Lecture 5: Road Safety Measures

Introduction

- Road safety measures
  - Any technical device or programme that has improving road safety as the only objective or at least one of its stated objectives.
  - May be directed at any element of the road transport system: patterns of land use, the road itself, road furniture, traffic control devices, motor vehicles, police enforcement, road users and their behaviour, etc.

Introduction

- Road safety measures
  - Institutional organisation of road safety
  - Road infrastructure
  - Vehicles and safety devices
  - Road safety education and campaigns
  - Driver training
  - Traffic law enforcement
  - Post crash care
  - …

Institutional Organisation of Road Safety

- Refers to a variety of measures which, together, form the basis for the implementation of measures in all fields of road safety.
- The measures relate to:
  - the general organisational framework,
  - road safety visions,
  - road safety targets and strategies,
  - the provision and allocation of financial resources,
  - tools and strategies for selection and implementation of (cost-effective) road safety measures,
  - …

Institutional Organisation of Road Safety

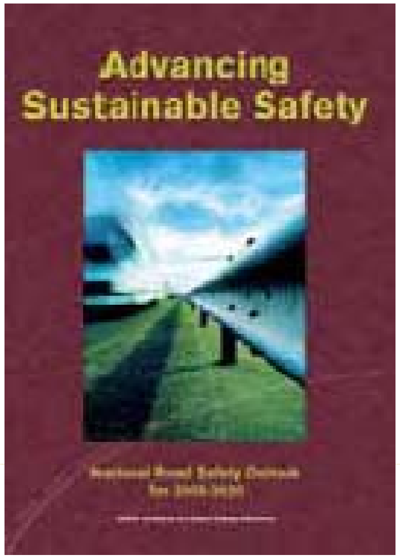
- Vision Zero in Sweden
  - In 1997, the Swedish Parliament adopted the Vision Zero, a bold new road safety policy based on four principles:
    - Ethics: human life and health are paramount; they take priority over mobility and other objectives of the road transport system.
    - Responsibility chain: the providers, professional organisations and professional users are responsible for the safety of the system. The users have the responsibility to follow rules and regulations. If the road users fail to follow rules and regulations, the responsibility falls back on the providers of the system.
    - Safety philosophy: humans make errors; road transport systems should minimise the opportunity for error and the harm done when errors occur.

Institutional Organisation of Road Safety

- Vision Zero in Sweden
  - Driving mechanisms for change: providers and enforcers of the road transport system must do their utmost to guarantee the safety of all citizens and each of the participants should be ready to change to achieve safety.
  - The adoption of Vision Zero in Sweden helped in developing further research and implementing a new system design.
  - www.visionzeroinitiative.com

Institutional Organisation of Road Safety

- Sustainable Safety in the Netherlands
  - The Sustainable Safety vision aims to prevent crashes and if they still occur, to minimise their consequences.
  - It has been the leading vision in the road safety policy of the Netherlands since the early nineties.
  - www.sustainablesafety.nl



Institutional Organisation of Road Safety

- Sustainable Safety in the Netherlands
  - There are five main principles: functionality, homogeneity, predictability, forgivingness, and state awareness.
    - E.g., one of the consequences of the principle homogeneity is that motorised traffic and vulnerable road users (pedestrians, cyclists) can only interact if speeds of motorised traffic are low. If speeds cannot be kept low, separate facilities for vulnerable road users are required.
    - Measures to realise this included a substantial increase in the number and size of 30km/h zones in built-up areas; the introduction of 60km/h zones outside built-up areas, and speed reduction at intersections.

Road Infrastructure

- Defined as the basic facilities, services and installations needed for the functioning of transport on highway, roads, and streets.
- It is a wide area and covers:
  - land use and network planning,
  - (re)construction and design of road sections and intersections,
  - signing and marking,
  - maintenance,
  - quality assurance procedures, e.g., safety audits, safety impact assessments and safety inspections,
  - …

Road Infrastructure

- Low speed zones in residential areas
  - In many countries, low speed zones have been introduced in residential areas, near schools and in shopping areas.
  - In Europe, 30km/h zones are most common.

Road Infrastructure

- Low speed zones in residential areas
  - Apart from a speed limit sign, low speeds must be maintained by physical measures, e.g., road narrowings, speed humps and curves.




  - A UK study showed that 30km/h zones reduced crashes by 27%, crashes causing injury by 61%, and serious injury crashes by 70%.

