FCTUC DEPARTAMENTO DE ENGENHARIA CIVIL
FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE DE COIMBRA

# Roundabouts in Portugal
# State of the Art

STOCKHOLM ROUNDABOUT DESIGN AND CAPACITY SEMINAR , 1ST JULY

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# Outline

## Evolution of roundabouts in Portugal

## Current situation

- Roundabout types
- Main problems

## Previous research

- Speeds and trajectories

## Current research

- Headway distribution models
- Estimation of critical headways
- Pedestrian effect on roundabout capacity

# History of roundabouts in Portugal

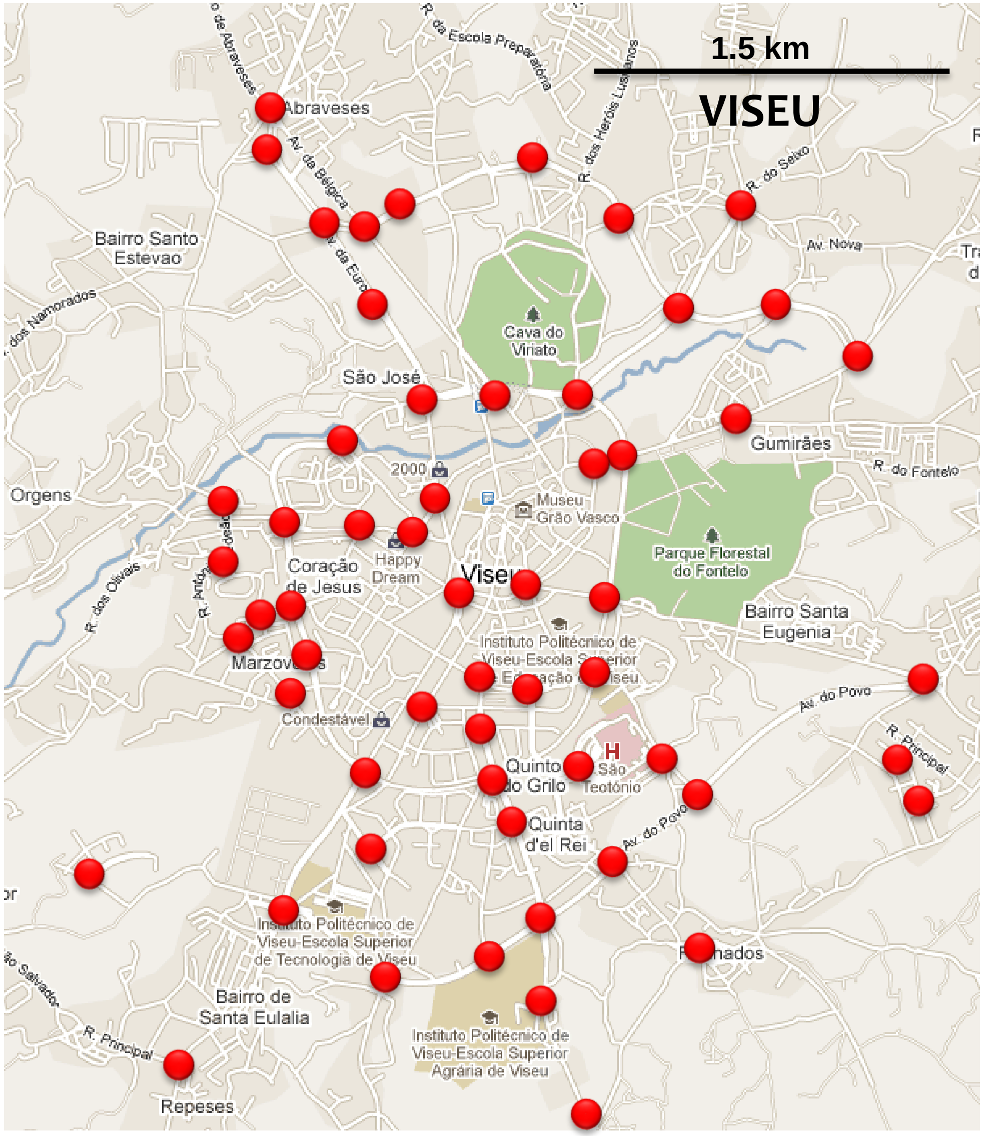
- Portugal has the first roundabouts constructed according to the Henard's Principles
- Since the 80's the number of roundabouts has increased exponentially
- The exact number of roundabouts is unknown but there are certainly some thousands.

Praça Marquês Pombal, Lisboa, 1930



# Background

PORTUGAL



# Background

## Roundabout types

- Single lane roundabouts – a few examples, normally located on rural or residential areas
- Multilane roundabouts - the most common in Portugal, namely on urban collectors roads
- Compact roundabouts (with truck aprons) – have became popular
- Mini roundabout – extremely rare
- Others types (double roundabouts, signalized) – extremely rare

# Roundabouts in Portugal

## Main Problems

- We have a Roundabout Design Guide…

  … but the document has not yet been published.

- The Road Code doesn't include rules about how to circulate on roundabouts …

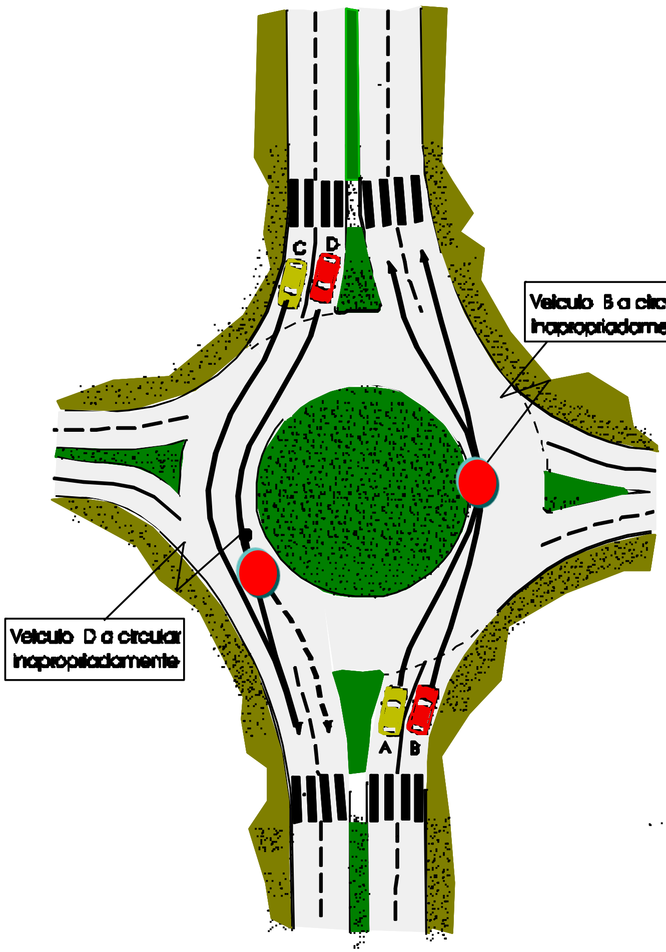
  … and there are a lot of contradictory recommendations

