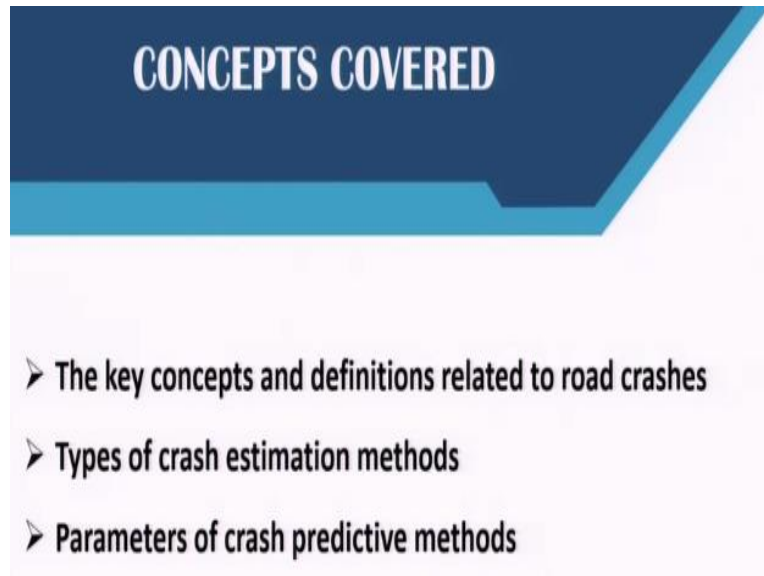


**Introduction to Multimodal Urban Transportation System**  
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**Lecture – 57**  
**Urban Transport and Sustainability:**  
**Road Crash Estimation and Elements of Predictive Methods**

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Welcome back friends. Now that we have introduced you to safety and pedestrian safety, in this lecture what we are going to expose you to are the different estimation methods of road crashes in general. Then we will subsequently look at specifically pedestrians and bicycle crashes, but you must first understand the concepts and definitions related to road crashes, how they are estimated and what are the parameters involved in these estimation methods.

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So, you would now notice that in most of the transportation safety literature, we are using the word crash rather than accident. Because more and more research is showing that all of these events may not be an accident. For example, the meaning of the word accident in English means that it happens suddenly or without anybody's intervention or anything's intervention, but what we are noticing is that many of these accidents can be predicted. And if they can be predicted that means they can be avoided or stopped as well. So, hence this word crash seems to be a better fit. So, when we say crash what we mean is that a set of events that result in injury or property damage due to collision of at least one motorized vehicle and may involve collision with another motorized vehicle, a bicyclist, a pedestrian, or an object okay. So, a crash does not always necessarily lead to a fatality or a death.


It may be just a property damage kind of a crash. It may be involving multiple vehicles or just one vehicle crashing with an object on the road or it may be a vehicle crashing with either a pedestrian or bicyclist. So, everything inclusive of all these terminologies is what is a crash.

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## Crash estimation

Any methodology used to forecast or predict the 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.



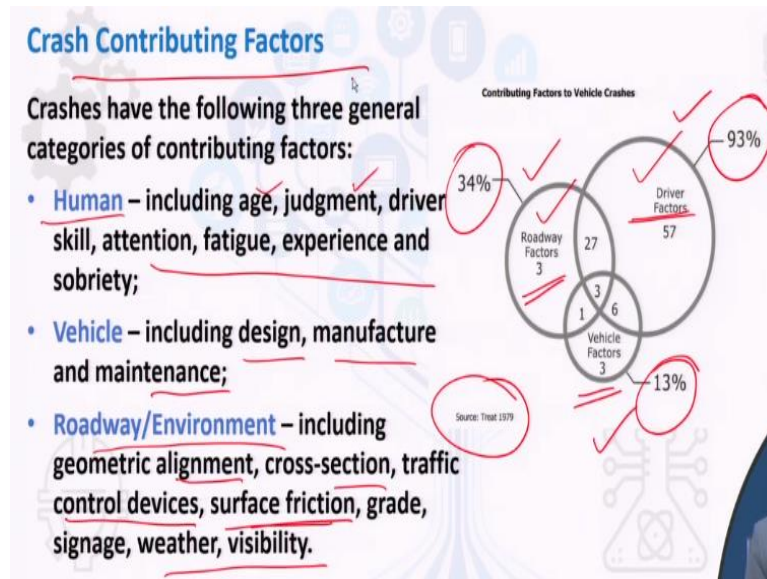
Source: <https://www.newindianexpress.com/states/odisha/2020/feb/01/nhai-finds-8-black-spots-in-ganjam-2097509.html>

