Lecture 1: Basic Concepts

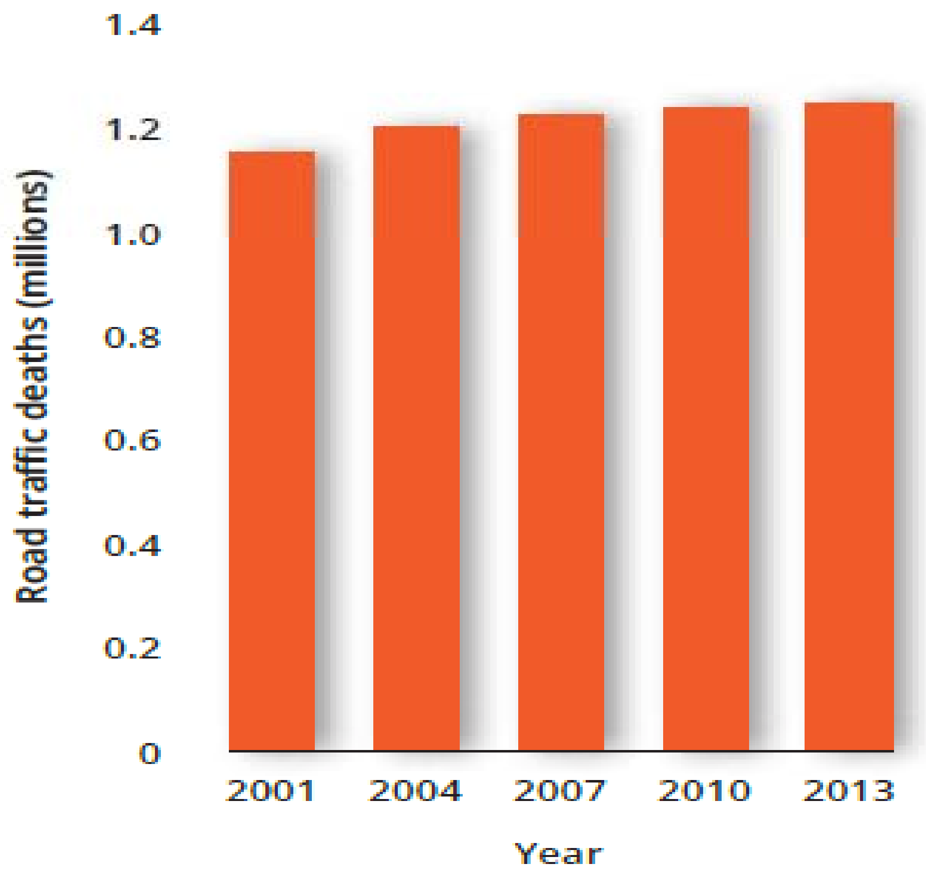
Introduction

Global Road Safety Status

- Road crashes are one of the world's largest public health issues

Global Road Safety Status

- The number of road fatalities is still increasing worldwide.