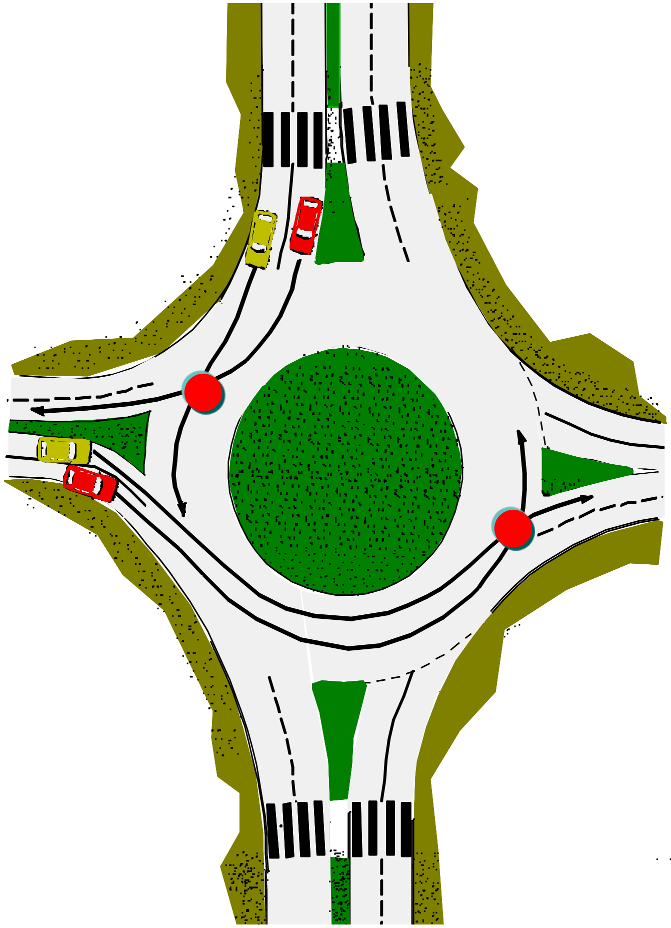


- Fortunately, most drivers drive correctly!

## Main Problems

Tipical behaviours…



# Background

PORTUGAL

**Main problems**

geometrical design problems…

excessive number of lanes in the ring

large roundabouts

lack of entry deflection

lack of channelization

traffic signals\

# Background

PORTUGAL

**Main problems**

Obstructions in the central island…

# Previous research

PORTUGAL

**Driver behavior**

The study was based on 2100 trajectories collected under free flow conditions

## The instrumented vehicle

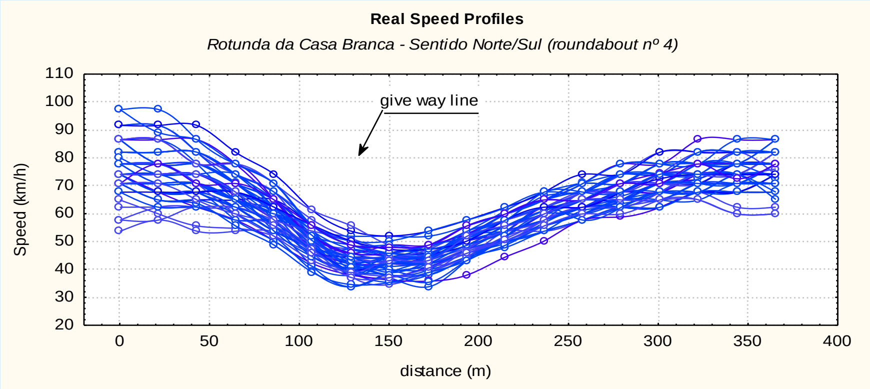

- **14 drivers**
- **20 circuits per driver in 10 roundabouts**

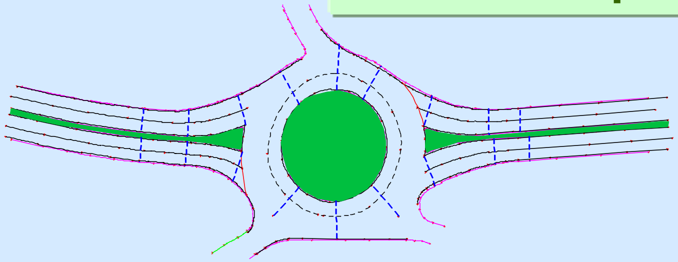
**DATA COLLECTION VARIABLES:**

- drivers’ control actions
- dynamic response of the vehicle
- Vehicle position (with IR beacons)

