المركز الوطني لسلامة الطرق
National Road Safety Center

Supporting Services for the Establishment and Operation of the
National Centre for Road Safety
in the Kingdom of Saudi Arabia

Statistical Data Analysis for Road Safety

Module 9

Training Courses

Road Safety Data

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Road Safety Experts

S1

General contents

- Data & Indicators for Road Safety Analysis
- Variables for Road Safety
- Risk
- Road safety outcomes: road accidents and casualties counts
- Statistical properties of Road Accident Data

Data and Indicators for Road Safety Analysis (1/2)

- **Accident Data:**
  - Fatal Accidents, with victims (injuries), with property damage only
  - Victims and persons involved
  - Vehicles involved

Fundamental statistics

- **Other Data (1):**
  - Speeds
  - Driving under the influence of drugs
  - Safety belt and child restraints and helmet use
  - Road user attitudes and perceptions

Data and Indicators for Road Safety Analysis (2/2)

- **Other Data (2):**
  - Road infrastructure design and maintenance
  - Crashworthiness of vehicles
  - Post-crash care
  - Road safety rules, regulations and interventions

- **Exposure in danger Data:**
  - Traffic (vehicle-kilometres, passenger-kilometres)
  - Length of road network
  - Population, drivers' population

some form of the amount of travel either by vehicle or on foot

Variables for Road Safety Analysis

Road environment:

- Residential or not area
- Accident day
- Time
- Month
- Year
- Roadway
- Weather condition
- Roadways condition
- Lighting
- Street type

Vehicles:

- Vehicle type
- Vehicle age
- Vehicle nationality
- Vehicle brand
- Car Safety belt

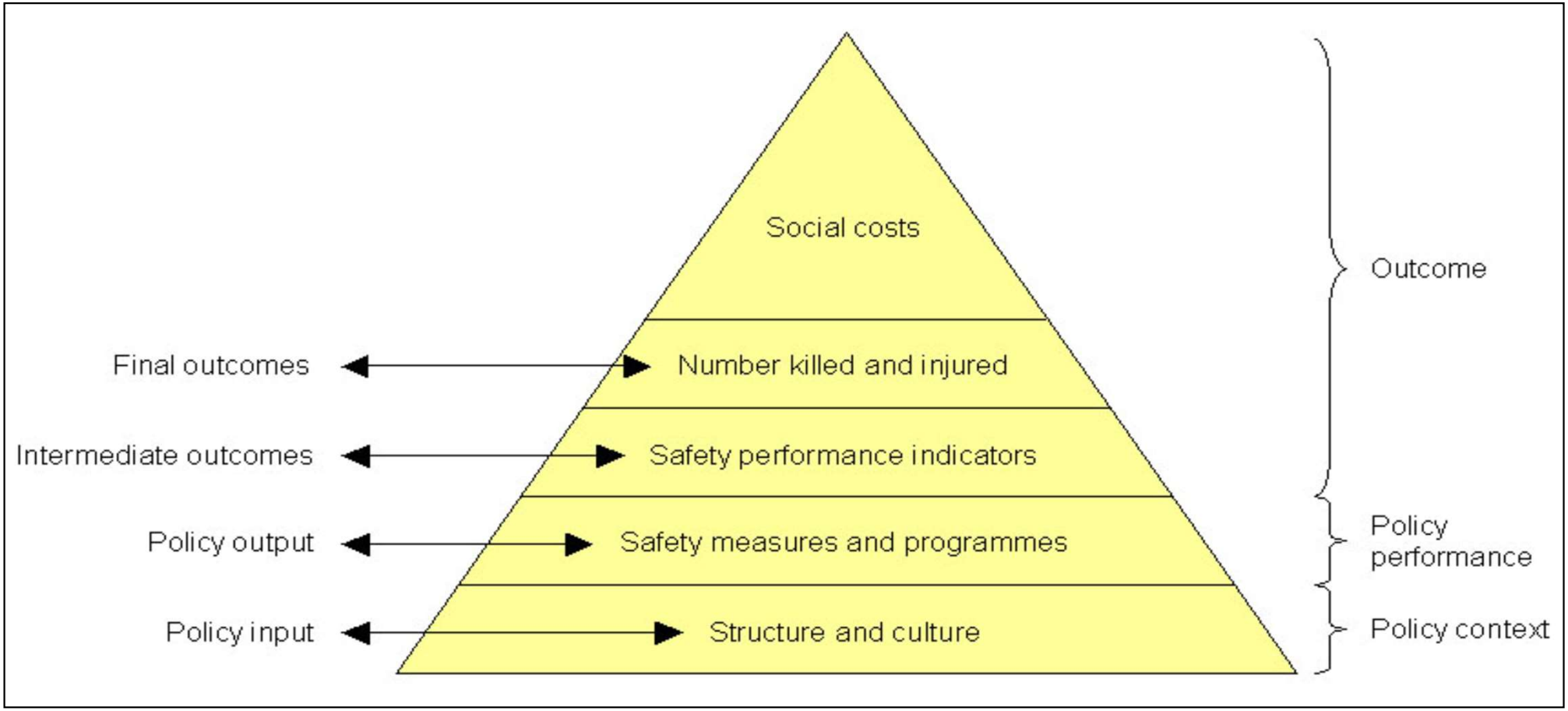
Road users:

- Number of occupants
- Breath alcohol test
- Driver license
- Possession of driving license (years)
- Sex
- Age
- Nationality
- Use of security equipment
- Victim status

Accident characteristics:

- Type of accident
- Location of accident
- Maneuver type
- Traffic arrangement

The Road Safety "Pyramid"



General Definition of Risk

There are a number of definitions of risk in use in different forms of safety science, road safety and elsewhere.

The approach taken here is practical:

A risk is the expected road safety outcome, given a certain exposure (i.e. per unit of exposure).

The outcome is usually the number of accidents or victims of a certain type, but it could also be expressed in monetary terms, encompassing the full socio-economic consequences of road accidents.