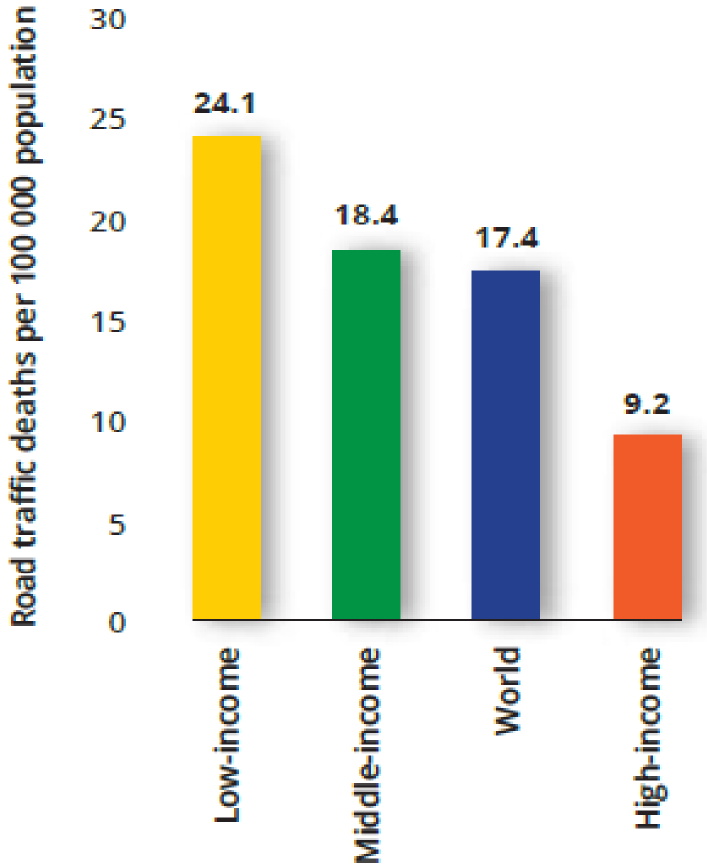


Global Road Safety Status

- Road fatalities by age groups

Global Road Safety Status

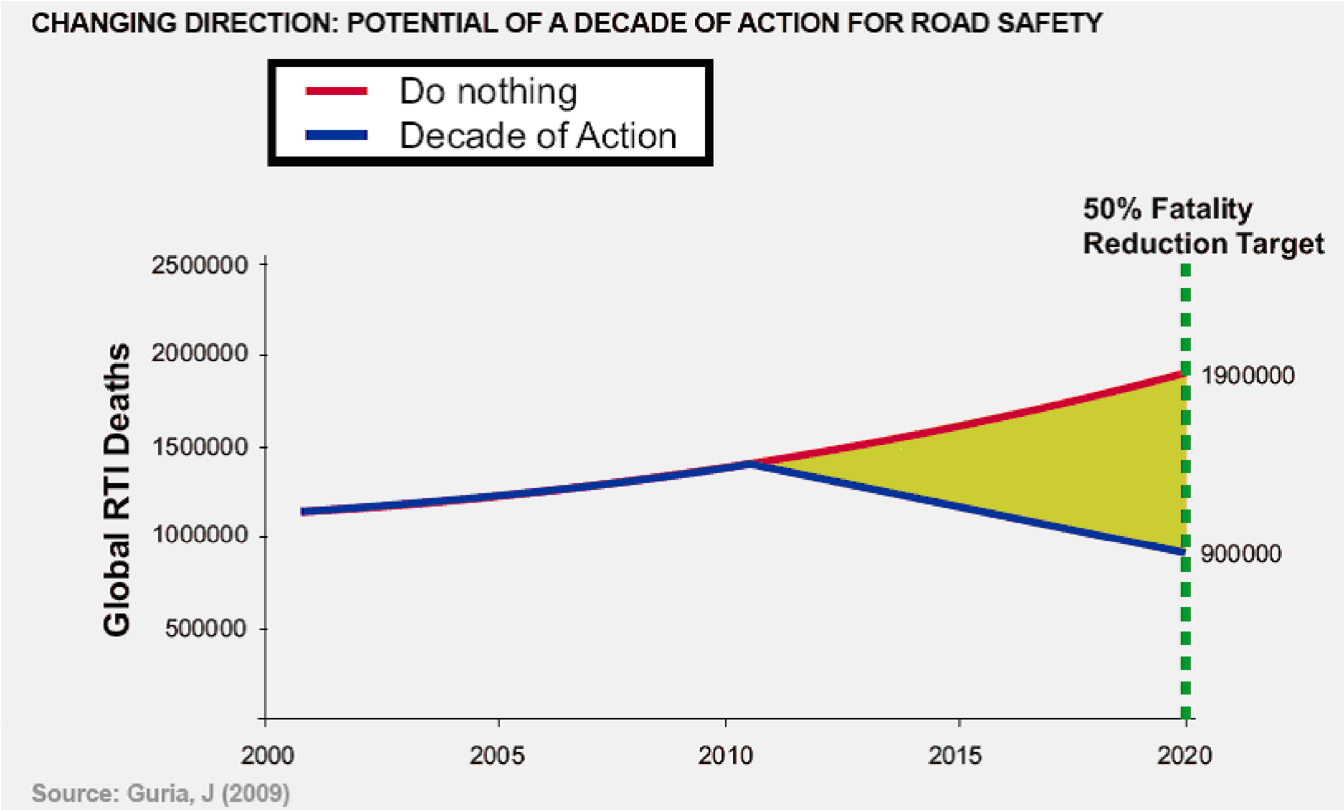
- There is great disparity in fatality rate by country income status.



The rates in low- and middle-income countries are more than twice higher than that in the high income countries

Global Road Safety Status

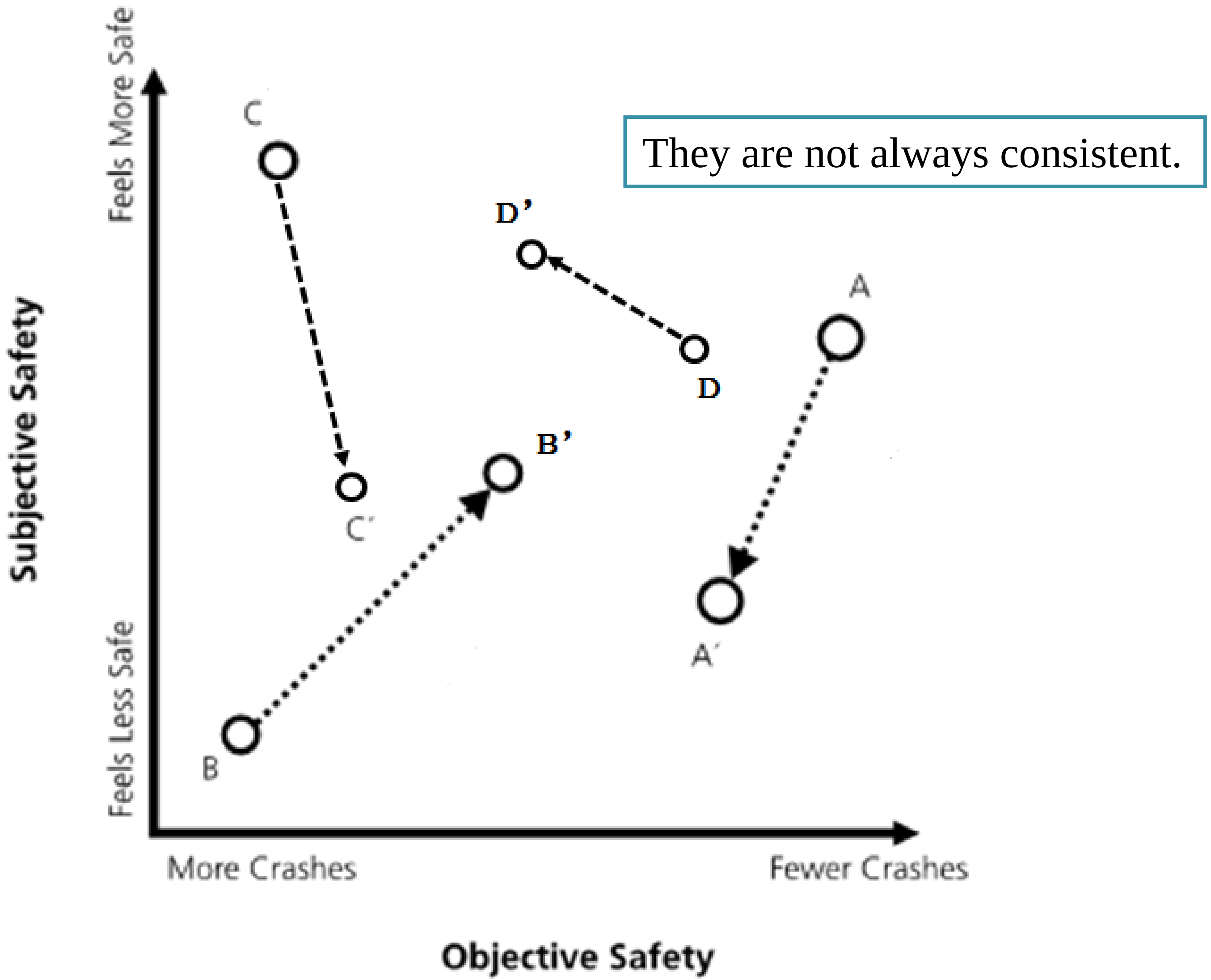
- In 2010, the UN General Assembly launched the Decade of Action for Road Safety (2011–2020)



Some Definitions

- **What is safety?**

  Safety in Highway Safety Manual refers to the crash frequency and/or crash severity and collision type for a specific time period, a given set of geometric and operational conditions.
- **Objective safety:** refers to use of a quantitative measure that is independent of the observer, such as crash frequency and severity.
- **Subjective safety:** concerns the perception of how safety a person feels on the transportation system. Values vary among observers for the same site.