So, when we want to estimate a crash, one way to know about a crash or an accident is after the fact that the accident happens. Now, that is a very reactive way of understanding or knowing where the crash has happened, but if you had to predict a crash or if you had to estimate that this roadway is likely to have n number of crashes in the next month or in the next year, then it is a proactive measure, and you make some interventions so that these crashes can be prevented. So, that is why it is especially important nowadays in today's transportation arena to estimate the crashes. So, when we say estimate of crashes what we are usually trying to do is we are trying to develop different methodologies to predict crash frequency, how frequently a crash can occur. So, it can be on an existing roadway for existing conditions during the past or in the future. So, if you already have data about the number of accidents or crashes in the past, then for that a roadway you can say for example on state highways in such and such state and in this district, there were n number of crashes per year. So, that is kind of a crash frequency that is quite easy to understand simple terminology of understanding what crash frequencies in the past are.

But can you use the same trend and predict that the crash frequency will be the same in the future or not that is what something we will tell you how to do that okay. So, it can be for an existing roadway, it can be for existing roadway for alternative conditions, maybe different conditions cause different crash frequencies, or it could be for a totally new roadway as well, that a new roadway is being built between two points. So, what is the probability or what is the prediction that how many crashes will occur there or how frequently they will occur. So that is also something that must be considered. So that this is the best time to consider the crash frequencies for a new roadway because vehicles have not yet started playing on that

roadway so that you can incorporate safety measures proactively to reduce the probability of those crashes happening.

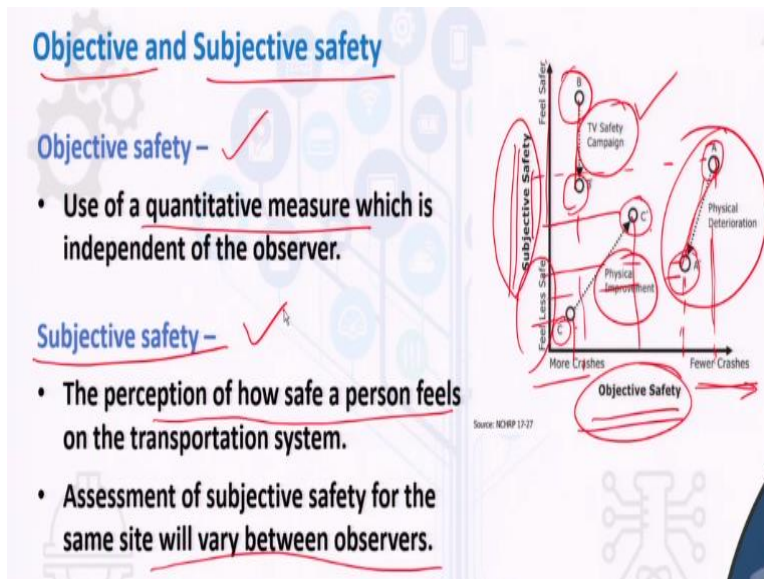
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Now, what are the different contributing factors when it comes to crashes? So, what you will see in this picture on the right-hand side is overall what are the 3 different types of factors that we group them under. One is the roadway factors; the other are the vehicle factors and then there are driver factors. So, you will see this is a little bit of an old data set, but these percentages may differ as we are improving our research day by day. But overall, what we have seen is the crashes may occur due to different driver related factors, different roadway related factors and different vehicle related factors. So, driver related, or human factors include age, judgment, driver skill, attention, fatigue whereas vehicle related factors include the design of the vehicle, the maintenance of the vehicle, the manufacturer, what type of vehicle is it.

And whereas the roadway or the environment include the geometric alignment, cross section, traffic control devices, meaning signals or unsignalized intersection, the surface friction, grade, weather, visibility and all. So, these are broadly all the different types of factors that contribute to crashes on a facility on a highway or urban road.