The need for risk

If one needs to compare the road safety levels of different situations (e.g. between road categories or different modes or different countries), one somehow **has to measure** the road safety performance in each situation and **compare the measurements** according to a selected scale.

The leading road safety performance measure is either the **number of (serious or fatal) accidents** or the number of victims, or a **combination** of such measures (per unit of exposure).

The Need For Risk Figures

→if the road safety problem is to be compared with other health hazards, it is common to **compensate** for the number of persons at risk of being killed in a road accident.

→On that purpose, the annual number of persons killed in road accidents in a certain year divided by the relevant population size is often used.

→The general basic form of road safety performance measures is commonly called a **risk or rate**

Risks, Odds and Odds-Ratios

	Involved in accidents	Not involved in accidents	Total
Males	75	50	125
Females	35	50	85
Total	110	100	210

- **Risk of accident involvement**: Males = 75/125 = 0,6, Females = 35/85 = 0,41
- **Risk ratio or Relative risk** males / females = 0,6/0,41 = 1,46 or 46% more likely to be involved in an accident
- **Odds of accident involvement**: Males = 75/50 = 1,5, Females = 35/50 = 0,7
- **Odds ratio** males / females = 1,5 / 0,7 = 2,14 or 'males have more than double odds of accident involvement than females'
- Some methods yield odds ratios rather than risk ratios

Road safety Final Outcomes (1/2)

- **Fatality rates:**
  - However, although the number of road fatalities is an important and informative road safety performance measure, it may not adequately address all analyses needs; simply counting the number of crashes, injuries or fatalities is often an imperfect indicator of the level of road safety.
  - Fatalities or injuries need to be adjusted in relation to some measure reflecting the degree of exposure to the road traffic risk.

    Key variable in traffic safety & mobility

  - Resulting in **fatality rates**, e.g. fatalities per inhabitant, vehicle type, or kilometer travelled.

    Exposure Indicators

→ Typical risks per exposure

Road Safety Final Outcomes (2/2)

- **Additional comparative data such as:**
  - the rate of improvement in road safety.
  - the scope of the safety problem of vulnerable road users.
  - the scope of the safety problem of rural roads.
  - the scope of the problem of vulnerable age groups (children, elderly)
  - the scope of injury problem (e.g. injury accidents per fatality)

Statistical Properties of Road Accident Data (1/5)

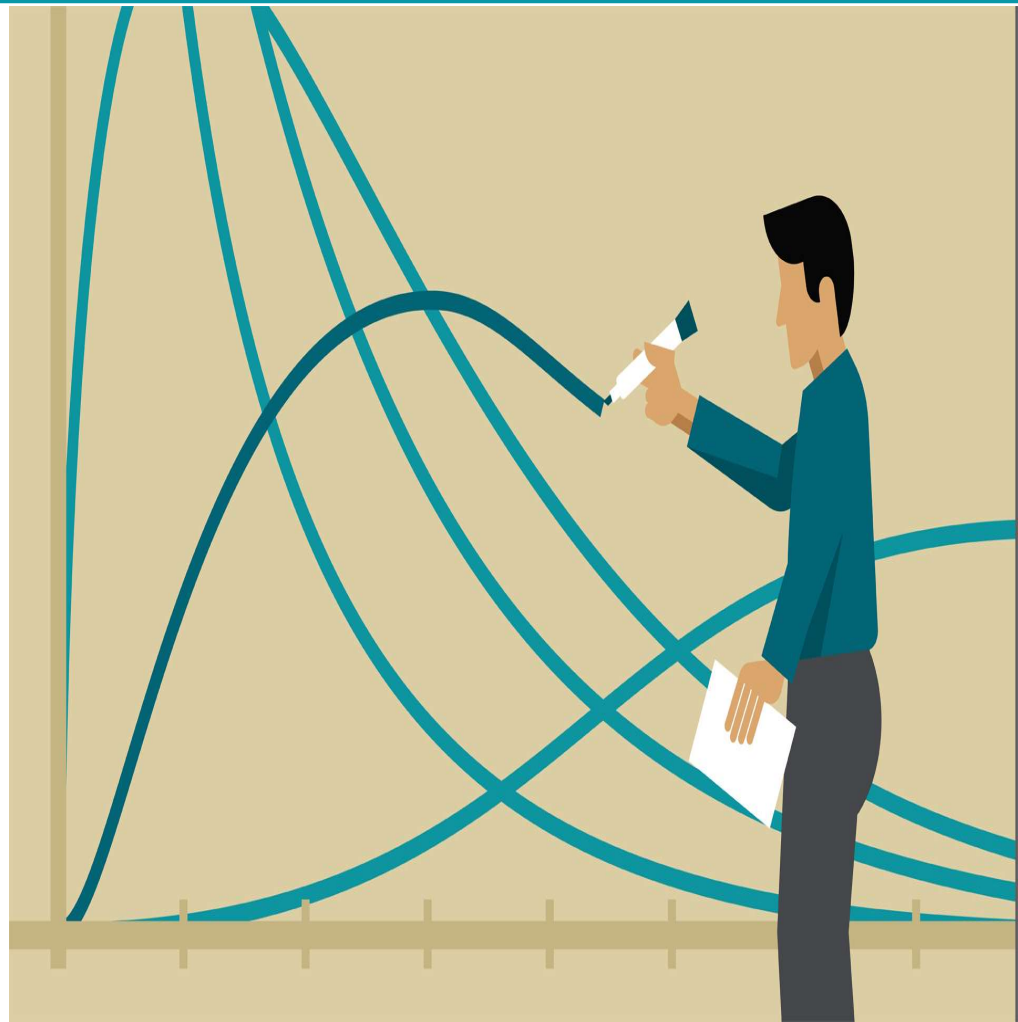
- **The Poisson Theorem:**

  - Properties of binomial (Bernoulli) trials, i.e. random independent trials with exactly two possible outcomes: **success or failure**.
  - The probability of success assumed to be the same at each trial → the distribution of the sum of all successful trials tends to a *Poisson statistical distribution*.
  - Modern versions of this standard theorem do not require the probability of each trial to be the same, and state that under reasonable conditions the probability distribution of the sum of all successful trials would tend to a *Poisson probability distribution*.