Road Infrastructure

- Roundabouts
  - Most European countries apply roundabouts at junctions and their numbers are increasing rapidly, e.g., since 1986, over 2000 roundabouts have been built in the Netherlands.

Road Infrastructure

- Roundabouts
  - Aimed at lowering junction speeds and removing right angle and head-on collisions.
  - Have a greater capacity than normal give-way or signalized junctions.
  - A driver approaching a roundabout is forced to lower his entry speed, which reduces crash severity.
  - Studies have shown that when converting an ordinary junction to a roundabout, injury crashes will decrease by 32% for a three-leg junction and 41% for a four-leg junction.

Road Infrastructure

- Rumble strips
  - Are milled into the asphalt surface of a road shoulder or between lanes in opposite directions in combination with ordinary road markings.

Road Infrastructure

- Rumble strips
  - Vibrate and make a noise when a vehicle passes over them and alert drivers to the potential crash danger changing lanes poses.
  - Research from different countries has shown that the number of injury crashes can be reduced by over 30% by shoulder rumble strips and by over 10% by centreline rumble strips.

Road Infrastructure

- Variable message signs
  - Adaptation of speed limits and communication of warnings via ‘Variable Message Signs’ (VMS) – depending on traffic, weather and road conditions, has been applied successfully in different countries, mainly on congested or crash-prone motorway sections.

Road Infrastructure

- Variable message signs
  - Many of these systems are implemented to solve a specific problem, e.g., ‘congestion warning systems’. They can help to harmonise traffic flow and increase throughput on congested sections.
  - It has been observed that warning displays alone do not have much influence on speed behaviour, while speed limits justified by warnings or explanations have significant effects.

Road Infrastructure

- Road safety audits
  - A formal procedure for independent assessment of the crash potential and likely safety performance of a specific design for a road or traffic scheme.
  - The idea was first developed in Great Britain and is applied now in many other countries.

Road Infrastructure

- Road safety audits
  - Audits are based on detailed checklists listing the items to be examined. They are often described as a first step leading to the implementation of a complete quality management system for roads.
  - The benefits of road safety audits are that they reduce the future risk of crashes as a result of new transport infrastructure schemes and unintended effects of road design.
  - The estimations in different countries indicate that the cost of audits is less than 1% of the construction cost of the whole project.

Vehicles and Safety Devices

- Vehicles and vehicle safety devices play an important role in traffic safety.
  - The design of a vehicle affects the protection of occupants in case of a crash and the chance of serious injury to unprotected, vulnerable road users.
  - Additional safety devices, e.g.,
    - Seatbelts and airbags offer additional protection to car occupants.
    - Protective clothing and helmets for two-wheelers help to mitigate the consequences of a crash.
    - Intelligent driver support systems, including in-vehicle, between-vehicle and road-vehicle technologies, help the driver to perform tasks safely, preventing errors and violations which may otherwise have resulted in a crash.

Vehicles and Safety Devices

- EuroNCAP
  - The European New Car Assessment Programme (Euro NCAP) performs crash tests of the most popular cars sold in Europe to assess the protection they offer to its occupants and to pedestrians, which include:
    - a frontal impact test at 64km/h into an offset deformable barrier,
    - a side impact test at 50km/h,
    - a side impact pole test at 29km/h, and
    - tests with pedestrian head and leg (partial) dummies at 40km/h.
  - Safety performance is evaluated for adults and children. Seat-belt reminders are also taken into account in the evaluation.

Vehicles and Safety Devices

- EuroNCAP
  - Based on the results, adult occupant protection, pedestrian protection, and child protection are evaluated on scales of 1 to 5 stars, the more stars, the better the protection.
  - An evaluation study showed that the risk of severe or fatal injuries is reduced by around 12% for each extra EuroNCAP star rating.

Vehicles and Safety Devices

- Driver support systems
  - Lane Departure Warning System
    - Warning or intervening when a driver crosses the side line of his driving lane.
  - Intelligent Speed Assistance
    - Giving feedback to drivers about the speed limit in force or even restricting vehicle speed according to the speed limit in force.
  - Adaptive Cruise Control or Collision Avoidance System
    - When a driver approaches too close to the car ahead of him.
  - Seatbelt Reminders
    - When a driver and passengers forget to use a safety belt.
  - Electronic Stability Control
    - When a drvier is about to lose control of the vehicle.

Road Safety Education and Campaigns

- To promote knowledge and understanding of traffic rules and situations,
- To improve skills through training and experience,
- To strengthen or change attitudes towards risk awareness, personal safety and safety of other road users.