The difference between objective and subjective safety

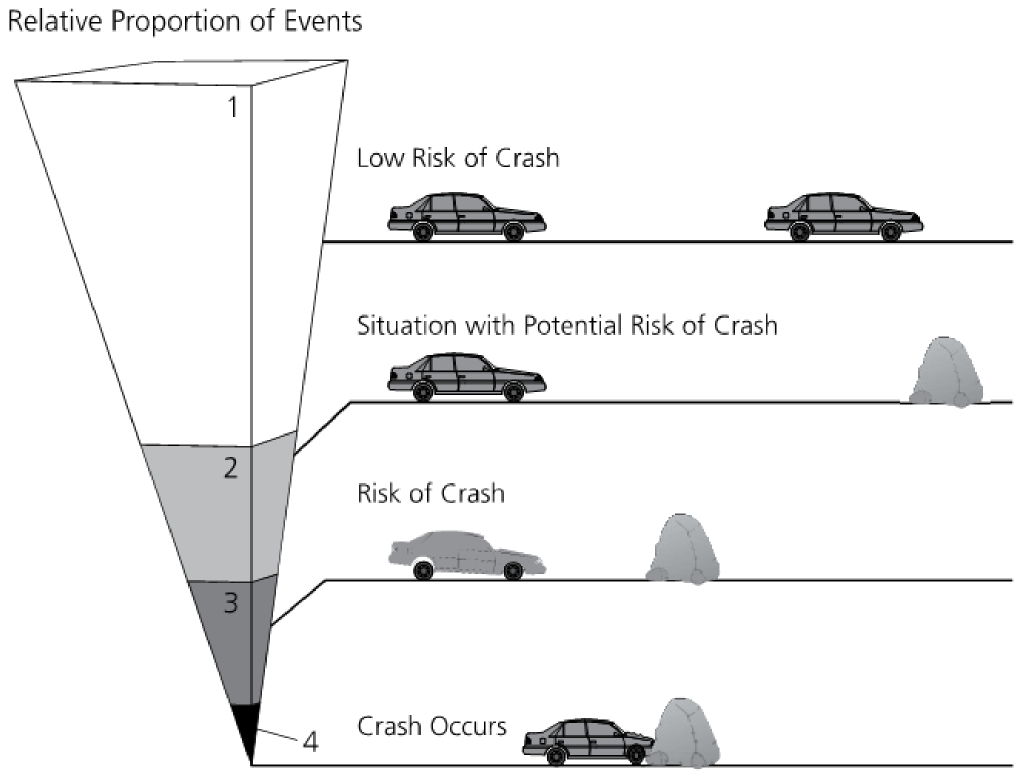
Some Definitions

- **Crash**

  is defined as a set of events that results in injury or property damage due to the collision of at least one motorized vehicle and may involve collision with another motorized vehicle, a bicyclist, a pedestrian, or an object.
- The terms “crash” and “accident” are used interchangeably.

Some Definitions

- Crashes are **rare** events
  - Crashes represent only a very small proportion of the total number of events that occur on the transportation system.



Some Definitions

- Crashes are **rare** events
  - Crashes represent only a very small proportion of the total number of events that occur on the transportation system.
- Crashes are **random** events
  - Crashes occur as a function of a set of events influenced by several factors, which are partly deterministic (they can be controlled) and partly stochastic (random and unpredictable).
  - Circumstances that lead to a crash in one event will not necessary lead to a crash in a similar event.

Some Definitions

- **Crash Frequency**: is defined as the number of crashes occurring at a particular site, facility, or network in a given time period (e.g., one year), also named **observed average crash frequency**.

$$\text{Crash Frequency} = \frac{\text{Number of Crashes}}{\text{Period in Years}}$$

- **Expected Average Crash Frequency**: is defined as the estimate of long-term average crash frequency of a site, facility, or network under a given set of geometric design and traffic volumes in a given time period.
  - The observed crash frequency over a short period is not a reliable indicator.
  - The true long-term average crash frequency is unknown and must be estimated instead.

Some Definitions

- **Crash Severity:** refers to the level of injury or property damage due to a crash.
- Crash severity can be divided into categories according to the KABCO scale:
  - *K*- Fatal injury: an injury that results in death
  - *A*- Incapacitating injury: any injury, other than a fatal injury, that prevents the injured person from walking, driving, or normally continuing the activities the person was capable of performing before the injury occurred
  - *B*- Non-incapacitating evident injury: any injury, other than a fatal injury or an incapacitating injury, that is evident to observers at the scene of the crash in which the injury occurred

Some Definitions

  - *C*- Possible injury: any injury reported or claimed that is not a fatal injury, incapacitating injury, or non-incapacitating evident injury and includes claim of injuries not evident
  - *O*- No Injury/Property Damage Only (PDO)
- Other classifications do exist.
- A crash may cause a number of injuries of varying severity, the term crash severity of a crash refers to the most severe injury caused by this crash.

Some Definitions

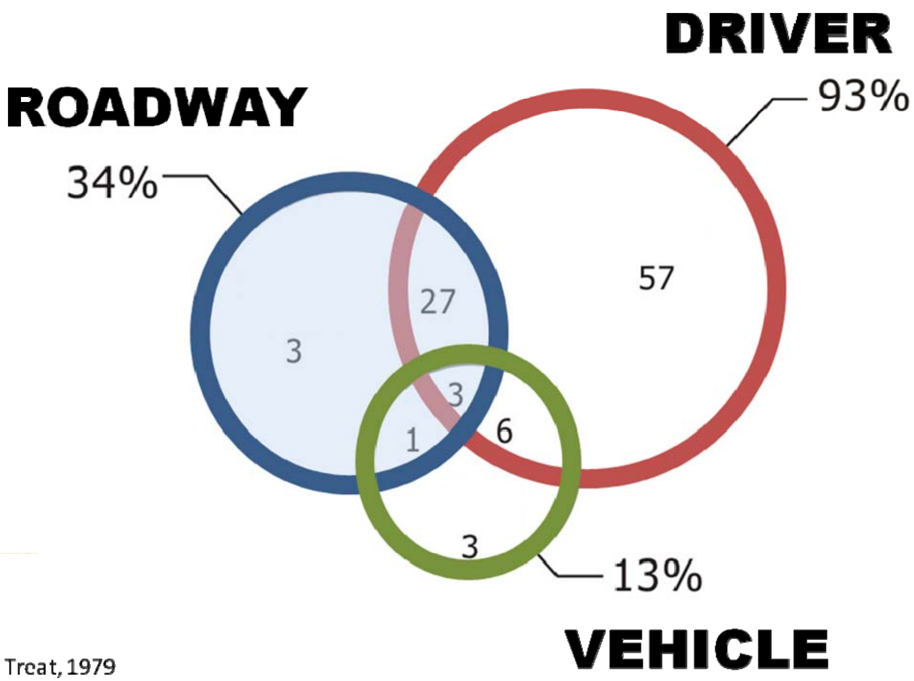
- **Crash Estimation**: refers to any methodology used to estimate the expected average crash frequency of:
  - An existing roadway for existing conditions during a past or future period;
  - An existing roadway for alternative conditions during a past or future period;
  - A new roadway for given conditions for a future period.
- **Crash Evaluation**: refers to determining the effectiveness of a particular treatment or a treatment program after its implementation.
  - Effectiveness refers to a change in the expected average crash frequency (or severity) for a site or project.