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So, these are different types of means of understanding how you can improve the safety of a facility. Similarly, when there is physical deterioration, so when a road or a bridge or anything is deteriorating in age, so what you start to suddenly feel is, you were feeling safer

here, but you suddenly now start to feel less safe because that bridge is getting less and less safe. At the same time, maybe objectively as well there are increasing number of crashes.

Here there are fewer crashes, now there are more crashes, but the slope of the line says that your feeling of safety is reducing by a larger amount than the actual objective safety or the actual number of crashes that are taking place. So different measures give result to different types of objective and subjective safety implications. So, you are not only looking at the objective safety, but at the same time you must look at subjective safety of your highway or the facility in your area.

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**Descriptive Analysis**

- Methods which summarize in different forms the history of crash occurrence, type and/or severity at a site.
- Focus on summarizing and quantifying information about crashes that have occurred at a site.

**Example:**

Variable	Levels	Number of Death	% of Total Death	Number of Injuries	% of Total Injuries	Total Number of Crashes	% of Total Crashes	Mean of Injuries per Crash	Mean of Death per Crash
Road junction type	Mid-block/no junction	1143	89.1	4234	61.2	21660	63.0	0.314	0.014
	Y junction	17	1.9	302	6.8	1572	4.6	0.478	0.005
	T junction	113	4.9	676	6.9	3800	11.1	0.201	0.005
	Roundabout	34	1.1	464	11.3	2917	8.3	0.440	0.001
	Four leg junction	57	3.8	564	11.4	4005	11.7	0.318	0.004
	Five leg junction	26	6.23	62	2.18	483	1.4	0.501	0.048
Total		1390		6302		34457			

Source: <https://www.semanticscholar.org/paper/Descriptive-Analysis-of-Road-Traffic-Crashes-in-Aurat/08e8304de9972aa03afddff4edaee03683d38d8ea>

Then different descriptive analysis or descriptive measures have been developed over the years, which gives you an idea about the number of crashes or the frequency of crashes that are happening. For example, you may want to say you have decided that you want to know the number of accidents because of the different types of intersections that are there in your area. So, it may be at a midblock intersection, it may be at a Y intersection, it may be at a T intersection, it may be a roundabout, four legged or even five-legged junction. So, you can divide it up in that way and understand what the safety implications at different types of intersections in your city are. So, to know different parameters that are involved in understanding the road safety you may include just purely the number of people that have died at each of these or the percentage of death, number of injuries. Remember all crashes do not lead to death, there may be a lot of crashes that lead to minor injuries, major injuries and then maybe they lead to death. So, you may want to know either the total number or the


percentage, just the total number of crashes or you want to divide it up into different types of injuries, minor injury or mean of the injuries or mean of the deaths.

So, you can develop different types of descriptive statistics, which will give you a clearer picture based on where you want to know about the safety of your facility in the city. So, similarly, you can do it for different types of roads, you can do it for daytime, nighttime, so you can do it for multiple parameters, and you can calculate all these. These are all done so that the measure that you implement to improve, it should be specific. So, in this type of situation, you must look at possibly midblock section is the most vulnerable section in this case. So, you must improve the safety of the pedestrians crossing at midblock for example maybe, so, what type of intervention do you put? You should not go for an intervention that is more effective at a signalized intersection versus now you have to think of something that is more practical for midblock sections. So that is the reason why you develop all different types of descriptive statistics.

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**Quantitative Predictive Analyses**

- To calculate an expected number and severity of crashes at sites with similar geometric and operational characteristics for existing conditions, future conditions and/or roadway design alternatives.
- Focus on estimating the expected average number and severity of crashes.



Source: <https://www.team-bhp.com/forum/road-safety/206476-car-crash-investigation-research-analysis.html>

You also must know quantitatively how well to predict. Prediction always has a lot of errors. Now, when you are trying to predict anything, you need essentially lot of input values. The better the input values, the more precise the input values, the better will be your prediction. So, a system that we are moving towards is to capture all incidents or all crashes that happen at a roadway and write down the parameters then and there. So, when an accident happens, you would see that not only the police arrives, maybe the ambulance arrives at that spot, we are also trying to have an engineer along with them arrive at the spot so that the engineer can

help point out some deficiencies in the roadway, design, or the intersection design or whatever it is. So that all the parameters are captured at the same time of the crash.