Road Safety Education and Campaigns

- The BOB Campaign in Belgium
  - The campaign has been present in Belgium since 1995. 15 EU Member States have copied it or have adapted it to their specific situation.
  - BOB is the name of a person who does not drink when (s)he has to drive and who brings his/her friends home safely.
  - The aim of the campaign is to convince people not to drink and drive, and to make drink driving socially unacceptable.
  - www.bob.be/index.htm

BOB

Road Safety Education and Campaigns

- The BOB Campaign in Belgium
  - The campaign is always combined with extensive enforcement during the campaign period.
    - Permanent elements (e.g., the BOB website, the BOB van, leaflets, key hangers, t-shirts)
    - Periodic elements (e.g., road side billboards and TV/radio advertisements)
  - The post-test showed that the BOB campaign is highly appreciated. Around 35% of the respondents say they have 'been' BOB and around two thirds of the people say they know someone who acts like BOB.
  - During the campaign period the percentage of drunk drivers drops from 9% to around 4%.

Driver Training

- Young, inexperienced drivers have a much higher risk of getting involved in a crash than older, more experienced drivers.
- Driver training is an important tool for preparing people to drive safely and for raising awareness of the risks of driving motorised vehicles.
  - Driving schools
    - The most common approach - professional training by certified instructors, followed by a (practical and theoretical) test and, if passed, a driving licence.

Driver Training

- Accompanied driving
  - Professional training has been supplemented with accompanied practice with parents or other licensed adults.

- Insight-based driver training
  - Provide insight into the reasons behind the need for risk awareness, skills, rules and regulations.
  - The aim is to work towards the ultimate goal of driver training, i.e., to create drivers who are safe and safety-oriented, and not just technically competent.

Traffic Law Enforcement

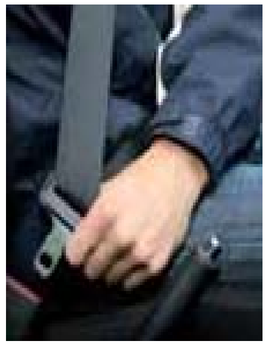
- Aims to prevent traffic offences by increasing the objective and subjective chance of getting caught.
  - The number and frequency of actual police controls along the road determine the objective chance of being caught.
  - Based on the objective chance and other channels (e.g., read in newspapers or hear from friends or colleagues), drivers estimate their own chance of being stopped for a traffic offence. This is the subjective chance of being caught.

Traffic Law Enforcement

- Automatic speed cameras
- Section controls
- Random breath testing
- Targeted seatbelt enforcement
- Penalty point systems





