Road Safety Analysis Methods and Procedures

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Chair, TRB Task Force for the Development of a Highway Safety Manual

Objectives for the Presentation

- Give some background
- Provide an overview of the Highway Safety Manual
- Outline proposed approach to safety prediction method

Structure for the Presentation

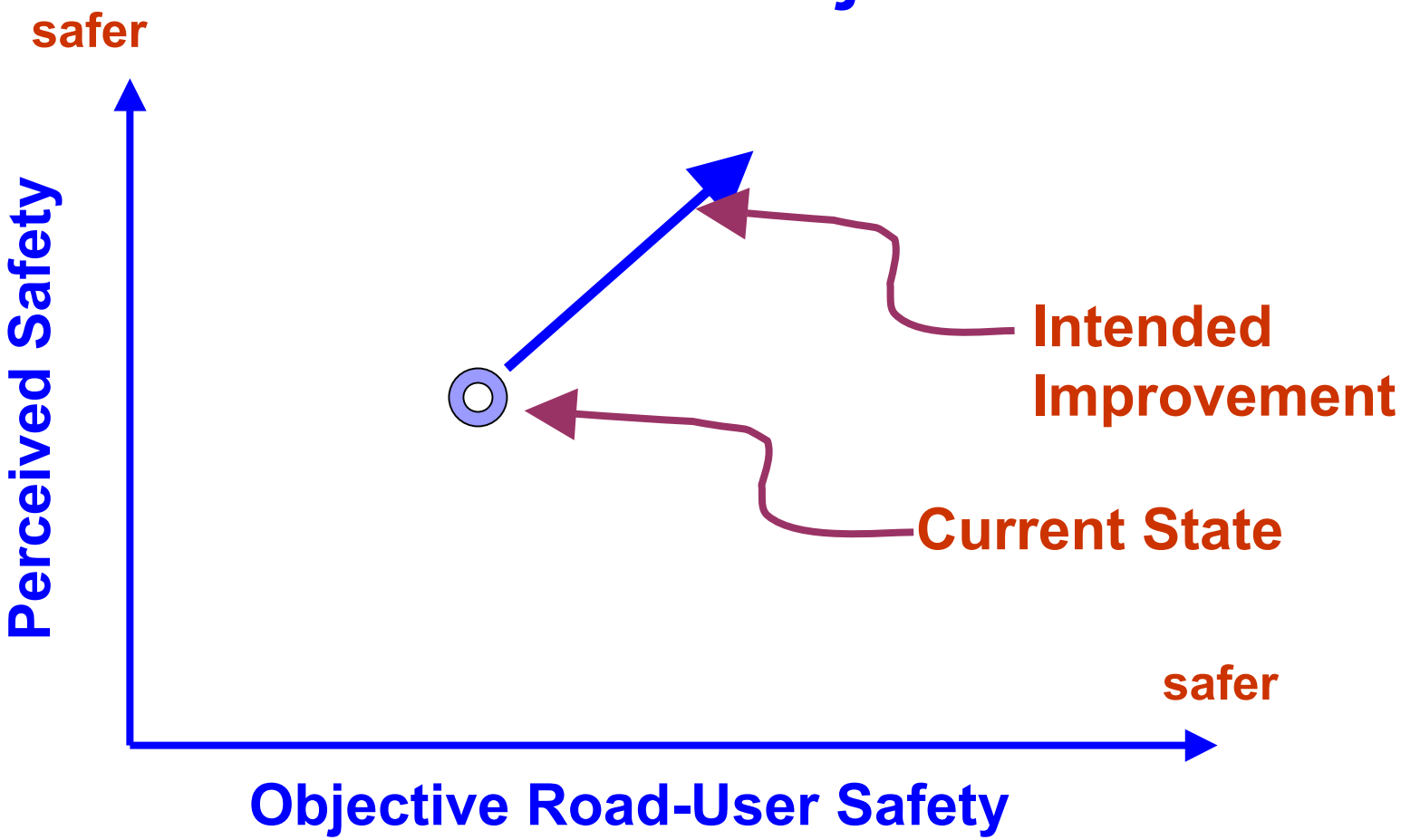
- What do we mean by "SAFETY?"
- Frameworks for safety analysis
- Approaches to safety analysis
- The importance of safety analysis in the road design process
- Developing a Highway Safety Manual

What Do We Mean by “Safety?”

Subjective and Objective Safety

- *Subjective*: How road-user feels
- *Subjective*: How safe we think a design is
  (based upon meeting design criteria)
- *Objective Measure of Safety*:
  - Expected Number of Crashes, by Type and Severity