Statistical Properties of Road Accident Data (2/5)

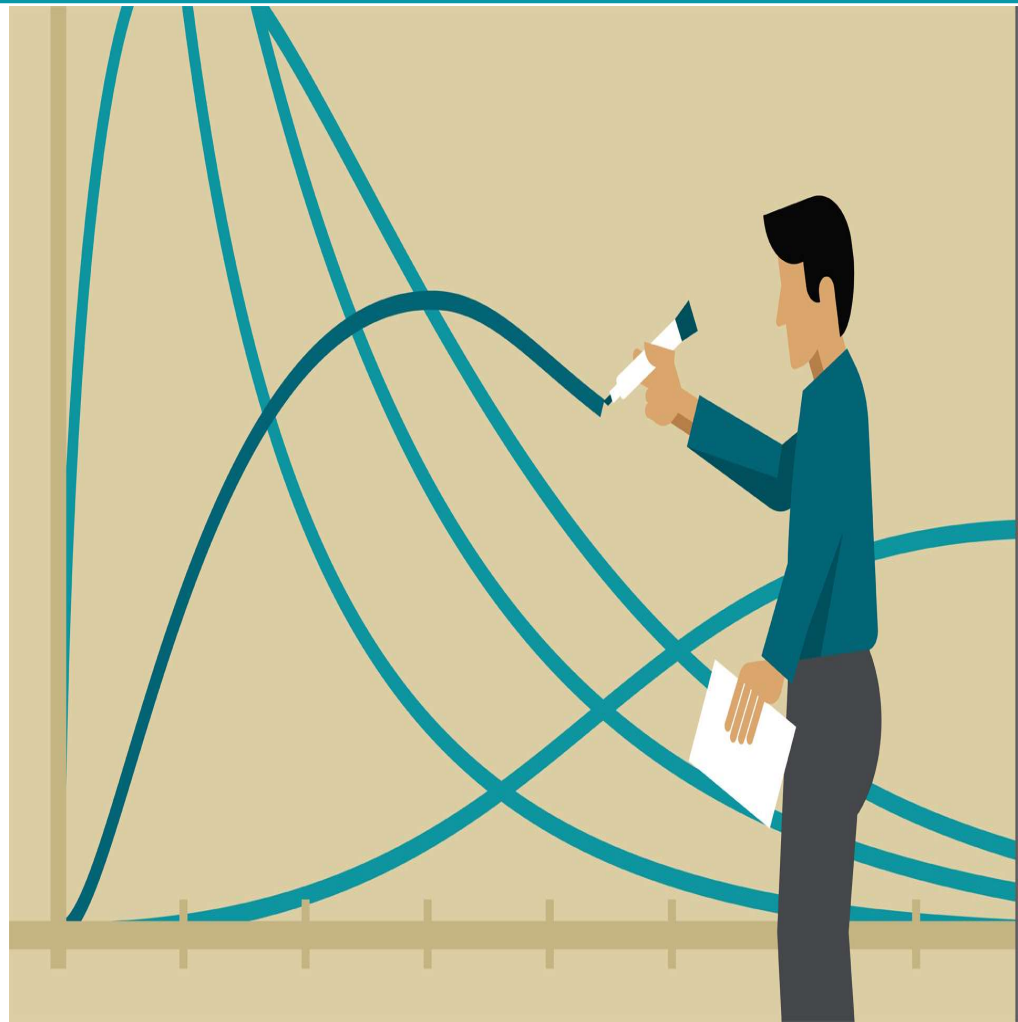
- **Road Safety Analysis**

"if a traffic safety outcome can be regarded as the sum of the outcomes of many independent events that had a (very) small probability of resulting in an accident, the distribution of that sum (i.e. the number of events that resulted in an accident) will tend to the Poisson distribution with parameter equal to the sum of the probabilities of resulting in an accident".



Statistical Properties of Road Accident Data (3/5)

- The trials should be considered as situations that may result in one accident.
- The number of accidents will be approximately Poisson distributed *given* the pedestrian crossings, near misses and other information determining both the number of trails n and their nature reflected in the values $p_1 \ldots p_n$.
- This result is relevant to the distribution of the number of accidents, not the number of victims or other outcomes of accidents.
- It is *assumed* that the outcomes of the events are independent.