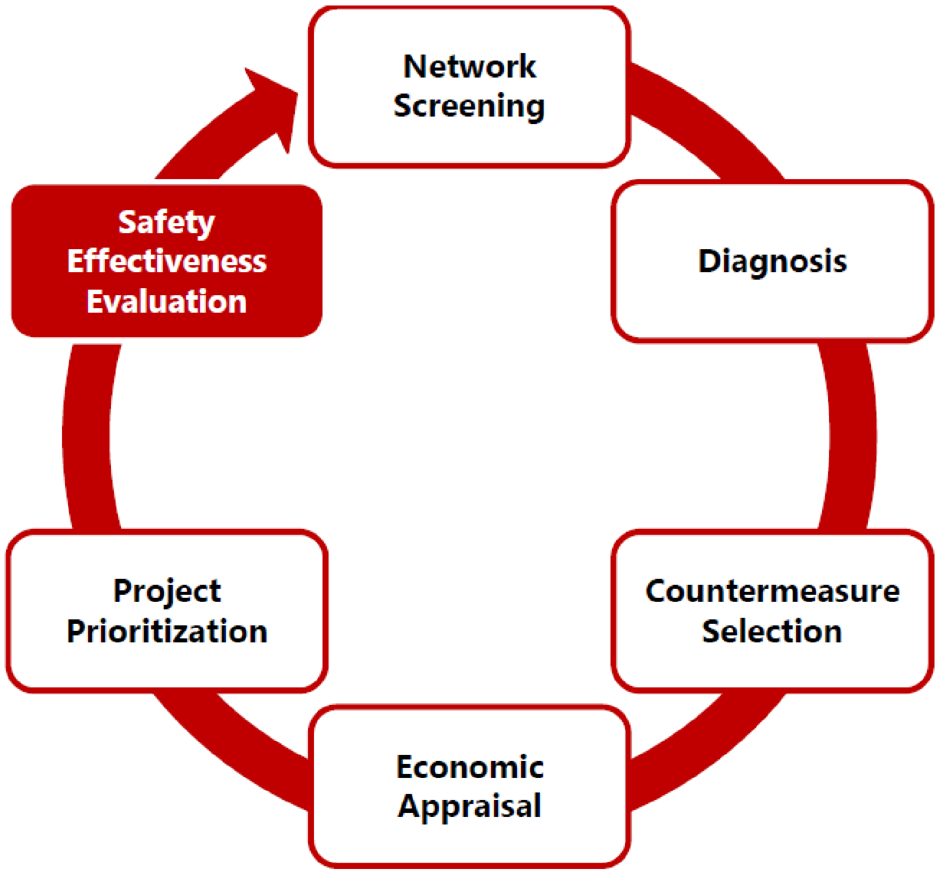


Post Crash Care

- Takes place after a crash has occurred and deals with optimising the chances of medical and psychological recovery of the victims.
- The care after a crash consists of:
  - first aid,
  - emergency call,
  - efficient response of emergency systems,
  - security and safeguarding of the crash site,
  - transportation and emergency medical treatment,
  - further treatment at medical centres, and
  - psychological support of victims and their relatives.

Lecture 6: Safety Effectiveness Evaluation

Introduction



Road safety management process (see HSM)

How does a particular measure/ treatment (or group of measures/ treatments) have affected the safety performance (crash frequency and severity) at the treated locations?

Introduction

- Safety Effectiveness Evaluation can include:
  - 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 safety effectiveness of specific types of projects or countermeasures in comparison to their costs.

Introduction

- Safety Effectiveness Evaluation 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.

Introduction

- 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 by highway agencies 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, e.g., 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.

Introduction

- Two types of observational studies can be classified:
  - Observational before-after studies
    - The most common approach used for effectiveness evaluation.
    - Data are collected for specific time periods before and after the treatment is implemented.
  - Observational cross-sectional studies
    - There are many situations in which a before-after study is not feasible, e.g., treatment installation dates are not available; crash and traffic volume data for the period prior to treatment implementation are not available; …
    - Data are collected for a specific time period for two groups. One implements the treatment, and the other does not.

Before-After Analysis

- Effectiveness (θ) = comparison of crash number after with before

$$\theta = \frac{L}{K} = \frac{\text{number of crashes in after period}}{\text{number of crashes in before period}}$$

If $\theta < 1$, crash numbers $\downarrow$

If $\theta > 1$, crash numbers $\uparrow$

If θ close to 1, no effect

Before-After Analysis

- Example:

  Installing traffic signals on an intersection.

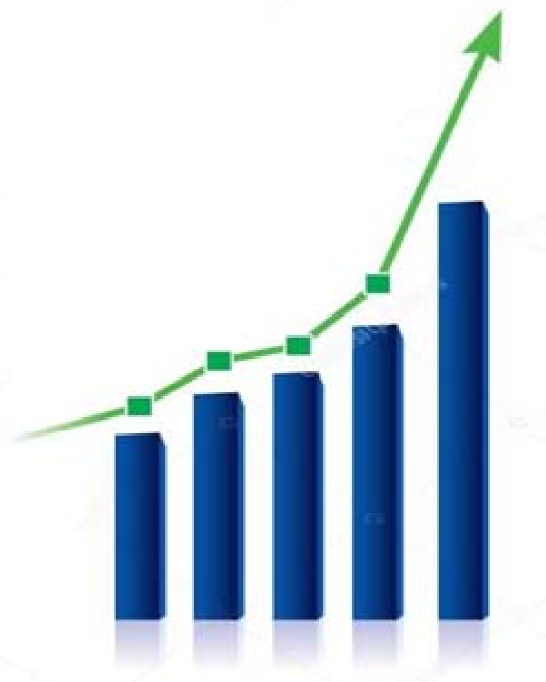
Nr. of crashes	
Before (-1)	***After (+1)***
10	**5**

$$\theta = \frac{L}{K} = \frac{5}{10} = 0.5$$

=> The number of crashes decreases by traffic signals = (1-0.5) = 50%

Before-After Analysis

- Two confounding variables
  - Trend
  - Regression to the mean (RTM)



Before-After Analysis

- Trend: Influence of factors that change over time
  - Changes in registration level of crashes, e.g., reporting system, reporting rate, etc.
  - Changes of behavior due to awareness campaigns, changing legislation, changes in public attitude, etc.
  - Changes in vehicle characteristics, e.g., ABS, airbags, mass, size, etc.
  - Effects of weather, e.g., hours of sunshine, drought, frost, etc.
  - …