Perceived and Objective Safety

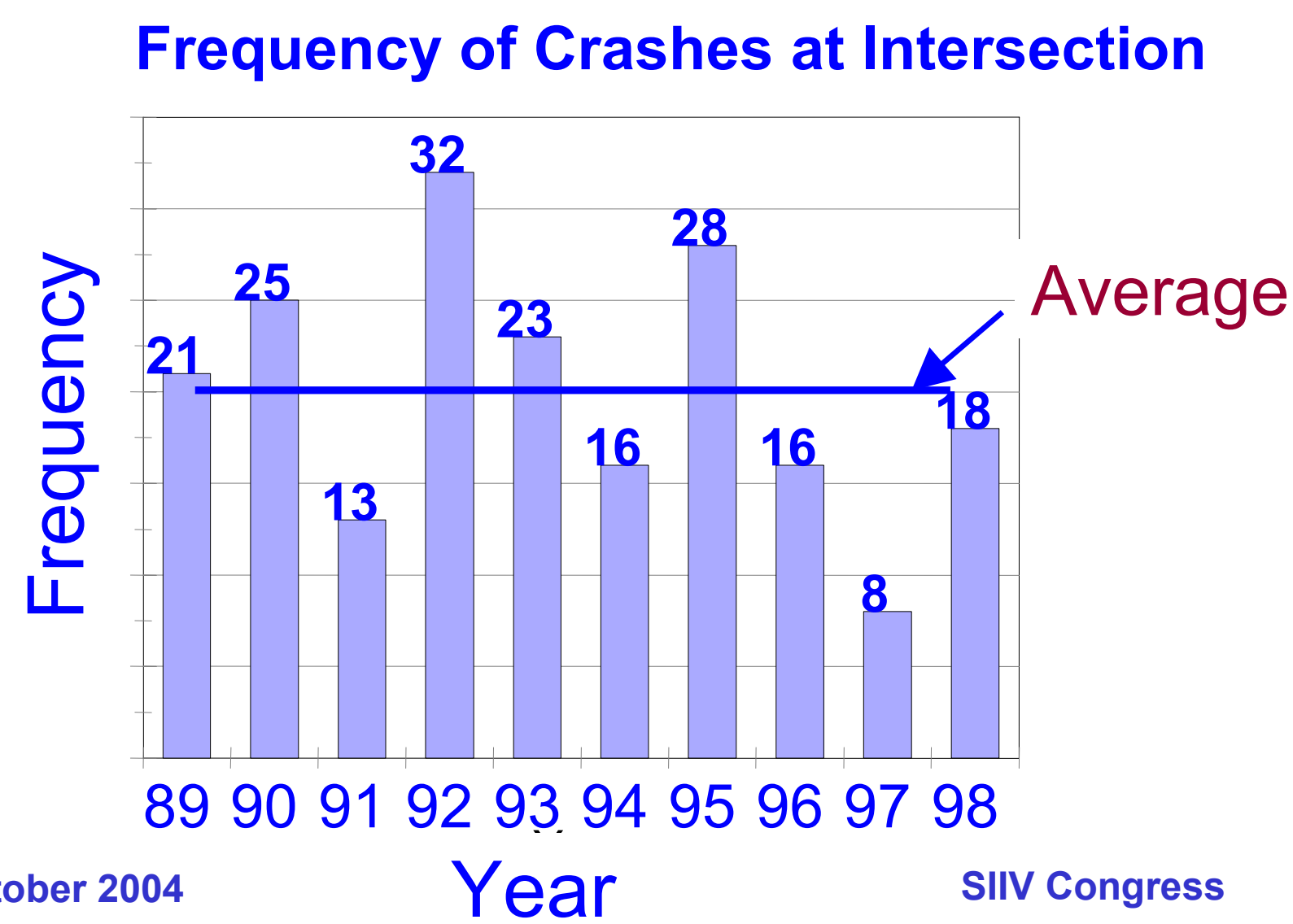


Adapted from Hauer, Observational Before-After Studies in Road Safety

Objective Measure of Safety

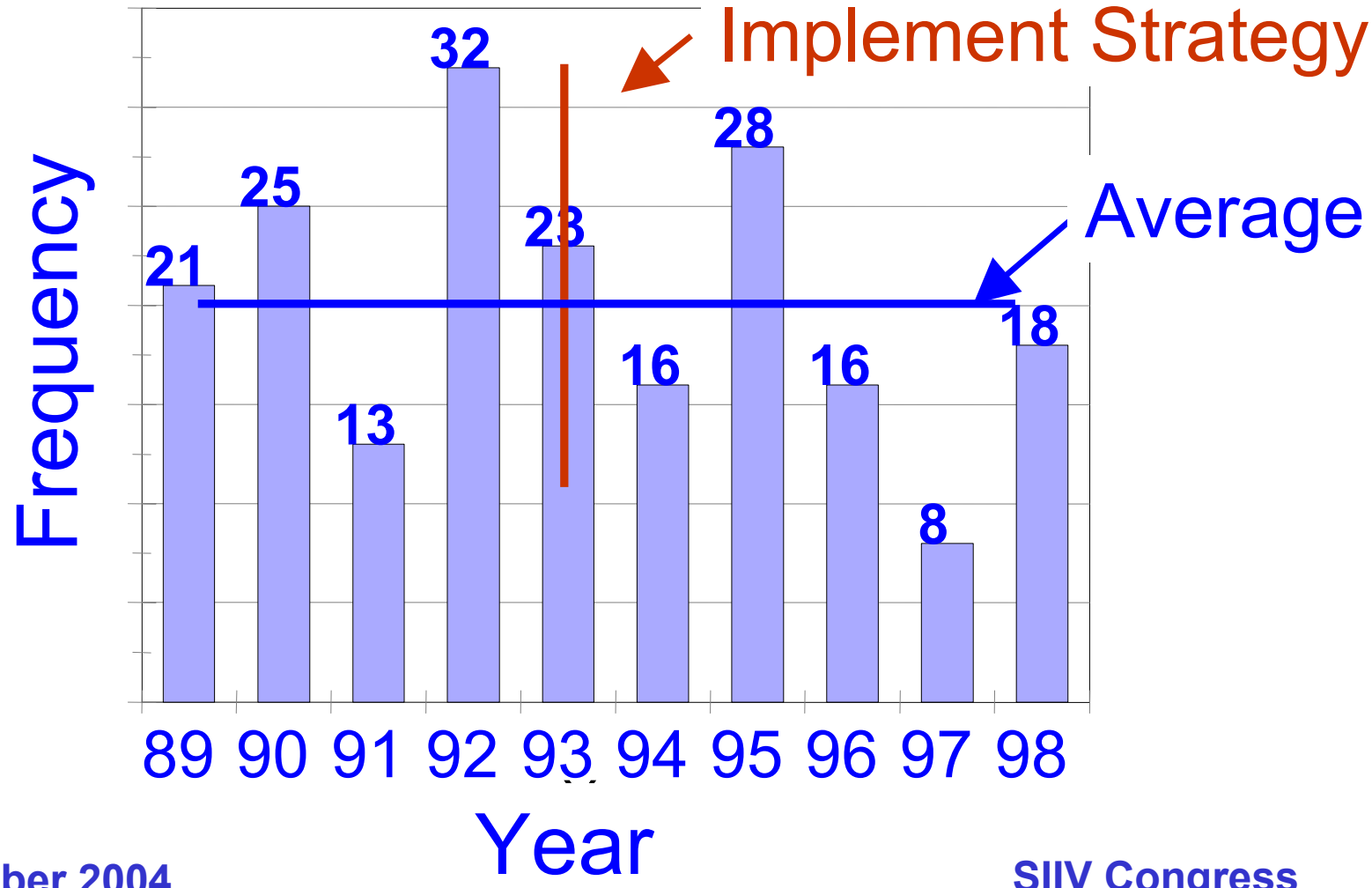
- Crashes are rare events
- An annual count is subject to random variation about a mean for a given time and condition
- Random variation produces **"regression to the mean"**
- A more stable measure is "**expected value**" based upon history & prediction

Random Variation in Annual Count



Regression to the Mean

Frequency of Crashes at Intersection



Bayesian Approach to Expected Value of Safety (History Available)

- Use 2 sources to get expected value
  - Reported crashes at the location
  - The accident frequency expected at similar entities, using a safety performance function (SPF)
- Expected Value = Weighted Average of the two clues

Bayesian Approach to Expected Value of Safety (History Available)

- *Estimate of the Expected Accidents for an entity*

$$A_E = W*A_{ES} + (1-W)A_C$$

Where:

W = Weight ($0 \leq \text{Weight} \geq 1$)

A_{ES} = Accidents expected on similar entities (Safety Performance Function)

A_C = Count of accidents on this entity

Safety Performance Function

- An equation giving an estimate of, the average accidents/(km-year),
- A function of values for some characteristics of the facility (e.g., ADT, Lane width, . . .) and of several regression parameters.
- Simple Example:

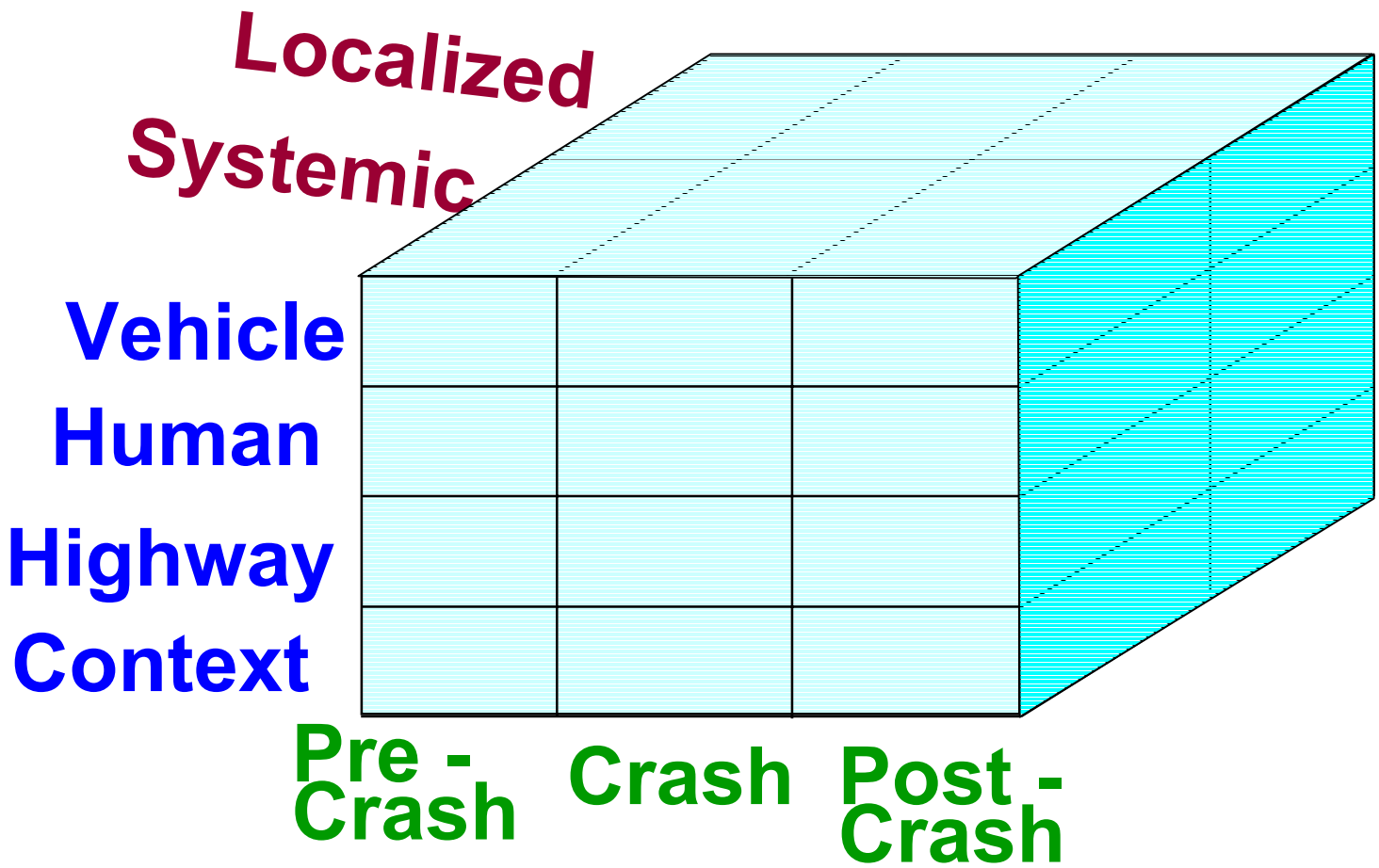
$$A_{ES} = 0.0224 \times ADT^{0.564}$$

ADT = Average Daily Traffic

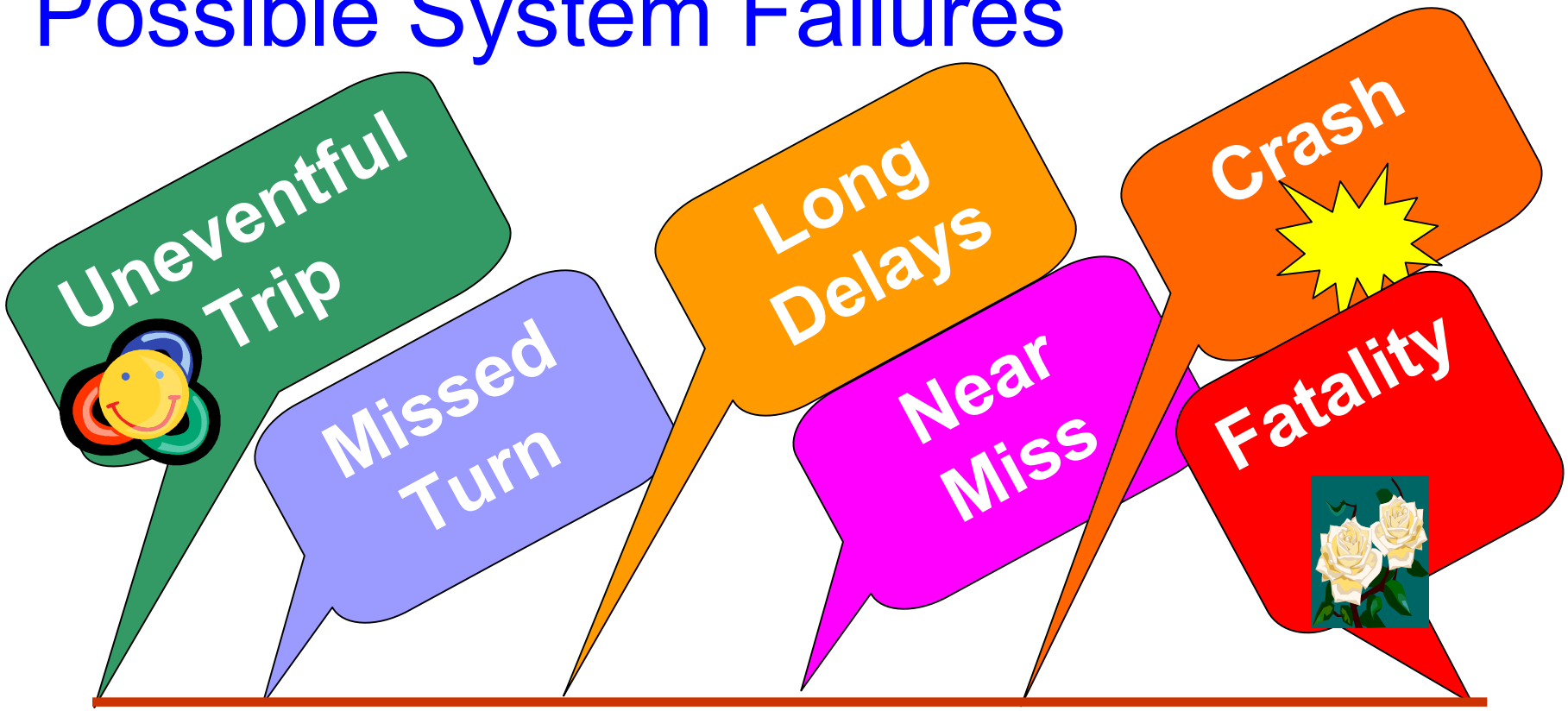
Frameworks for Safety Analysis

Or...Several Ways to Think About Crashes

A Generalized Framework for Road Safety Analysis



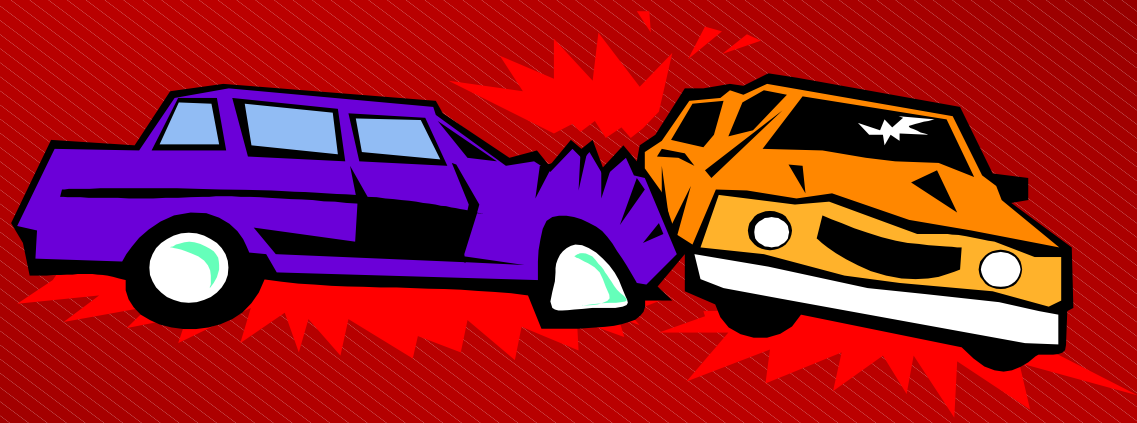
A Crash is an Extreme of a Set of Possible System Failures



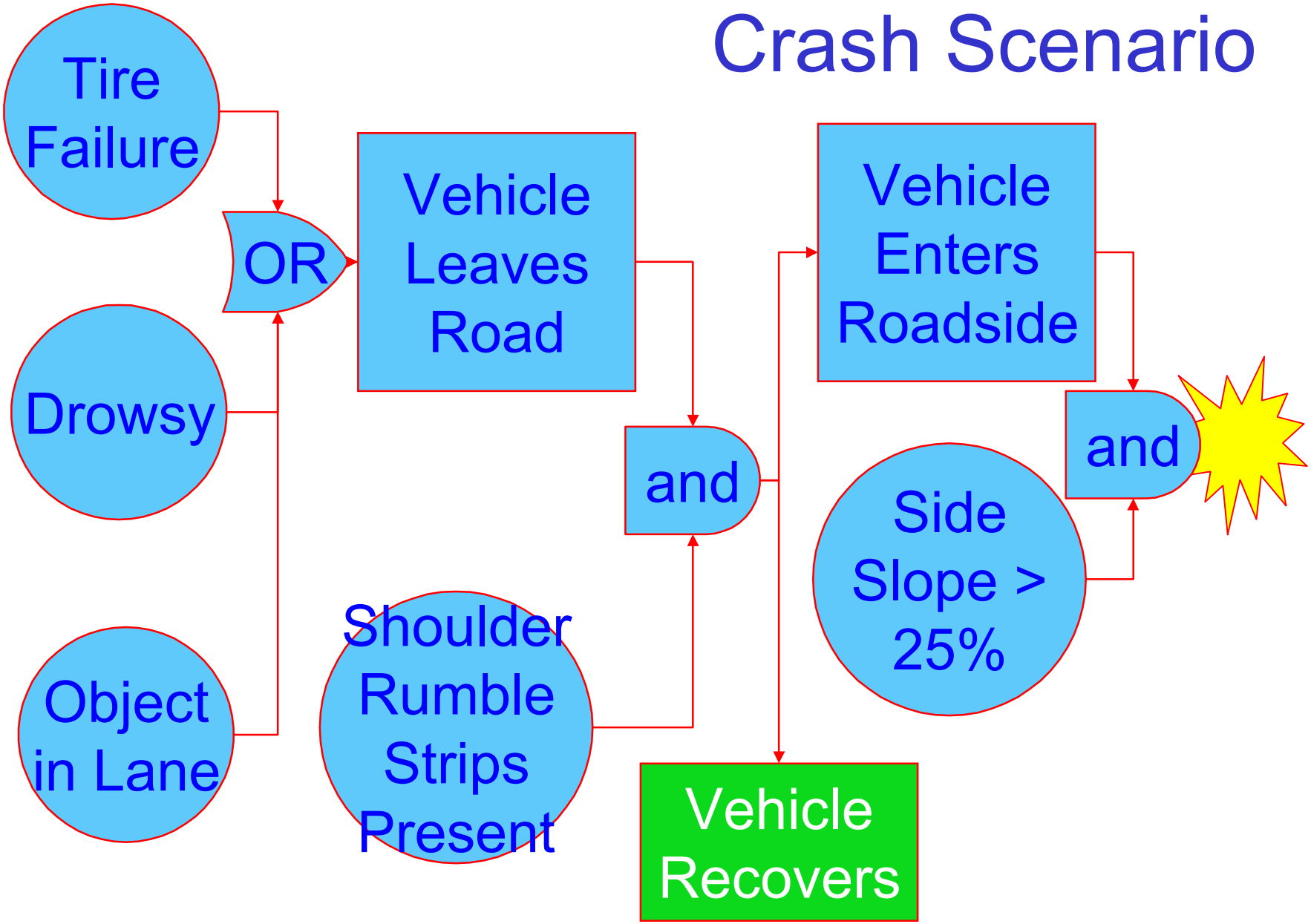
Worse System Failures

A Crash is a Sequence of Events

- At More Than One Location
- Over a Period of Time



Crash Scenario



Approaches to Safety Analysis

Safety Analysis – Assumed Context

- Highway Design
- Improvements to Existing Facilities
- New Facilities
- Not Addressing Strategies Directed at Road-User or Vehicle (But Equally Important)

Non-Quantitative Approaches to Safety Analysis

- Policy Compliance
- Assessment Using Adjunct Principles/Guidelines
  - design consistency
  - driver work load
  - positive guidance
  - other human factors
- Possibly within context of a Safety Audit

Quantitative Approaches to Safety Analysis (Using Objective Measures)

- Crash Reduction Factors (CRF)
- Statistical Models (SPF)
- Simulation (Surrogates)
- Driving Simulators

Crash Reduction Factors - Example

Low Speed Intersections	
Treatment	**% Reduction**
Lighting	15-25
Improved Sight Distance	30-50
Delineation & Signing	10-20

Source: Ogden, Safer Roads, 1996

Mathematical Models – Example Safety Performance Function

- Rural Two-Lane Highway
- Two-Way Stop; 4-Legged Intersection
- Regression Analysis

$$N_{bi} = exp(-9.34 + 0.60 lnADT_1 + 0.61 lnADT_2 + 0.13 ND_1 - 0.0054 SKEW_4)$$

- Others: Neural Network, Genetic Algorithms…

New Safety Analysis Initiative in US – A Highway Safety Manual

- To Use Combination of Statistical Models and Crash Reduction Factors
- Sponsor: The Transportation Research Board (TRB)
- Task Force to Develop a Highway Safety Manual (HSM)
- Main Subject of This Presentation

Review

Review

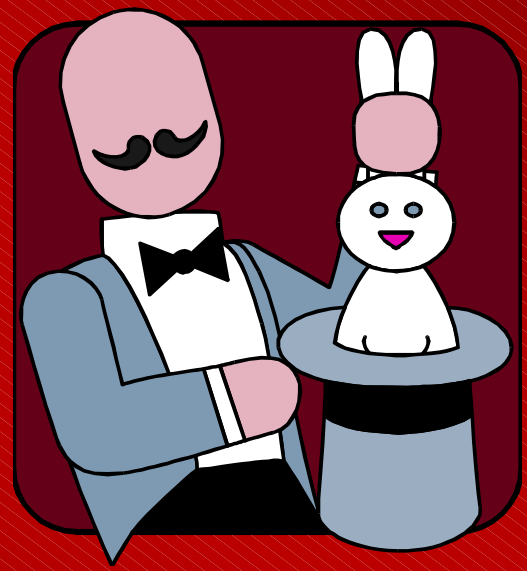
- Need to Recognize the Difference Between Subjective and Objective Safety
- Objective Measures of Safety Should be Based Upon Expected Values
- Crashes Involve a Sequence of Events
- Crashes are System Failures