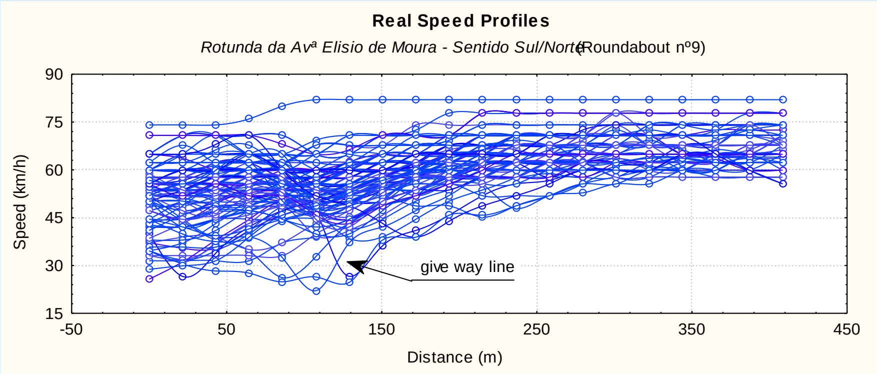

## Speed Profile Analyses

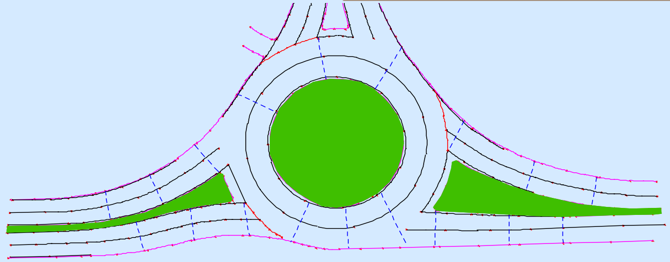
### Speed Dispersion



**Good example**



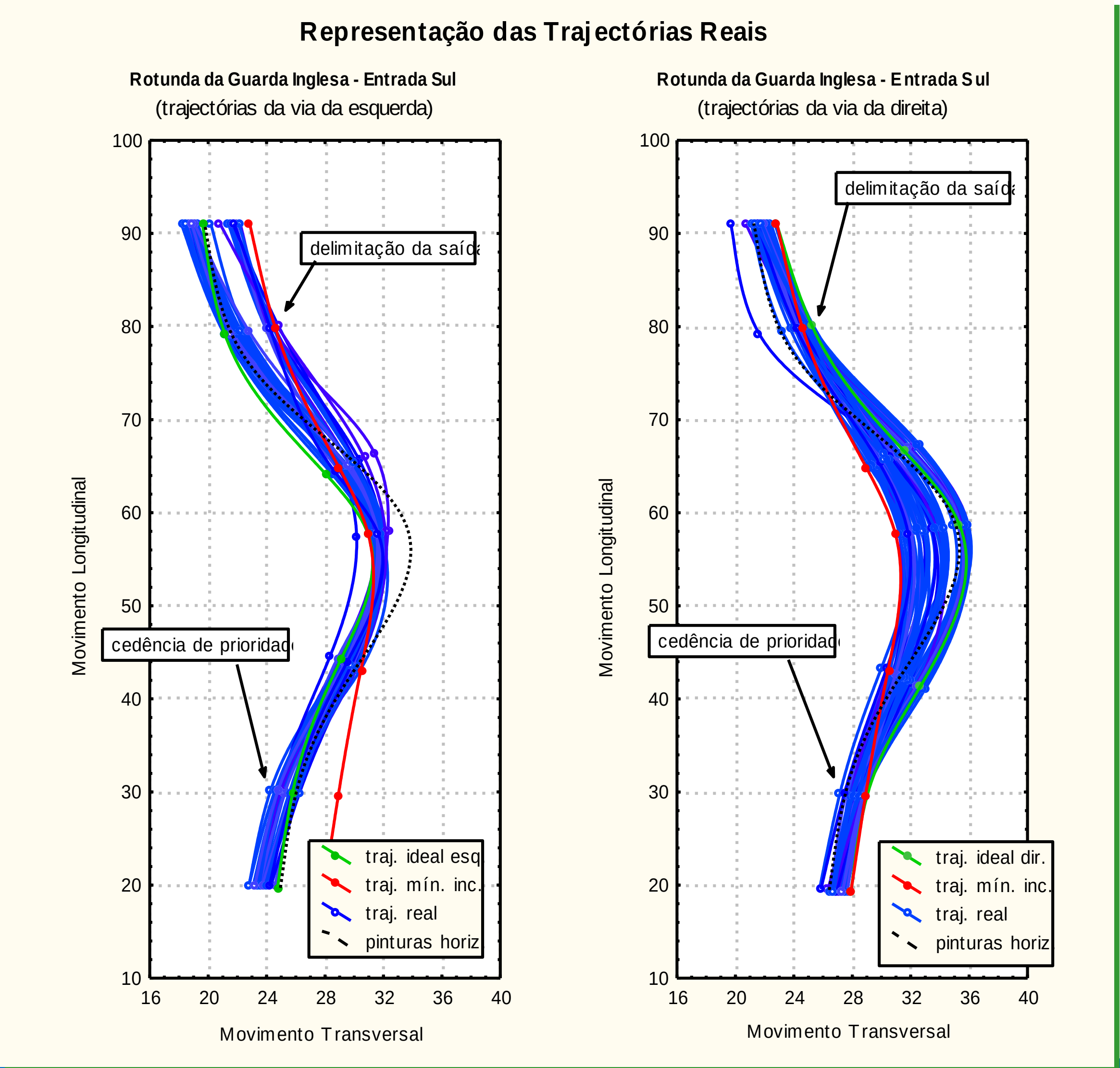



**Bad example**

# Previous research

PORTUGAL

## Trajectories

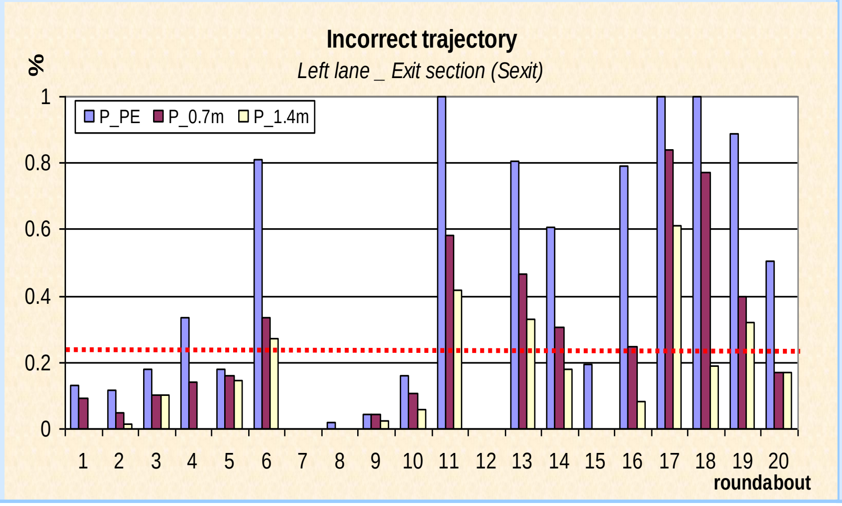


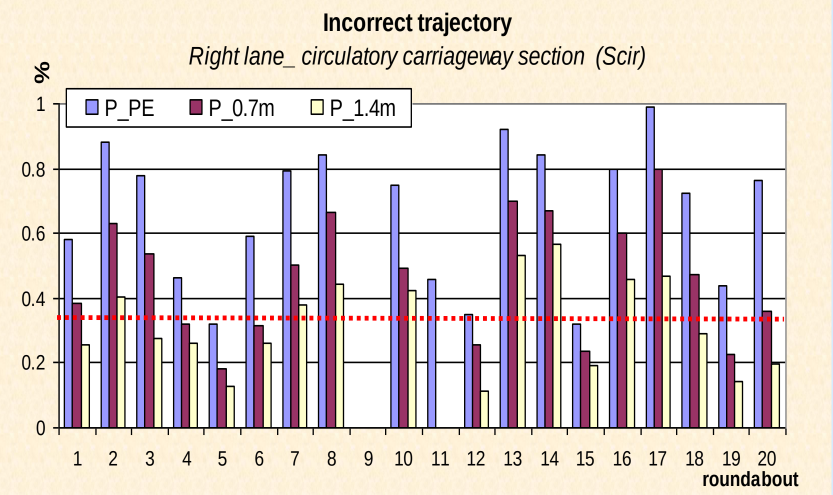

## Driver behaviour

drivers' behavior results from a relative valorization of the "temptation/desire" to minimize driving discomfort and the "obligation" to respect road markings.

## Trajectory Analyses

### Real Trajectory Adequacy – Right Lane/Left Lane




- Higher average deviations at the right lane
- Best designs can expect 20% of incorrect trajectories on right lane

