headache or dizziness</td>
</tr>
<tr>
<td>AIS 0</td>
<td>Uninjured</td>
<td>No injury</td>
</tr>
</tbody>
</table>
## Other Classifications of Crash Severity

### Kabco Scale (AIS)

<table>
<thead>
<tr>
<th>Code</th>
<th>Severity</th>
<th>Injury Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Fatal</td>
<td>Any injury that results in death within 30 days of crash occurrence.</td>
</tr>
<tr>
<td>A</td>
<td>Incapacitating</td>
<td>Any injury other than a fatal injury which prevents the injured person from walking, driving, or normally continuing the activities the person was capable of performing before the injury occurred. e.g., severe lacerations, broken limbs, skull, etc.</td>
</tr>
<tr>
<td>B</td>
<td>Injury Evident</td>
<td>Any injury, other than a fatal injury or an incapacitating injury which is evident to observers at the scene of the crash in which the injury occurred. e.g., abrasions, bruises, minor cuts etc.</td>
</tr>
<tr>
<td>C</td>
<td>Injury Possible</td>
<td>Any injury reported which is not a fatal, incapacitating or non-incapacitating evident injury. e.g., pain, nausea, hysteria etc.</td>
</tr>
<tr>
<td>O</td>
<td>Property Damage Only</td>
<td>Property damage to property that reduces the monetary value of that property.</td>
</tr>
</tbody>
</table>
Factors Affecting Transportation Safety

**Engineering**
- Roadway/Guideway Geometry
- Roadway/Runway/Guideway Surface Condition
- Crash Barriers/Safety Nets, etc., for Roadway and Runway

**Environment**
- Visibility
- Ice
- Path-crossing Birds and Animals

**Policy**
- Speed Limits
- Differential Speed Limits
- Large-Vehicle Dimensions
- Managed Lanes

**Driver/Operator/Pilot Characteristics**
- Traffic Safety Education
- Age
- Sobriety
- Incapacitation
- Fatigue

**Transporting Vehicle Characteristics**
- Age
- Safety Features
- Size/Dimensions

**Enforcement**
- Frequency of Patrols
- Driver/Operator/Pilot Licensing
- Restrictions
The Engineering Factors - Highway Example

- **Carriageway**: Lane width, pavement surface type, pavement friction
- **Median**: Median width and type
- **Exposure**: Section length, section traffic volume
- **Alignment**: Vertical slope and sight distance, horizontal sight distance and curve characteristics
- **Shoulder**: Shoulder type, shoulder width, shoulder rumble strips
- **Roadside Features**: Side slopes, ditches, obstructions (fences, road signs, etc.), utility poles
- **Traffic Control Devices**: Pavement markings, road signs, etc.
- **Technology**: Fixed infrastructure or in-vehicle cautionary or guidance devices
Procedural Framework for Safety Impact Evaluation
Procedural Framework For Safety Impact Evaluation

Step A3: Establish the Base Case Scenario (No Intervention)

Step A4: Establish the Intervention Scenario

Step A5: Estimate the Number of Crashes for the Base Case

Step A6: Estimate the Number of Crashes with Intervention

Step A7: Determine the Change in Engineering Factor Dimension due to the Intervention

Step B3: Identify all Engineering Factors to be Changed by the Intervention

Step B4: Determine the Change in Engineering Factor Dimension due to the Intervention

Step B5: Establish the Crash Reduction Factors

Either

Approach A
(The Crash Rate/Equation)

Or

The Crash Reduction Factor (CRF) Approach

Step B6: Apply CRFs to Factor Change

Step B7: Establish Crash Reduction Factors

Step 7: Determine the Change in Safety Levels due to the Intervention

Step 8: Establish the Monetary Cost of Each Crash

Step 9: Determine Overall Safety Cost Savings (or Increase) due to the Intervention

(Apply Unit Crash Costs to Change in Safety Levels)
Example of Approach A

A 6-mile urban “minor arterial” highway section is to receive major upgrading that will improve the design standards to the freeway and expressway category.

Assume that crash reduction factors for the individual treatments associated with the upgrade are unknown, and crash prediction equations for both facility types are not available.