Review

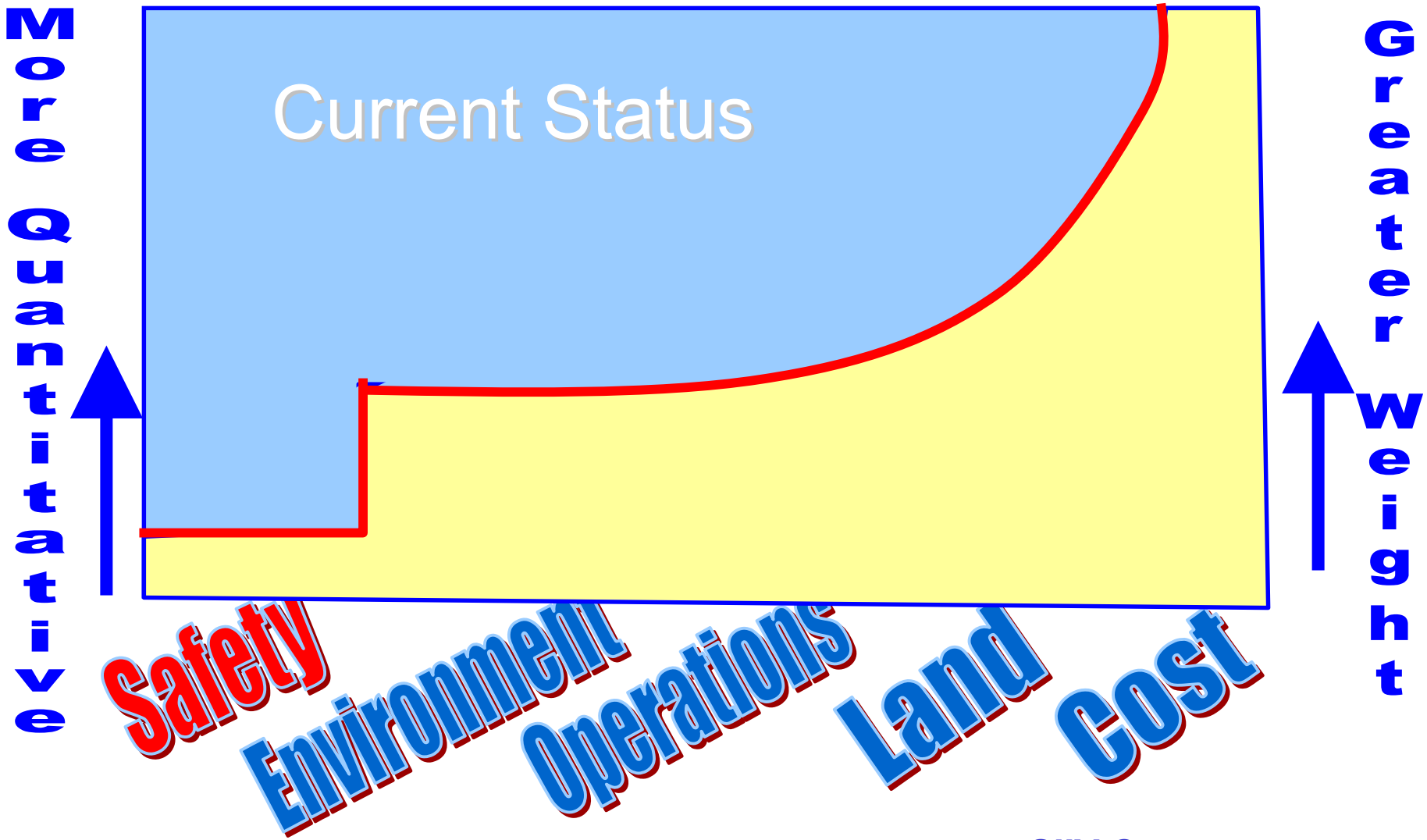
- Safety Analyses Should Look At:
  - the whole system,
  - all phases of the crash
  - both systemic and site specific
- Current Design Process Lacks Adequate Consideration of Safety
- Significant Improvements Needed, to Allow Safety to be Considered Equally
- Quantitative Methods are in Greatest Need of Improvement

Need for an HSM

- Low Confidence in Safety Information



Role of Safety in Design Decisions



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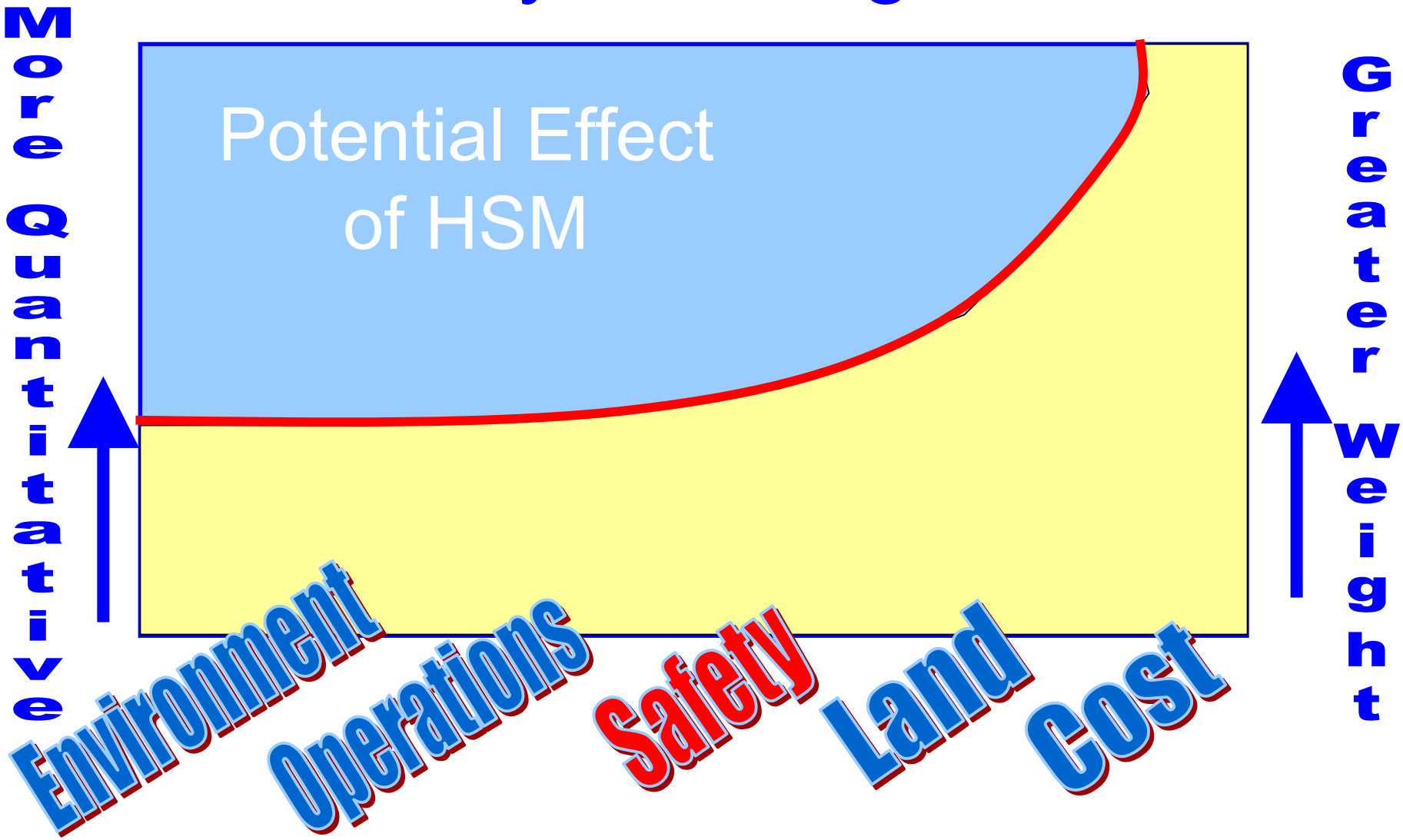


Factors in Favor of a HSM

- New Approaches to Safety Prediction
- New Emphasis on Safety as a Criterion
- Recognized Need to Stop Depending Upon Design Standards as Sole Reflection of Safety
- Need for a Technology Transfer Function

Developing a Highway Safety Manual

October 2004

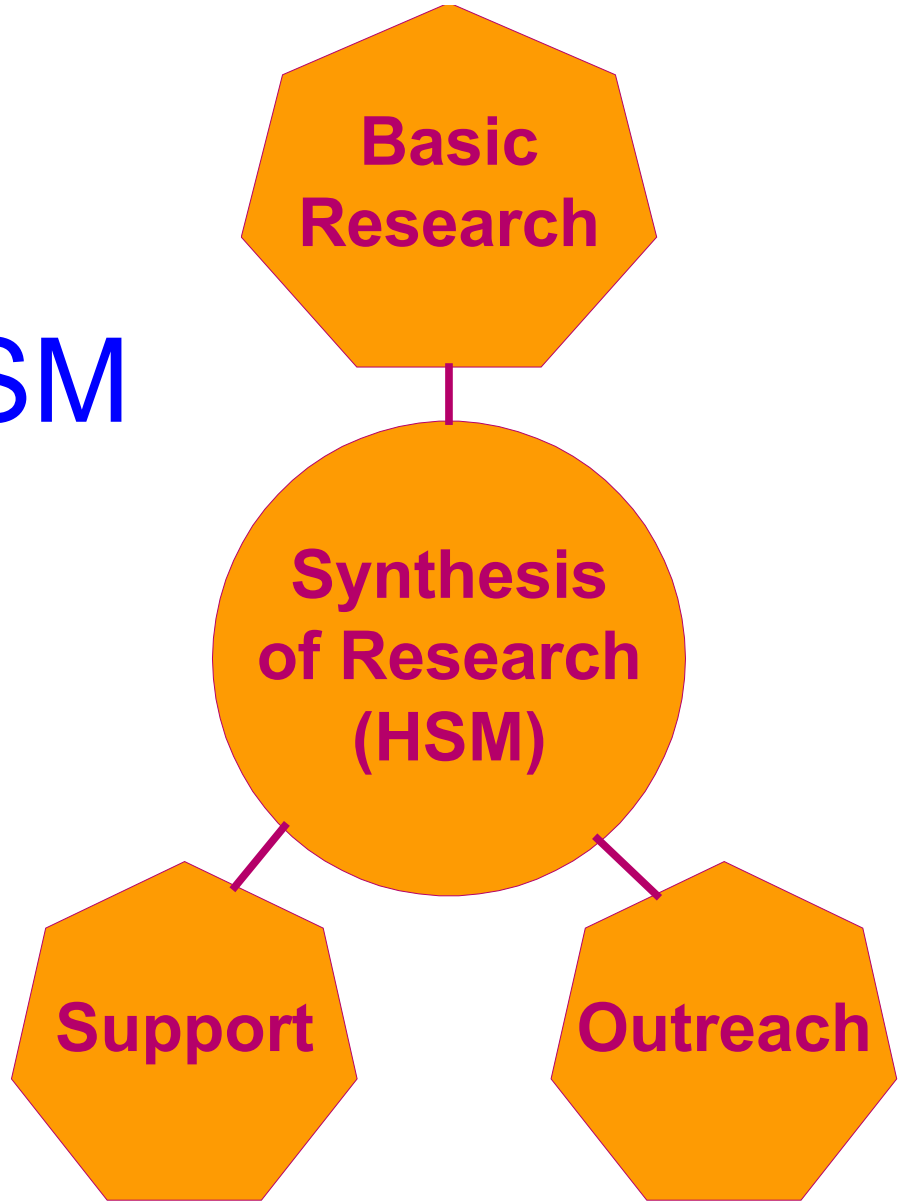
SIIV Congress

Purpose of the HSM?