## Main Conclusions

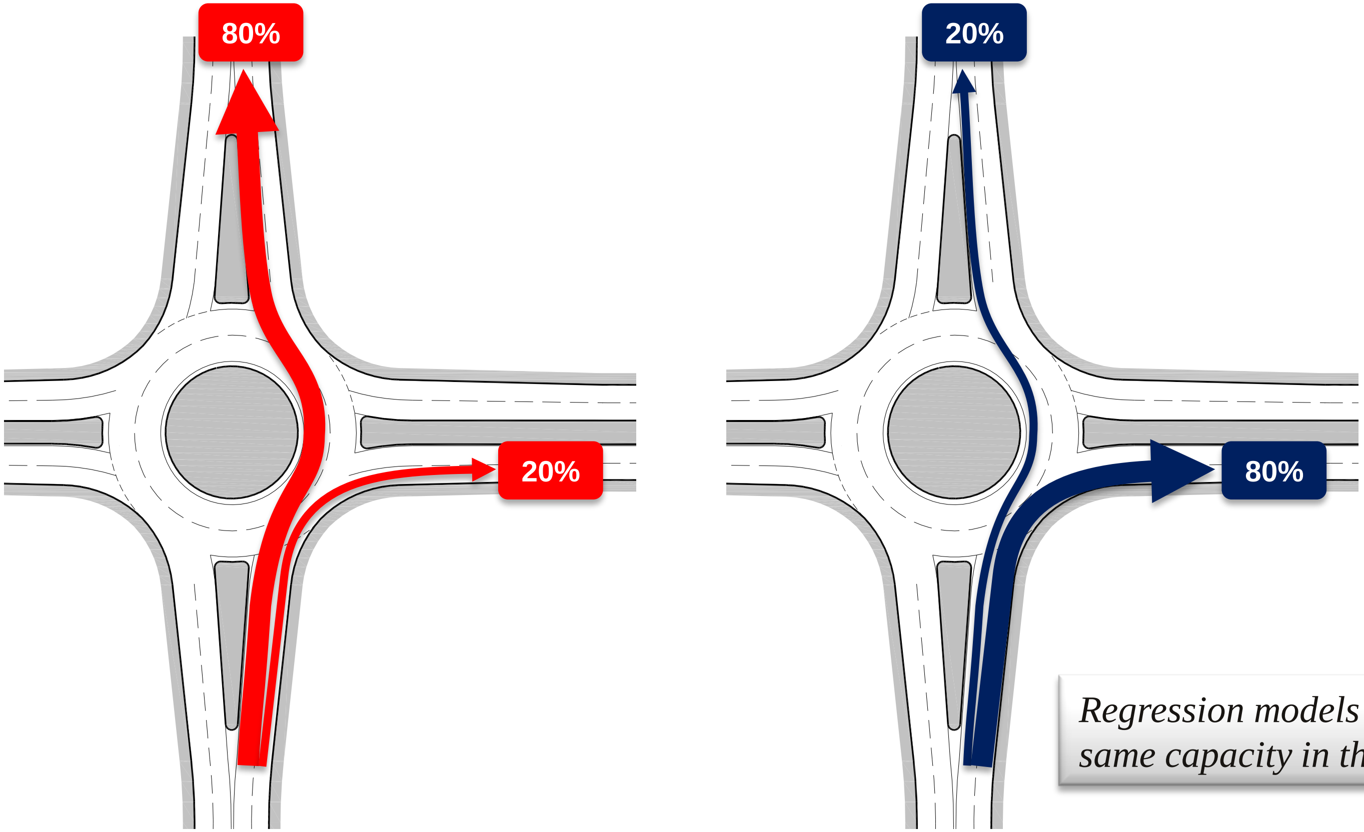
### Speed and Trajectory Profiles

- There is a linear and positive correlation between approach speed and entry speed;
- **Low trajectory deflections** usually results in greater acceptance by drivers in maintaining their circulation lane. However this also results in high entry speeds and big behavioral heterogeneities;
- High deflection levels tend to impose high levels of discomfort which induce drivers to invade adjacent lanes searching for more direct and comfortable trajectories.
- Global results confirm the hypothesis that drivers' behavior results from a relative valorization of the "temptation/desire" to minimize driving discomfort and the "obligation" to respect road markings.
- Some "Lane Invasion" is inevitable even in well designed roundabouts. Global results have shown that adequate drivers' behavior can be expected to be observed at well designed roundabouts.

# Recent research

## Gap-acceptance models: motivation

Linear regression models are insensible to entry flow distribution and opposing flow distribution

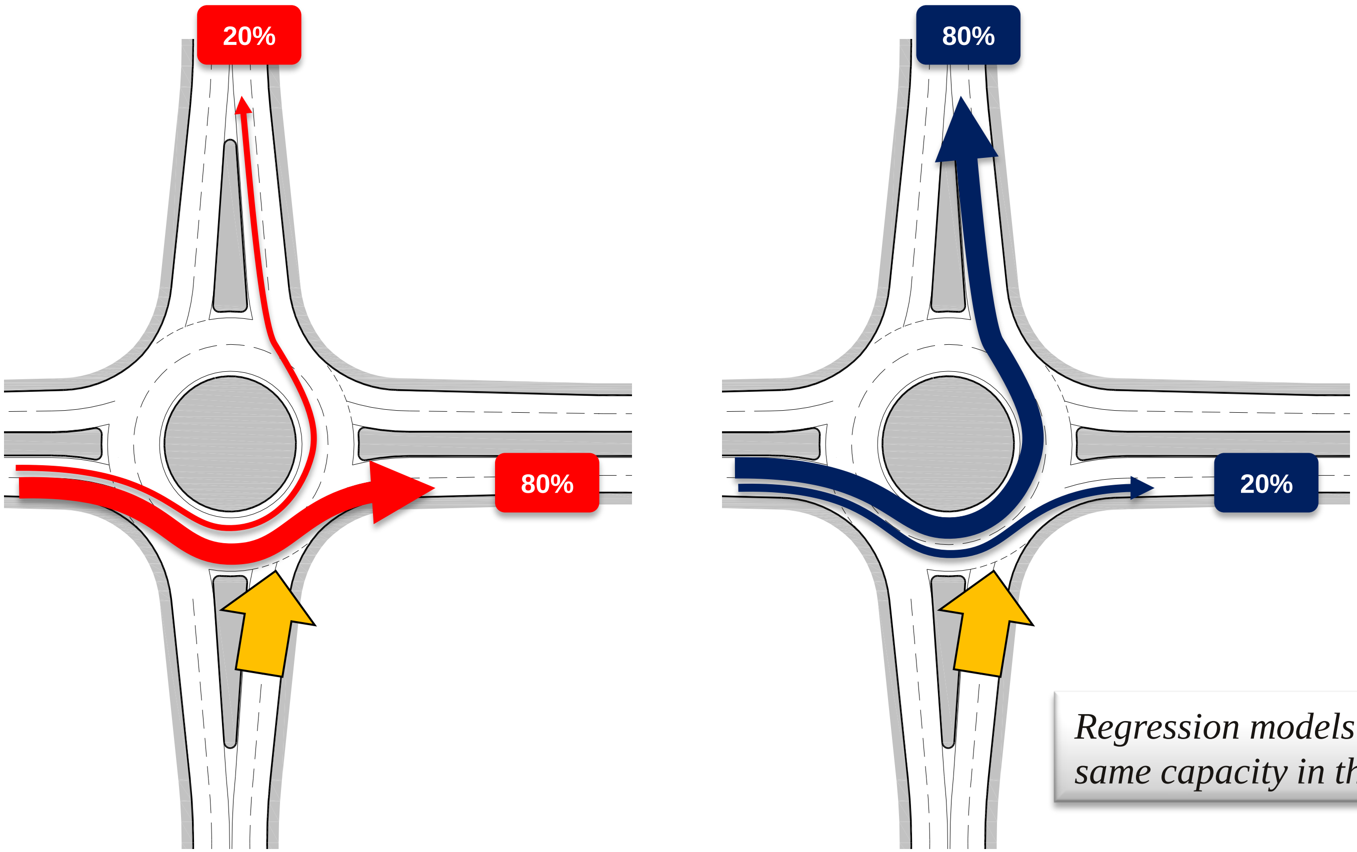



*Regression models predict the same capacity in these two cases.*

# Recent research

## Gap-acceptance models: motivation

Linear regression models are insensible to entry flow distribution and opposing flow distribution