By collecting all those parameters, then you can hope to develop a predictive model which will give you better results. So, it is important for us to do such kind of accident investigation right at the spot and you must have different types of people come there, so not only the ambulance, not only the police, but also maybe engineers on the spot so that they can verify how different parameters or what are the different parameters that were involved for that crash.

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**Evolution of Crash Estimation Methods**

- Crash estimation using observed **crash frequency and crash rates** over a short-term period, and a long term period (e.g., more than 10 years)
- **Indirect safety measures** for identifying high crash locations. Indirect safety measures are also known as **surrogate measures**
- **Statistical analysis techniques** (specifically the development of statistical regression models for estimation of crash frequency), and statistical methodologies to incorporate observed crash data to improve the reliability of crash estimation models.

Now, how have the different crash estimation methods evolved? We have already talked about crash frequency. The other thing that people now look at rather than just crash frequency is something called a crash rate. That tells you that how many crashes are happening per n number of miles of vehicles driven on that road. So, the point is the more the number of vehicles, the likelihood that the number of crashes will increase is higher.

So, it is not just the frequency or how many accidents are happening per year or per month, it is also how many vehicles are on that road or how many vehicles have been driven on that road. So that is something is called a crash rate and then there are of course a lot of indirect safety measures known as surrogate measures that have been developed. Surrogate measures usually mean for example if you do not wear a helmet, you are more likely to be involved in an injury or fatality related crash if you are on a two-wheeler. So, people are trying to relate the wearing of helmet or the wearing of a seatbelt when you are in a car to the probability of



you being involved in a major crash or a major injury crash. So different types of crashes you can categorize that into. So, these are called surrogate measures or indirect measures. So, when you do not have good information, good data on your roadway segment direct number of accidents or information that is available firsthand, if you do not have that kind of data, then what you do usually is try to predict an accident using different types of indirect measures and those indirect measures are usually called surrogate measures. And then there are of course statistical techniques, which looks at what is the best model that fits the existing number of accidents. Usually, people will see that can regression models estimate crash frequency or can Poisson models or negative exponential models fit the crash frequency that is happening.

So, those are all statistical tools, then again if those can also help in predicting future crashes if the models fit is very good. If the models fit is very good, then you can predict these crashes in the future as well.

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**Observed Crash Frequency and Crash Rate Methods**

Crash frequency and crash rates are often used for crash estimation and evaluation of treatment effectiveness.

- **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.

**HAVOC ON ROADS: HOW CITIES FARE**

City	Accidents		Ranking	
	2017	2018	2017	2018
Chennai	7,257	7,580	1	1
Delhi	6,673	6,515	2	2
Bengaluru	3,297	4,611	12	3
Bhopal	3,393	3,508	4	4
Indore	4,513	3,434	3	5

City	Deaths		Ranking	
	2017	2018	2017	2018
Delhi	1,584	1,690	1	1
Chennai	1,299	1,260	2	2
Kanpur	682	698	4	3
Jaipur	813	692	3	4
Bengaluru	653	686	6	5

Source: Ministry of road transport & highways

So, crash frequency or crash rates are often used for crash estimation and evaluation, they are simplistic. So, for example, you many times see such statistics in the newspapers or in the digital media or in the TV showing the number of accidents that have happened per city per year and how well they rank. So, these are easy to understand and since these crashes have already happened, so the validity, the acceptance of these numbers is high.

People do believe in these numbers, but you know it does not provide a means of predicting crashes, it is just a very reactive method. So just know about the crash after the crashes

happen. That is an old way of trying to deal with reducing the number of crashes. So, it does not give you alternatives, it does not give you different methods of prediction or anything like that.

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**Crash and Crash Frequency**

- ✓ **Crash Frequency** - the number of crashes occurring at a particular site, facility or network in a one-year period.

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

- ✓ **Crash Rate** - the number of crashes that occur at a given site during a certain time period in relation to a particular measure of exposure

$$\text{Crash rate per 100 million vehicle miles traveled} = \frac{(C \times 100,000,000)}{(V \times 365 \times N \times L)}$$

C = Number of crashes in the study period

V = Traffic volumes using average annual daily traffic (AADT) volumes

N = Number of years of data

L = Length of the roadway segment in miles

However, if you look at each of those methods the crash frequencies, simply the number of crashes divided by the period in either years or months or whatever you are looking at and crash rate, which is a better measure than crash frequency. What it says is that a crash rate per 100 million vehicles miles traveled. So, if more the number of vehicle miles VMT or VKT traveled on the road, the number of crashes is likely to be higher.