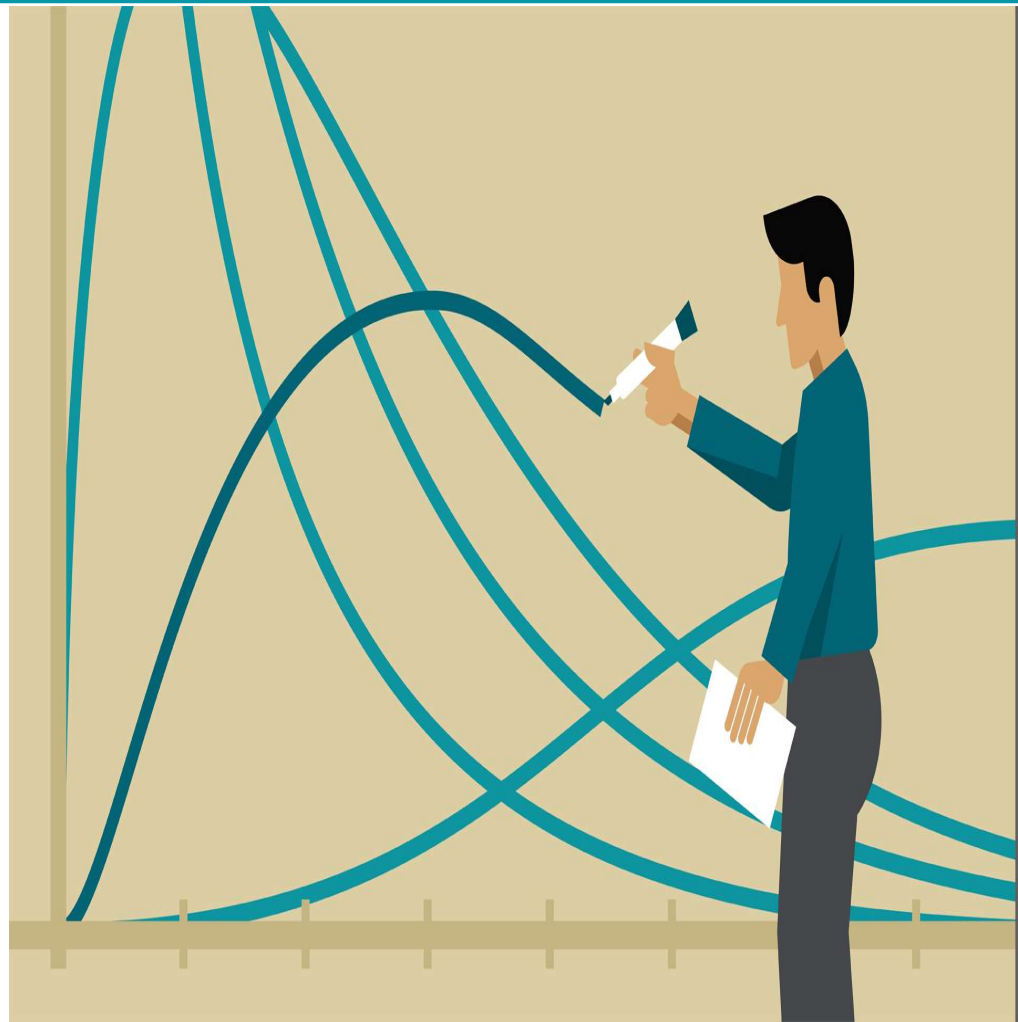


Statistical Properties of Road Accident Data (4/5)

- Only registered accidents exceeding a certain level of severity are usually considered.

→This would yield: "*a small probability of resulting in an accident with a certain severity* ***and*** *being registered*".

- The registration system cannot be saturated by the accident process (e.g. limited police resource allocation to less severe accidents would have an effect on the applicability of the theorem above).

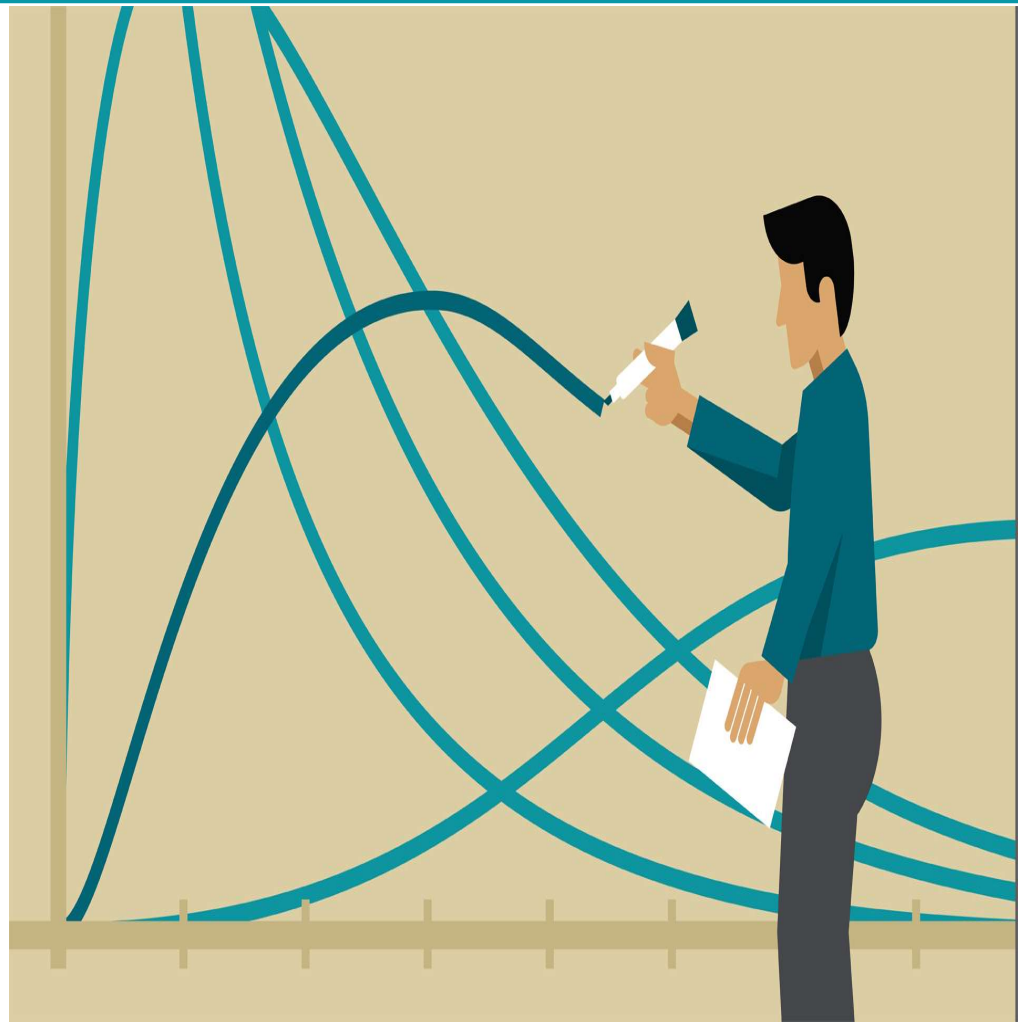


Statistical Properties of Road Accident Data (5/5)

In practice, the distribution of accident counts will never be exactly according to a Poisson distribution, if only due to the limited number of trials on which it is based.

If a count is based on a high number of trials (e.g. annual national counts), it is likely that for all practical purposes the count follows a Poisson distribution.

Variants of the Poisson distribution are commonly used in the analysis of road safety count data.



