Statistical Issues in Road Safety
– Part I: Uncertainty, Variability, Sampling

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Why statistics in road safety research?

Our questions are not simple:

- **When and how accidents occur?**
  - Understanding a situation → observe & estimate

- **Why accidents occur?**
  - Understanding relationships → observe & estimate; association models

- **What can affect occurrence of accidents?**
  - Evaluation of actions → experimental studies; intervene and then observe & estimate; → test effectiveness
Why statistics in road safety research?

Road safety and traffic issues are complex:

- When and how accidents occur?
  - Multiple inter-connected factors
- Why accidents occur?
  - Multiple factors may be associated; but causal relationship?
  - What is the ‘risk’ of occurrence? – probability, chance, usually not 0 or 1
- What can affect occurrence of accidents?
  - Variability in exposures and in probabilities of occurrence
  - Need proper experimental designs

→ **Uncertainties**
Statistics – definitions I & II

- Old definition – measurements of the state: ‘stat’ & ‘ics’
  - Summarized → description of the population
  - Still used today:
    - Census – e.g. injury surveillance, FARS, IRTAD
    - Counts:
      - Police records of reported crashes – e.g. FIR
      - All hospitalizations due to trauma
      - All insurance claims for injuries/deaths

- Definition based on how to misuse/abuse information
  - A way to cheat and lie
  - A way to find results
  - Over-emphasis on ‘significance’ and p-values
Statistics – definition III

- Scientific definition – measurements on a sample from the population
Role of statistics in addressing our questions

- Addressing our research questions in the face of uncertainty
  - Inherent variability in what we are studying
  - Incompleteness of information from sampling
  - Role of chance

- Statistics is the methodological science that allows for the understanding of quantitative information in the midst of uncertainty
  - Quantify it, Understand it, Reduce it, Control it
    - Probability (risk) models
    - Descriptive analyses
    - Controlled studies
    - Regression models
Modeling risks

- We want to understand risks
- We need to control uncertainty in the estimation of the risks
  - Risk model of a trend in a given locality – mathematical functions
  - Risk models in multiple individuals or localities – statistical models
- Statistical methods are concerned with
  - ways to ‘control’ uncertainty
  - reduce variability
  - reduce sampling uncertainty
  → to understand estimates of risks or relationships among quantitative factors and risks in a population
Probabilities are not well understood

- A probability is a theoretical mathematical concept
  - Derived from theoretical postulates – ‘updated’ with data [Bayes]
  - ‘Estimated’ from data – frequency approach

- Properties

\[ Pr(A) + Pr(\text{Not } A) = 1 \]
\[ Pr(A \cup B) = Pr(A) + Pr(B) - Pr(A \cap B) \]
\[ Pr(A \cup B) + Pr(\text{Not } A \text{ or } B) = 1 \]
Probabilities are not well understood

- A probability is a prediction in the future, it does not provide a ‘certainty’

What is the probability of electrocution?

Is the probability of rain wrong?
Relative risks of driving under different scenarios against not using phone

- Talking on a handheld phone
- Talking on a hands-free phone
- Drunk with BAC=0.10%
- Texting or reading email
- Talking with an adult passenger

Probabilities are not well understood.

Source: UNC Highway Safety Research Center, DTH/Natasha Smith
Probabilities are not well understood

- Probabilities of being in a crash are low

- But the expected loss is HIGH:
  \[ E(L) = \Pr(\text{crash}) \times L(\text{per crash}) \times \text{Exposure}(t) \]
Uncertainty

- When we estimate ‘risks’ as a probability – we do it with uncertainty!!

- Instantaneous conditional risk $\rightarrow$ hazard function $h(t|X)$
- Number of accidents/victims $\rightarrow$ distribution function (e.g. Poisson model, Negative binomial model, …)

- **Example:** Delhi pedestrian risks – from individual to collective
  - Individual risk is very low $\sim 0.00007 = 7 \times 10^{-5}$ [how obtained?]
  - Collective risk is high since exposure is high 13,000,000 exposed [who is ‘exposed’?]
  - $\rightarrow$ expect 910 pedestrian fatalities
Trends in road fatalities

Provides ‘estimates’ of risk of dying in a crash

Uncertainty

- When we estimate ‘risks’ – we do it with uncertainty!!

→ Addressing our research questions in the face of uncertainty
  - Inherent variability in what we are studying
  - Incompleteness of information from sampling
  - Role of chance

- Also: measurement error in everything we study!
  - Estimating numerator: outcomes
  - Estimating denominator: exposures
The study of variability

- Every crash is so particularly, uniquely different
- Statisticians do NOT study individual crashes or persons, but study groups of crashes or persons
  - The behavior of the group is called the ‘distribution’ of the behavior
- Researchers focus on the central tendency (mean, median, mode)
- Statisticians focus on the variability (variance, range)

Abbreviated Injury Score (AIS) in emergency department patients

- Occupants of motorized vehicles
- Motorcycle riders
- Vulnerable road users
Incompleteness $\rightarrow$ Uncertainty

- In order to understand a situation $\rightarrow$ must study several occurrences
  - HOW MANY?
- Since we cannot usually study ALL situations, we study an incomplete subset
  - A ‘sample’ is never complete, leading to uncertainty
  - How representative is it of the complete set?
Why do we have uncertainty?