- To provide the *best factual information* and tools available, in a *useful* form, to facilitate roadway planning, design, operations, and maintenance decisions based upon *explicit consideration of their safety consequences*

Functions to Produce & Implement an HSM

Synthesis of Research is the Core Function



Synthesize Research for Users
The Core Technology Transfer Function

- Analytical Tools - Readily Adapted & Integrated to Operations
- Results are:
  - reasonable
  - useful
  - consistent
  - precise & accurate
- "Validated" by Appropriate Authority(ies) &Institutionalized

Outline for Initial Version of the HSM

Part I – Introduction and Fundamentals

Part II – Knowledge

Part III – Predictive Methods

Part IV – Safety Management of a Roadway System

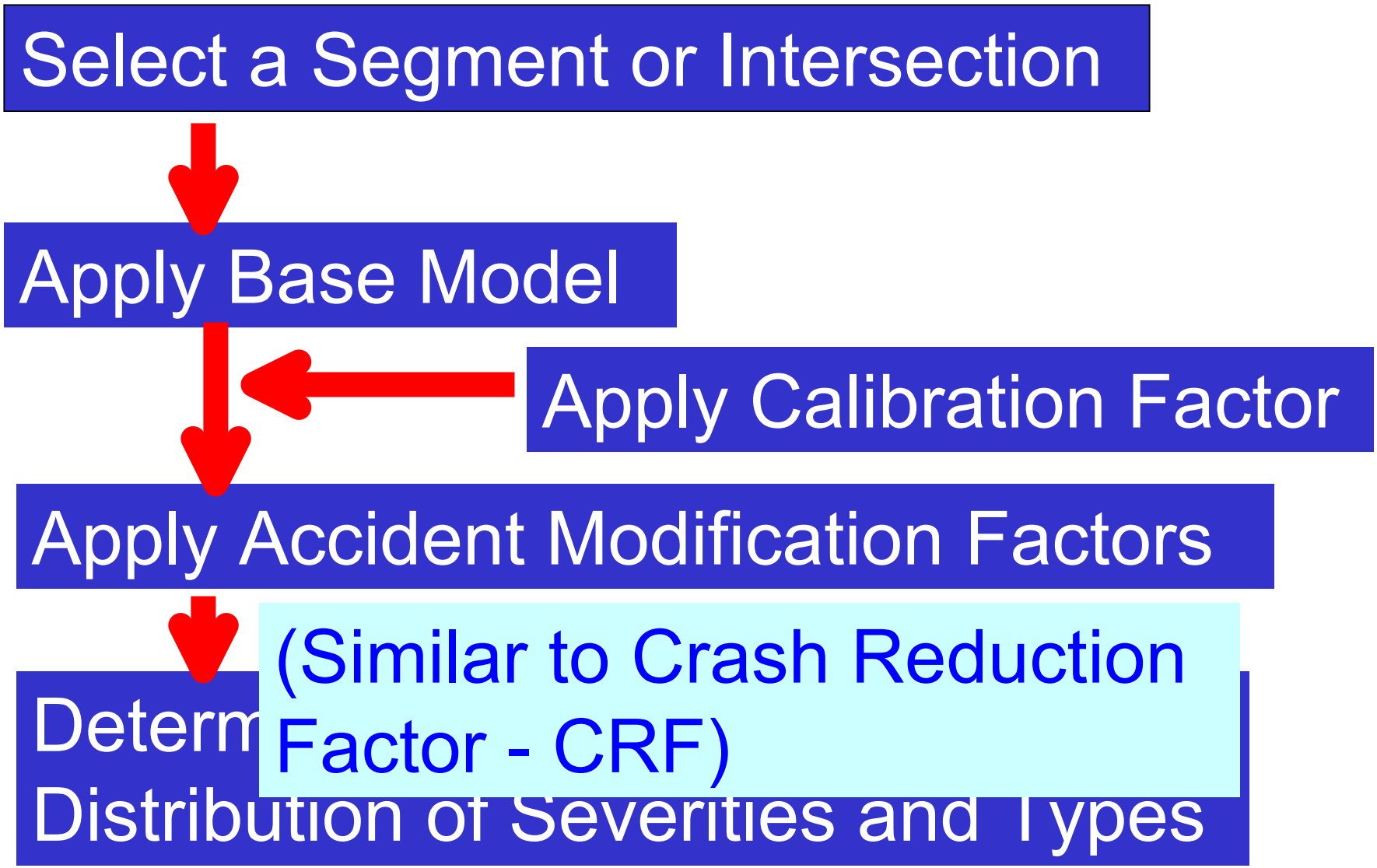
Part V – Safety Evaluation

Glossary

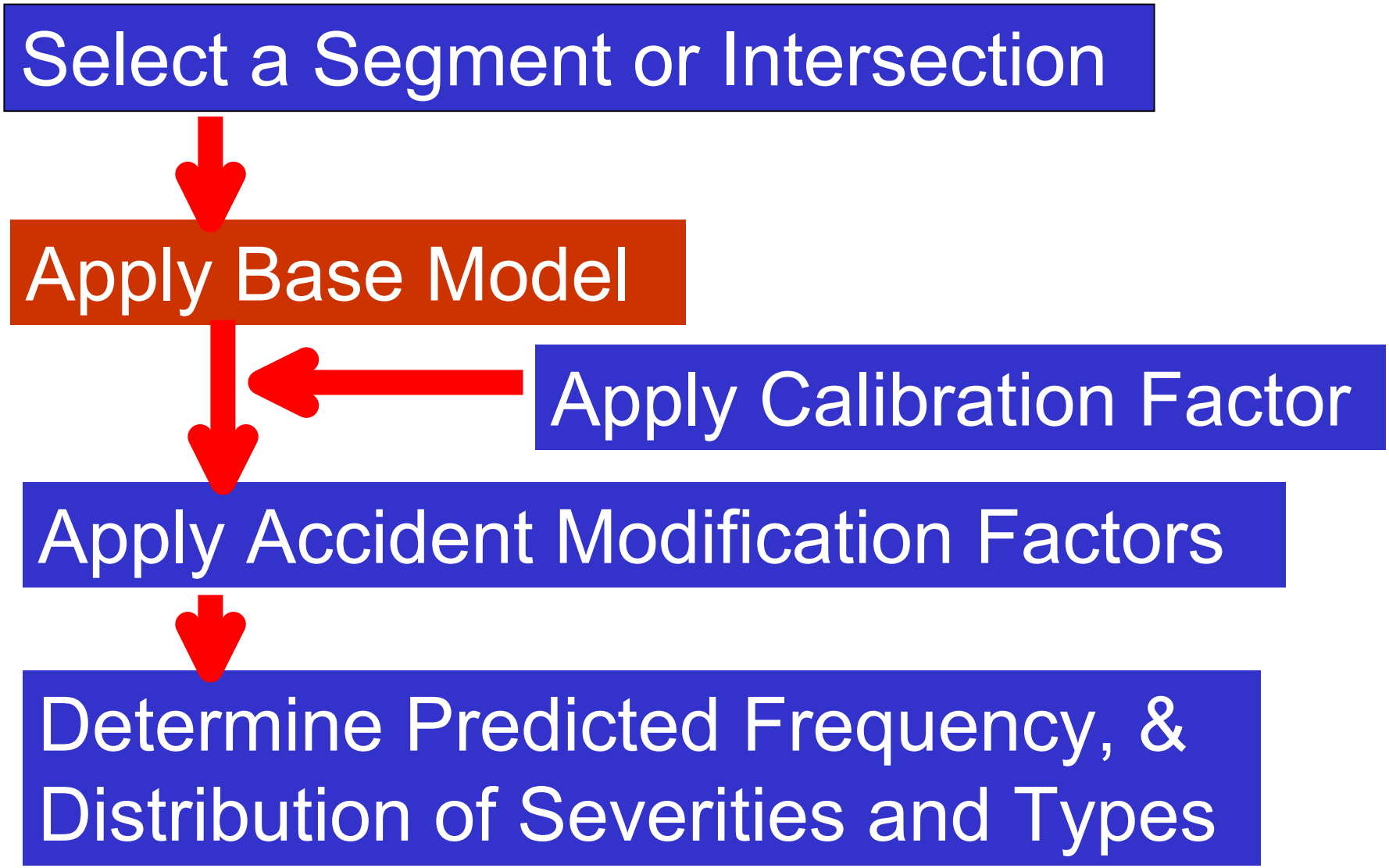
Part III – Predictive Methods (Initial Version)

- Rural Two-Lane Highways
- Urban/Suburban Highways
- Rural Multi-lane Highways
- Applicable for Existing Facilities & Planned Improvements

Proposed Prediction Method



Proposed Prediction Method



Base Models are Derived from General Prediction Models

- Relates Objective Measure to Key Geometric and Operational Features
- Usually Use Regression Analyses
- Used Data from States in a Federal Data Base
- Base Condition Defined and Applied to Regression Equation
- Result is Base Model

Regression Model – Example for Two-Lane Rural Road Segment

- Nbr = EXPOSURE exp (A)(B)
- A= (0.6409 + 0.1388STATE – 0.0846LW – 0.0688RHR + 0.0084DD)
- B=(∏WHiexp(0.0450DEGi))(∏WViexp(0.4652Kj))(∏WGiexp(0.1048GRi))
- WXi are weighting factors for sections along the segment being analyzed

Base Conditions (Not "Ideal")

Variable	Base
Lane width (LW)	12 ft
Shoulder width (SW)	6 ft
Roadside hazard rating (RHR)	3
Driveway density (DD)	5/mi
Horizontal curvature (*DEGi)*	None
Vertical curvature (*Kj)*	None
Grade (*GRi)*	Level

