



Co-funded by the
Erasmus+ Programme
of the European Union

European Road Safety Partnership - Network Wide Road Safety Assessment
KA220-HED - Cooperation partnerships in higher education
Form ID: 2023-1-PL01-KA220-HED-000156844

Spring School Weimar 2026

EuroS@P

EUROPEAN ROAD SAFETY PARTNERSHIP

NETWORK WIDE ROAD SAFETY ASSESSMENT

Reactive Approach– Introduction to Crash Data

Carmelo D'Agostino - Lund University (Sweden)



Università
di Catania

Bauhaus-
Universität
Weimar



Sveučilište u Zagrebu



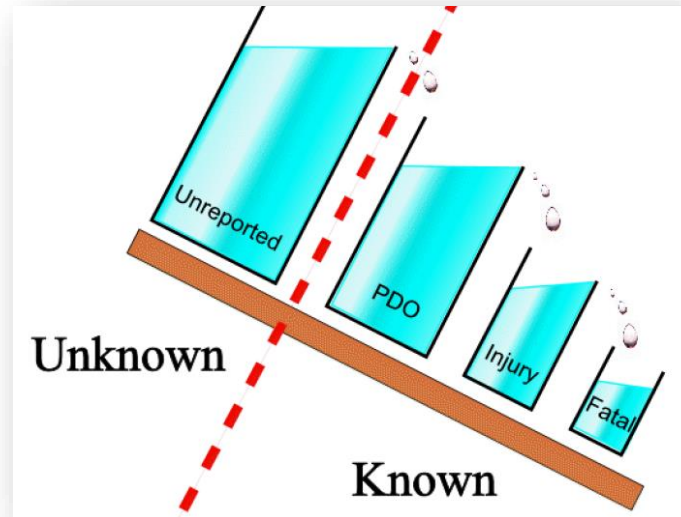
LUNDS
UNIVERSITET

Characteristics of road accidents

- Accident severity:
 - Injury accident: at least one injured person, regardless of the injury type.
 - Fatal accident: at least one killed person
 - Serious injury accident: no fatalities. At least one serious injured person
 - Slight injury accident: no fatalities or serious injuries. At least one slight injury victim
 - Property Damage Only (PDO) Accident: accident with no injured or killed person
 - Unknown: accident with no reported severity data

Characteristics of road accidents

- Underreporting
 - The amount of reported accidents gets lower as the severity increases



- We should only consider accidents with victims

Characteristics of road accidents

- Underreporting is maximum in these cases:
 - Single-vehicle accidents
 - Pedestrian accidents
 - Accidents involving bicycles, mopeds or motorcycles

Characteristics of road accidents

- Crash risk is associated to mobility
 - Mobility demand increases as the society develops
 - Mobility is related to crash risk
 - Road safety is not the only factor that has an influence on choosing a transportation mode
 - Road is the most important ground transportation mode

Characteristics of road accidents

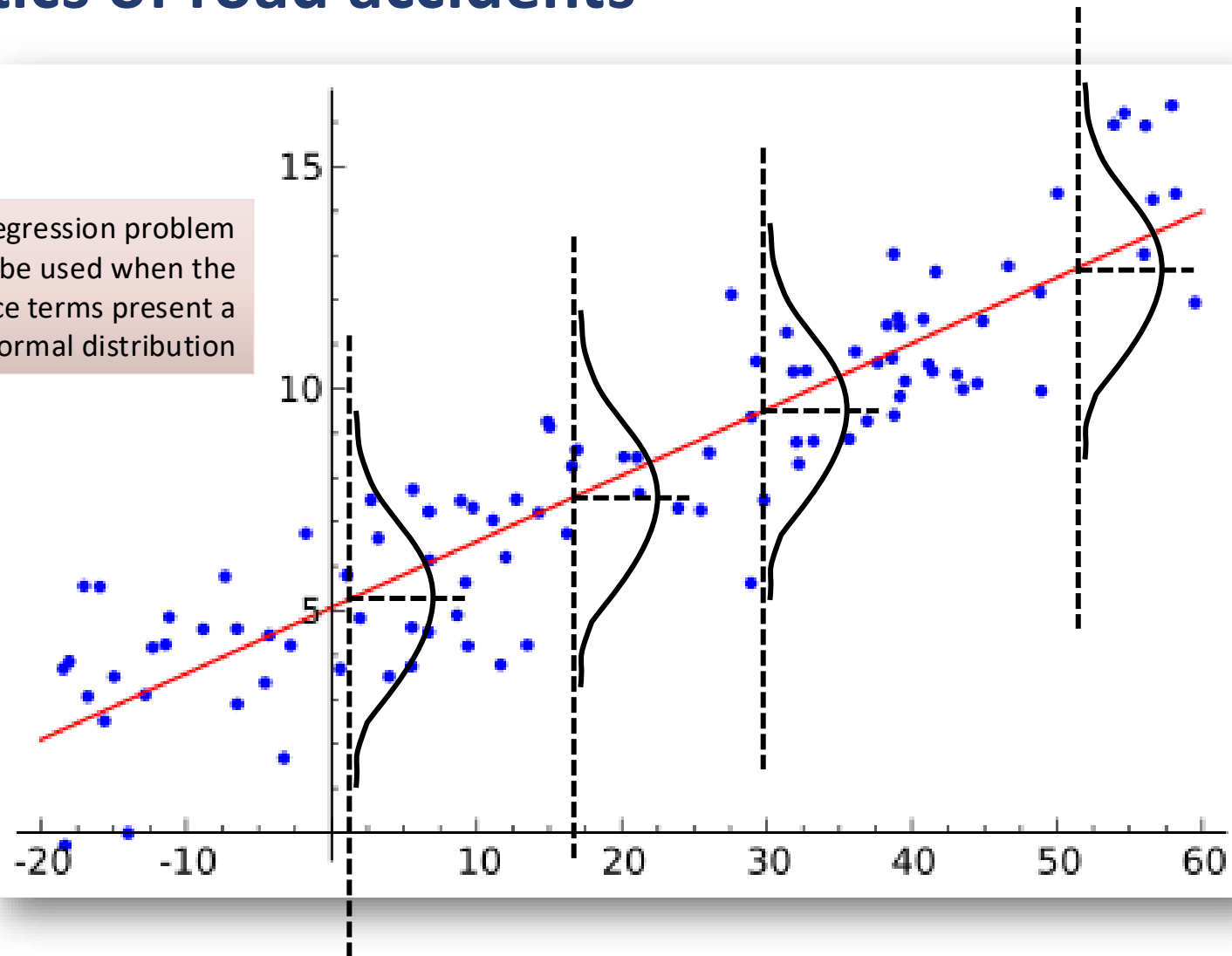
- Exposure to the risk:
 - Likelihood of being involved in a road accident
- Measurement:
 - Intersections: AADT (veh/year)
 - Road segments: AADT·[segment length] (veh·km/year)
- A high exposure is needed in order to observe road crashes
 - Long periods of time have to be considered
 - Additional techniques may be used (traffic conflicts)

