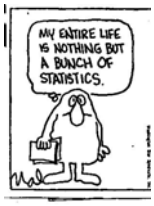

Statistical Issues in Road Safety: Uncertainty, Variability, Sampling

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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

Exposure → Outcome

- What can affect occurrence of accidents?
  - Evaluation of actions → experimental studies; intervene and then observe & estimate;
    → test effectiveness

Action → Outcome

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

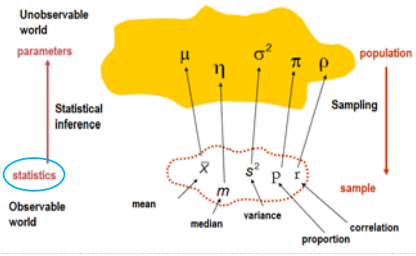
→ Uncertainties

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
  - A way
  - Ov[illegible]phasis on 'significance' [illegible]-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

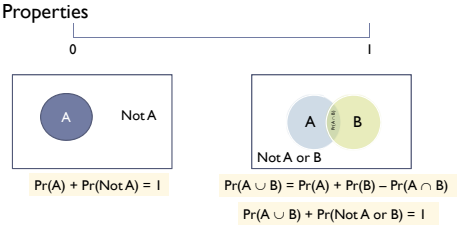
Modeling risks

- 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



$Pr(A) + Pr(\text{Not } A) = 1$

$Pr(A \cup B) = Pr(A) + Pr(B) - Pr(A \cap B)$

$Pr(A \cup B) + Pr(\text{Not A or B}) = 1$

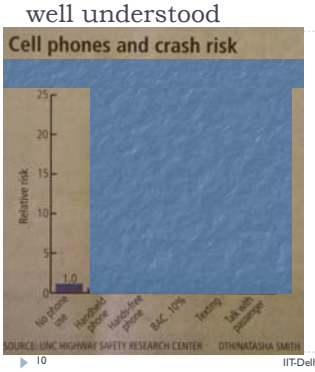
Probabilities are not well understood

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

What is the probability of electrocution?

Probabilities are not well understood

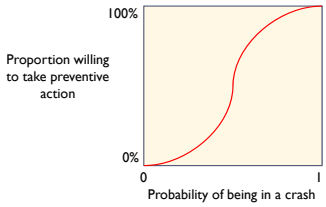
Relative risks of driving under different scenarios against not using phone



- 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

- Probabilities of being in a crash are low



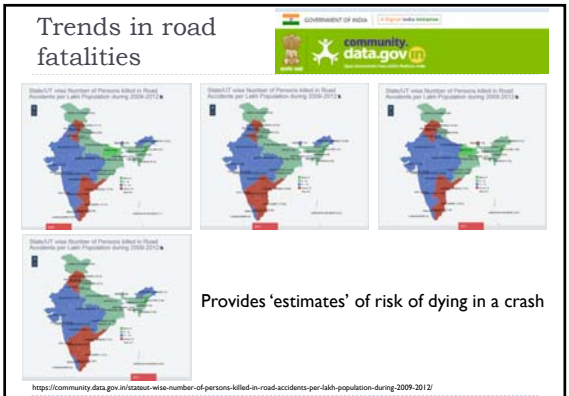
- But the expected loss is HIGH:

$E(L) = Pr(\text{crash}) * L(\text{per crash}) * \text{Exposure}(t)$

Uncertainty

- When we estimate 'risks' as a probability – we do it with **uncertainty**!!
  - Instantaneous conditional risk → hazard function $h(t|X)$
  - Number of accidents/victims → distribution function (e.g. Poisson model, Negative binomial model, …)
- Example: Delhi pedestrian risks – from individual to collective
  - Individual risk is very low ~ $0.00007 = 7 * 10^{-5}$ [how obtained?]
  - Collective risk is high since exposure is high 13,000,000 exposed [who is 'exposed'?]
  - → expect 910 pedestrian fatalities

Trends in road fatalities



Provides 'estimates' of risk of dying in a crash

https://community.data.gov.in/statest-wise-number-of-persons-killed-in-road-accidents-per-lakh-population-during-2009-2012/

Uncertainty

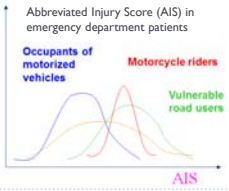
- When we estimate 'risks' – we do it with **uncertainty**!!

→ 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)

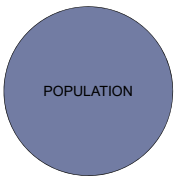


Incompleteness → Uncertainty

- In order to understand a situation → 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?

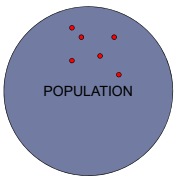
- Uncertainty from variability & incompleteness



Assume we want to study a population

Why do we have uncertainty?

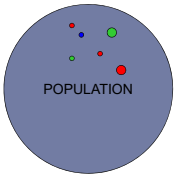
- Uncertainty from variability & incompleteness



If all in a population are exactly the same, then we need to study _____

Why do we have uncertainty?

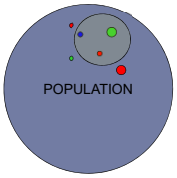
- Uncertainty from variability & incompleteness



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

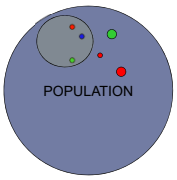
Q1: Is the sample representative?
Q2: Is the sample size adequate?

Why do we have uncertainty?

- Uncertainty from chance

We sample a few →
Chance gave us the following sample

Q1: Is the sample representative?

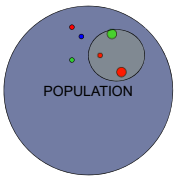


Why do we have uncertainty?

- Uncertainty from chance

We sample a few →
Chance gave us the following sample

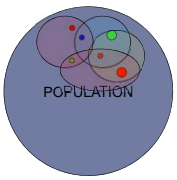
Q1: Is the sample representative?



Why do we have uncertainty?

- Uncertainty from sampling

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



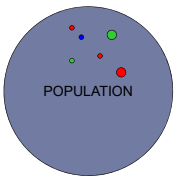
We usually take only 1 sample →
Chance gives 1 of many possible

The one we get is 'the luck of the draw' !!

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

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


MEDIA & MARKETING

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Beware: Garbage In means Garbage Out

Understanding data is the key to marketing success

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

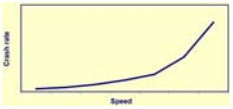
- What are the effects on risks of doing X?
  - X = decisions in engineering, planning, regulation & policy; education, …
- Examine links between variables/factors and safety risks
- Themes
  - Accident analysis and prevention
  - Behavioral and social issues
  - Trauma care services
  - Legal and compliance issues

→ relationships

Unique issues in injury research

- Non-constant exposure → impact on appropriateness of indicators
- Counting rare events → impact on demonstrating effects and distributional models
- Multiple factors → complexities
- Intervening on the extreme cases → 'regression to the mean'
- Study design options → 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?