Overdispersion (variation)

"After the unknown model parameters are estimated, one usually finds that the accident counts are over dispersed",

- the differences between the accident counts and model predictions are larger than what would be consistent with the assumption that accident counts are Poisson distributed
- The problem rises from the replications used in the generic model. replications would never be carried out under the exact same conditions. The number of trials and the values of the probability of resulting in an accident will differ between replications.
- In other words: replications will be drawn from a different Poisson distribution each time!

Overdispersion **can** be estimated!

The Role of Trials in Exposure (1/2)

- In the context of risk exposure data, the number of trials plays a central role. The number of trials is the number of times road users in general are exposed to a possible accident. **The number of trials should be the best theoretical measure of road accident risk exposure.**

  All other things kept equal, the expected number of accidents increases with the number of trials.

→In most practical situations, however, the relationship is more complicated

The Role of Trials in Exposure (2/2)

- In road safety research, the basic unit of exposure (e.g. trial) can be considered **the trip**, characterized by a distance and a duration, and divided in sub-units over space or time.
- the risk model is continuous rather than discrete!.
- the use of both distance and time for characterising each trial is required, because trips are bound to be different.
- In practice one has to resort to more practical measures of exposure than the number of trials : vehicle- and person-kilometres of travel, the time spent in traffic, the length of the road network, vehicle fleet, etc.

Safety performance function - contents

- Safety Performance function
- Statistical implication & exposure indicators
- Safety Performance Indicators
- Road safety structure and culture

Safety Performance Function (1/5)

- The general definition of risk can be written as follows:

  [the expected number of accidents] = [units of exposure] * [risk (factors)] (1)

- Risk as a function, mapping exposure onto safety outcomes.
- Risk could be therefore modelled as a function of risk factors; this function is called a "**safety performance function“**
- This definition is consistent with the ‘risk as a probability’ approach.
- Estimate the individual risk as a very small number (between 0 and 1)

Safety Performance Function (2/5)

- Provided that exposure is continuously measured over time and space!
- For comparison purposes, **risk will be often considered as an (incidence) rate** (between 0 and infinity)

  both the nominator and denominator are expressed per time unit. consider multiple events over time
- Risk rate = [the number of accidents] / [the amount of exposure].
- [the number of accidents] = [the amount of exposure] * [risk rate] (2)

Safety Performance Function (3/5)

- other types of safety outcomes may be relevant e.g. number of casualties, number of persons or vehicles involved in accidents, or even number of near-misses, other incidents etc.
- risk can be defined as the original safety performance function divided by the amount of exposure.

→ risk **cannot** be regarded independent from exposure, if only because of its definition.

Safety Performance Function (4/5)

- The risk function is a non-linear one, and there are specific conditions enabling a reliable linear approximation. More specifically:
  - The consequences of not considering a non-linear safety performance function will be most important when exposure varies significantly within a given unit, for instance studying hourly observations on a road section over all hours of a day. When variations are small and relatively stable, for instance when national accident statistics with population figures are considered, as is the case in the present paper, the relationship may be well approximated by a linear function. rate of improvement in road safety.

Safety Performance Function (5/5)

- such an approximating function not necessarily crosses the origin, the prominent "mistake" is the use of risk outside its 'linear validity range'.
- the safety performance function should be known for each level of aggregation (e.g. country) considered in a comparison.
- If the aggregation is over a heterogeneous set of road sections, it will be very difficult to assess the safety performance function of the aggregation even if it were available for all contributing sections.

  In many cases the benefits of using safety performance functions do not outweigh the disadvantages of their complex estimation.

Statistical Implications (1/2)

- **Observations are likely to be biased**: not all accidents are counted and / or exposure may be under- or over- estimated. Moreover, estimates for these biases may be missing.
- **The number of accidents is intrinsically variable**: it is impossible, except for the case in which no accident can possibly occur, to predict the exact number of accidents. If one has to assess the potential variation in one observation, a Poisson approximation may be sufficient when the actual count is large enough. However, if two apparently equal areas need to be compared - or even the same area for a different time period - overdispersion issues have to be considered.

Statistical Implications (2/2)

- **The exposure figures are likely to be estimates themselves, inducing thus bias in the risk rates**. This means that the variance in their estimates (i.e. the variance of the measurement error in the estimates) needs to be accounted for as well.
- **the exposure measures are approximations, proxies to the "true" exposure** (e.g. one vehicle-kilometre may correspond to a different number of trials (i.e. trips) if it is travelled on a motorway or on a parking lot; the same number of vehicles may be used for more kilometres in a different time period).

The potential errors and biases mentioned above have to be borne in mind and, when possible, corrected or accounted for.

Exposure Indicators (1/2)