Characteristics of road accidents

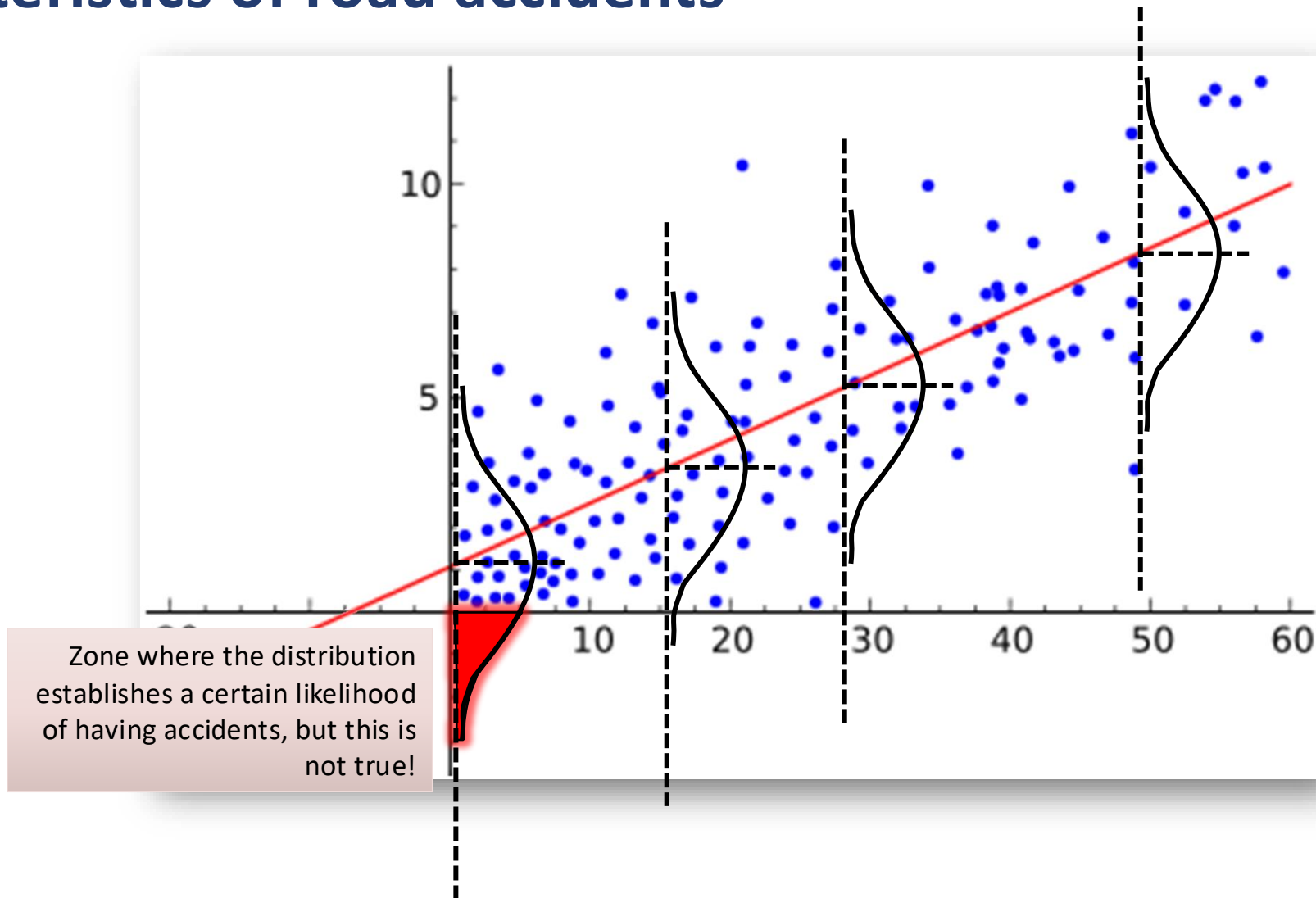
- Road crashes are:
 - **Rare.** Their frequency is very low. Thus, a large amount of data is needed for any analysis
 - **Random.** They are highly variable. This is why large periods of data are needed.
 - **Discrete.** They can only be discrete, non-negative values.
- Usually, the number of accidents is modeled instead of crash rates.

Characteristics of road accidents

A typical regression problem
can be used when the
disturbance terms present a
normal distribution



Characteristics of road accidents



Characteristics of road accidents

- A normal distribution cannot be used for modeling accidents.
 - Rare, random, discrete, heteroskedastic
- Accidents behave like a Poisson distribution, instead.

$$P(y_i) = \frac{e^{-\lambda_i} \cdot \lambda_i^{y_i}}{y_i!}$$

- $P(y_i)$ is the probability of the element i to have y_i accidents per unit of time
- λ_i is the expected number of accidents per unit of time (Poisson parameter)