Some Definitions

- **Crash Evaluation** is based on comparing results obtained from **Crash Estimation**:
  - Evaluating a single application of a treatment to document its effectiveness;
  - Evaluating a group of similar projects to document the effectiveness of those projects;
  - Evaluating a group of similar projects for the specific purpose of quantifying the effectiveness of a countermeasure;
  - Assessing the overall effectiveness of specific projects or countermeasures in comparison to their costs.

Factors Contributing to a Crash

- In general, crashes have the following three categories of contributing factors: *Human, Vehicle, and Roadway.*
- Each crash is in most cases a direct consequence of failure in one or several of these three factors who influence each other.



Treat, 1979

Factors Contributing to a Crash

- These contributing factors influence the sequence of events before, during, and after a crash.
  - **Before-crash events**: reveal factors that contributed to the risk of a crash occurring, and how the crash may have been prevented.

    e.g., whether the brakes of one or both of the vehicles involved were worn.
  - **During-crash events**: reveal factors that contributed to the crash severity and how engineering solutions or technological changes could reduce crash severity.

    e.g., whether a car has airbags and if the airbag is deployed correctly
  - **After-crash events**: reveal factors influencing the outcome of the crash and how damage and injury may have been reduced by improvements in emergency response and medical treatment.

    e.g., the time and quality of emergency response to a crash

Factors Contributing to a Crash

- **The Haddon Matrix**: a framework for relating a series of events of crash to the categories of crash-contributing factors.

PERIOD	Contributing Factor		
	Human	**Vehicle**	**Roadway**
Before crash	attitude, vision, education, alcohol/drug use, fatigue...	Vehicle design, vehicle inspection, safety equipment...	road design, weather conditions, road operation and maintenance, lighting...
During crash	driving speed, failure to wear a seat belt...	bumper heights, headrest design, airbag operations...	pavement friction, grade, roadside environment, fixed objects...
After crash	age, health, first aid training...	fuel system integrity, ease of removal of injuried passengers...	the time and quality of the emergency response, subsequent medical treatment...

Strategies to Reduce Crashes

- By understanding the crash contributing factors and what period of a crash event they relate to, crashes and crash severities can be reduced by implementing specific measures.
- A reduction in crashes and crash severity may be achieved through changes in:
  - The behavior of humans;
  - The condition of the roadway/environment;
  - The design and maintenance of technology, including vehicles, roadways, and the environment technology;
  - The provision of emergence medical treatment, medical treatment technology, and post-crash rehabilitation;
  - …

Strategies to Reduce Crashes

- Strategies to influence the above aspects include:
  - **Engineering**

    e.g., modify signal phasing; use of median barriers; require minimum design standards…
  - **Enforcement**

    e.g., mandate use of helmets or seatbelts; prohibit cell phone use while driving; penalize illegal behavior, such as excessive speeding and drunken driving…
  - **Education**

    e.g., driver training programs, public awareness campaigns, and training of engineers and doctors…
  - **Emerging technologies**

    Advanced driver assistance systems; smart infrastructure sensing systems; autonomous vehicles…

Data for Crash Analysis

Data Needed for Crash Analysis

- **Crash data:** the data elements in a crash report describe the overall characteristics of the crash. While the specifics and level of detail of the data vary, in general, the most basic crash data include:
  - crash location,
  - date and time,
  - crash severity,
  - collision type,
  - basic information about the roadway, vehicles, and people involved.

Data Needed for Crash Analysis

- **Facility data:** the roadway or intersection inventory data provide information about the physical characteristics of the crash site. The most basic inventory data typically include:
  - roadway classification,
  - number of lanes,
  - length,
  - presence of medians and shoulder width.
- Intersection inventories typically include:
  - road names,
  - area type,
  - traffic control,
  - lane configurations.

Data Needed for Crash Analysis

- **Traffic volume data:**
  - annual average daily traffic (AADT),
  - average daily traffic (ADT),
  - intersections total entering volumes (TEV),
  - vehicle-miles travel on a roadway segment,
  - pedestrian crossing counts,
  - turning movement volumes.

Data Limitations

- **Data Quality and Accuracy**: Crash data are typically collected on standardized forms by trained police personnel. Not all crashes are reported and not all reported crashes are recorded correctly.
- Errors may occur at any stages of the collection and recording of crash data and may be due to:
  - Incorrect entry: entry of road names, road surface, level of crash severity, vehicle types, impact description, etc.
  - Imprecise entry: the use of general terms to describe a location
  - Subjectivity: where data collection relies on the subjective opinion of an individual, inconsistency is likely

Data Limitations

- **Crash Reporting Thresholds**: In most countries, crashes must be reported to police when damage is above a minimum value threshold. When threshold change, the change in observed crash frequency does create a condition where comparisons between previous years cannot be made.
- Typically, the increase of the minimum value is followed by a drop in the number of reported crashes. This decrease in reported crashes does not represent an increase in safety.
- It is important to be aware of crash reporting thresholds and to ensure that a change to reporting thresholds did not occur during the period of study under consideration.

Data Limitations

- **Crash Reporting and the Frequency-Severity Indeterminacy**: not all reportable crashes are actually reported to police and, therefore, not all crashes are included in a crash database.
- Studies indicate that crashes with greater severity are reported more reliably than crashes of lower severity. This situation creates an issue called frequency-severity indeterminacy, which represents the difficulty in determining if a change in the number of reported crashes is caused by an actual change in crashes, a shift in severity proportions, or a mixture of the two.