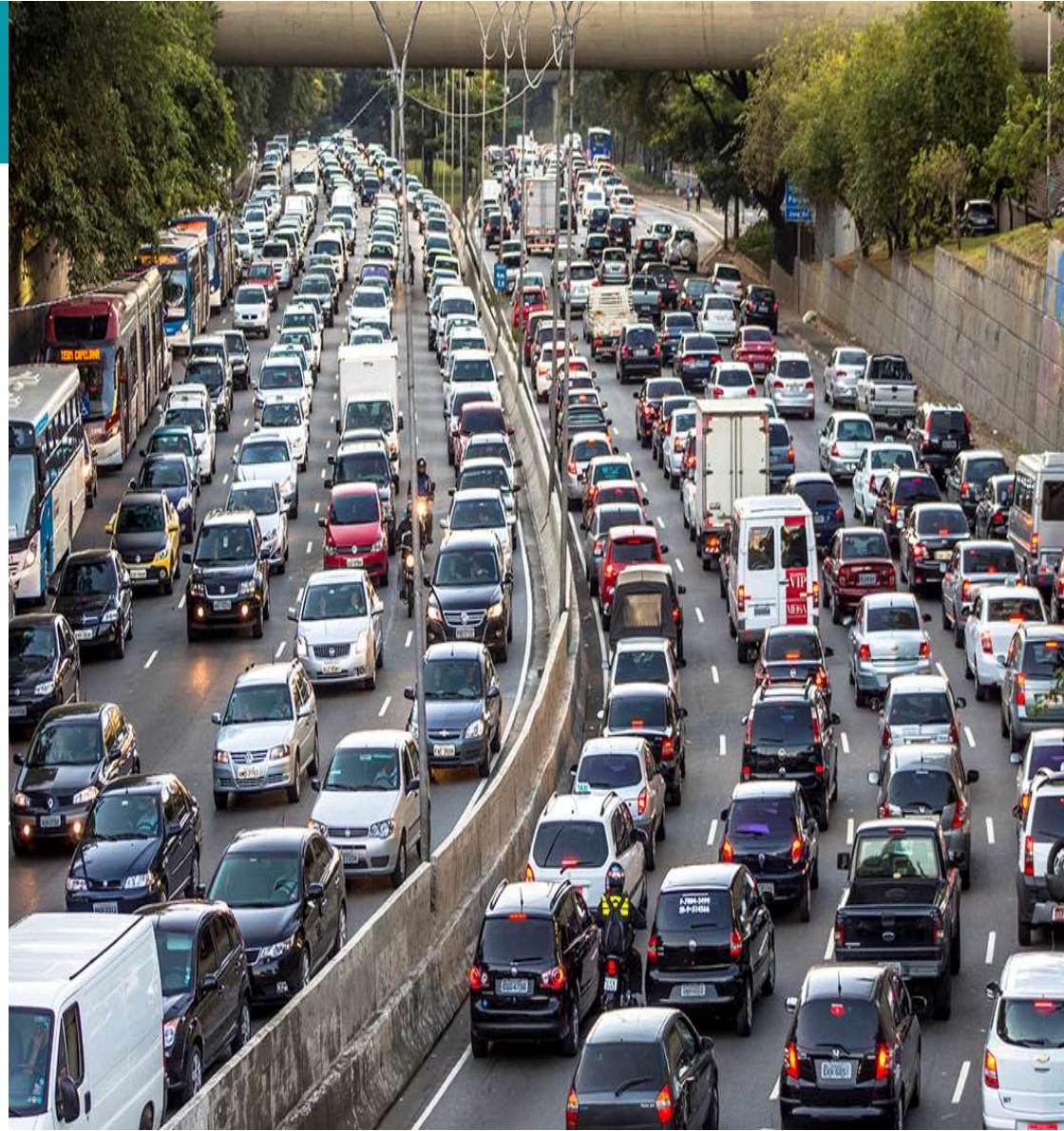
- The measure of exposure is mostly selected based on its theoretical importance.

  However, quite often the preferred exposure measure is unavailable or in an inadequate level of disaggregation.

→ an alternative (proxy) exposure measure may have to be selected.

Exposure Indicators (2/2)

- The exposure measures can be roughly classified into two groups:
  - **Traffic estimates**: road length, vehicle-kilometres, fuel consumption and vehicle fleet.
  - **Persons at risk estimates**: person-kilometres, population, number of trips, time in traffic and driver population.



S1. Road Safety Data – Exposure Indicators

- Risk and exposure data
  - exposure indicator: Population
  - Number of Fatalities per 100,000 population

Expresses the **Mortality rate** - Overall risk of being killed in traffic for the average citizen

✓	✗
Population is a reliable number that is available from all countries	Does not say anything about the level of motorization
This rate can be compared with other causes of death	Not meaningful to compare safety levels between high and low motorized countries

S1. Road Safety Data – Exposure Indicators

- **5 Best countries**

1 San Marino*
2 Maldives *
3 Micronesia *
4 Norway
5 Switzerland
6 Singapore
7 Sweden
8 UK

- **Kingdom of Saudi Arabia**
- # 153 out of 175 (2016)

- **5 worst countries**
- Dominican Republic
- Burundi
- Zimbabwe
- Saint Lucia
- Liberia

Source: World Health Organization (2016)

S1. Road Safety Data - Exposure Indicators

- Risk and exposure data
  - exposure indicator: Annual distance (Kilometers) Travelled

Safety quality of road traffic
Theoretically the *best indicator* to assess the **level of risk of the road network**

✓	✗
A better exposure measure than population and vehicles	Not available in all countries, regions or roads
Can be used for regions and for roads	Non-motorised vehicles are not taken into consideration
	Limited number of countries collect distance travelled data

S1. Road Safety Data - Exposure Indicators

- 5 Best countries

1 Norway
2 Switzerland
3 Sweden
4 UK
5 Ireland (EIRE)

- Kingdom of Saudi Arabia
- N/A

- 5 worst countries

New Zealand
Belgium
USA
Czechia
Republic of Korea

Source: OECD (2018) – 22 countries – per billion vehicle-kilometers

S1. Road Safety Data - Exposure Indicators

- Risk and exposure data
  - exposure indicator: Number of vehicles
  - Number of fatalities per 10 000 vehicles

Alternative to kilometers travelled index

Comparison between countries with **similar traffic and car-use characteristics**
Requires reliable statistics on the number of vehicles

✓

Number of vehicles are available in most countries

Annual distance is unknown

✗

This factor is unreliable sometimes, since the register is not updated

Scrapped vehicels are not removed from the database

Non-motorised vehicles are not taken into account in some countries

S1. Road Safety Data - Exposure Indicators

- 5 Best countries

1 Norway
2 Switzerland
3 Sweden
4 UK
5 Japan

- Kingdom of Saudi Arabia
- N/A

- 5 worst countries

Mexico
Chile
Colombia
Jamaica
Morocco

Source: OECD (2018) – 39 countries

Exposure Indicators Properties

Measure of exposure	Unit		Analysis context								Disaggregation				Accuracy / errors			Other possible bias	Optimal use
	Traffic	Persons at risk	Traffic	Mobility	Road operations	Vehicle industry	Driver training	Epidemiology	Temporal variation	Regional variation	Road User category	User characteristics	Vehicle characteristics	Road characteristics	sampling	non-response	measurement		
Vehicle - kilometres	•	•	•		•				•	•		•	•	•	•	•	•		
Person - kilometres		•	•	•					•	•	•	•	•	•	•	•	•		
Road Length	•		•		•					•				•				economic influences	developping countries
Fuel consumption	•	•	•			•			•				•					pricing differences, vehicle efficiency	aggregate level
Vehicle Fleet	•		•			•							•						when average distance travelled is the same
Population		•						•		•	•	•			•			foreign population	comparing health hazards
Driver population		•	•				•	•				•						licensing framework	when average distance travelled is the same
Number of trips	•	•	•	•	•				•	•	•	•	•	•	•	•	•		when average trip length and speed are the same
Time in traffic		•	•						•	•	•	•	•	•	•	•	•		