Characteristics of road accidents

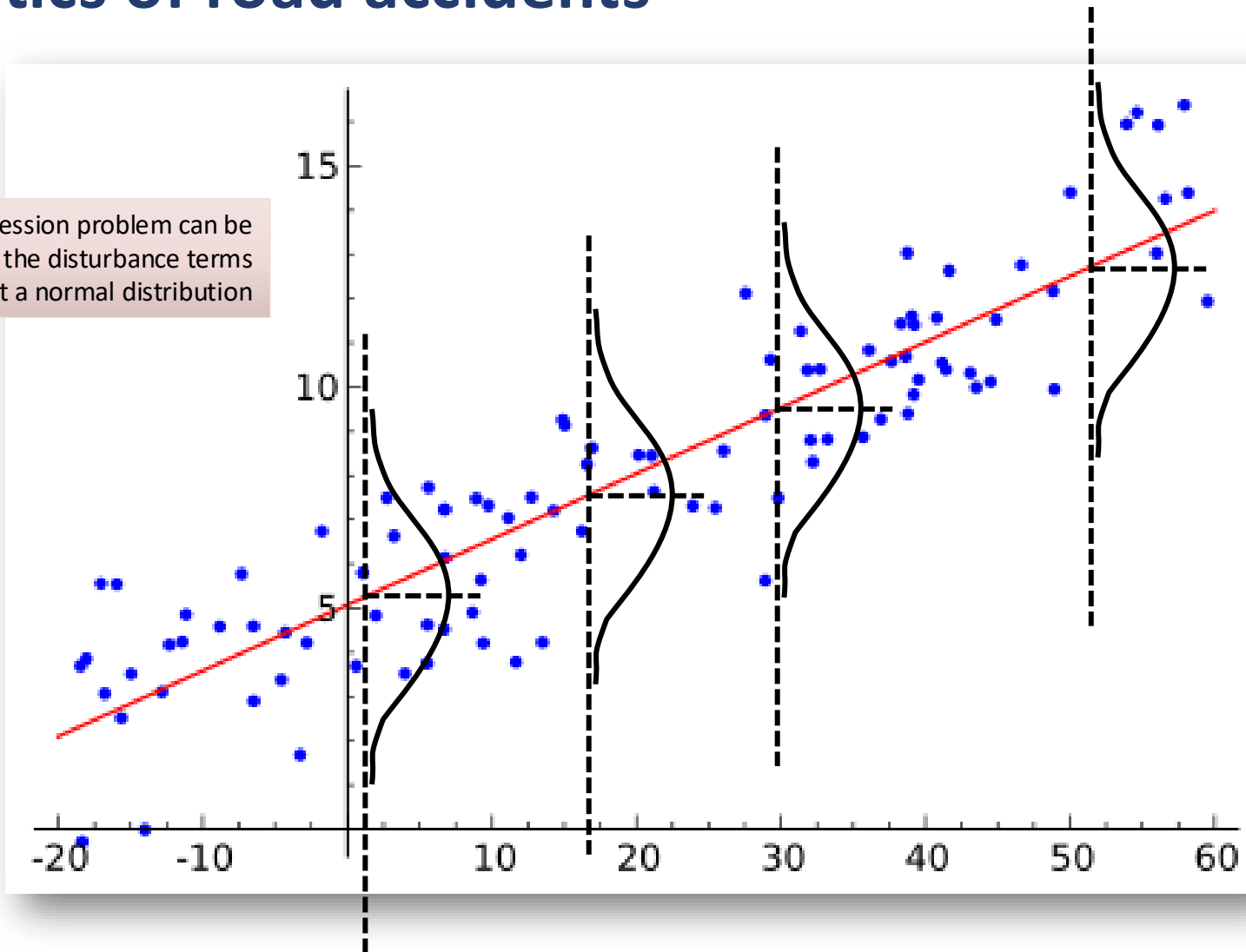
- The Poisson distribution is suitable for modeling road accidents:
 - Discrete outcomes
 - Heteroskedastic regression models (mean=variance)

Characteristics of road accidents

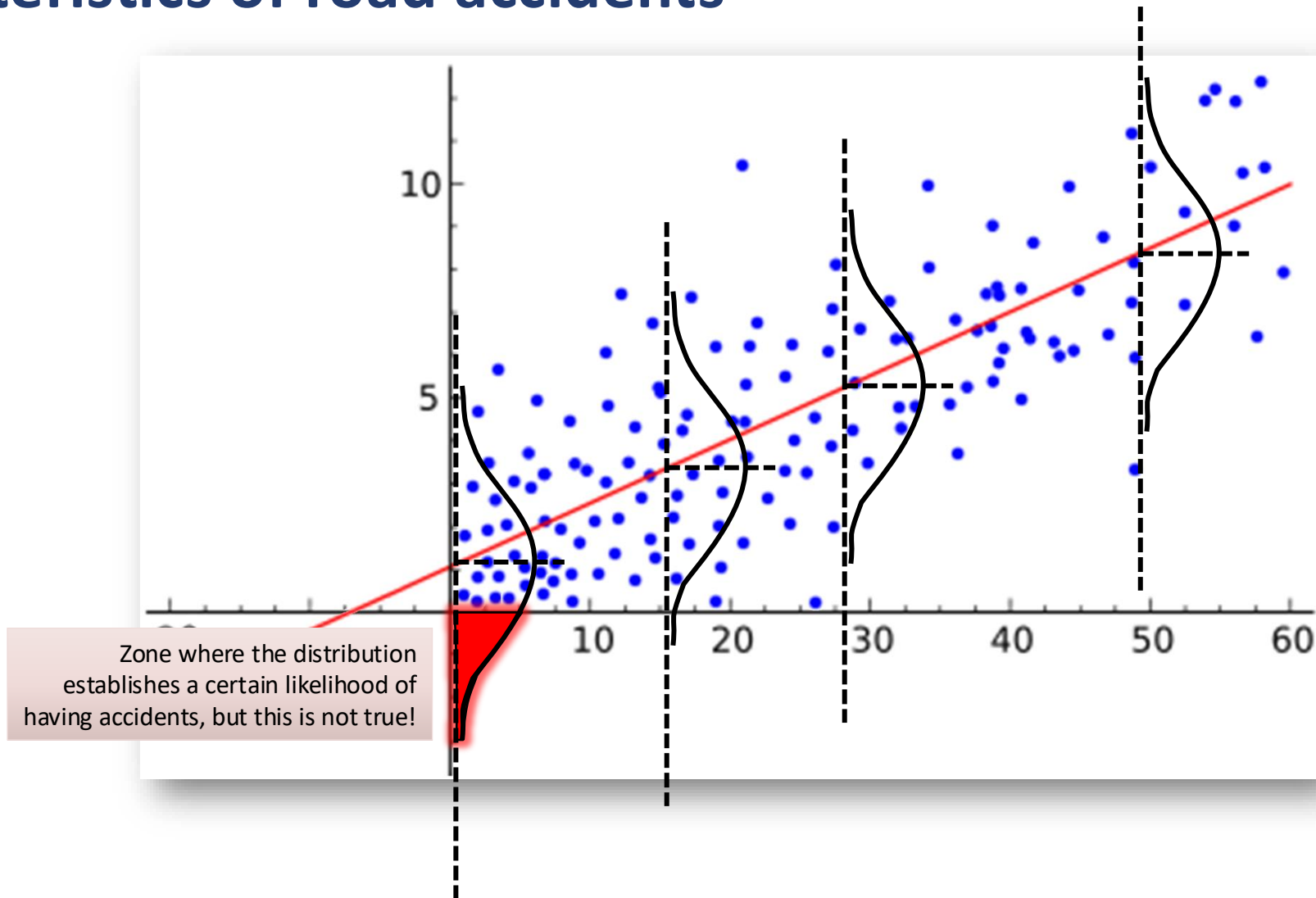
- The normal distribution can also be used under very specific circumstances:
 - When modeling crash rates instead the number of accidents (not recommended).
 - When the average number of accidents is not low, the Poisson distribution tends to adapt a normal-shape.