Data Limitations

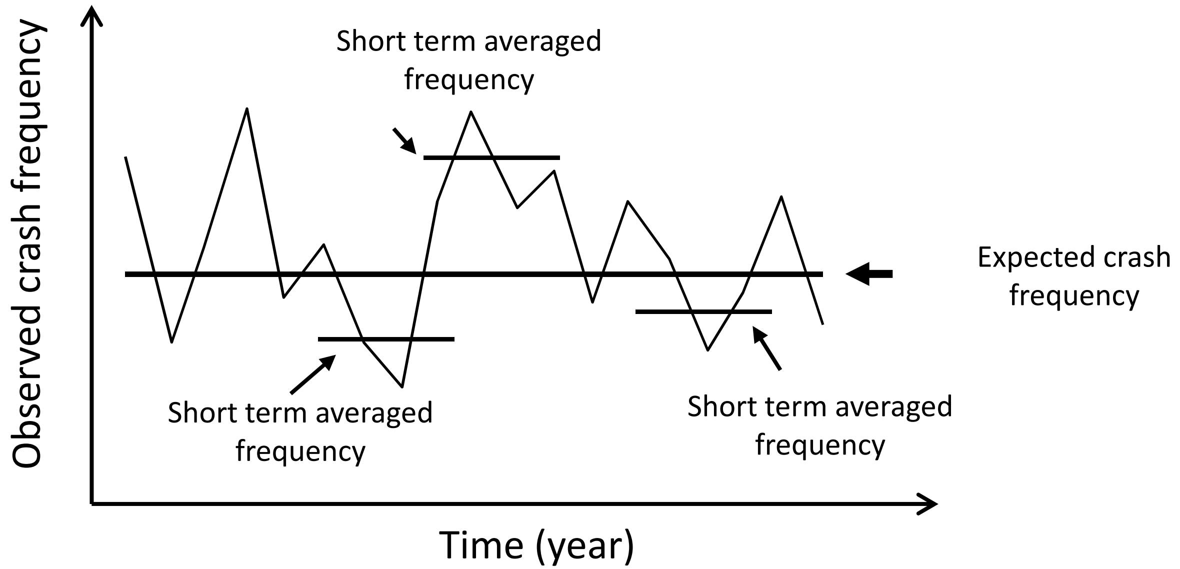
- **Differences between Crash Reporting Criteria of Jurisdictions:** differences exist between jurisdictions regarding how crashes are reported and classified.
- Different definitions, criteria, and methods of determining and measuring crash data may include:
  - crash reporting thresholds,
  - definition of terms and criteria relating to crashes, traffic, and geometric data,
  - crash severity categories.

Randomness and Change

- Limitations associated with natural variations in crash data and the changes in site conditions are due to inherent characteristics of the data itself, not limitations due to the method by which the data is collected or reported.
- Limitations due to randomness and change include:
  - Natural variability in crash frequency
  - Regression-to-the-mean and regression-to-the-mean bias
  - Variations in roadway characteristics
  - Conflict between crash frequency variability and changing site conditions

Randomness and Change

- **Natural variability in crash frequency**
  - Crashes are random events, crash frequencies naturally fluctuate over time at any given site.



  - The randomness of crash occurrences indicates that short-term crash frequencies along are not a reliable estimator of long-term crash frequency.

Randomness and Change

- **Regression-to-the-Mean (RTM)**: the crash fluctuation over time makes it difficult to determine whether changes in the observed crash frequency are due to changes in site conditions or are due to natural fluctuations.
- When a period with a comparatively high crash frequency (or low crash frequency) is observed, it is statistically probable that the following period will be followed by a comparatively low crash frequency (or high crash frequency). **The tendency is known as regression-to-the-mean**.
- Failure to account for the effects of RTM introduces the potential for **RTM bias**, also known as selection bias.

Randomness and Change

- RTM bias occurs when sites are selected for treatment based on short-term trends in observed crash frequency.
- RTM bias can result in the overestimation or underestimation of the effectiveness of a treatment.
- Without accounting for RTM bias, it is not possible to know if an observed reduction in crashes is due to the treatment or if it would have occurred without the modification.
- The effect of RTM bias is accounted for when treatment effectiveness and site selection is **based on a long-term average crash frequency**.

Randomness and Change

- **Variations in Roadway Characteristics and Environment:** A site's characteristics, such as traffic volume, weather, traffic control, land use, and geometric design, are subject to change over time.
- The variation of site conditions over time makes it difficult to attribute changes in the expected average crash frequency to specific conditions.
- Variation in conditions also plays a role in evaluation of the effectiveness of a treatment. Changes in conditions between a "before" period and an "after" period may make it difficult to determine the actual effectiveness of a particular treatment.

Randomness and Change

- **Conflict between crash frequency variability and changing site conditions:** The implications of crash frequency fluctuation and variation of site conditions are often in conflict.
  - The year-to-year fluctuation in crash frequencies tends toward acquiring more years of data to determine the expected average crash frequency.
  - Changes in site conditions can shorten the length of time for which crash frequencies are valid for considering averages.
- This push/pull relationship requires considerable judgment when conducting large-scale analyses and using crash estimation procedures based on observed crash frequency.

Crash Data Selection

- Purpose of the study
  - e.g., when estimating the effect of a particular treatment on safety, we need to understand the occurrence of what kind of crashes will be affected by this treatment.
- Time frame
  - Data from outside the selected time period will not be considered.
- There are two factors to be compromised:
  - Desire for larger sample sized
  - Desire for time frames within which conditions have not changed (too much)

Crash Data Selection

- There are two types of study locations:
  - **Spots:** are short segments of the roadway that help identify the problem point location, such as intersections, curves, and short bridges.
    - Geometric and other features at a spot should be noticeably different from surrounding spots. Recommended spot lengths are from 0.2 to 0.3 miles.
    - A fixed distance of 100-200 feet along each of the approach leading to the intersection is used in most of the cases.
  - **Sections:** are longer, rather homogeneous sections of the roadway. Recommended section lengths are from 1 to 2 miles.

