DEFINITIONS OF SAFETY MEASURES

Step 1 – Identify Potential Sites

- Measure accident experience by;
  - Total number of crashes
  - Crash density (crashes per mile)
  - Crash rate
    - Crashes per million vehicle miles (segments)
    - Crashes per million entering vehicles (intersection)

Step 1 – Identify Potential Sites

- Measure accident experience by;
  - Number quality control
  - Rate quality control
  - Crash severity
  - Severity index
    - Ratio of injury and fatal crashes to total crashes

Problems Using Crash Counts

- Observed accident counts
  - Common method to rank accident locations
  - Lack of accuracy in accident reports
  - Must be normalized to common basis
- Regression to-the-mean phenomenon
  - An unusually high count is likely to decrease without improvement
  - Such location may not require improvement

Example of Regression to-the-Mean

- Crash data for 1974-76 and 1977 for 1072 San Francisco intersections
- No real change in average accidents per intersection from 1974-77 remained essentially constant at 1.1 accidents/intersection/year

Table A-1. Illustrating the Regression-to-the-Mean Phenomenon

Number of intersections	Accidents/ intersection in 1974-76	Accidents/year/ intersection in 1974-76	Accidents/ intersection in 1977	% Change
256	0	0	0.25	Large increase
218	1	0.33	0.55	67%
173	2	0.67	0.70	Small increase
121	3	1.00	1.04	Small increase
97	4	1.33	1.08	–19%
70	5	1.67	1.33	–20%
54	6	2.00	1.56	–22%
32	7	2.33	2.25	–3%
29	8	2.67	1.62	–39%

Normalize Crash Counts to Crash Density

- Crash frequency must be normalized to common section length and time period, i.e., crash density
- For example;

Location	Section Length	AADT	PDO	Injury A	Injury B	Injury C	F	# Acc	# Yrs	acc/mi/yr
A	0.8 mi	4200	12	1	2	1	0	16	3	6.67
B	1.2 mi	3500	15	0	2	3	1	21	2	8.75
C	2.2 mi	2400	22	0	1	4	0	27	1.5	8.18

Crash Rates for Highway Sections

- Accident experience for highway sections may be represented as;

$$\frac{\text{Crashes}}{\text{million veh miles}} = \frac{\text{Crashes}}{365(\text{Period})(\text{ADT})(\text{LNG})/1{,}000{,}000}$$

Location	Period, yrs	Section Length, mi	AADT, vpd	Total Accidents	Crash, million veh miles
A	3.0	0.8	4200	16	4.35
B	2.0	1.2	3500	21	6.85
C	1.5	2.2	2400	27	9.34

Average Crash Rates

Accident Rates and Costs by Road Type

Location and Road Type	Fatal Accidents Number per MVM	Injury Accidents Number per MVM	Property Damage Only Accidents Number per MVM	Total Accidents Number per MVM
Rural				
No Access Control				
2 lanes	0.07	0.94	1.39	2.39
4 or more lanes, undiv.	0.05	0.89	1.95	2.89
Partial Access Control Divided expressway	0.04	0.44	0.76	1.24
Freeway	0.03	0.27	0.49	0.79

Source: NHI, 2005

Crash Rates for Spot Locations

- Accident experience at intersection locations may be represented as

$$\frac{\text{Crashes}}{\text{million entering vehicles}} = \frac{\text{Crashes}}{365(\text{Period})(\text{ADT})/1{,}000{,}000}$$

Crash Rate Calculation: Intersection

Example: For N = 25 crashes for 3 years

ADT (N) = 10,000 ADT (S) = 9,000

ADT (E) = 3,500 ADT (W) = 4,000

Sum (ADT)s=(10,000+9,000+3,500+4,000)

= 26,500

$CR = N / \{[\text{Sum (ADT)s} /2] \times 365 \times 10^{-6}\}$

$CR = 25/ \{26{,}500/2] \times 3 \text{ yrs} \times 365 \times 10^{-6}\}$

CR = 1.72 crashes per million entering vehicles

2-17

Source: NHI, 2005

Typical Collision Types at Rural Intersections

TABLE 59 Variation in accident type and rate with type of control—rural municipalities (*128*)

Type of Control	Accident Type - Percent of Total				Accident Rate (accidents per million entering vehicles)
	Rear-End	Angle	Sideswipe	Other	
Traffic Signal	43	37	12	8	1.26
Yield or Stop Sign	29	49	10	12	1.08

2-18

Source: NHI, 2005

Average Intersection Crash Rates

- Average of 1.5 crashes per year for Un-Signalized Intersections in rural areas– recent California analysis*
- Average of 2.5 crashes per year in urban areas