So, number of crashes into 100 million divided by the volume on that road every day, number of years you want it for the total length segment that you are looking at. So that is essentially how you determine the crash rate.

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## Numerical Problem #1

Find the crash frequency and crash rate of the following

**Road Segment A:**

A three-mile section of road that has had four crashes over five years and has a traffic volume of 4,000 vehicles per day.

**Road Segment B:**

A three-mile section of road that has had 10 crashes over five years and has a traffic volume of 12,000 vehicles per day

So, if you are given simple problems like this, say for example on road segment A, which is a three-mile section, it has had 4 crashes over 5 years and has a traffic volume of 4000 vehicles per day, whereas the next segment B is also a three-mile section, but it has had 10 crashes over 5 years and has a traffic volume of 12,000 vehicles per day. So, if you determine crash frequency and crash rate, what do you expect to see?

Which is the worst segment, or which is the better segment? That is what you essentially want to compare these two segments to see which is the worst segment and then maybe prioritize. Usually, you want to help both segments, but if you must only prioritize, then you would have to pick which segment to improve.

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### Numerical Problem #1 - Solved

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

Road Segment A:  $4/5 = 0.8$  ✓

Road Segment B:  $10/5 = 2$

**Crash rate –** 
$$\text{Crash rate per 100 million vehicle miles traveled} = \frac{(C \times 100,000,000)}{(V \times 365 \times N \times L)}$$

Road Segment A:  $(4 \text{ crashes} \times 100,000,000) / (4,000 \text{ vehicles per day} \times 365 \times 5 \text{ years} \times 3 \text{ miles}) = 18.2 \text{ crashes per 100 million vehicle miles traveled}$  ✓

Road Segment B:  $15.2 \text{ crashes per 100 million vehicle miles traveled}$

So, if you purely looked at crash frequency, then you would have seen that segment A where 4 crashes in 5 years 0.8, whereas 10 crashes in 5 years is 2. So, you would have thought that segment B is a worse segment. However, if you start now looking at the crash rate which depends upon how many vehicles are traveling on that road, then you would see that segment A, the crash rate in segment A is 18.2 crashes per 100 million vehicles traveled.

Whereas segment B is only 15.2 per 100 million vehicles traveled that gives you an idea of maybe road segment A is a more serious situation and we must focus more there because the crash rate is higher on segment A, although crash frequency is lower. So that is why more and more people are looking at crash rates rather than just the frequency of crashes.

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### Indirect Safety Measures

Provide surrogate methodology when accident frequencies are not available because –

- Roadway or facility is not yet in service, or
- Roadway has been in service for a short time, or
- Crash frequencies are low, or
- Roadway or facility has significant unique features.

Surrogates based on events which are proximate to and usually precede the accident event.

Eg. at an intersection, the encroachment time, i.e. the time during which a turning vehicle infringes on the right of way of another vehicle may be used as a surrogate estimate.

### FATAL ERRORS

Error	Killed	Gravely Injured
Not wearing helmet	35,975	36,678
Not wearing seatbelt	28,896	33,264
Driver using cellphone	3,172	3,668

\*2017 figures

Source: <https://timesofindia.indiatimes.com/india/98-helmetless-riders-died-per-day-in-india-last-year/articleshow/66126827.cms>

Surrogates that presume existence of a causal link to expected accident frequency.

Eg. proportion of occupants wearing seatbelts may be used as a surrogate for estimation of crash severities.

What are the indirect means of understanding safety, like we said the surrogate methodology is used primarily because maybe a road or a facility is not yet in service, so it is a road that is just being built, so you do not have any previous data on the road, so how can you predict what the crashes will be on that road or it has been only just open for the last few months or a few weeks, so you do not have a lot of data on it.

So, how can you then predict, or maybe crash frequencies are low. Frequencies are low; however, people are complaining that there are a lot of accidents that are leading to fatalities maybe. So, you do not know then how you deal with it or if it has some unique features like it has lots of curves, horizontal curves, or vertical curves more than the average amount number of curves.