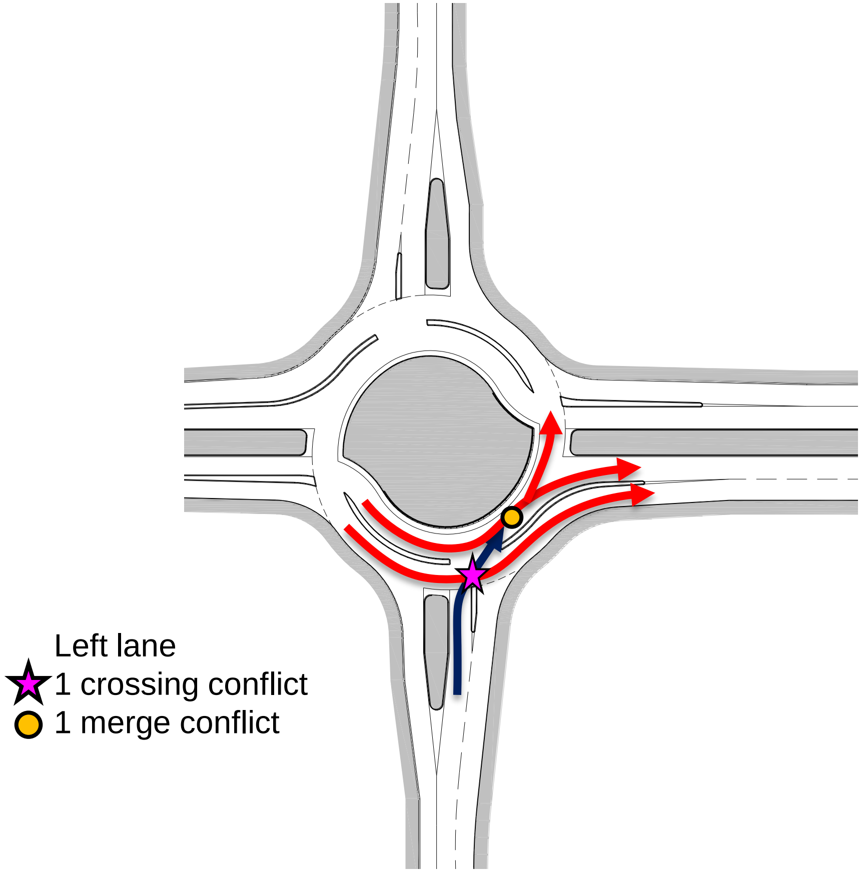

*Regression models predict the same capacity in these two cases.*

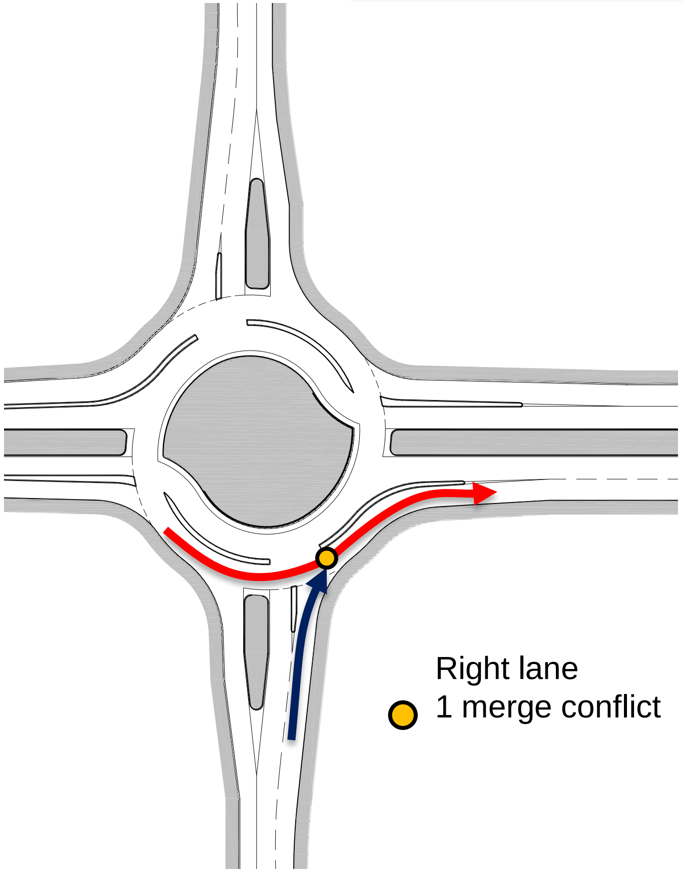
# Recent research

## Gap-acceptance models: motivation

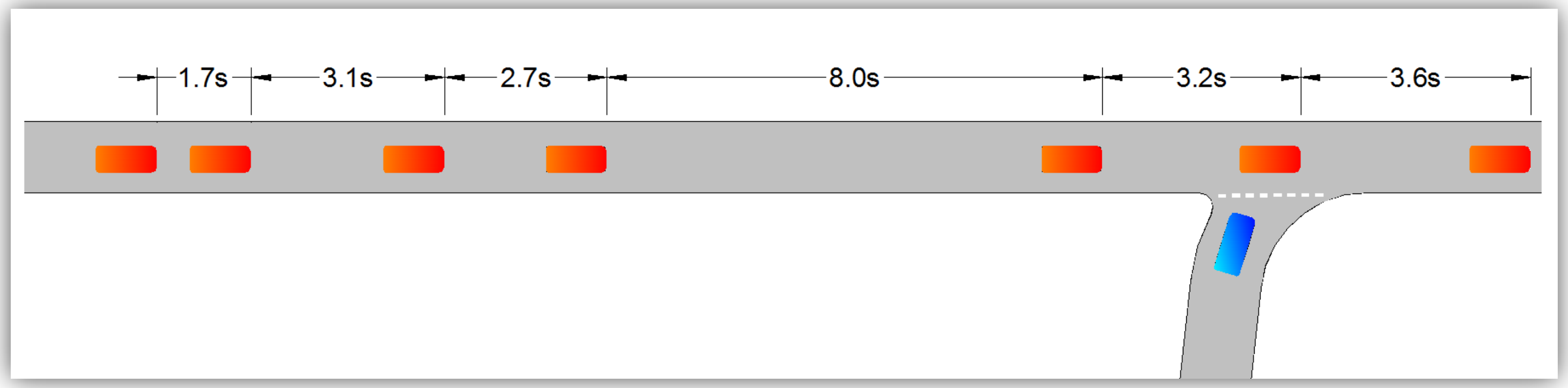
Linear regression models are inadequate to study new layouts, particularly when lane-by-lane analyses is required.

*This is particularly important when using the more complex capacity formulas (e.g., Hagring) that are sensible to traffic distribution among entry and circulatory lanes*



# Headway distribution model




### Motivation

- The representation of inter-vehicular time intervals in the major stream is one of the building block of gap-acceptance models

$$F(t) = 1 - e^{-\lambda t}$$

### Simplest approach: the Negative Exponential Distribution

- Only one parameter $\lambda$. Easy to estimate.
- Method of moments: $\lambda = q$ (average flow in the opposing stream)
- Resulting capacity model: Siegloch formula