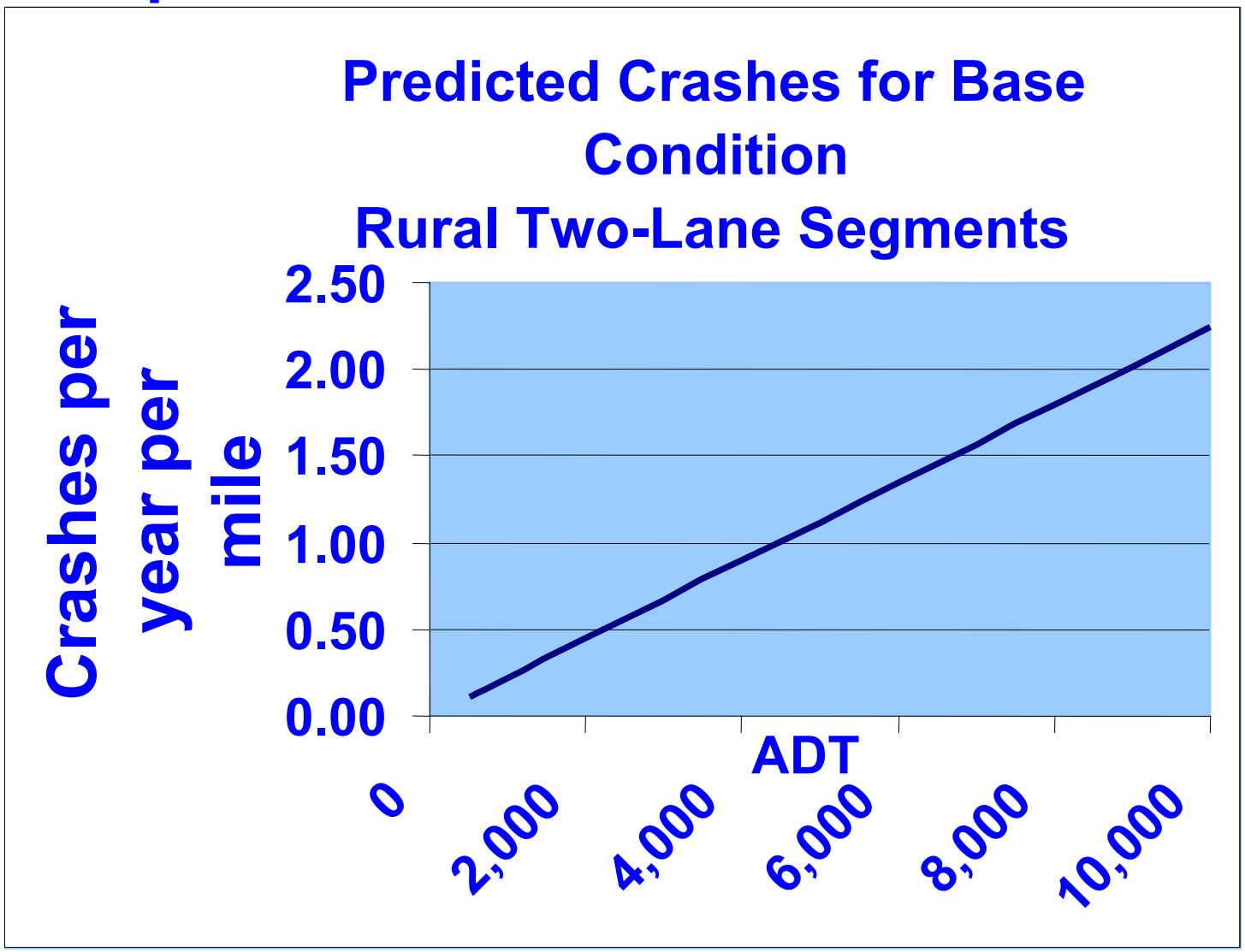
Base Model (Base Conditions) Rural Two-Lane Highways (SPF)

- $Nbr = (ADT)(L)(365)(10^{-6})\ exp(-0.4865)$

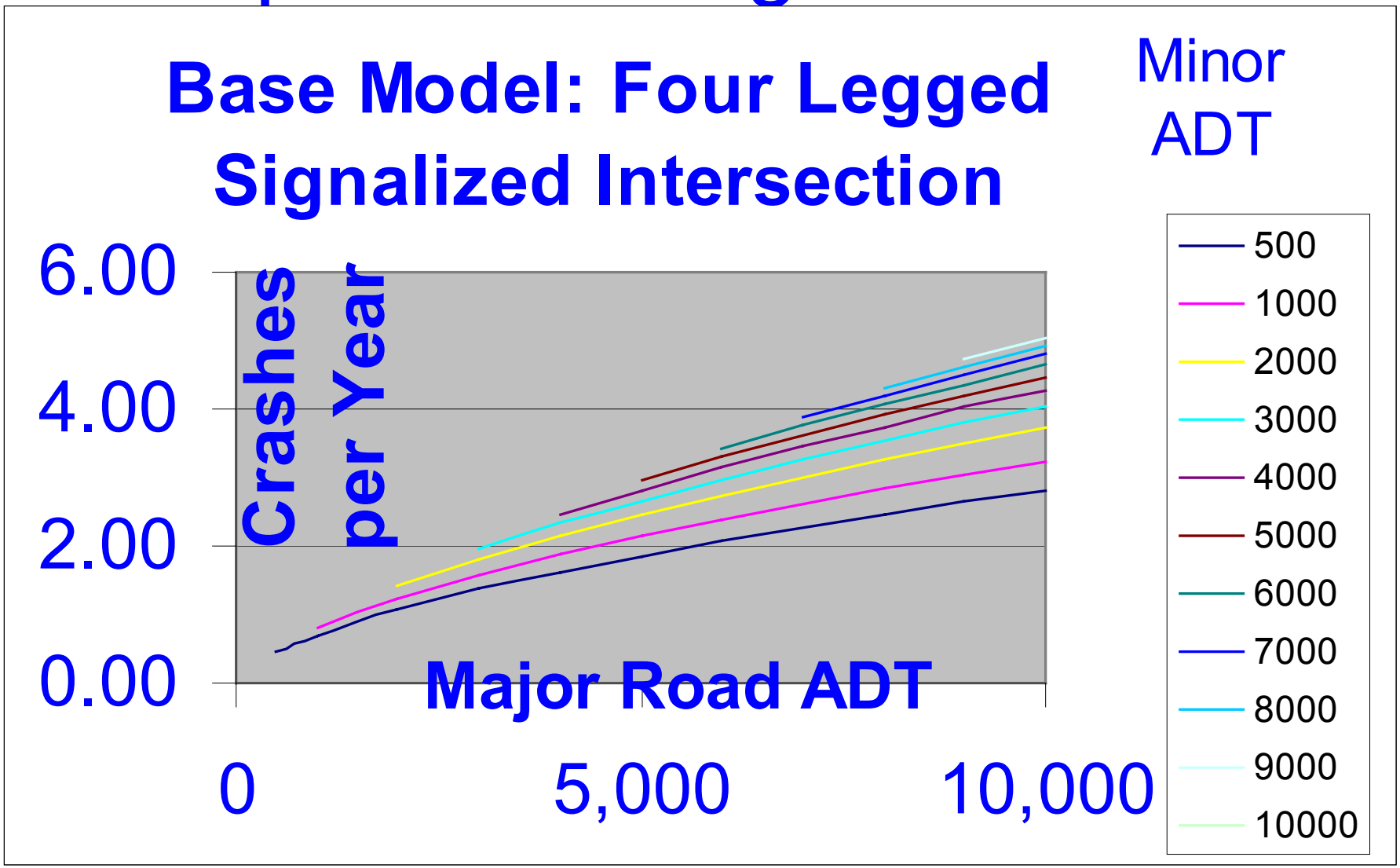
Reduced From

- Nbr = EXPO exp (A)(B) , where:
- A= (0.6409 + 0.1388STATE – 0.0846LW – 0.0688RHR + 0.0084DD)
- B=(∏WHiexp(0.0450DEGi))(∏WViexp(0.4652Kj)) (∏WGiexp(0.1048GRi))

Example SPF


Predicted Crashes for Base Condition
Rural Two-Lane Segments
Crashes per year per mile
2.50
2.00
1.50
1.00
0.50
0.00
ADT
0
2,000
4,000
6,000
8,000
10,000

Example SPF - Signalized



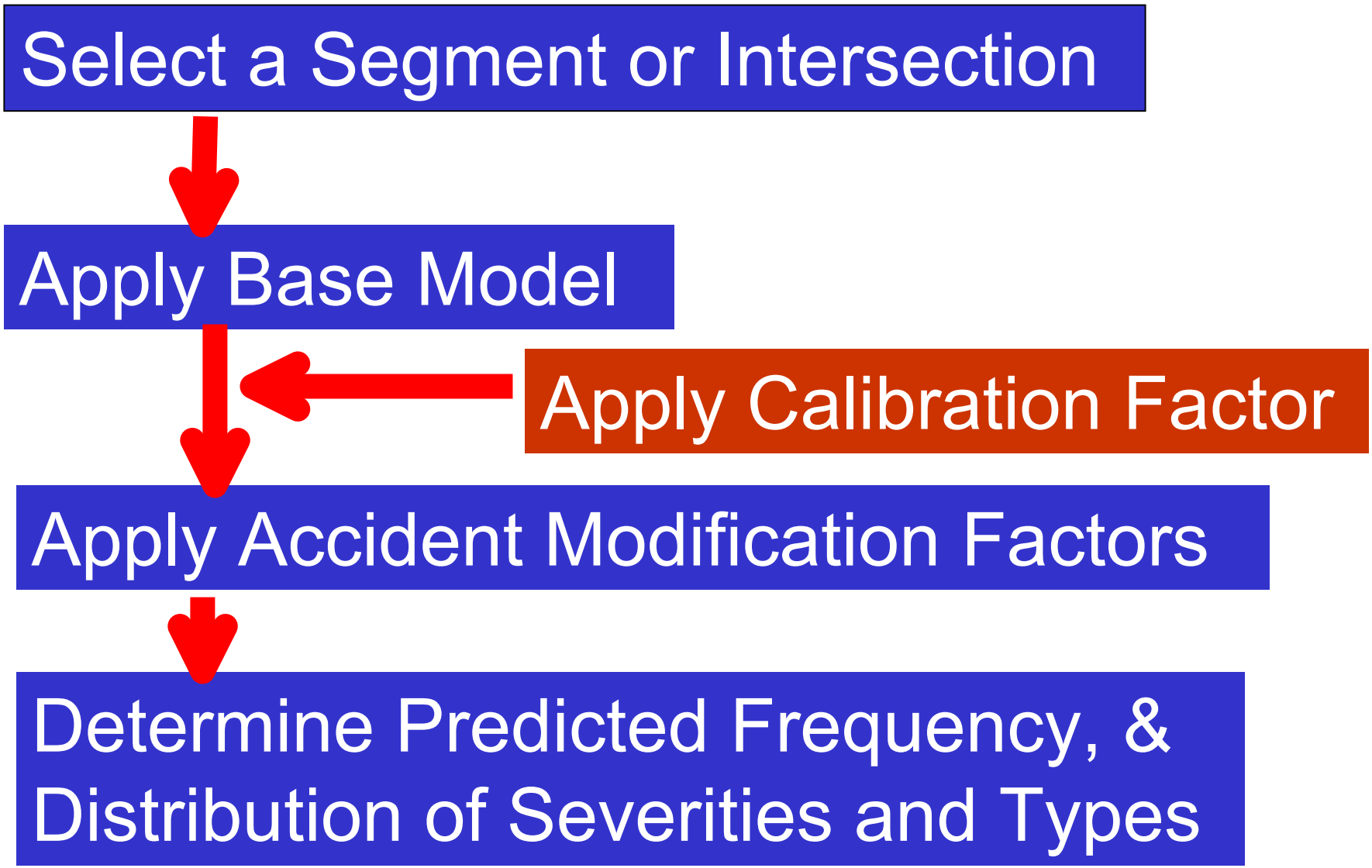
Why Not Just Use Original Equation ?