Characteristics of road accidents

A typical regression problem can be used when the disturbance terms present a normal distribution



Characteristics of road accidents



Characteristics of road accidents

- An accident can be understood as follows:
 - A Binomial distribution in which:
 - The number of repetitions n is very large (traffic exposure)

$$n \rightarrow \infty$$

- The likelihood of a crash to happen (p) is very low

$$p \rightarrow 0$$

- Both n and p are not known, but their product is the expected number of accidents of a certain location per unit of time (λ_i indicates the element)

$$n \cdot p = \lambda_i$$

Characteristics of road accidents

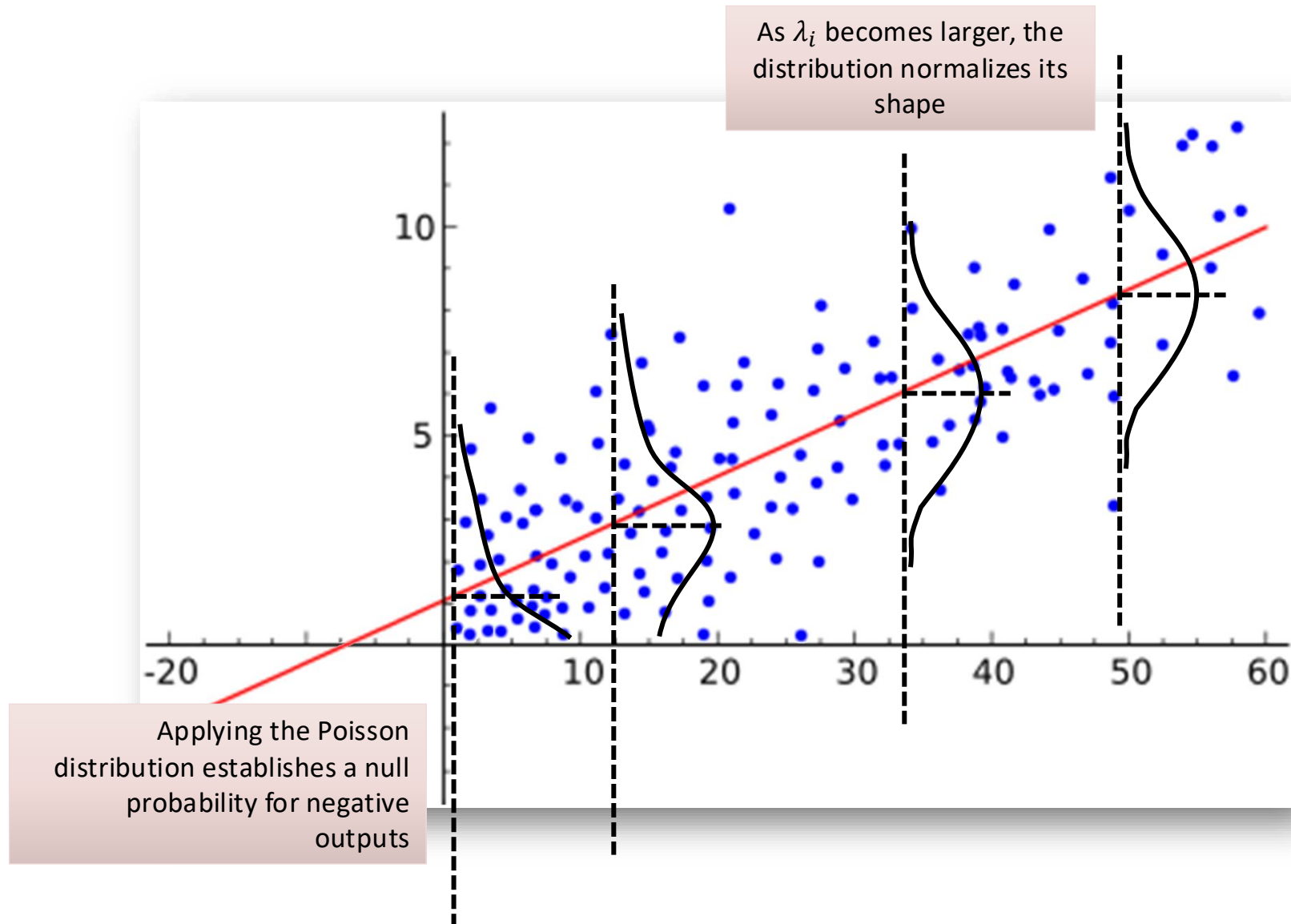
- An accident can be understood as follows:

- This is known as the Poisson process, which models discrete, non-negative events like road crashes