Before-After Analysis

- Control for trend
  - Selection of a comparison group
    - Comparable to treated sites
    - Sufficiently large number of crashes

$$\theta = \frac{L/K}{N/M}$$

N = observed number of crashes in the comparison group in the after period
M = observed number of crashes in the comparison group in the before period

Before-After Analysis

- Control for trend

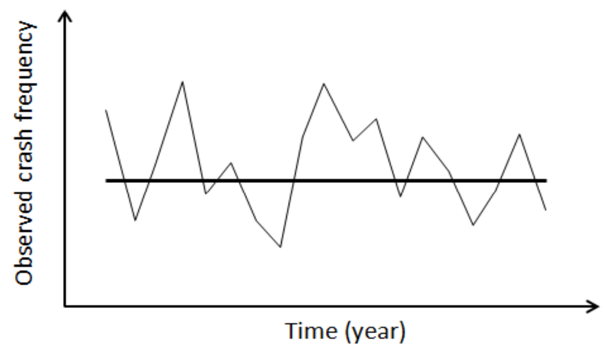
	Before (-1)	*After (+1)*
The site	**10**	**5**
Countrywide	**1000**	**800**

θ = (L/K)/(N/M) = (5/10) / (800/1000) = 0.625

=> The number of crashes decreases by traffic signals = (1-0.625) = 37.5% < 50%

Before-After Analysis

- Regression to the mean
  - The crash fluctuates over time, which makes it difficult to determine whether changes in the observed crash frequency are due to changes in site conditions or due to natural fluctuations.
  - When a period with a comparatively high (or low) crash frequency is observed, it is statistically probable that the following period will be followed by a comparatively low (or high) crash frequency. This tendency is known as **regression to the mean**.



Before-After Analysis

- Regression to the mean

Year	***-4***	***-3***	***-2***	***-1***		***+1***
Nr. of crashes	**5**	**5**	**5**	**10**		**5**

  - RTM occurs from year -1 to +1
  - Decrease caused by traffic signals = rather 0% than 50%

Before-After Analysis

- Regression to the mean
  - Failure to account for the effects of RTM introduces the potential for **RTM bias**.
    - 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.
  - How to account for the RTM bias?

Before-After Analysis

- NOT observed crash number during before period, but expected number of crashes.

$$\theta = L/K \quad \Rightarrow \quad \theta = L/E[k|K]$$

E[κ|K] = expected count of crashes given the observed number of *K* crashes

- Control for RTM
  - Tendency for an abnormally high (or low) number of crashes to return to values closer to the long term mean.

Before-After Analysis

- Regression to the mean
  - Failure to account for the effects of RTM introduces the potential for **RTM bias**.
    - 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.
  - How to account for the RTM bias?
    - The effect of RTM bias can be accounted for when site selection and treatment effectiveness is based on **a long-term expected average crash frequency**.

Empirical Bayes Method

- A method to estimate expected average crash frequency with the purpose of
  - increased precision of estimation, and
  - correction for the RTM bias.
- Joint use of two major clues:
  - Predicted crash frequency of similar entities, and
  - Observed crash frequency of treated entity.

$$N_{expected} = N_{predicted} \oplus N_{observed}$$

Empirical Bayes Method

observed crashes at treated entity

$$E[\kappa|K] = w \times E[\kappa] + (1 - w) \times K$$

expected crashes at similar entities

a crash prediction model (or safety performance function)

$$w = \frac{1}{1 + E[k] \times a}$$

where α = overdispersion parameter, which is calculated through the crash prediction model.

Empirical Bayes Method

- Two confounding variables
  - Trend
  - Regression to the mean (RTM)

$$\theta = \frac{L / E[k|K]}{N / M}$$

L = observed number of crashes at the treated sites in the after period
E[κ|K] = expected count of crashes given the observed number of K crashes
N = observed number of crashes in the comparison group in the after period
M = observed number of crashes in the comparison group in the before period