Crash Estimation Methods

Crash Estimation Methods

- Observed crash frequency and crash rates
- Indirect safety measures
- Statistical methods

Crash Frequency & Crash Rate

- Crash frequency and crash rates are often used for crash estimation.
  - **Crash frequency**: is defined as the number of crashes occurring at a particular site, facility, or network in a given period

$$\text{Crash Frequency} = \frac{\text{Number of Crashes}}{\text{Period in Years}}$$

  - **Crash rate**: is defined as the number of crashes that occurs at a given site during a certain time period in relation to a particular measure of exposure

$$\text{Crash Rate} = \frac{\text{Average Crash Frequency in a Period}}{\text{Exposure in Same Period}}$$

Crash Frequency & Crash Rate

- Some commonly used crash rates
  - Mortality rate:

$$R = \frac{F \times 1,000,000}{P}$$

R = the number of fatalities per million inhabitants

F = total number of road fatalities

P = number of population

  - Fatality rate:

$$R = \frac{F \times 1,000,000}{M}$$

R = the number of fatalities per million registered vehicle

F = total number of road fatalities

M = number of registered vehicles

Crash Frequency & Crash Rate

- Some commonly used crash rates
  - Crash rate:

$$R = \frac{C}{L}$$

R = the number of crashes per kilometer road length

C = total number of crashes on the considered section

L = length of the section

  - Crash involvement rate:

$$R = \frac{N \times 100{,}000{,}000}{V}$$

R = crash involvement per 100 million vehicle miles traveled

N = total number of drivers of vehicles involved in crashes

V = total vehicle miles traveled

Crash Frequency & Crash Rate

- Some commonly used crash rates
  - Crash per million involved vehicles per kilometer:

$$R = \frac{C \times 1{,}000{,}000}{V \times L \times T \times 365}$$

R = the number of crashes per million involved vehicles per kilometer

C = total number of crashes on the roadway section

T = the time frame of the analysis (years);

V= the average AADT of the segment; and

L = the length of the selected roadway segment (km).

Crash Frequency & Crash Rate

- Crash rates may be interpreted as the probability (based on past events) of being involved in a crash per instance of the exposure measure.
  - e.g., if the crash rate on a roadway segment is one crash per one million vehicle miles per year, then a vehicle has a one-in-a-million chance of being in a crash for every mile traveled on that roadway segment.
- The logic behind the use of crash rates is: People are exposed to transportation risks when they travel. Assuming that everything else remains the same, the more travel there is, the more risk people will incur.
- In this sense, it will not be proper to use absolute number to compare different situations.

Crash Frequency & Crash Rate

- Crash frequency and crash rates are often used as a tool to identify and prioritize sites in need of modifications and for evaluation of the effectiveness of treatments.
- Typically, those sites with the highest crash rate or perhaps with rates higher than a certain threshold are analyzed in detail to identify potential modifications to reduce crashes.
- They are also often used in conjunction with other analysis techniques, such as reviewing crash records by one or more of the following: year, collision type, crash severity, or environmental conditions to identify other apparent trends or patterns over time.

Crash Frequency & Crash Rate

- Advantages:
  - Understandability - observed crash frequency and rates are intuitive to most members of the public;
  - Acceptance - it is intuitive for members of the public to assume that observed trends will continue to occur;
  - Limited alternatives - in the absence of any other available methodology, observed crash frequency is the only available method of estimation.
- Disadvantages:
  - Crash estimation methods based solely on historical crash data are subject to a number of data limitations;
  - The use of crash rate incorrectly assumes a linear relationship between crash frequency and the measure of exposure;

Indirect Safety Measures

- Also known as surrogate safety measures. They provide a surrogate methodology when crash frequencies are not available, e.g.,
  - the roadway or facility is not yet in service or has only been in service for a short time,
  - when crash frequencies are low or have not been collected.
- The important added attraction of indirect safety measures is that they may save having to wait for sufficient crashes to materialize before a problem is recognized and a remedy applied.

Indirect Safety Measures

- Two basic types:
  - Surrogates based on events which are proximate to and usually precede the crash event.
    - e.g., at an intersection encroachment time, the time during which a turning vehicle infringes on the right-of-way of another vehicle may be used as a surrogate estimate.
  - Surrogates that presume existence of a causal link to expected crash frequency.
    - e.g., proportion of occupants wearing seatbelts may be used as a surrogate for estimation of crash severities.
- Conflict studies are another indirect measurement of safety.
  - Direct observation of a site is conducted in order to examine "near-crashes" as an indirect measure of potential crash problems at a site.

Indirect Safety Measures

- Strength:
  - The data for analysis is more readily available.
  - There is no need to wait for crashes to occur.
- Limitation:
  - The relationship between the surrogate events and crash estimation is unproven.

Statistical Methods

- Statistical models, or predictive models, have been developed which address some of the limitations of other methods identified above:
  - Address RTM bias
  - Provide the ability to reliably estimate expected average crash frequency for
    - existing roadway conditions,
    - changes to existing conditions, or
    - a new roadway design prior to its construction and use.

Predictive Method

Predictive Method

- Provides a structured methodology to estimate the expected average crash frequency (by total crashes, crash severity or collision type) of a site, facility or roadway network for a given time period, geometric design and traffic control features, and traffic volumes.
- Also allows for crash estimation in situations where no observed crash data is available.
  - This is done using a statistical model developed from data for a number of similar sites.
- The expected average crash frequency ($N_{expected}$) is estimated using a predictive model estimate of crash frequency ($N_{predicted}$) and, where available, observed crash frequency ($N_{observed}$).

Predictive Method

- The predictive models vary by facility and site type but all have the same basic elements:
  - **Safety Performance Functions (SPFs)**: statistical ”base” models are used to estimate the average crash frequency for a facility type with specified base conditions.
  - **Crash Modification Factors (CMFs or AMFs)**: defined as the ratio of the effectiveness of one condition in comparison to another condition. CMFs are multiplied with the crash frequency predicted by the SPF to account for the difference between site conditions and specified base conditions.
  - **Calibration factor (C)**: multiplied with the crash frequency predicted by the SPF to account for differences between the jurisdiction and time period.

Predictive Method

$$N_{predicted} = N_{SPF\ x} \times (AMF_{1x} \times AMF_{2x} \times \ldots \times AMF_{yx}) \times C_x$$

Where,

$N_{predicted}$= predictive model estimate of crash frequency for a specific year on site type x (crashes/year);