- Uncertainty from variability & incompleteness

Assume we want to study a population

**POPULATION**
Why do we have uncertainty?

- Uncertainty from variability & incompleteness

If all in a population are exactly the same, then we need to study _____
Why do we have uncertainty?

- Uncertainty from variability & incompleteness

Subjects in a population are NOT exactly the same, so then we need to study _____
Why do we have uncertainty?

- Uncertainty from variability & incompleteness

We sample a few → We have observed an incomplete part of the population

Q1: Is the sample representative?  
Q2: Is the sample size adequate?
Why do we have uncertainty?

- Uncertainty from chance

We sample a few → Chance gave us the following sample

Q1: Is the sample representative?
Why do we have uncertainty?

- Uncertainty from chance

We sample a few ->
Chance gave us the following sample

Q1: Is the sample representative?
Why do we have uncertainty?

- Uncertainty from sampling

We usually take only 1 sample →
Chance gives 1 of many possible

The one we get is ‘the luck of the draw’ !!

We use it to ‘guess’ at the population, but we are never certain!

20 possible samples of size 3 – all equally likely to happen
Uncertainty

How can we eliminate the uncertainty?
- Reduce: stratified sampling
- Eliminate: study the entire population!

→ Census; all medical records; all car crashes, ...

→ There is no need for statistics, except for summarizing information

...but, $$$ and often impractical or impossible!
Sampling process

- How do we select the sample?

- Criteria
  - Sample should be ‘like the population’ → representative
  - Sample should be selected without introducing personal biases → objective
  - Sample should provide a ‘correct estimate’ of the population parameter → unbiased
  - Sample should provide a ‘precise estimate’ of the population parameter → ‘adequate’ size

→ ‘Probability’ sample = we know the probability of selection of each person in the population
Sampling process

- ‘Probability’ samples
  - Simple random sample
  - Systematic random sample
  - Stratified random sample
  - Cluster random sample
  - Area random sample
  - Complex multi-stage probability sample

- What about ‘purposively selected’ sample?
  - Convenience sample = garbage sample
  - ‘internet’ sample?

- What about not sampling and studying the entire population?
What about BIG data?

- Large, fast computers can handle HUGE datasets
- ‘Data mining’ methodologies permit finding trends

- BUT, if the HUGE dataset is ‘biased’, the bias is NOT gone
Other sources of uncertainty

Imprecision

- Systematic errors – biases
  - Systematic measurement errors
    - Recall bias
    - Observer (instrument) bias
    - Data sources have different quality – classification bias
  - Systematic sampling errors
    - Selection biases
    - Data sources – different coverage
    - Non-response bias – missing data

- Random errors
  - Variation due to measurement
  - Variation due to sampling chance!
How can statistics help us?

- Statistics helps understand the behavior of quantitative data in GROUPS.

  - In a **population**, we want to know:
    - Behavior of a single variable at a given time point – **risks**
    - Behavior of single variable over time - **trends**
    - Behavior of multiple variables – **relationships**

  - In a **sample** from the population, we are able to obtain:
    - Behavior of a single variable at a given time point – **estimation**
    - Behavior of single variable over time – **time series analyses**
    - Behavior of multiple variables – **regression models**
Research questions in Road safety

- What are the effects on risks of doing X?
  - X = decisions in engineering, planning, regulation & policy; education, ...

- Examine links between variables/factors and safety risks

- Themes
  - Accident analysis and prevention
  - Behavioral and social issues
  - Trauma care services
  - Legal and compliance issues

→ relationships
Unique issues in injury research

- Non-constant exposure $\rightarrow$ impact on appropriateness of indicators
- Counting rare events $\rightarrow$ impact on demonstrating effects and distributional models
- Multiple factors $\rightarrow$ complexities
- Intervening on the extreme cases $\rightarrow$ ‘regression to the mean’
- Study design options $\rightarrow$ observational vs experimental
Exercise

Research Question:
Do lower speeds lead to safer roads?

How do we answer this question?
- What type of study?
- How we define ‘lower’? How do we define ’safer’?
- Who or what do we study? How many?
- Who or what do we compare results to? How many?
- What data do we collect? How do we measure it? When do we measure? For how long do we measure?
- What is a meaningful relationship?
- How can we know if what we observe could have been due to chance?