- Nbr = EXPOSURE exp (A)(B)
- A= (0.6409 + 0.1388STATE – 0.0846LW – 0.0688RHR + 0.0084DD)
- B=(∏WHiexp(0.0450DEGi))(∏WViexp (0.4652Kj))(∏WGiexp(0.1048GRi))
- WXi are weighting factors for sections along the segment being analyzed

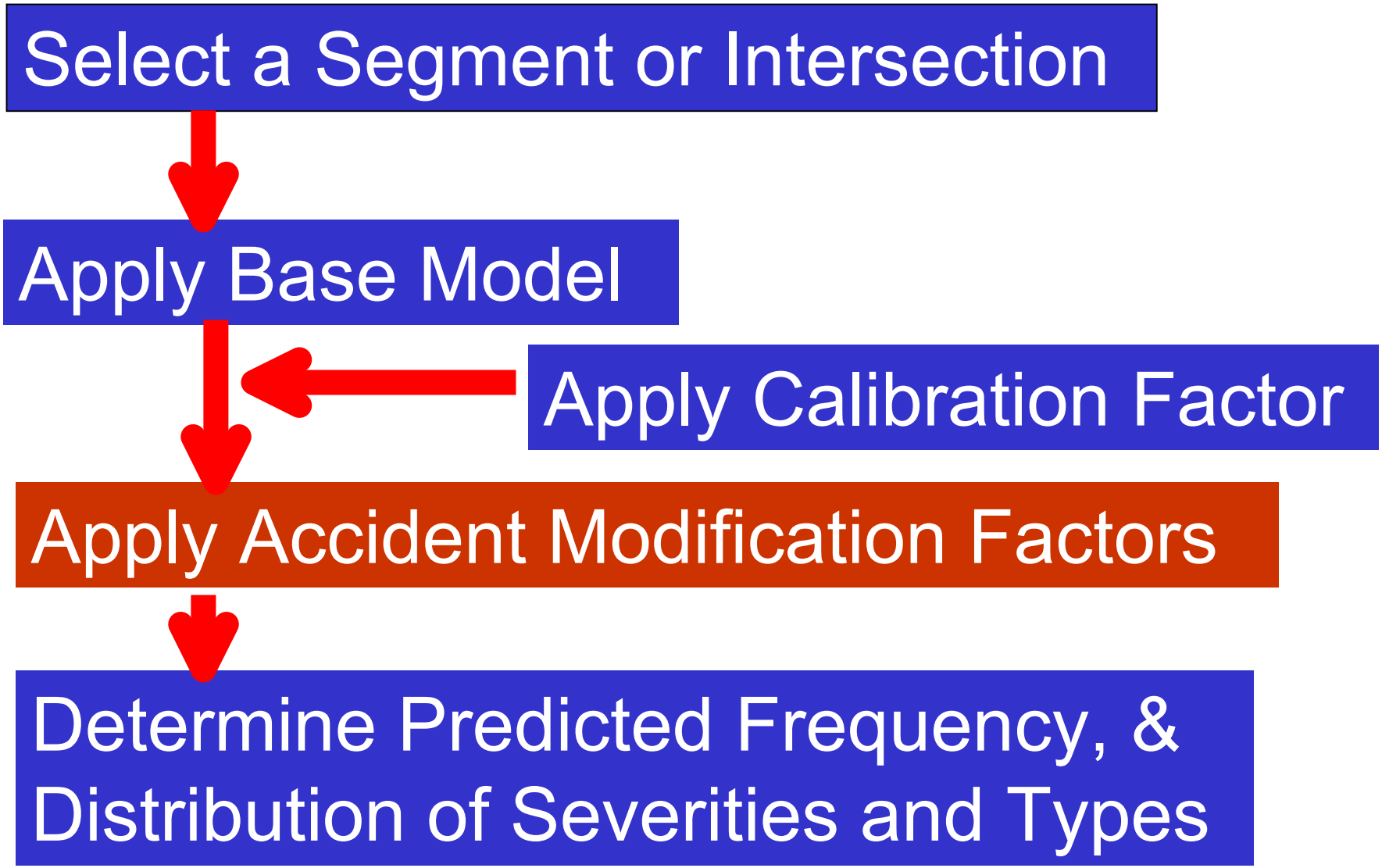
Limits of Regression Models

- Regression analysis produces general estimates, but not cause and effect for individual variables
- Coefficients cannot be relied upon to represent incremental effects of individual geometric design and traffic control features
- Accident Modification Factors are Needed Instead (AMFs)

Proposed Prediction Method



Proposed Prediction Method



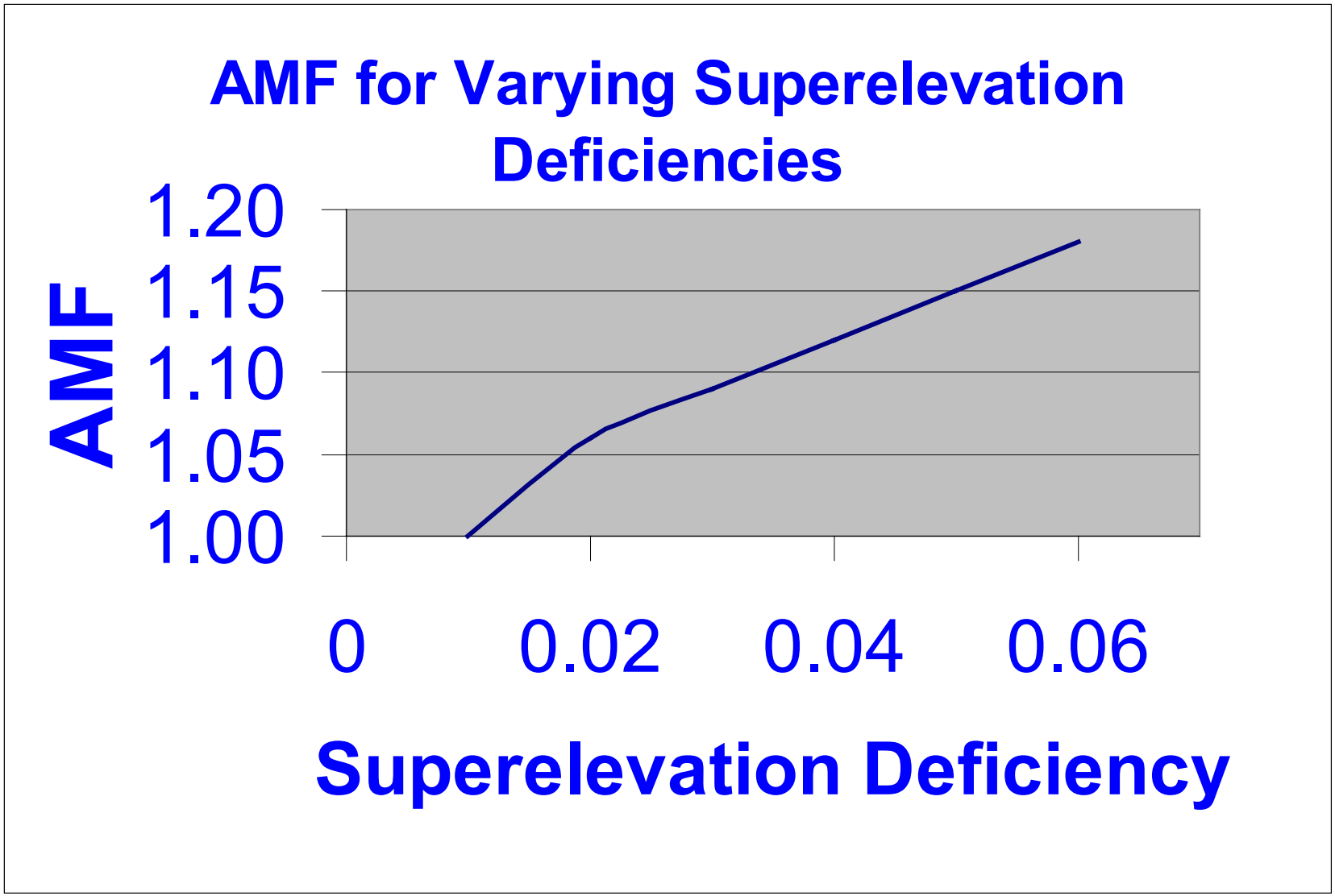
Method for Application of AMFs

- *Nrs = Nbr Cr (AMF1r, AMF2r, …AMFnr)*
- Where:
  - *Nrs* = predicted number of total roadway segment accidents per year
  - *Nbr* = predicted number for base conditions;
  - *Cr* = calibration factor for use for a particular geographical area.
  - *AMF1r, … AMFnr* = accident modification factors for each key geometric and operational feature

How Were Proposed AMFs Determined?

- Collective judgment of an expert panel
- Based upon comprehensive literature review by the expert panel.