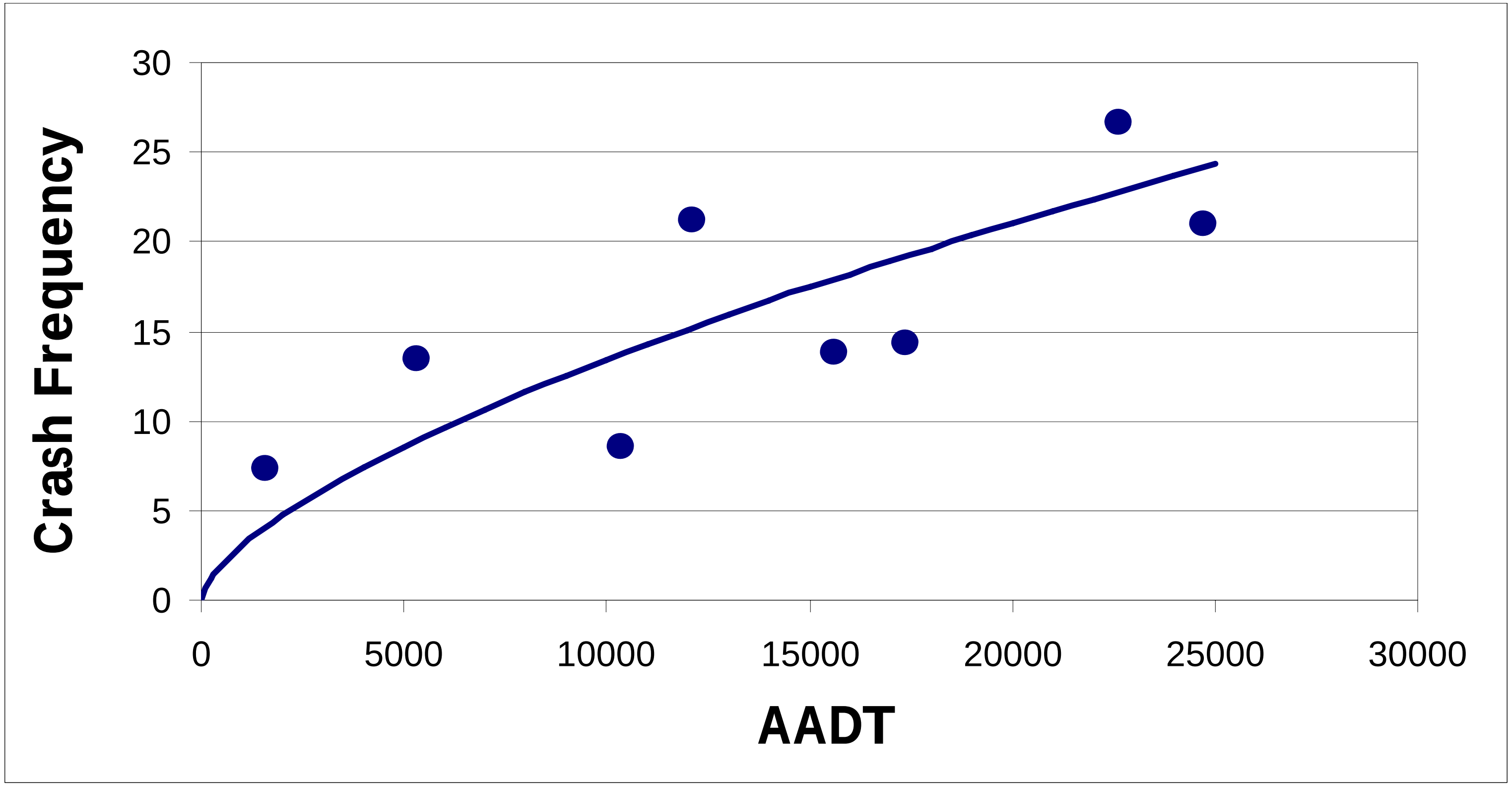
$N_{SPF\ x}$= predicted average crash frequency determined for base conditions with the Safety Performance Function representing site type x (crashes/year);

AMF_{yx} = Accident Modification Factors specific to site type x;

C_x = Calibration Factor to adjust for local conditions for site type x.

Advantages of Predictive Method

- Addresses regression-to-the-mean bias as the method concentrates on long-term expected average crash frequency rather than short-term observed crash frequency;
- Reduces the reliance on availability of limited crash data for any one site by incorporating predictive relationships based on data from many similar sites;
- Accounts for the fundamentally nonlinear relationship between crash frequency and traffic volume.



Crash Frequency
30
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
AADT

Safety Performance Functions

- In HSM, Safety Performance Functions (SPFs) are regression equations that estimate the average crash frequency for a specific site type (with specified base conditions) as a function of annual average daily traffic (AADT) and, in the case of roadway segments, the segment length (L).
- A SPF for roadway segments on rural two-lane highways

$$N_{SPF\ rs} = (AADT) \times (L) \times (365) \times 10^{(-6)} \times e^{(-0.4865)}$$

Crash Modification Factors

- Crash Modification Factors (CMFs) represent the relative change in crash frequency due to a change in one specific condition (when all other conditions and site characteristics remain constant).
- A CMF may serve as an estimate of the effect of a particular geometric design or traffic control feature or the effectiveness of a particular treatment or condition:
  - illuminating an unlighted road segment,
  - paving gravel shoulders,
  - signalizing a stop-controlled intersection,
  - choosing a signal cycle time of 70 seconds instead of 80 seconds,
  - …

Crash Modification Factors

- CMFs are the ratio of the crash frequency of a site under two different conditions.

$$AMF = \frac{Expected\ average\ crash\ frequency\ with\ condition\ 'b'}{Expected\ average\ crash\ frequency\ with\ condition\ 'a'}$$

Example

Using a SPF for rural two-lane roadway segments, the expected average crash frequency for existing conditions is 10 injury crashes/year (assume observed data is not available). The base condition is the absence of automated speed enforcement. If automated speed enforcement were installed, the AMF for injury crashes is 0.83. Therefore, if there is no change to the site conditions other than implementation of automated speed enforcement, the estimate of expected average injury crash frequency is

0.83 x 10 = 8.3 crashes/year

Crash Modification Factors

- The values of CMFs are determined for a specified set of base conditions.
  - Under the base conditions (i.e., with no change in the conditions), CMF = 1.
  - CMF < 1 indicates the alternative treatment reduces the estimated average crash frequency in comparison to the base condition.
  - CMF > 1 indicates the alternative treatment increases the estimated average crash frequency in comparison to the base condition.

Crash Modification Factors

- The relationship between a CMF and the expected percent change in crash frequency

$$\textit{Percent Reduction in Accidents} = 100 \times (1.00 - AMF)$$

If an AMF = 0.90 then the expected percent change is 100% × (1.00 - 0.90) = 10%, indicating a reduction in expected average crash frequency.

If an AMF = 1.20 then the expected percent change is 100% × (1.00 - 1.20) = -20%, indicating an increase in expected average crash frequency.

Crash Modification Factors

- CMFs can be multiplied together to estimate the combined effects of the respective elements or treatments.

Example

Treatment 'x' consists of providing a left-turn lane on both major-road approaches to an urban four-leg signalized intersection and treatment 'y' is permitting right-turn-on-red maneuvers. These treatments are to be implemented and it is assumed that their effects are independent of each other. An urban four-leg signalized intersection is expected to have 7.9 accidents/year. For treatment t_x, $AMF_x = 0.81$; for treatment t_y, $AMF_y = 1.07$.