$$P(y_i) = \frac{e^{-\lambda_i} \cdot \lambda_i^{y_i}}{y_i!}$$

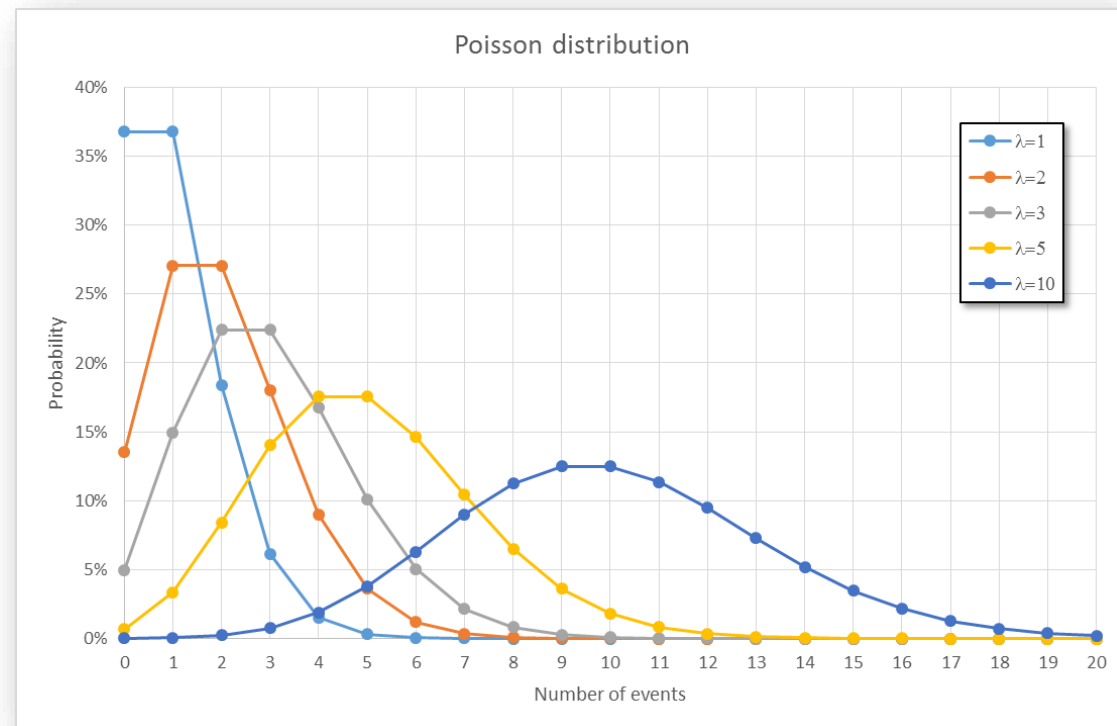
- $P(y_i)$ is the probability of the element i to have y_i accidents per unit of time
- λ_i is the expected number of accidents per unit of time (Poisson parameter)

Characteristics of road accidents



Characteristics of road accidents

- Parameters of the Poisson distribution:
 - Mean: λ_i
 - Variance: λ_i

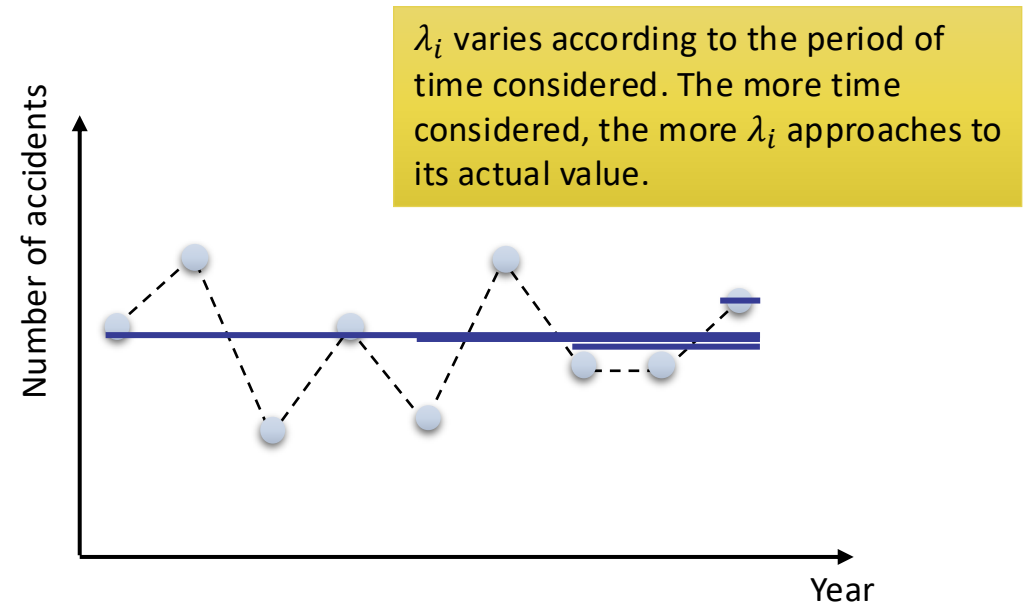
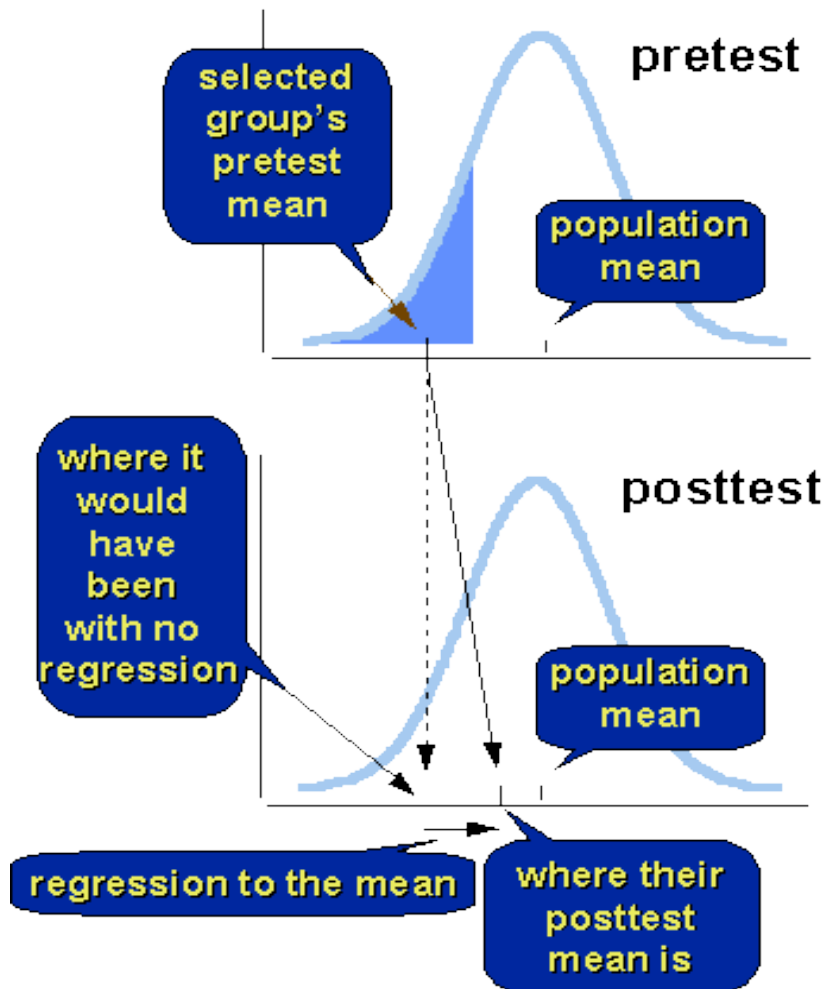