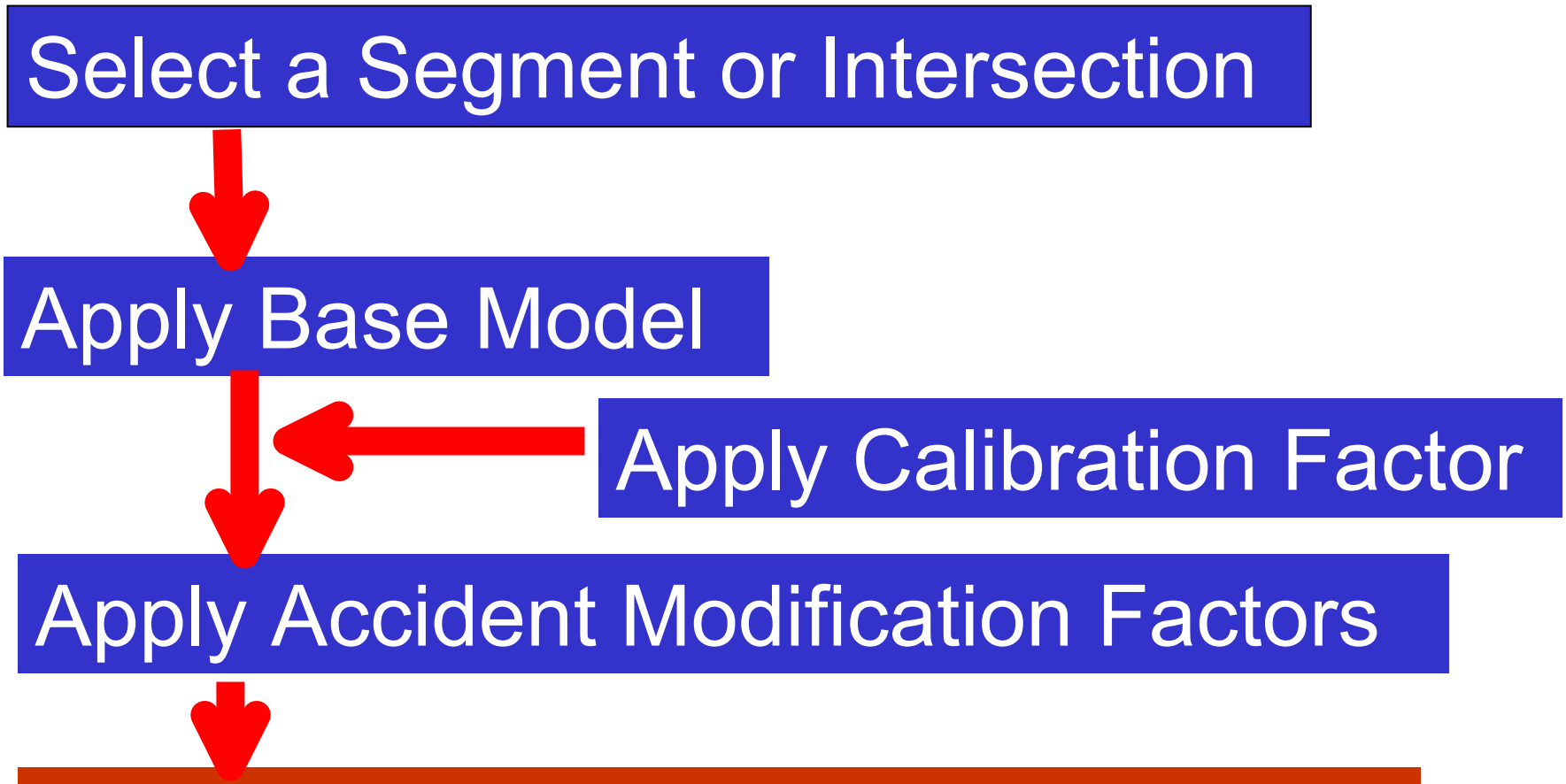
Example AMF – Two Lane Segment



AMF for Superelevation Deficiency (SD)

- *AMF =*
  - *1.00 for SD≤0.01*
  - *1.00 + 6(SD-0.01);* for 0.01<SD<0.02
  - *1.06 + 3 (SD – 0.02);* for SD≤0.02
- Base condition: Meets AASHTO Standard (i.e., SD=0)
- Applies to total roadway segment accidents for roadway segments located on horizontal curves.

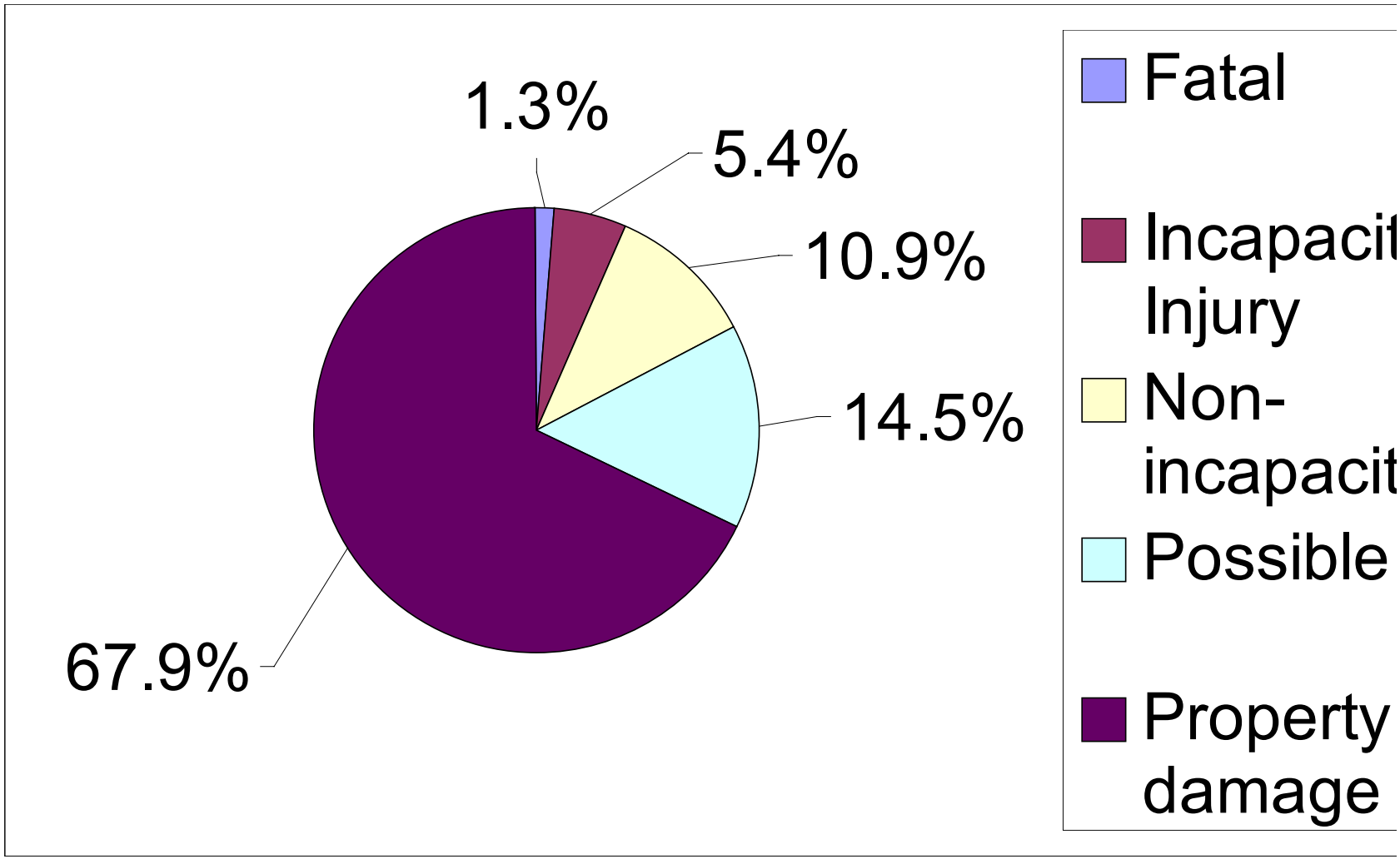
Proposed Prediction Method



Crash Severity and Type Distributions

- Use Default or Local Distributions
- Apply to Predicted Frequency

Example Severity Distribution



Applying the Results

- Sum the estimates for each segment and intersection
- If Current Crash History is Available, Make a Weighted Estimate

$$A_E = W^*A_{ES} + (1-W)A_C$$

- Results Used as Input to the Broader Evaluation & Decision Making Process

Status of Modeling for the HSM

- No Models Have Been Adopted Yet
- Currently Assessing Model for Two-Lane Rural Highways
- Research Underway on Models for
  - multilane rural highways
  - urban & suburban arterials
- Results Expected in About 24 Months

Assessment of Proposed Models for Two-Lane Rural Highways

- Review by Panel of Statisticians
- Review and Comment by Potential Users
- Task Force Review
- Federal Highway Administration Validation Project

Results of FHWA Validation Project

- An Updated Set of Base Models for Predicting Crashes Using AADT
- Based On Larger Sample Sizes
- Slightly Modified Sets Of Independent Variables

Validation Conclusions

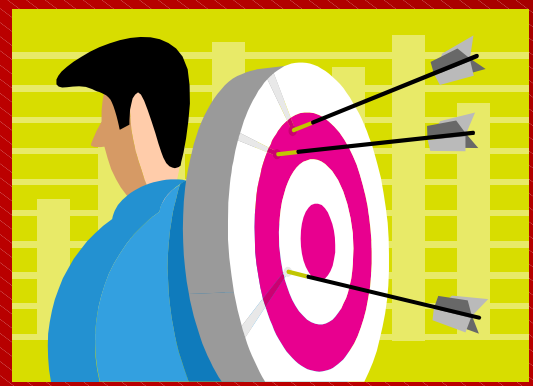
- AMF's should be continually improved
- Should replace use of expert opinions to derive AMF's
- Instead, use the results of valid before-after studies as time progresses

Key Issues

- Quality of crash data
- Quality and availability of other safety data
- Proposed method does not account for combined effects of factors
- Evolving approaches to modeling

Targeted Users

- Primary - Analysts Studying the Impact of Actions on Roadway Users
  - *planning, design, operations & maintenance studies*
- Secondary Users
  - management
  - educational Institutions



Schedule and Basic Cost for First Edition of the Highway Safety Manual

End of Presentation

http://www.highwaysafetymanual.org/