Comparative assessment of exposure indicators (1/2)

- no general rule is known concerning the preferred measures of exposure.
- Vehicle- and person-kilometres of travel, and vehicle / person – hours or time spent in traffic, are conceptually closer to the theoretical definition of exposure
- However, they are largely based on travel and mobility surveys or traffic counts systems, which are sampling methods subject to a number of errors affecting their accuracy
- vehicle fleet or driver population are incomplete measures of exposure if one considers the trip as the basic trial.

Comparative assessment of exposure indicators (2/2)

- can be considered as exposure measures, only if they are completed with some measurement of time or distance travelled, or considered over a one year period
- are not suitable for assessing the exposure of non-motorised road users, such as pedestrians and bicyclists.
- road length only provides a measurement of accident density.
- **Under certain conditions, these measures may be efficient for the purposes of a particular analysis.**

Performance Indicators – Definition (1/3)

"Any measurement that is causally related to crashes or injuries, used in addition to a count of crashes or injuries in order to indicate safety performance or understand the process that leads to accidents."

In other words:

Any variable which is used in addition to statistics on accidents or injuries to measure changes in operational conditions.

- A variable that is used in addition to accidents or injuries to measure changes in safety performance:
  - Has a causal relationship to accidents or injuries.
  - Is representative of the operational level of road safety, which is also affected by structural and cultural characteristics and road safety policies

Performance Indicators – Definition (2/3)

- **The purpose of SPI is:**
  - to reflect the current safety conditions of a road traffic system (i.e. they are considered not necessarily in the context of a specific safety measure, but in the context of specific safety problems or safety gaps);
  - to measure the influence of various safety interventions, but not the stage or level of application of particular measures,
  - to compare between different road traffic systems (e.g. countries, regions, etc).

Performance Indicators – Definition (3/3)

- **The SPIs are often referred to as 'intermediate outcomes'. SPIs may concern:**
  - the road infrastructure (e.g. reflecting the degree to which roads comply to design standards or are subject to inspections),
  - the vehicles (e.g. median age of the fleet or vehicle crashworthiness)
  - the road users (e.g. speeding behaviour, alcohol consumption, use of protective equipment).

Performance Indicators – Roads

Area considered	Indicator
Road design	Percentage of rural road network not satisfying design standards
Pavement	Percentage of paved roads of rural road network
Pavement	Road surface friction on winter time and on wet surfaces

Performance Indicators – Vehicles

Crashworthiness of the passenger car fleet	Average percentage occupant protection score for new cars sold
Crashworthiness of the passenger car fleet	Average percentage score of pedestrian protection for new cars sold
Crashworthiness of the passenger car fleet	Renewal rate of passenger cars
Crashworthiness of the passenger car fleet	Median age of the passenger car fleet
Crashworthiness of the passenger car fleet	Percentage of new cars with the top star rating according to EuroNCAP
Technical inspection	percentage of technically defective vehicles

Performance Indicators – Road Users

Speeding	Mean speed on motorways
Speeding	Mean speed on rural roads
Speeding	Mean speed on urban roads
Speeding	Percentage of drivers above speed limit in roadside checks
Speeding	Roadside police speed checks per 1,000 population
Alcohol-impaired driving	Percentage of drivers above legal alcohol limit in roadside checks
Alcohol-impaired driving	Roadside police alcohol tests per 1,000 population
Use of protective systems in cars	Daytime seat belt wearing rates on front seats of cars (aggregated for driver and front passenger)
Use of protective systems in cars	Daytime wearing rates of seat belts on rear seats of cars
Helmets	Daytime helmet wearing rates for driver and for passenger for mopeds and motorcycles
Helmets	Daytime helmet wearing rates for bicycles
Protective or reflective clothing	Protective clothing wearing rates for motorcyclists
Protective or reflective clothing	Reflective clothing wearing rates for bicyclists
Phoning	Rates of driving while using a mobile phone (handheld / hands-free) for car drivers
Pedestrians	Share of illegal road crossings in urban areas

Structural and cultural Indicators

- Population density, age etc.
- Economic indicators (GDP per capita)
- Mobility and Exposure
- Weather and climate

- Road user attitudes, beliefs and motivations
- Structure of road safety management

Performance Indicators – Suggestion

- **Suggested performanace indicators**
  - Vehicle Speed & number of speed limit violations, ratio of drivers exceeding the speed limit (per road category),
  - seat belt, child restraint use ratio
  - helmet usage
  - using mobile phone “while driving”
  - number or length of road sections in which a Road Safety Audit or Inspection was performed,
  - (per road category),
  - number of seat belt, helmet and child restraint violations,

Road Safety Programmes and Measures (1/2)

- National vision and strategy for road safety
- Monitoring of road safety programmes
- Budget for road safety programmes
- Legislation:
  - Speed limits
  - Driver Training
  - Road safety audits and inspections
  - Vehicles technical inspections

Road Safety Programmes and Measures (2/2)

- **What type of analysis?**

  →Macroscopically

  →Interventions analysis

Road Safety Structure and Culture - examples

When intuition misleads us - Example 1

Practical experience

What is the speed of the overtaking vehicle in the situation shown in the following video?