So, such unique features may also lead to developing a unique surrogate measures which tells you about the safety of that area. So, here you have seen that people are, like we were talking, not wearing helmet versus not wearing a seatbelt and drivers using cellphone. So, it has been noticed that if you are using a cellphone, then the number of grievous injuries is higher and even the number of killed is that much. So, you can then use these surrogate measures to predict how crash frequency will happen and what type of crash will happen. For example, say for example at an intersection the encroachment time that is the time during which a turning vehicle infringes on the right of way of another vehicle can be used as a surrogate estimate. So, for example if you have you know free left turns and many intersections you have.

So, the free left turn time and through vehicle is coming on the main road, so there is a possibility that these two vehicles may collide or during the free left turn, maybe somebody is trying to cross, a pedestrian is trying to cross that road. So, they may interact or collide with each other. So, the encroachment time may be a surrogate measure for safety at an intersection and we have already looked at or talked about wearing seatbelts or not wearing helmets being a surrogate measure.

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**Crash Estimation using Statistical Methods**

- These models provide the ability to reliably estimate expected average crash frequency for not only existing roadway conditions, but also for changes to existing conditions, or for a new roadway design prior to its construction and use.
- The reliability of the model is partially a function of how well the model fits the original data and partially a function of how well the model has been calibrated to local data.



Source: [https://en.wikipedia.org/wiki/Speed\\_bump](https://en.wikipedia.org/wiki/Speed_bump)      Source: <https://www.flickr.com/photos/annp/583756031/>

When we start looking at the statistical method, we have already told you that these may be either simple regression equations or they may also be Poisson or negative binomial. People are tending to look at negative binomial and Poisson because usually when we look at the number of crashes that happen on one roadway for example over the year or two years, they are usually termed as rare events.

I mean rare events as in you would see that there are a lot of accidents happening, but in terms of count or in terms of if you count each crash as an event, so for over 365 days you may find you may find only there are 50 accidents that have happened. So, 50 out of 365 days seems like a rare event. So that is why some researchers are modeling crashes as rare events. However, it is imperative that these statistical models have a good fit.

Otherwise, you may not be able to predict the future crashes very accurately and calibration to local data is important. So, once you have your statistical model, you then calibrate it. Maybe the model was developed in another city, in another town, in another country, you have to calibrate it to local conditions that validate it with the actual number of accidents that have happened. Only then statistical models can be used with confidence.

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**Basic Elements of the Predictive models**

**Safety Performance Functions (SPFs):** Statistical "base" models are used to estimate the average crash frequency for a facility type with specified base conditions.

**Accident Modification Factors (AMFs):** AMFs are the ratio of the effectiveness of one condition in comparison to another condition.

**Calibration factor (C):** Multiplied with the crash frequency predicted by the SPF to account for differences between the jurisdiction and time period for which the predictive models were developed and the jurisdiction and time period to which they are applied.

So, in these predictive models, what people use in general are these are what are called safety performance functions. So, if you are really a person that is working in transportation safety arena, then you will be dealing with a lot of these safety performance functions, SPF. These are statistical base models used to estimate average crash frequency for a particular facility with specified base conditions.

These are equations most likely regression equations, sometimes they are negative exponential equations that have been developed for a certain base condition. Now, if you take that to another condition then like we said you must calibrate it to those conditions and then use it in order to predict. So, we will show you what safety performance functions are. Then

accident modification functions or AMFs are the ratio of the effectiveness of one condition in comparison to the other condition.

So, now you have developed a countermeasure, maybe you have implemented a countermeasure to reduce safety. So, what is the modification factor because of that implementation of that safety measures, maybe you have increased police patrolling. So because of increased police patrolling on that roadway how have accidents changed. So, the ratio of before and after gives you the actual modification factor.

Then somebody else in some other neighborhood or in some other city can also think that well if I have more police patrolling this roadway, maybe my accidents would also go down. So, those are called accident modification factors. Finally, the calibration factors are these are multiplied with the crash frequency predicted by the SPF to account for differences between the jurisdiction and the time-period for which they were developed. So, maybe this was developed 5 years ago for a different city. However, now you want to use it 5 years later for a different city. So, you must calibrate it to your area, to the time period. So, all those calibrations are involved in this.