Estimate the number of crashes with and without the upgrade. Assume traffic volumes of 7,520 and 7,800 vpd before and after the upgrade, respectively.
Motor Vehicle Traffic Fatality and Injury Rates by Functional Class (FHWA)

<table>
<thead>
<tr>
<th>Area Class</th>
<th>Functional Class</th>
<th>Number of Crashes (per 10^6 VMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fatal</td>
</tr>
<tr>
<td>Rural</td>
<td>Interstate</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Other Principal Arterial</td>
<td>1.96</td>
</tr>
<tr>
<td></td>
<td>Minor Arterial</td>
<td>2.33</td>
</tr>
<tr>
<td></td>
<td>Major Collector</td>
<td>2.51</td>
</tr>
<tr>
<td></td>
<td>Minor Collector</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>3.52</td>
</tr>
<tr>
<td>Urban</td>
<td>Interstate</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Other Freeway &amp; Expressways</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Other Principal Arterial</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>Minor Arterial</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>Collector</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>1.33</td>
</tr>
</tbody>
</table>
Solution

No local safety information available => national crash rates used

Use Table 6-3:

Without Improvement:
For urban minor arterials, rate of fatal crashes = 1.08 per 10^6 VMT
Annual VMT = 7,520,600*365 = 16,468,800
Number of fatal crashes expected per annum = 16,468,800 * 1.08 = 18

With Improvement:
For urban freeways and expressways, rate of fatal crashes = 0.75 per 10^6 VMT
Annual VMT = 7,800,600*365 = 17,082,000
Number of fatal crashes expected per annum = 17,082,000 * 0.75 = 13

These numbers can be used to determine the safety benefit of the improvement and its corresponding monetary value (Steps 7, 8, and 9).
Example 2 for Approach A

In a bid to reduce congestion, it is proposed to add a lane to an existing urban freeway that currently has a volume-capacity ratio of 1.15.

It is expected that after the capacity expansion, the volume-capacity ratio would fall to 0.75.

Determine the percentage change in crash rate.
Solution

\[ \frac{V_0}{C_0} = \text{volume-capacity ratio without imprvt.} = 1.15 \]
\[ \frac{V_1}{C_1} = \text{volume-capacity ratio with improvement} = 0.75 \]

Using the equation in Table 6-4, the reduction in crash rate is given by:

\[
\% \Delta C = 100 \left( \frac{3.0234 \times 0.75 - 1.11978 \times (0.75)^2}{3.0234 \times 1.15 - 1.11978 \times (1.15)^2} - 1 \right) = 17.95\%
\]
Example 3 of Approach A

A rural 6-mile long interstate road segment has a traffic volume of 25,000 per day.

As part of a corridor improvement project, the existing shoulder width is widened from 4ft to 8ft. Estimate the number of fatal crashes with and without the improvement.

Use the crash rates in Table 6-3 and the accident modification factors in Appendix 6-3. Assume that the VMT remains the same.
Solution

From Table 6-3, fatal crash rate for rural interstates = 1.05 per million VMT

Without Improvement:

Expected number of fatal crashes = 1.05(25,000,3656)/1000,000 = 57
Accident Modification Factor for 4ft. shoulders = 1.15
Modified expected number of fatal crashes = 571.15 = 66

With Improvement:

Expected number of fatal crashes = same as above = 57
Accident Modification Factor for 8ft. shoulders = 0.87
Modified expected number of fatal crashes = 570.87 = 50
Approach B of the Procedural Framework

Step A3
Establish the Base Case Scenario (No Intervention)

Step A4
Establish the Intervention Scenario

Step A5
Estimate the Number of Crashes for the Base Case

Step A6
Estimate the Number of Crashes with Intervention

Step A7
Determine Overall Safety Cost Savings (or Increase) due to the Intervention

Step B3
Identify all Engineering Factors to be Changed by the Intervention

Step B4
Determine the Change in Engineering Factor Dimension due to the Intervention

Step B5
Establish Crash Reduction Factors

Step B6
Apply CRFs to Factor Change

Step 7
Determine the Change in Safety Levels due to the Intervention

Step 9
(Apply Unit Crash Costs to Change in Safety Levels)
Example 1 for Approach B

An intersection improvement project in a certain city is proposed.

It involves the provision of left-turn lanes at the signalized intersection between two major urban arterials.

Also, the signal timing was redesigned to include a dedicated green phase for left-turns. Currently, there are 55 fatal/injury crashes per year at the intersection.

What reduction in fatal/injury crashes can be expected due to the project?
Solution

- If $CW$ and $CWO$ are the number of crashes at similar sites that are with improvement and without improvement, respectively, at a given time, the crash reduction can be given by:

$$CRF = \left( \frac{C_{WO} - C_W}{C_{WO}} \right) \times 100 = \left( 1 - \frac{C_W}{C_{WO}} \right) \times 100$$

- From Appendix 6-1, the appropriate CRF is 0.67.

$$\Rightarrow C_{WO} - C_W = \left( \frac{CRF \times C_{WO}}{100} \right) = \frac{67 \times 55}{100} = 37$$

- Estimated number of crashes saved due to improvement = 37 fatal/injury crashes per year.
Example 2 for Approach B

Stretch of an existing multi-lane urban minor arterial highway is to have a median installed, full control of access from local roads.

Also, pavement is to be resurfaced to improve skid resistance.

Assuming the effects of such improvements on safety are mutually exclusive and complementary, determine the safety impacts of the corridor improvement project in terms of total crashes.