Empirical Bayes Method

- To analyze whether the effect of a measure is significant:
  - 95% confidence interval (*CI*) around θ

$$CI_{LB} = \exp[\ln(\theta) - 1.96 \times s]$$

$$CI_{UB} = \exp[\ln(\theta) + 1.96 \times s]$$

where s = standard deviation calculated by

$$s^2 = \frac{1}{L} + \frac{1}{E[\kappa|K]} + \frac{1}{N} + \frac{1}{M}$$

  - Result is only significant if 1 is not in the interval

Empirical Bayes Method

- To estimate the overall effect for all sites with the same measure
  - Meta-analysis
    - One overall effect estimate

$$\text{Overall index of effectiveness} = \exp\left[\frac{\sum_{l=1}^{n} w_l * \ln(Effl)}{\sum_{l=1}^{n} w_l}\right]$$

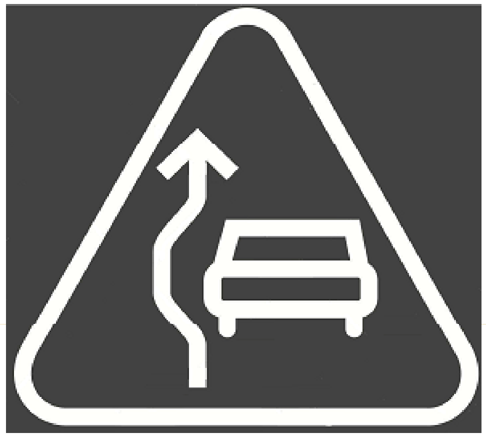
where $w_l = \frac{1}{s_l^2}$

    - Significance by a 95% confidence interval

$$95\%CI = \exp\left[\frac{\sum_{l=1}^{n} w_l * \ln(Effl)}{\sum_{l=1}^{n} w_l} \pm 1.96 * \frac{1}{\sqrt{\sum_{l=1}^{n} w_l}}\right]$$

Computational Procedures

- 4 Phases and 13 steps
- A case study
  - Passing lanes have been installed to increase passing opportunities at 13 rural two-lane highway sites. An evaluation is to be conducted to determine the overall effect of the installation of these passing lanes on total crashes at the 13 treatment sites.



Computational Procedures

- Basic input data

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Site No.	Site length (L) (mi)	AADT (veh/day)		Observed before total crash frequency by year (crashes/site/year)					Observed crash frequency in before period	Observed after total crash frequency by year (crashes/site/year)		Observed crash frequency in after period
		Before	After	Y1	Y2	Y3	Y4	Y5		Y1	Y2	
1	1.114	8,858	8,832	4	4	1	5	2	16	1	1	2
2	0.880	11,190	11,156	2	0	0	2	2	6	0	2	2
3	0.479	11,190	11,156	1	0	2	1	0	4	1	1	2
4	1.000	6,408	6,388	2	5	4	3	2	16	0	1	1
5	0.459	6,402	6,382	0	0	1	0	0	1	0	1	1
6	0.500	6,268	6,250	1	1	0	2	1	5	1	0	1
7	0.987	6,268	6,250	4	3	3	4	3	17	6	3	9
8	0.710	5,503	5,061	4	3	1	1	3	12	0	0	0
9	0.880	5,523	5,024	2	0	6	0	0	8	0	0	0
10	0.720	5,523	5,024	1	0	1	1	0	3	0	0	0
11	0.780	5,523	5,024	1	4	2	1	1	9	3	2	5
12	1.110	5,523	5,024	1	0	2	4	2	9	4	2	6
13	0.920	5,523	5,024	3	2	3	3	5	16	0	1	1
Total				26	22	26	27	21	122	16	14	30

Computational Procedures

- Phase 1 EB estimation of the expected average crash frequency in the before period
  - Step 1 Using the applicable SPF to calculate the predicted average crash frequency, $N_{predicted,\ B}$, for site *i* during each year *y* of the before period.

$$N_{spf\ rs} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)}$$

Overdispersion parameter $k = \dfrac{0.236}{L}$

To simplify the calculation, 1) it is assumed that AADT is constant across all years in this case study; 2) it is also assumed that the roadway characteristics match base conditions and therefore all applicable CMFs and the calibration factor are equal to 1.0.