Characteristics of road accidents

- Although accidents usually behave according to the Poisson process, there are two important limitations:
 - Overdispersion
 - The Poisson distribution requires both mean and dispersion to be λ_i
 - When road crashes are analyzed, it is normal that they distribute in a different way, showing a higher variance
 - Negative Binomial Regression
 - Large amount of zeros
 - Sometimes the large amount of zeros is the result of two different phenomena that should be analyzed
 - ZIP Models (Zero-Inflated-Poisson Models)

Characteristics of road accidents

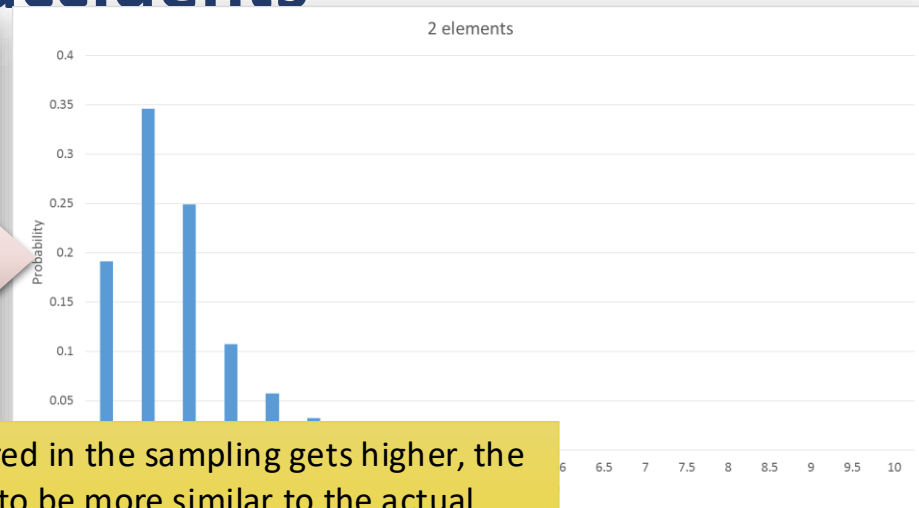
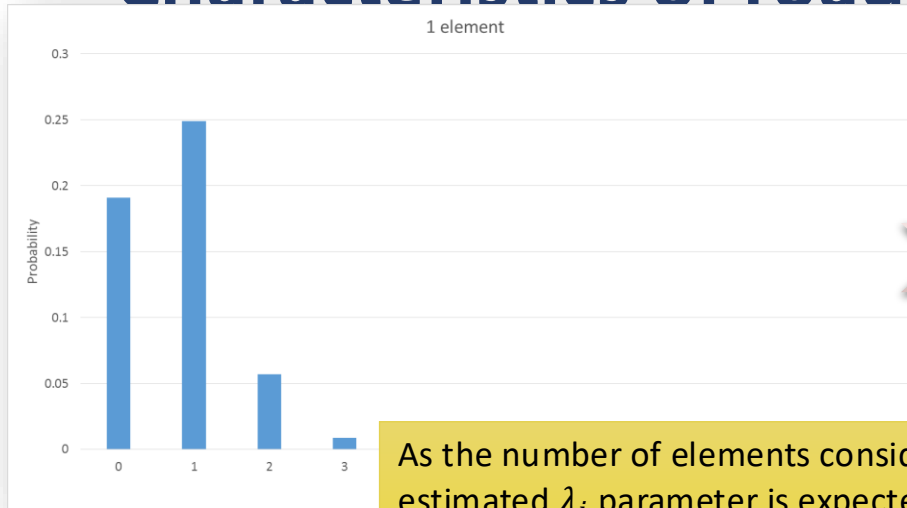
- The most important parameter for the Poisson distribution is λ_i but...
- Do we really know its value??



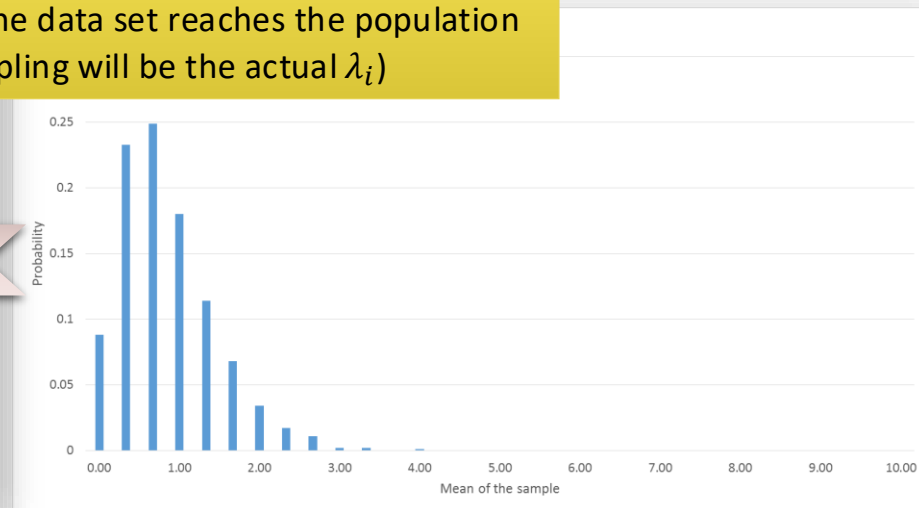
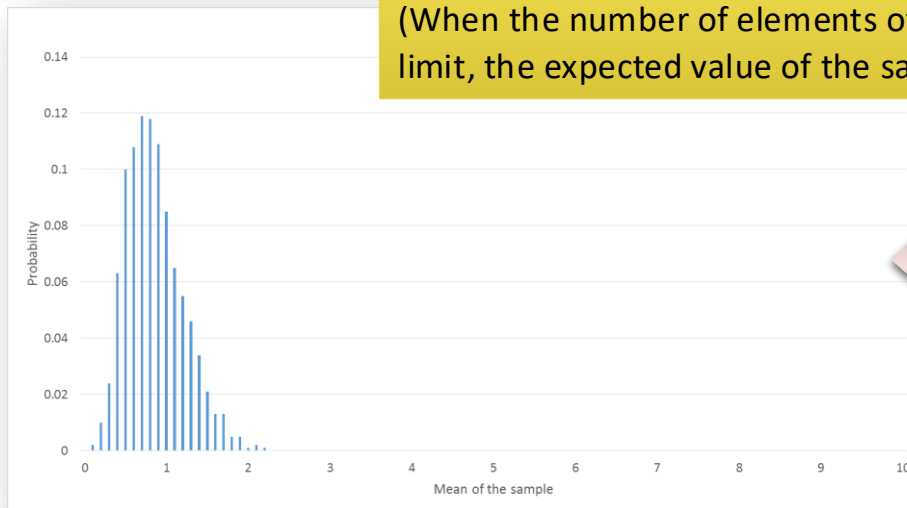
Characteristics of road accidents