The total number of crashes is 23 per year without the improvement.
Solution

From Appendix 6-1, the crash reduction factors are:

- Median installation: 25% \(\Rightarrow\) 6 crashes saved
- Resurfacing (to improve surface friction): 10% \(\Rightarrow\) 2 crashes saved

Total reduction in total crashes \(= 6 + 3 = 8\)

Number of crashes after improvements \(= 23 - 8 = 15\)

Therefore, there are 23 and 15 crashes without and with improvement, respectively.

These numbers can be used to determine the safety benefit of the improvement and the corresponding monetary value of this benefit (see Steps 7 and 9).
How are the “Safety Benefits” Determined? (Step 7)

Safety benefits of the transportation project = 0.5(U₁ - U₂)*(V₁ + V₂)

U₁ and U₂ = unit “costs” of safety (e.g., nr. of crashes per million VMT per year) without and with the improvement,

V₁ and V₂ are the travel demand values (millions of VMT) without and with the improvement, respectively.
Step 8 Establish the Unit Monetary Crash Cost

What is the cost in dollars, of:
- a fatality crash
- an injury crash
- a crash that involves property damage
How to develop a cost for each crash severity type

- Insurance
- Medical Costs
- Loss of market productivity,
- Any damage to property
- Loss of household productivity
- Loss to workplace
- Pain and suffering
## Unit Crash Costs

<table>
<thead>
<tr>
<th>Code</th>
<th>Severity</th>
<th>Unit Cost (2005$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Fatal</td>
<td>$3,654,299</td>
</tr>
<tr>
<td>A</td>
<td>Critical</td>
<td>$181,276</td>
</tr>
<tr>
<td>B</td>
<td>Severe</td>
<td>$46,643</td>
</tr>
<tr>
<td>C</td>
<td>Serious</td>
<td>$22,201</td>
</tr>
<tr>
<td>PDO</td>
<td>Moderate</td>
<td>$2,116</td>
</tr>
</tbody>
</table>

(updated from NSC, 2001).
Example

The injury crash rate with and without the improvement project at a rural 2 lane highway is 2.87 and 3.5 per million VMT, respectively.

Determine the safety benefits in monetary terms due to the reduction in the injury crashes.

Assume average vehicle occupancy rate = 1.00. Annual VMT is 1.5 million and 1.8 million for the without-improvement and with-improvement scenarios, respectively.
Solution

Crash rate without improvement = 3.5 per million VMT
Crash rate with improvement = 2.87 per million VMT

Safety savings (reduction in nr. of crashes)
\[= 0.5 (U_1 - U_2) (VMT_1 + VMT_2) = 0.5 (3.5 - 2.87) (1.5 + 1.8) = 1.04\]

From the Table showing Unit Crash Costs,
Average cost of injury crash = $150,270.

Injury crash cost savings = 1.04 * $150,270 = $156,281 due to the improvement project in the first year.
Safety Related Legislation
Legislation that influenced Transportation Safety

1991 Intermodal Surface Transportation Efficiency Act (ISTEA)
- Helped establish safety management systems at various states
- Helped establish databases and knowledge bases needed for systematic safety impact evaluation of transportation projects.

1998 Transportation Equity Act for the 21st Century (TEA-21)
- Focused on 5 deployment goals designed to improve the efficiency, safety, reliability, service life, environmental protection, and sustainability of the nation’s surface transportation system.

2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)
- Reaffirmed national emphasis on transportation safety.
- Established core Highway Safety Improvement Program to reduce highway fatalities.
- Doubled funds for safety infrastructure
- Required results-driven strategic highway safety planning.
Software Packages for Safety Impact Evaluation
The Interactive Highway Safety Design Model (IHSDM)

The 2006 release of IHSDM may be downloaded free-of-charge at http://www.ihsdm.org. User technical support is also available free-of-charge. An IHSDM Training Course is available through the FHWA’s National Highway Institute.
The Interactive Highway Safety Design Model (IHSDM)

- Used to assess safety impacts of geometric design decisions
- Checks existing or proposed designs against design policy values
- Estimates expected safety performance of new designs
- Helps transportation planners to incorporate safety considerations in project selection.
- Contains modules for crash prediction, design consistency monitoring, driver/vehicle interaction, and intersection safety diagnostics.
- Version 3d focuses on rural two-lane highways (future versions expected to include other road classes).
The Indiana’s Safety Management System (SMSS)
The Indiana’s Safety Management System (SMSS)

- Has modules for assessing project-level or network-level safety impacts of transportation projects
- Modules include needs assessment (physical and monetary), safety monitoring and crash prediction, hazardous location identification, and optimal allocation of safety resources at network level
- Determines the safety effect of individual treatments
- Produces outputs that can be used for economic efficiency analysis of transportation projects.