***NCHRP 500, Volume 5: A Guide for Addressing Unsignalized Intersection Collisions, 2003.**

2-19

Source: NHI, 2005

Problems Using Accident Rates

- Accident rates are based on observed counts therefore regression-to-the-mean difficulty applies
- Relationship between accident frequency and ADT is not linear
- Therefore, accident rates at different volume levels may not give a true picture
  - Low ADT likely to give high accident rate

Problem with Using Accident Rates

- Non-linearity
  - Lack of linearity between accident frequency and AADT

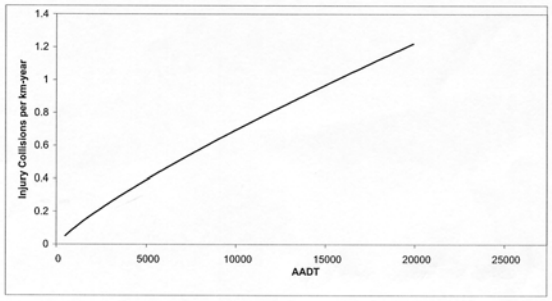

Figure A-1. Safety Performance Function for Two-Lane Rural Arterial Highways in Ontario

Safety Performance Functions
~ *Highway Segments* ~

- Level 1: Relationship for previous figure is

$$SPF = Acc/yr = (length) \times a(AADT)^{b}$$

- Level 2: General relationships of the form

$$SPF = Acc/yr = (length)\ a(x_1)^{b1}\ (x_2)^{b2}\ldots(x_n)^{bn}$$

where

$a, b^1, b^2, \ldots, b^n$ are parameters

$x_1, x_2, \ldots, x_n$ are traffic and geometric variables

Safety Performance Functions
~ Intersections ~

- Level 1

$$SPF = Accidents/yr = a(AADT)^{b}$$

- Level 2

$$SPF = Accidents/yr = a(AADT_{MAJ})^{b1}\ (AADT_{MIN})^{b2}$$

Crash Reduction Factors (CRF)

- CRF = expected percent decrease in a particular type of crash after a countermeasure is employed

Accident Modification Factor (AMF)

- Base condition of AMF is 1.0
- Example
  - An improvement that decreases accident frequency by 10% would have an AMF = .90
  - An increase in accident frequency of 10% would have AMF – 1.10

Relation of CRF to AMF

- CRF = 1 – AMF
- Other terms
  - CMF (crash modification factor) is same as AMF
  - ARF (accident reduction factors) is same as AMF

Multiple Countermeasures Effects

- Conservative estimate assumes largest CRF is most effective
- This approach is pessimistic
- Cannot warrant adding more than one countermeasure by its form
  - Safest effect not always provided by building just one countermeasure

Compound Multiple Countermeasure Effect

- Aggregate countermeasure effect
  - Multiplication compound effect

$$CRF_{COM} = 1 - (1-CRF_1)\,(1-CRF_2)$$

Example

$CRF_1 = 0.20$; $CRF_2 = .25$

$CRF_{COM} = 1 - (1-.2)\,(1-.25)$

$CRF_{COM} = .40$

Accident Severity Indicated By

- Fatalities
- Injuries
- Property damage only

Injury Accidents May Be Further Stratified

- Injury type A – incapacitating
- Injury type B – non-incapacitating
- Injury type C – possible injury

Severity Index

Severity index (SI) is the ratio of crashes involving an injury or fatality to total crashes

TABLE 14 Default distribution for accident severity level used in RSRAP (7)

Accident severity level	Proportion of total accidents	
	Roadway segments	Intersections
Fatal and injury	0.321	0.397
Property damage only	0.679	0.603
TOTAL	1.000	1.000

2-20

Source: NHI, 2005

FHWA Costs per Accident

Accident Type	
PDO	$2,300
Type C Injury	$22,000
Type B Injury	$42,000
Type A Injury	$208,000
Fatal	$3,000,000

Source: Highway Safety Manual

Traffic Crash Costs:

AIS Level Severity	Descriptor		Cost Per Injury (Dollars)
Property Damage Only			65,000
AIS 3	Serious Injury	(C)	175,000
AIS 4	Severe	(B)	565,000
AIS 5	Critical	(A)	2,290,000
AIS 6	Fatal		3,000,000

2-30

Source: NHI, 2005

Safety Benefits

- Annual safety benefits =

  CRF_F x (fatal acc.) x fatal $

  $+CRF_I$ x (injury acc.) x injury $

  $+CRF_{PDO}$ x (PDO acc.) x PDO $

  OR

- Annual safety benefits =

  CRF x (total acc.) x weighted value accident

PSI_{INDEX} Approach

PSI_{INDEX} = CRF_F x (fatal accident)

+ CRF_I x (injury accident)

+ CRF_{PDO} x (PDO accident)