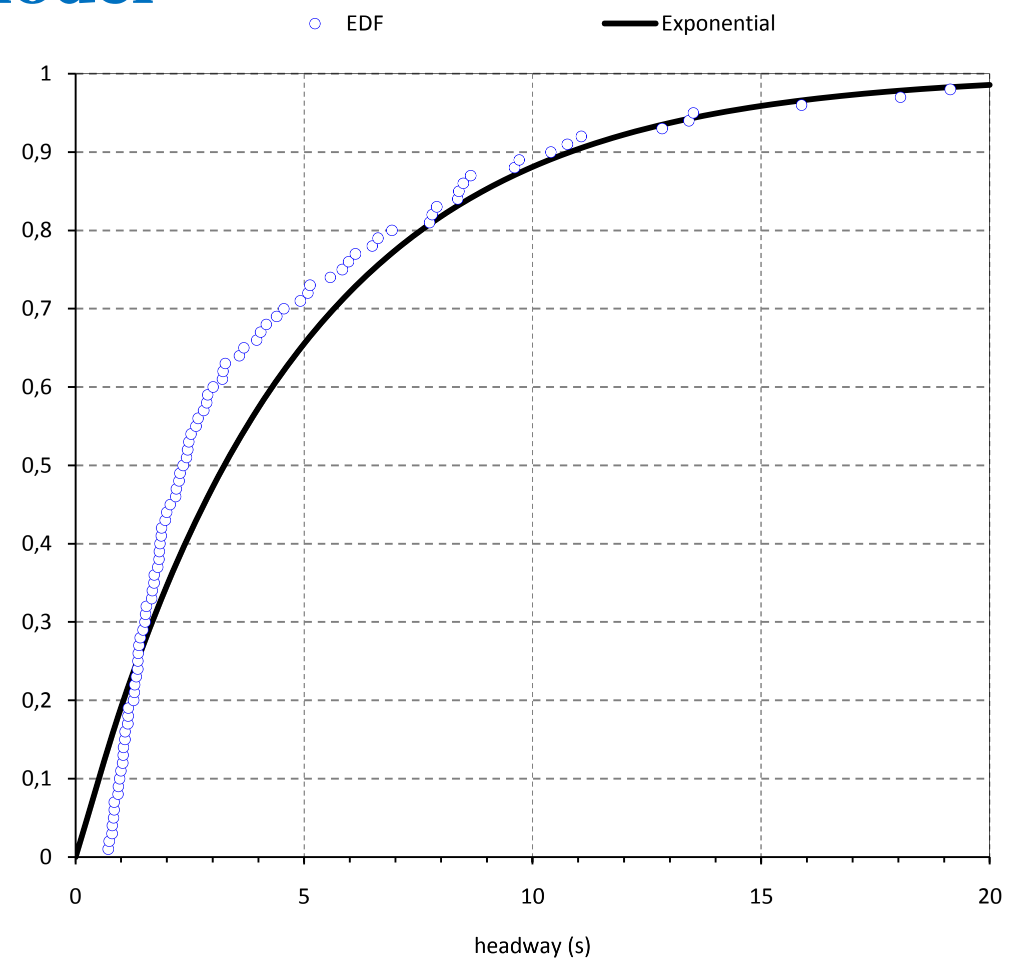
$$C = \frac{q_M \, e^{-q_M t_c}}{1 - e^{-t_f}}$$

# Recent research

## Headway distribution model

### Limitations of the exponential model

- Allows unrealistic short headways
- Does not describe platooning
- Can be considered realistic for very low/flow conditions only (<150 veh/h)



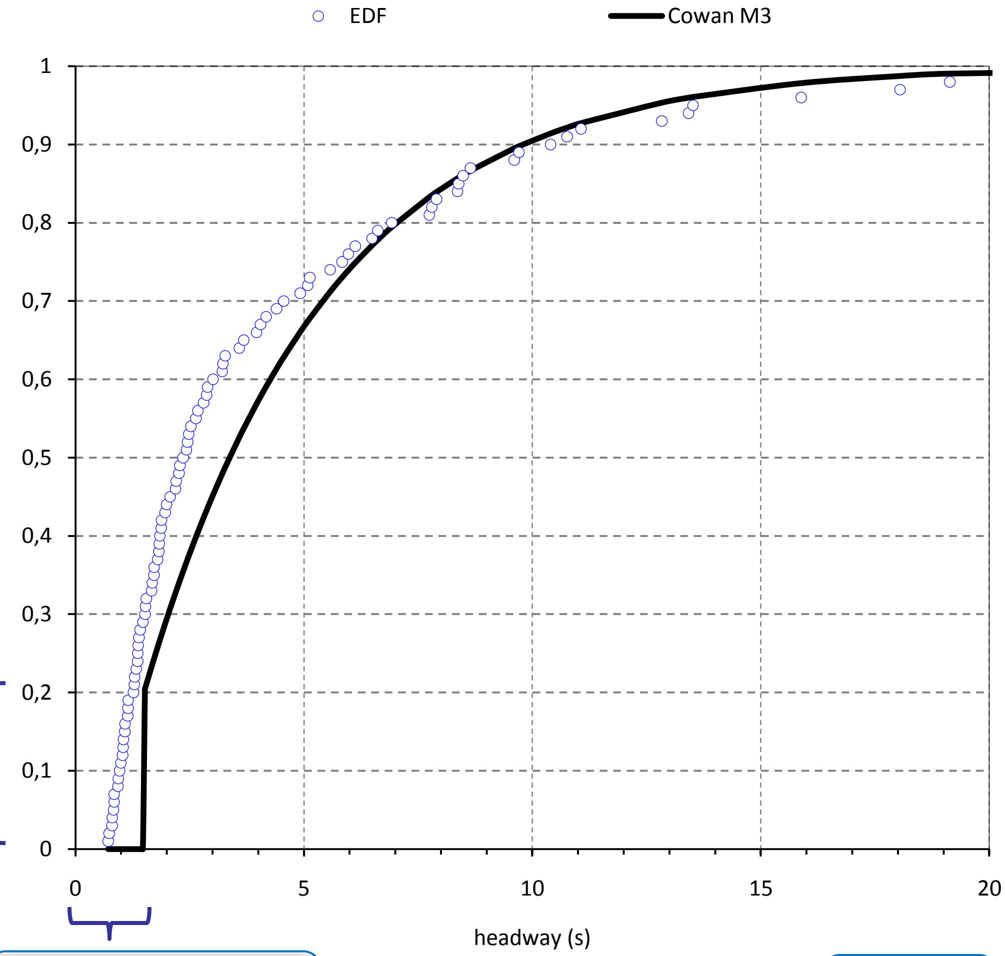
# Headway distribution model

### Alternative - Cowan M3 Distribution

- 3 Parameters ($\phi$, $\Delta$, $\lambda$)
- It is assumed that part of the drivers ($1-\phi$) are in platoons with a uniform headway ($\Delta$). The others ($\phi$) are "free" and distributed according to the neg. exponential distribution
- Method of moments:

$$\lambda = \frac{\phi q}{1-\Delta q}$$

Prop. of drivers in platoons (1-Φ)