Road Safety Structure and Culture - examples

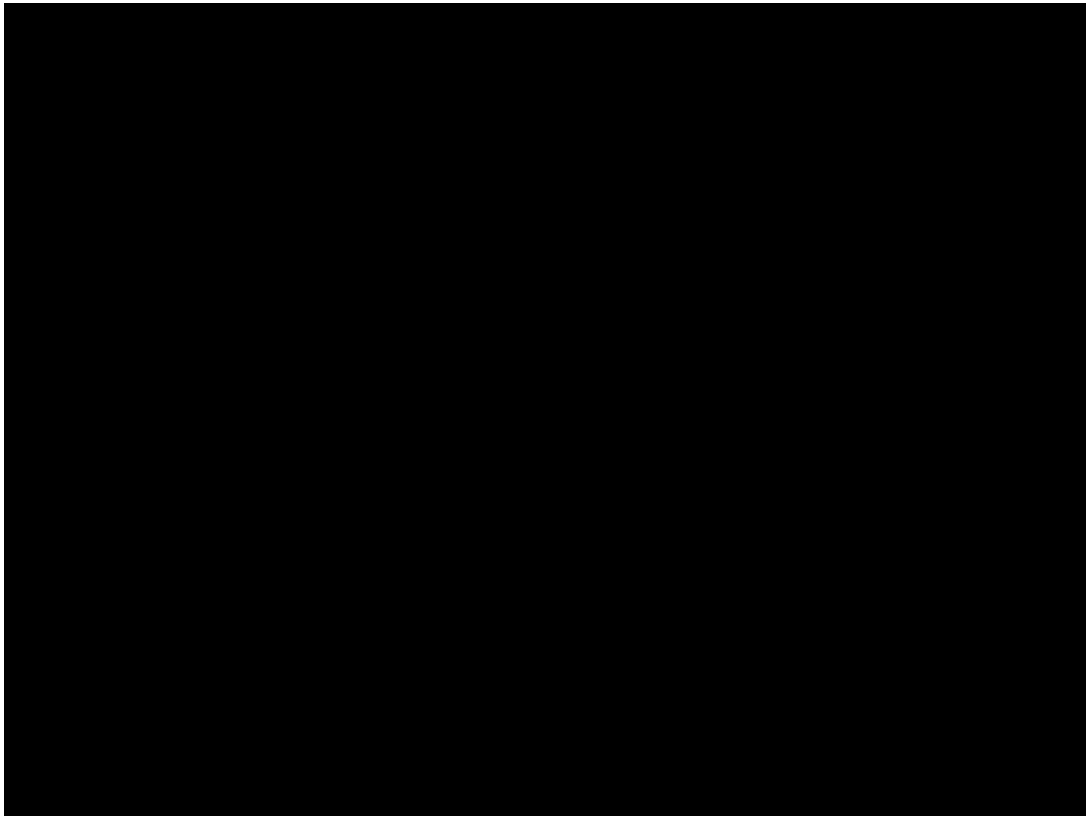
When intuition misleads us Exemple 1

Description of the video

Car 1 is driving with a speed of 50 Km/h.

Car 2 reaches 60 Km/h and starts to overtake car 1. When car 2 is at the side of car 1, a young girl is crossing the road in front of them.
Both cars brake at the same time.

What is the speed of the overtaking car at the time car 1 stopped ?



Road Safety Structure and Culture - examples

When intuition misleads us Example 2

Practical experience

One of you,the person with the closest estimate will have the chance to win a gift

The winner shall select one of these envelopes, The gift is in one of these envelopes. You have one chance of three to select the correct envelop and win the gift

1	2	3

Road Safety Structure and Culture - examples

When intuition misleads us Example 1

When you have selected one of the envelopes you will have the chance to change your mind and select another envelope

Road Safety Structure and Culture - examples

When intuition misleads us example 2

- Ebola virus disease (EVD), is a rare but severe, often fatal illness in humans.
- The virus is transmitted to people from wild animals and spreads in the human population through human-to-human transmission.
- The average EVD case fatality rate is around 50%.
- Case fatality rates have varied from 25% to 90% in past outbreaks.

Road Safety Structure and Culture - examples

When intuition misleads us continued

If infected you need to have be separated from other people. Othervise you can transmit the decease to other people. You also need treatment even if the treatments so far are not effective.

EBOLA

Many people refuse to be taken to hospital because they have experienced how their friends and relatives are brought to hospital and only return to be buried.

The logic is that it is dangerous to be taken to the hospital.

Road Safety Structure and Culture - examples

When intuition misleads us continued

We have many situations that are like the Ebola case

"My reaction time is so short so I can drive faster than others"

" I am a better driver than most other drivers"

"I dont use seat belts becase if I have a crash I am rather dead than having a life long disability"

"My baby is safer if I hold her in my lap when we are travelling in the car"

Summary of Road Safety Data (1/3)

- **ANALYSIS QUESTIONS**

- Is road safety management structure linked to road safety performance of a country?
- Have economically stronger countries better road safety performance?
- What are road user attitudes related to road safety ? Are outcomes affected? (intermediate or final)
- Are young drivers more risk-taking? → Do young drivers violate speed limits more often?
- Are more strict penalties for speeding accepted?
- How road safety programmes and measures affect road user behaviour?

Summary of Road Safety Data (2/3)

- **ANALYSIS QUESTIONS**

- Does lowering the speed limit affect driver speeds?
- Does an increase in alcohol controls reduce the drink-driving rates?
- What is the probability of being involved in a road accident for motorcyclists? For pedestrians? For the elderly? At nighttime? On motorways? …and so on…
- In relation to exposure!
- What is the probability of being killed in a road accident? With and without seat belt use?
- What will be the trend in road fatalities over the next years?

Summary of Road Safety Data (3/3)

- **ROAD SAFETY DATA**

- Accident and casualties counts
- Exposure data
- Performance indicators
- Structural and cultural indicators
- Road safety measures and interventions indicators
- per road, vehicle and user characteristics

THANK YOU!

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