- Example:
 - Set of $n > 2$ roundabouts
 - Similar characteristics
 - Same exposure
 - Similar λ_i expected (e.g. 0.8 acc/year)
 - 1000 different samplings, considering:
 - 1 element
 - 2 elements
 - 3 elements
 - 10 elements
 - The mean is calculated for each sampling

Characteristics of road accidents



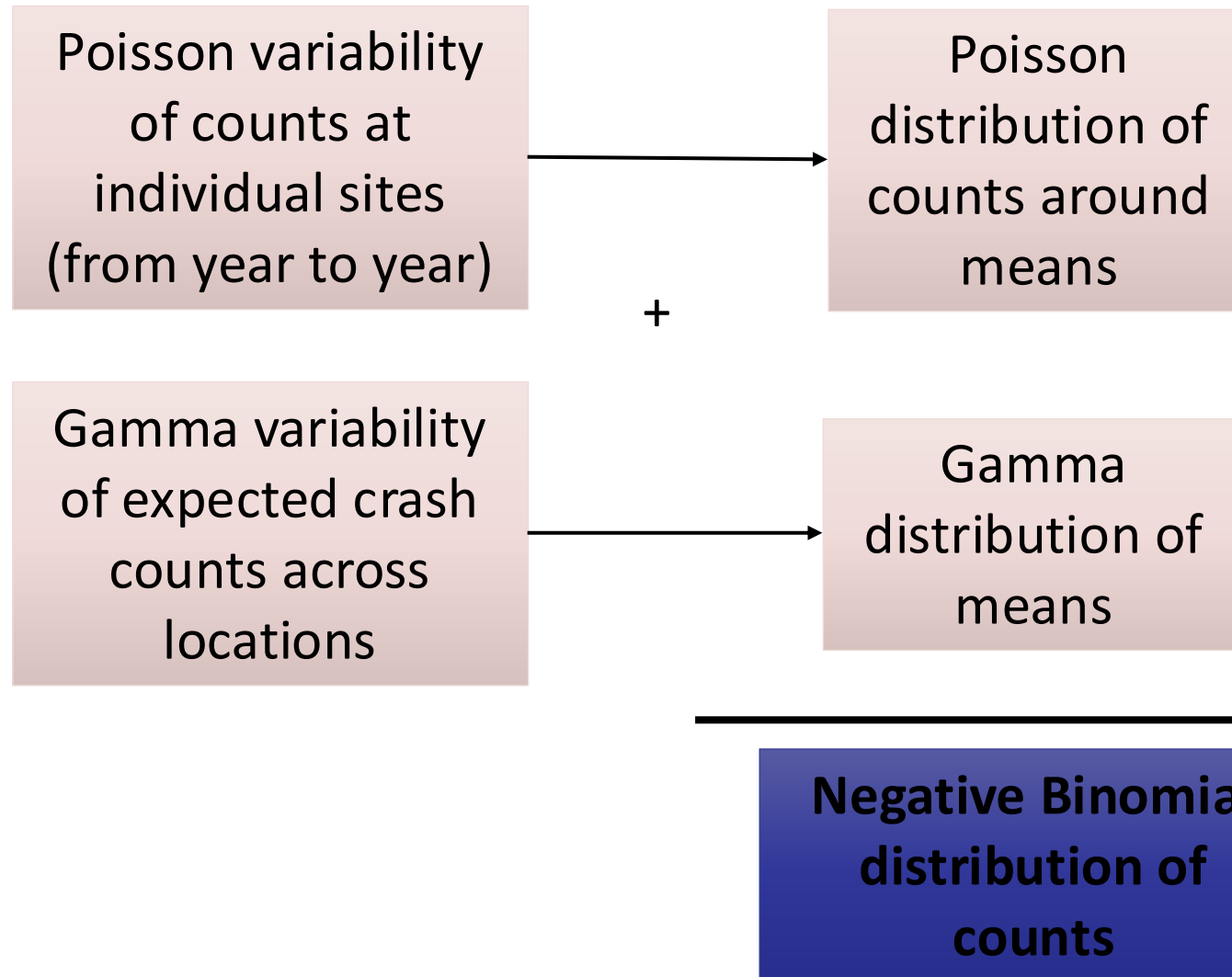
As the number of elements considered in the sampling gets higher, the estimated λ_i parameter is expected to be more similar to the actual one.
(When the number of elements of the data set reaches the population limit, the expected value of the sampling will be the actual λ_i)



Characteristics of road accidents

- λ_i distribution depends on:
 - The number of elements considered (as n gets higher, its dispersion decreases)
 - Its value itself (as it gets higher, the distribution will be more like a normal one)
- λ_i follows a Gamma distribution:
 - Mean: λ_i
 - Variance: $\frac{\lambda_i}{n}$

Characteristics of road accidents



Characteristics of road accidents

- The negative binomial distribution presents some important advantages:
 - It is a generalization of the Poisson distribution
 - Considers the uncertainty of the λ_i estimation
 - Its variance is higher than its mean, so it is valid for modeling overdispersed count data
- Conclusion:
 - If the sample mean and variance are similar, a Poisson regression can be performed
 - If the variance is pretty higher than the mean, a Negative Binomial Regression is suggested

Characteristics of road accidents

- Road crash accidents usually present a large amount of zeros due to two different phenomena:
 - An element is likely to present accidents, but it shows no accidents due to randomness
 - Count-process state
 - For example: no crashes in a roundabout within a year
 - The element is very safe and the possibility of having accidents is almost negligible
 - Zero-count state
- Solutions:
 - Zero Inflated Poisson (ZIP) regression model
 - Zero Inflated Negative Binomial (ZINB) regression model

Measurement of road safety

- Expected crash frequencies
 - Crashes/year
- Expected crash rates
 - Crashes/unit exposure
- Examples of unit exposures
 - 10^9 VMT (vehicle-mile-traveled)
 - 10^5 registered vehicles
 - 10^5 licensed drivers