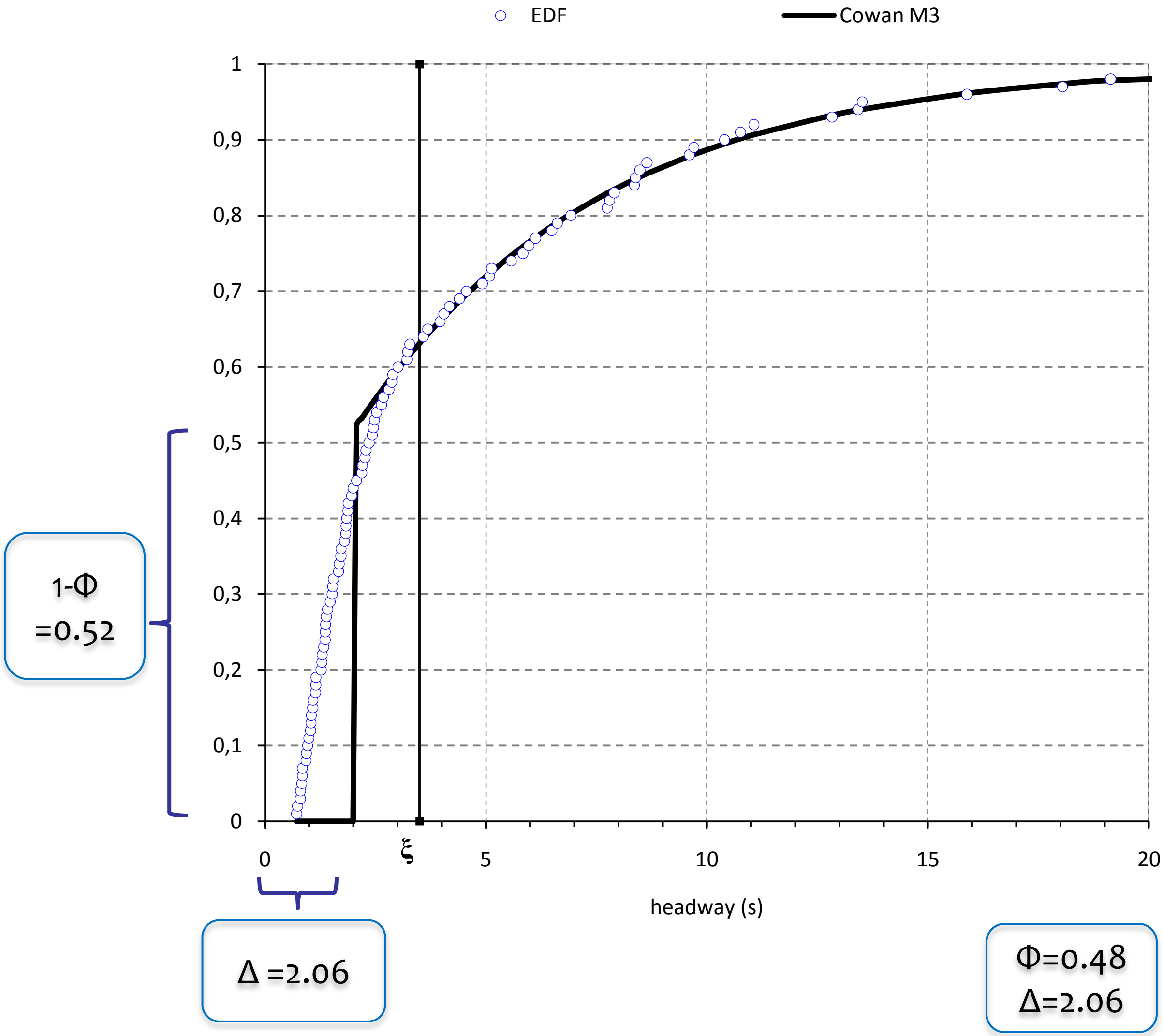

Headway in the platoons (Δ)

Φ=0.8
Δ=1.5

# Headway distribution model

### Estimation for a given observed distribution

- Using solver in Excel
- The fit is very bad for t< Δ but those intervals would be rejected anyway!



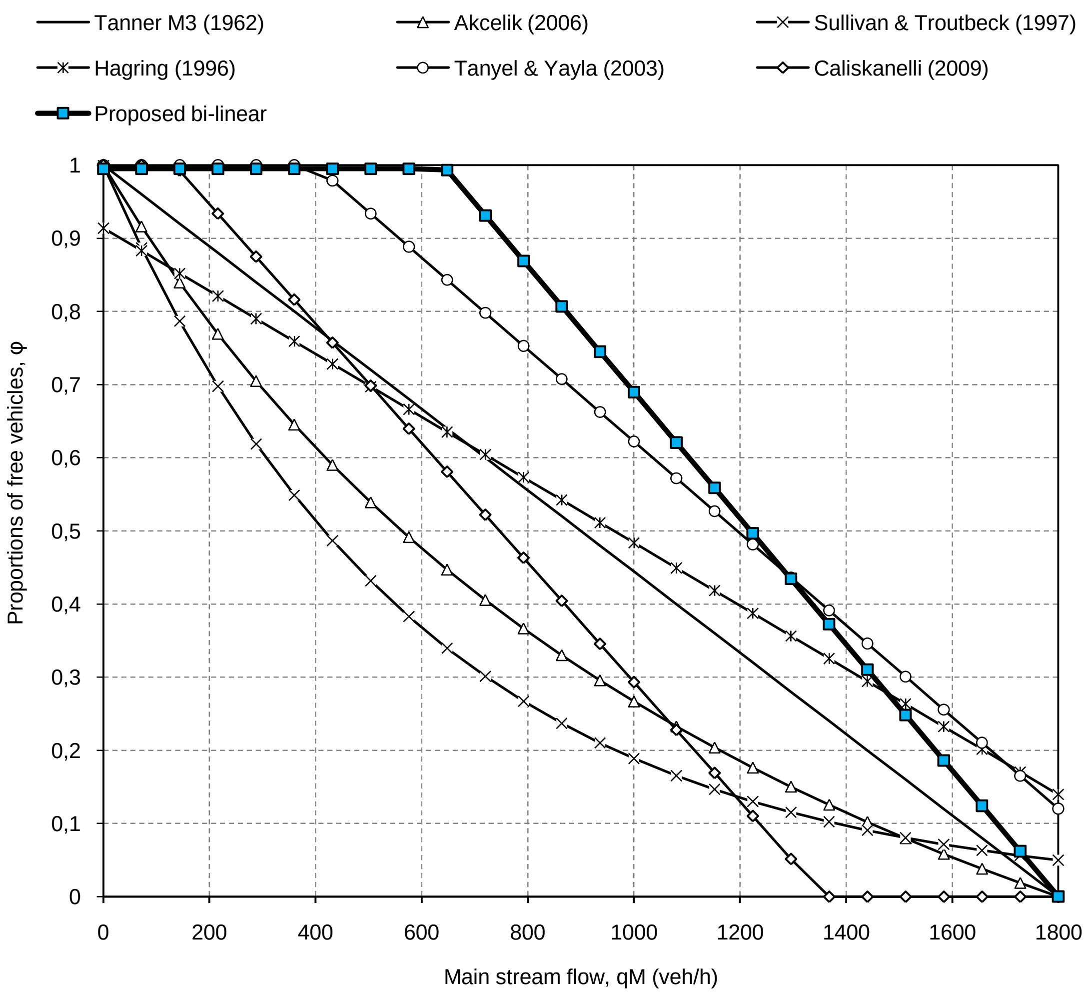
# Headway distribution model

## Inference of a bunching model - motivation:

- In practical application only the traffic flow is know, not the headway distribution
- So, it is necessary to relate Φ or Δ with the opposing flow, $q_M$
- A linear relation was assumed and calibrated using a large number of capacity estimates in sites where the headway distribution was known

$\Phi = 1.55 - 3.11\, q_M$

(for $q_M > 0.178$ veh/s, with $\Delta = 2$s)



# Recent research

## Headway distribution model

### Application of the calibrated Cowan M3 parameters to one-lane and two-lane roundabouts

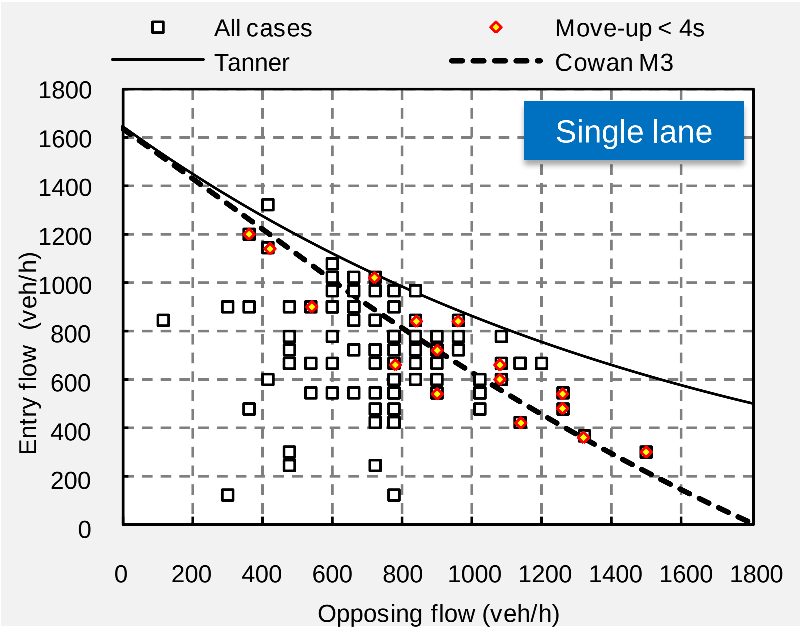
- General capacity formula for *n*-lanes, each having different Cowan M3 parameters
- Comparison against conventional model ($\phi$ = 1, $\Delta$ = 0 and $\lambda$ = q, with superimposed arrivals)