What accident frequency is to be expected if treatment x and y are both implemented?

expected accidents = 7.9 x 0.81 x 1.07 = 6.8 accidents/year.

Crash Modification Factors

- All CMF values are estimates of the change in expected average crash frequency due to a change in one specific condition. Some CMFs include a standard error, indicating the variability of the CMF estimation in relation to sample data values.
- The standard error of an estimated value serves as a measure of the reliability of that estimate. The smaller the standard error, the more reliable (less error) the estimate becomes.
- Standard error can be used to calculate a confidence interval for the estimated change in expected average crash frequency.

Crash Modification Factors

$$CI\ (y\%) = AMF_x \pm SE_x \times MSE$$

Where,

CI(y%) = the confidence interval for which it is y-percent probable that the true value of the AMF is within the interval;

AMF_x = Accident Modification Factor for condition x;

SE_x = Standard Error of the AMF_x;

MSE = Multiple of Standard Error

Desired Level of Confidence	Confidence Interval (probability that the true value is within the confidence interval)	Multiples of Standard Error (MSE)
Low	65-70%	1
Medium	95%	2
High	99.9%	3

Crash Modification Factors

Situation

Roundabouts have been identified as a potential treatment to reduce the estimated average crash frequency for all crashes at a two-way stop-controlled intersection. Research has shown that the AMF for this treatment is 0.22 with a standard error of 0.07.

The AMF estimates that installing a roundabout will reduce expected average crash frequency by 100 x (1 - 0.22) = 78%.

Using a Low Level of Confidence (65-70% probability) the estimated reduction at the site will be 78% ± 1 x 100 x 0.07%, or between 71% and 85%.

Using a High Level of Confidence (i.e., 99.9% probability) the estimated reduction at the site will be 78% ± 3 x 100 x 0.07%, or between 57% and 99%.

The higher the level of confidence desired, the greater the range of estimated values.

Calibration

- Crash frequencies, even for nominally similar roadway segments or intersections, can vary widely from one jurisdiction to another. Calibration is the process of adjusting the SPFs to reflect the differing crash frequencies between different jurisdictions.
  - The calibration factors will have values greater than 1 for roadways that, on average, experience more accidents than the roadways used in developing the SPFs.
  - The calibration factors for roadways that, on average, experience fewer accidents than the roadways used in the development of the SPF, will have values less than 1.

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Predictive Method

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Where,

$N_{predicted}$= predictive model estimate of crash frequency for a specific year on site type x (crashes/year);

$N_{SPF\ x}$= predicted average crash frequency determined for base conditions with the Safety Performance Function representing site type x (crashes/year);

AMF_{yx} = Accident Modification Factors specific to site type x;

C_x = Calibration Factor to adjust for local conditions for site type x.

Empirical Bayes Method

- Estimation of expected average crash frequency using
  - Only observed crash frequency
  - Only estimation using a statistical model
  - Both
- By combining observed crash frequency and the estimate of the average crash frequency from a predictive model, the statistical reliability (the probability that the estimate is correct) can be improved .
- The Empirical Bayes (EB) Method uses a weight factor to combine the two estimates into a weighted average.

Empirical Bayes Method

$$N_{expected} = w \times N_{predicted} + (1 - w) \times N_{observed}$$

Where,

$N_{expected}$ = expected average crashes frequency for the study period.

$N_{predicted}$ = predicted average crash frequency predicted using a SPF for the study period under the given conditions.

w = weighted adjustment to be placed on the SPF prediction.

$N_{observed}$ = observed crash frequency at the site over the study period.

$$w = \frac{1}{1 + k \times \left(\sum_{\text{all study years}} N_{Predicted} \right)}$$

Where,

k = overdispersion parameter from the associated SPF.

Effectiveness Evaluation

Effectiveness evaluation

- A process of developing quantitative estimates of the effect a treatment, a project, or a group of projects has on expected average crash frequency.
- Provides valuable information for future decision-making and policy development.
- Includes:
  - Evaluating a single project at a specific site to document the effectiveness of that specific project;
  - Evaluating a group of similar projects to document the effectiveness of those projects;
  - Evaluating a group of similar projects for the specific purpose of quantifying a CMF for a countermeasure;
  - Assessing the overall effectiveness of specific types of projects or countermeasures in comparison to their costs.

Effectiveness evaluation

- Effectiveness evaluations may use several different types of performance measures:
  - a percentage reduction in crash frequency,
  - a shift in the proportions of crashes by collision type or severity level,
  - a CMF for a treatment,
  - a comparison of the benefits achieved to the cost of a project or treatment.

Effectiveness evaluation

- There are two basic study designs that can be used for effectiveness evaluations:
  - Observational studies
    - Inferences are made from data observations for treatments that have been implemented in the normal course of the efforts to improve the road system. Treatments are not implemented specifically for evaluation.
  - Experimental studies
    - Treatments are implemented specifically for evaluation of effectiveness. Sites that are potential candidates for improvement are randomly assigned to either a treatment group, or a comparison group. Subsequent differences in crash frequency between the treatment and comparison groups can then be directly attributed to the treatment.
- Observational studies are much more common in road safety than experimental studies.

Effectiveness evaluation

- Two types of observational studies can be classified:
  - Observational cross-sectional studies
    - Data are collected for a specific time period for two groups. One implemented the treatment, and the other did not.
  - Observational before-after studies
    - Data are collected for specific time periods before and after the treatment was implemented.

Summary

- We studied some key concepts, definitions, and methods for road safety analysis.
- Crashes are rare and randomly occurring events. These events are influenced by a number of interdependent contributing factors which affect the events before, during and after a crash.
- Crash estimation methods are reliant on accurate and consistent collection of observed crash data. The limitations and potential for inaccuracy inherent in the collection of data need consideration.
- The observed crash frequency fluctuates year to year due to both natural random variation and changes in site conditions which affect the number of crashes.

Summary

- The observed crash frequency over a short period cannot be used to represent a reliable estimate of the long-term average crash frequency.
- In order to account for the effects of RTM bias, and the limitations of other crash estimations methods, a predictive method can be used for the estimation of the expected average crash frequency of a site.
- The predictive method uses statistical models, known as SPFs, and crash modification factors, CMFs, to estimate predicted average crash frequency. These models must be calibrated to local conditions to account for differing crash frequencies between different jurisdictions.

Summary

- To improve the reliability of the estimation, the EB Method can be used to combine the statistical estimate with the observed crash frequency of a specific site.
- The evaluation of a treatment's effectiveness involves comparing the expected average crash frequency of a roadway or site with and without the implemented treatment, using either observational before-after or cross-sectional studies.