Computational Procedures

- $N_{predicted,\,B}$

(1)	(14)	(15)	(16)	(17)	(18)	(19)
Site No.	Predicted before total crash frequency by year (crashes/year)					Predicted average crash frequency in before period
	Y1	Y2	Y3	Y4	Y5	
1	2.64	2.64	2.64	2.64	2.64	13.18
2	2.63	2.63	2.63	2.63	2.63	13.15
3	1.43	1.43	1.43	1.43	1.43	7.16
4	1.71	1.71	1.71	1.71	1.71	8.56
5	0.79	0.79	0.79	0.79	0.79	3.93
6	0.84	0.84	0.84	0.84	0.84	4.19
7	1.65	1.65	1.65	1.65	1.65	8.26
8	1.04	1.04	1.04	1.04	1.04	5.22
9	1.30	1.30	1.30	1.30	1.30	6.49
10	1.06	1.06	1.06	1.06	1.06	5.31
11	1.15	1.15	1.15	1.15	1.15	5.75
12	1.64	1.64	1.64	1.64	1.64	8.19
13	1.36	1.36	1.36	1.36	1.36	6.79
Total	19.24	19.24	19.24	19.24	19.24	96.19

Computational Procedures

- Phase 1 EB estimation of the expected average crash frequency in the before period
  - Step 2 Calculate the expected average crash frequency, $N_{expected,\,B}$, for each site *i*, summed over the entire before period.

$$N_{expected,B} = w_{i,B} N_{predicted,B} + (1 - w_{i,B}) N_{observed,B}$$

Where the weight, $w_{i,B}$, for each site i, is determined as:

$$w_{i,B} = \frac{1}{1 + k \sum_{\substack{Before \\ years}} N_{predicted}}$$

Computational Procedures

- $N_{expected,\ B}$

(1)	(20)	(21)	(22)
Site No.	Overdispersion parameter, k	Weighted adjustment, w	Expected average crash frequency in before period
1	0.212	0.264	15.26
2	0.268	0.221	7.58
3	0.493	0.221	4.70
4	0.236	0.331	13.54
5	0.514	0.331	1.97
6	0.472	0.336	4.73
7	0.239	0.336	14.06
8	0.332	0.366	9.52
9	0.268	0.365	7.45
10	0.328	0.365	3.84
11	0.303	0.365	7.82
12	0.213	0.365	8.70
13	0.257	0.365	12.64
Total			111.81

Computational Procedures

- Phase 2 EB estimation of the expected average crash frequency in the after period in the absence of the treatment
  - Step 3 Using the applicable SPF to calculate the predicted average crash frequency $\boldsymbol{N_{predicted,\,A}}$, for each site i during each year y of the after period.
  - Step 4 Calculate the Adjustment Factor, r_i, to account for the differences between the before and after periods in duration and traffic volume at each site i.

$$r_i = \frac{\sum_{\substack{After\\years}} N_{predicted,A}}{\sum_{\substack{Before\\years}} N_{predicted,B}}$$

Computational Procedures

- Phase 2 EB estimation of the expected average crash frequency in the after period in the absence of the treatment
  - Step 5 Calculate the expected average crash frequency, $\boldsymbol{N_{expected,\,A}}$, for each site i, over the entire after period in the absence of the treatment.

$$N_{expected,A} = N_{expected,B} \times r_i$$

Computational Procedures

- $N_{expected, A}$

(1)	(23)	(24)	(25)	(26)	(27)
Site No.	Predicted after total crash frequency (crashes/year)		Predicted average crash frequency in after period	Adjustment factor, r	Expected average crash frequency in after period without treatment
	Y1	Y2			
1	2.63	2.63	5.26	0.399	6.08
2	2.62	2.62	5.25	0.399	3.02
3	1.43	1.43	2.86	0.399	1.87
4	1.71	1.71	3.41	0.399	5.40
5	0.78	0.78	1.57	0.399	0.79
6	0.83	0.83	1.67	0.399	1.89
7	1.65	1.65	3.30	0.399	5.61
8	0.96	0.96	1.92	0.368	3.50
9	1.18	1.18	2.36	0.364	2.71
10	0.97	0.97	1.93	0.364	1.40
11	1.05	1.05	2.09	0.364	2.84
12	1.49	1.49	2.98	0.364	3.17
13	1.23	1.23	2.47	0.364	4.60
Total	18.53	18.53	37.06		42.88

Computational Procedures

- Phase 3 Estimation of the treatment effectiveness
  - Step 6: Calculate an estimate of the safety effectiveness of the treatment at each site *i* in the form of an odds ratio (OR_i)

$$OR_i = \frac{N_{observed,A}}{N_{expected,A}}$$

  - Step 7: Calculate the safety effectiveness as a percentage crash change at each site *i*.