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**Basic Elements of the Predictive models**

While the functional form of the SPFs varies, the predictive model to estimate the expected average crash frequency  $N(\text{predicted})$ , is generally calculated using

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

Where,

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

Usually, this is how you will see a predictive statistical model. So,  $N$  predicted or the number of crash or the crash frequency for a specific year on a specific type will be given by your SPF function, safety performance function, which is then multiplied by your accident modification factors and your calibration factor. So, this is a basic gross level model.

If you are trying to develop a predictive model for your area, it will have all these elements, but different factors will be there for your case calibration, the value of calibration may be less, maybe high. So, this is basically but this is how your model should look like.

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**Safety Performance Functions**

- 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).
- Base conditions are specified for each SPF and may include conditions such as lane width, presence or absence of lighting, presence of turn lanes etc.

$$N_{SPF} = (AADT)^a (L)^b (365)^c \times 10^{(d)} \times e^{(-0.48865)}$$

Where,

**An example of a SPF (for roadway segments on rural two-lane highways)**

$N_{SPF}$  = estimate of predicted average crash frequency for SPF base conditions for a rural two-lane two-way roadway segment (crashes/year);

AADT = average annual daily traffic volume (vehicles per day) on roadway segment;

L = length of roadway segment (miles).

Then, if you have looking at developing these safety performance functions, usually they will look like something like this. So, for example a safety performance function for roadway segment on rural two-lane highways. This is as specific as that it must be for a particular type of facility. So, if you had to develop a SPF for a two-lane rural highway, maybe this will look like this.

So, it has the vehicles per day, AADT, length of stretch, it is for all 365 days and then these have been developed based on all the data that has been collected. So, it looks like it is some form of exponential function that you are using to predict the average crash frequency for the base conditions. This is for base conditions for rural two-lane highways.

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## Accident Modification Factors

- Accident Modification Factors (AMFs) represent the relative change in crash frequency due to a change in one specific condition (when all other conditions and site characteristics remain constant).
- AMF 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.
- AMFs have also been developed for conditions that are not associated with the roadway, but represent geographic or demographic conditions surrounding the site or with users of the site (e.g., the number of liquor outlets in proximity to the site).

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

Now, like we said those are all for basic conditions. If you must now improve those conditions and you have taken certain strategies, maybe you must estimate the effect of geometric design or traffic control feature or the effectiveness of the particular treatment, so essentially you have to have accident modification factors that is the expected average crash frequency with condition b. Condition b is the improved condition, divided by the expected average crash frequency with condition a. So, that will give you by how much, how effective was your implementation on that roadway.

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## Numerical Problem #2a

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. Find the expected average crash frequency.

Solution:

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 –

$$N_{\text{(predicted)}} = \text{SPF} \times \text{AMF}$$
$$0.83 \times 10 = 8.3 \text{ crashes/year}$$

Simple examples using SPF for two-lane roadways, the expected average crash frequency of existing conditions is 10 injury crashes per year, assume observed data is not available. This is just using an SPF. The base condition in the absence of automated speed enforcement. So,

this is the base conditions where automated speed enforcement was not available. However, if automated speed enforcement was installed, the AMF for the injury crashes is 0.83.

It has been noticed that it is 0.83. So, what is the average crash frequency that you can expect? You just have to you know that this is the formula which will give you the expected or the predicted average frequency. You know your SPF, and you know your SPF is 10 and you know your accident modification factor for this kind of intervention. This is the kind of intervention for which accident modifying factor of 0.83. So, now you can expect that there will be 8.3 crashes per year, which are down from 10 crashes per year. So, that is quite simple.

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**Numerical Problem #2b**

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 left 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 tx, AMFx = 0.81; for treatment ty, AMFy = 1.07. What accident frequency is to be expected if treatment x and y are both implemented?

Solution:

$$N_{(\text{predicted})} = \text{SPF} \times \text{AMF}_x \times \text{AMF}_y$$
$$\text{expected accidents} = 7.9 \times 0.81 \times 1.07 = 6.8 \text{ accidents/year}$$

Similarly, if there is a treatment x which consists of providing a left-turn lane on both major-road approaches to an urban four-leg signalized intersection and treatment y is permitting left turn on red maneuvers, so you have free left turns that you can do. Both treatments are to be implemented and it is assumed that their effects are independent of each other. So, if both are implemented what will happen and if you assume that their effects are independent.