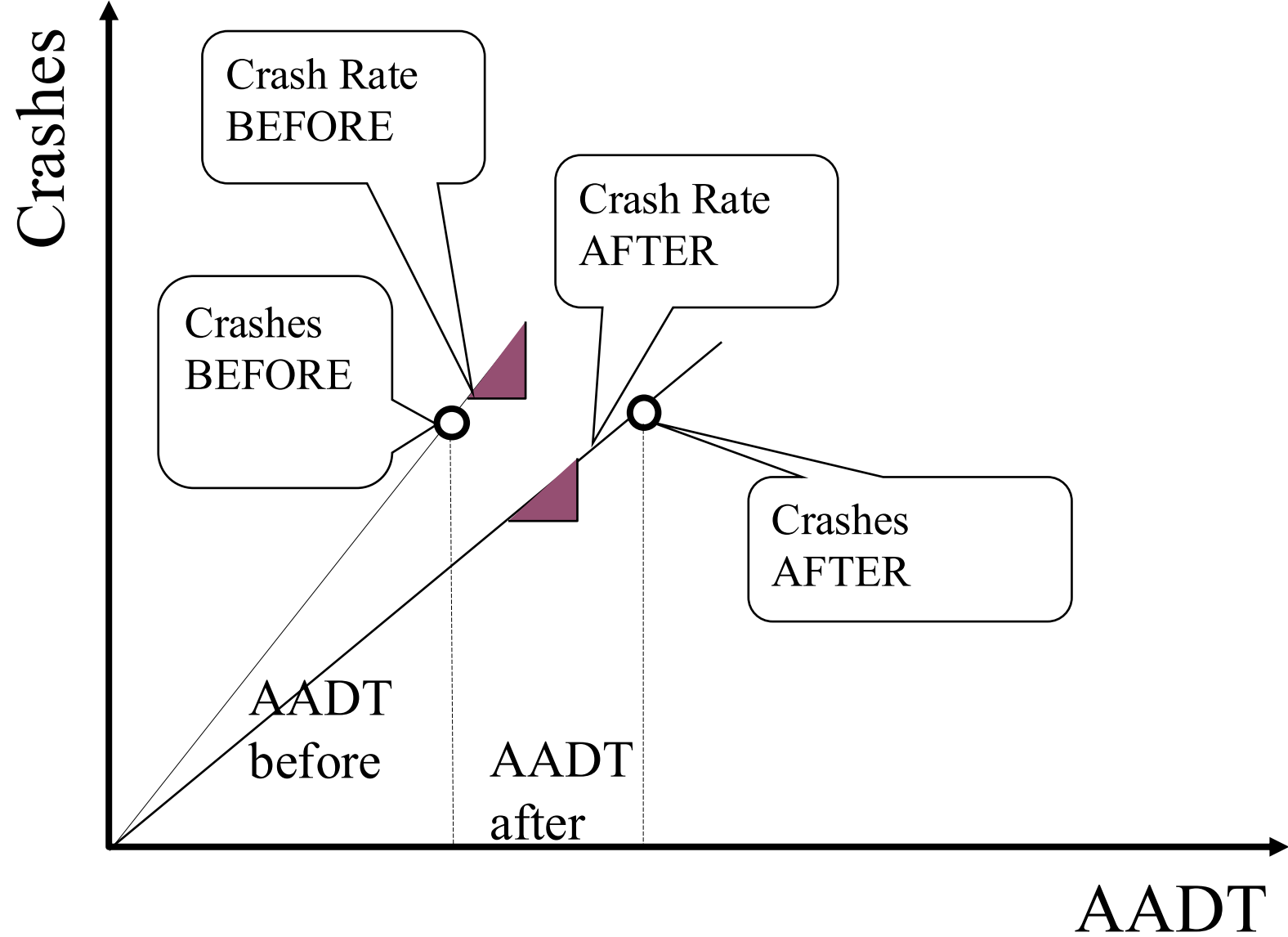
Measurement of road safety

- Crash frequency
 - Number of accidents on a road segment by year
 - Easiest way to determine a road segment hazard

Measurement of road safety

- Crash rates:
 - Risk measurement of a road segment, comparing:
 - Number of reported accidents
 - Traffic volume during a period of time
 - Number of accidents→product of:
 - Risk exposure (km traveled)
 - Risk level (number of accidents per km traveled)
- $AV=TT*CR$
 - AV: accidents with victims
 - TT: risk exposure
 - CR: crash rate

Crash Counts vs. Crash Rates



Measurement of road safety

- Risk exposure
 - [traffic volume]*[road segment length]
 - $TT = AADT \cdot 365 \cdot L$
 - Units: $10^6 \text{ vh} \cdot \text{km}$

Probability for an accident to take place

Measurement of road safety

- Crash rates:
 - General crash rates:
 - Relationship between number of accidents or victims and general statistical data (population, vehicles, ...)
 - They do not reflect the traffic influence on the number of accidents
 - Specific rates:
 - They reflect the risk level of suffering a road accident on a particular road segment
 - They are adequate for comparing safety levels at road networks

Measurement of road safety

- General rates
 - Accident rates per population:
 - $[\text{number of crashes}] / 100,000 \text{ inhabitants}$
 - $[\text{number of killed people}] / 100,000 \text{ inhabitants}$
 - Accident rates per number of vehicles:
 - $[\text{number of crashes}] / 100,000 \text{ vehicles}$
 - $[\text{number of killed people}] / 100,000 \text{ vehicles}$

Measurement of road safety

- Specific rates
 - Crash rate:
 - number of accidents with victims/ 10^6 vh·km
 - Fatality rate:
 - number of fatalities/ 10^6 vh·km
 - Severity rate:
 - number of fatalities/100 accidents with victims

Measurement of road safety

- Specific rates
 - Risk Index - EuroRAP:
 - number of fatal or serious injury accidents / 10^9 vh·km
 - Equivalent Property Damage Only Index (EPDO Index)
 - Number of equivalent PDO accidents, considering the following coefficients:
 - PDO accident: 1
 - Minor injury accident: 3,5
 - Serious injury or fatal accident: 9,5

Papers

- Montella A., Andreassen D., Tarko A., Turner S., Mauriello F., Imbriani L. L., Romero M. (2013). Crash Databases in Australasia, the European Union, and the United States: Review and Prospects for Improvement. Transportation Research Record: Journal of Transportation Research Board, No. 2386, pp. 128-136. Doi: 10.3141/2386-15.

Websites

- http://ec.europa.eu/transport/wcm/road_safety/erso/data/Content/introduction-2.htm
- http://ec.europa.eu/transport/road_safety/specialist/statistics/index_en.htm
- <http://www.nzta.govt.nz/resources/crash-analysis-system/>
- <http://www-fars.nhtsa.dot.gov/Main/index.aspx>
- <http://www.hsisinfo.org/>



LUND
UNIVERSITY