$$CMF_i = 100 \times (1 - OR_i)$$

Computational Procedures

- OR_i

(1)	(13)	(27)	(28)	(29)
Site No.	Observed crash frequency in after period	Expected average crash frequency in after period without treatment	Odds ratio	Safety effectiveness (%)
1	2	6.08	0.329	67.13
2	2	3.02	0.662	33.84
3	2	1.87	1.068	-6.75
4	1	5.40	0.185	81.47
5	1	0.79	1.274	-27.35
6	1	1.89	0.530	46.96
7	9	5.61	1.604	-60.44
8	0	3.50	0.000	100.00
9	0	2.71	0.000	100.00
10	0	1.40	0.000	100.00
11	5	2.84	1.758	-75.81
12	6	3.17	1.894	-89.44
13	1	4.60	0.217	78.26
Total	30	42.88		

Computational Procedures

- Phase 3 Estimation of the treatment effectiveness
  - Step 8: Calculate the overall effectiveness of the treatment for all sites combined, in the form of an odds ratio (*OR'*)

$$OR' = \frac{\sum_{All\ sites} N_{observed,A}}{\sum_{All\ sites} N_{expected,A}}$$

$$OR' = 30/42.88 = 0.700$$

Computational Procedures

- Phase 3 Estimation of the treatment effectiveness
  - Step 9: Obtain an unbiased estimate of the treatment effectiveness in terms of an adjusted Odds Ratio (*OR)*

$$OR = \frac{OR'}{1 + \dfrac{Var(\sum_{All\ sites} N_{expected,A})}{(\sum_{All\ sites} N_{expected,A})^2}}$$

where $Var(\sum_{All\ sites} N_{expected,A}) = \sum_{All\ sites} [(r_i)^2 \times N_{expected,B} \times (1 - w_{i,B})]$

$$OR = \frac{0.700}{1 + \dfrac{11.162}{42.88^2}} = 0.695 \ < 1$$

Computational Procedures

- Phase 3 Estimation of the treatment effectiveness
  - Step 10: Calculate the overall unbiased safety effectiveness as a percentage change in crash frequency across all sites.

$$CMF = 100 \times (1 - OR)$$

$$CMF = 100 \times (1-0.695) = 30.5\%$$

Computational Procedures

- Phase 4 Estimation of the precision of the treatment effectiveness
  - Step 11: Calculate the variance of *OR*.

$$Var(OR) = \frac{(OR')^2\left[\frac{1}{N_{observed,A}} + \frac{Var(\sum_{All\ sites} N_{expected,A})}{(\sum_{All\ sites} N_{expected,A})^2}\right]}{\left[1 + \frac{Var(\sum_{All\ sites} N_{expected,A})}{(\sum_{All\ sites} N_{expected,A})^2}\right]}$$

$$Var(OR) = \frac{0.700^2\left[\frac{1}{30} + \frac{11.162}{42.88^2}\right]}{\left[1 + \frac{11.162}{42.88^2}\right]} = 0.019$$

Computational Procedures

- Phase 4 Estimation of the precision of the treatment effectiveness
  - Step 12: Calculate the standard error of *OR* and *CMF*.

$$SE(\mathrm{OR}) = \sqrt{Var(\mathrm{OR})}$$

$$SE(CMF) = 100 \times SE(OR)$$

$$SE(OR) = \sqrt{0.019} = 0.138$$

$$SE(CMF) = 100 \times 0.138 = 13.8\%$$

Computational Procedures

- Phase 4 Estimation of the precision of the treatment effectiveness
  - Step 13: Assess the statistical significance of the estimated safety effectiveness:
    - If Abs[*CMF*/*SE*(*CM*F)] < 1.7, the treatment effect is not significant at the (approximate) 90% confidence level.
    - If Abs[*CMF*/*SE*(*CM*F)] ≥ 1.7, the treatment effect is significant at the (approximate) 90% confidence level.
    - If Abs[*CMF*/*SE*(*CM*F)] ≥ 2.0, the treatment effect is significant at the (approximate) 95% confidence level.

$$Abs[CMF/SE(CM\mathrm{F})] = 30.5/13.8 = 2.2 > 2.0$$

Computational Procedures

- Conclusion of the case study
  - The evaluation results indicate that the installation of passing lanes at the 13 rural two-lane highway sites reduced total crash frequency by 30.5% on average, and that this result is statistically significant at the 95% confidence level.

Summary

- Various road safety measures are available for road safety improvement.
- Safety effectiveness evaluation is an important step in setting up an effective road safety management.
- Before-after analysis is a useful tool for effectiveness evaluation. In doing so, some confounding variables should be taken into account.
- Empirical Bayes method is a valuable method to estimate $N_{expected}$ with the purpose of increased precision of estimation and correction for the RTM bias.