So, an urban four-leg signalized intersection is expected to have, so you have seen from other data somewhere else then it is expected to have 7.9 accidents in year, but at your location you have implemented these two treatments. So, how much do you expect it to change by? So, this is what is the base condition. You have these two accident modification factors, since they are independent of each other, you can multiply both.

And you can see that your accidents might reduce to 6.8 accidents per year. So that is quite simple understanding of how to carry out the statistical modeling.

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**Calibration**

- Calibration is the process of adjusting the SPFs to reflect the differing crash frequencies between different jurisdictions.
- Calibration can be undertaken for a single state, or where appropriate, for a specific geographic region within a state.
- Calibration provides a method to account for differences between jurisdictions in factors such as climate, driver populations, animal populations, accident reporting thresholds, and accident reporting system procedures.

Calibration. The last thing in your understanding how to predict crash frequencies is the process of adjusting the SPF to reflect different crash frequencies of different jurisdictions. Calibration can be undertaken for a single state or where appropriate within different geographical areas within the status as well. It accounts for factors such as climate, driver population, animal population, accident reporting thresholds, and accident reporting system procedure.

So, all of these may vary from place to place. So, in order to take into account all of these you have to adjust your SPF or your safety performance functions, only then you can use it for your jurisdiction. So, accident modification factors are interventions that you take, whereas calibration is you calibrate it to your jurisdiction. You have not implemented anything yet. But because the SPF was developed for a different jurisdiction, you had to bring it to your jurisdiction, so you must calibrate it, calibrate that function, or calibrate that equation or model to your jurisdiction. So that is kind of what the calibration is.

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## Calibration

The calibration procedure involves five steps:

- Step 1** – Identify facility type for which the applicable predictive model is to be calibrated
- Step 2** – Select sites for calibration of the predictive model for each facility type
- Step 3** – Obtain data for each facility type applicable to a specific calibration period
- Step 4** – Apply the applicable predictive model to predict total crash frequency for each site during the calibration period as a whole
- Step 5** – Compute calibration factors for use in predictive model

$$C_i \text{ (or } C_j) = \frac{\sum_{\text{all sites}} \text{observed crashes}}{\sum_{\text{all sites}} \text{predicted crashes}}$$


Simply the calibration factors are again summation of all observed crashes divided by summation of all predicted crashes. So, once you identify the facility type, select sites for calibration, obtain data for each facility for the specific calibration period, then you apply your predictive model to predict the crash frequency. Once you get the crash frequency, you also know what the observed crashes in your area are.

So, while you are calibrating you are not yet predicting it, you are calibrating so that your model should be as close as possible to the actual crashes that have happened. So, if this value is close to 1, then you would say that your observed and predicted crashes are very close to each other, your equations are predicting, or your model is predicting the crashes very well. So, then your calibration factor is almost close to 1.

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## REFERENCES

- **AASHTO, 2010. The Highway Safety Manual, American Association of State Highway Transportation Professionals, Washington, D.C.**
- <http://www.highwaysafetymanual.org>



So, that is the end of this lecture. Most of the materials here have been taken from the highway safety manual that has been developed by AASHTO in 2010 in USA. This is a particularly good resource when you are talking about safety in the highway arena in the transportation arena. So, I recommend that you guys go through this manual very carefully.

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## CONCLUSION

- Crashes are rare and randomly occurring events which result in injury or property damage.
- Crash estimation methods are reliant on accurate and consistent collection of observed crash data.
- The predictive method uses SPFs and AMFs to estimate predicted average crash frequency.
- These models must be calibrated to local conditions to account for differing crash frequencies.

In conclusion, we have introduced all the different types of crashes and how they occur. They are very random and rare, so it is important to have prediction tools so that you can then implement certain safety measures to reduce the occurrence of these crashes. We have introduced you to different types of safety performance functions and accident modification functions that allow you to use statistical tools to predict the average crash frequency in your area.

We have told you how to determine crash rates and finally it is important to know that these safety performance functions must be calibrated to local conditions in order to account for different crash frequencies. Thank you.