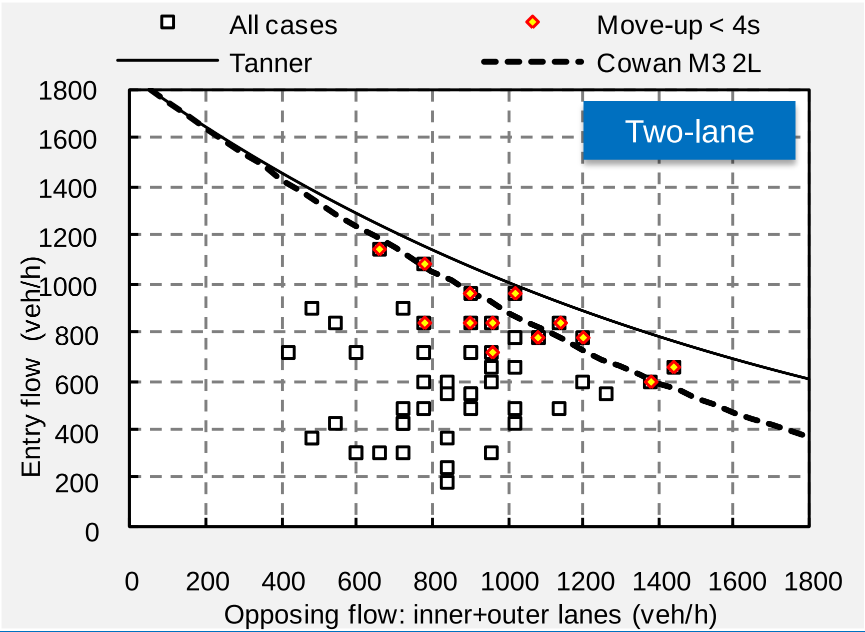
$\Phi$ =1.55 – 3.11 q

(for q > 0.178 veh/s, with $\Delta$=2s)

$$C_k = \frac{e^{-\sum_{i\in I_k}\lambda_i(t_{c,k}-\Delta_i)}\sum_{i\in I_k}\lambda_i}{1-e^{-t_{f,k}\sum_{i\in I_k}\lambda_i}}\prod_{i\in I_k}\frac{\phi_i}{\phi_i+\lambda_i\Delta_i}$$

$$\lambda = \frac{\phi q}{1-\Delta q}$$



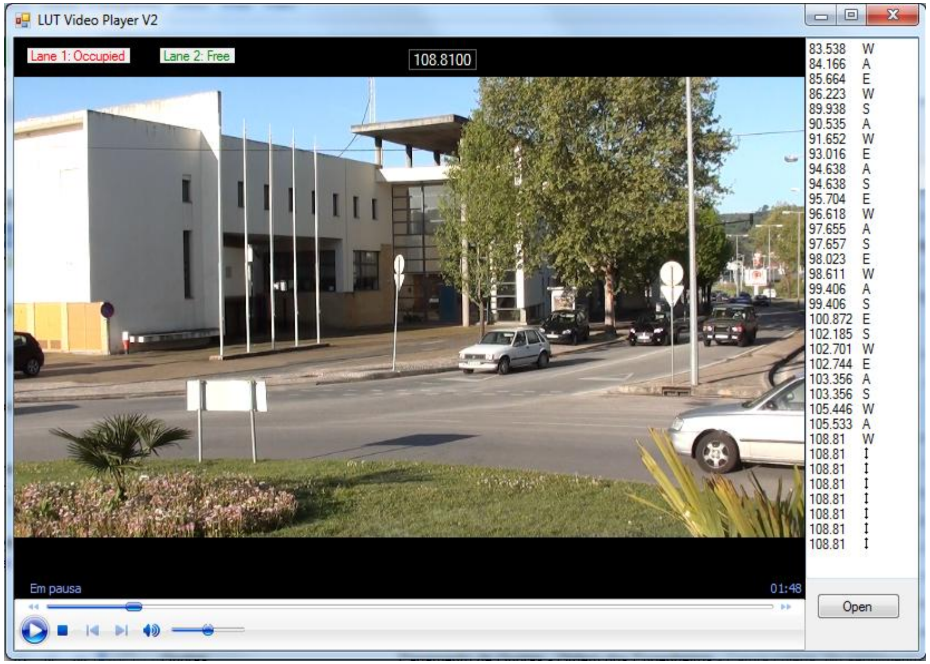



# Recent research

## Estimation of critical-headway and follow-up times

### Objectives

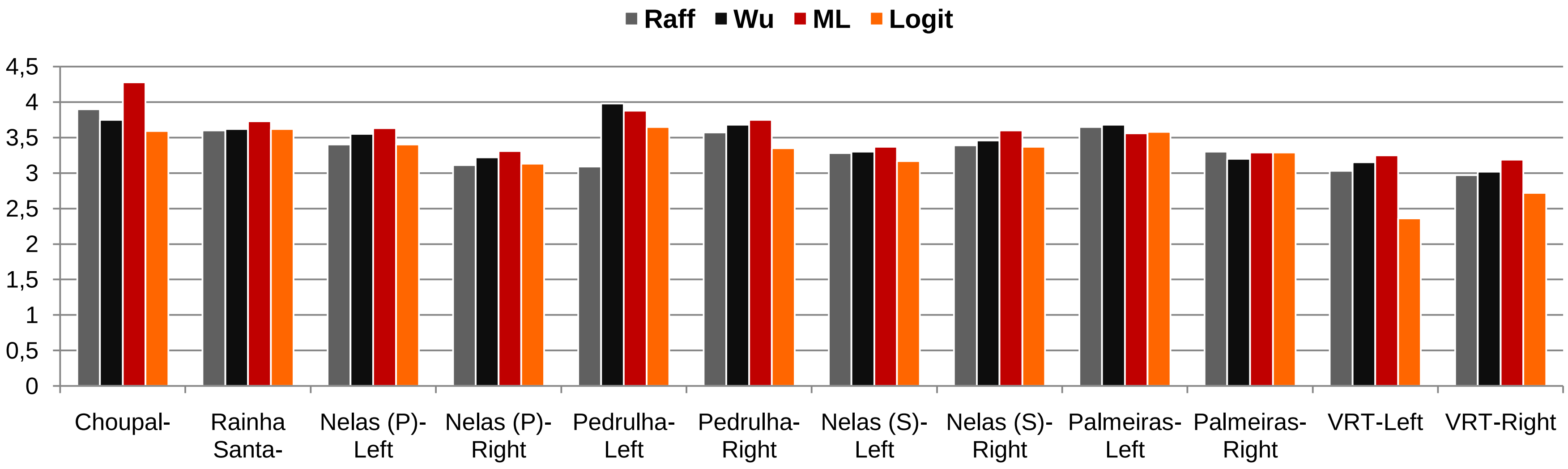
- Compare different methods (Raff, Wu, Maximum Likelihood, Siegloch) and obtain calibrated values for portuguese conditions
- Develop a critical-headway model based on microscopic variables

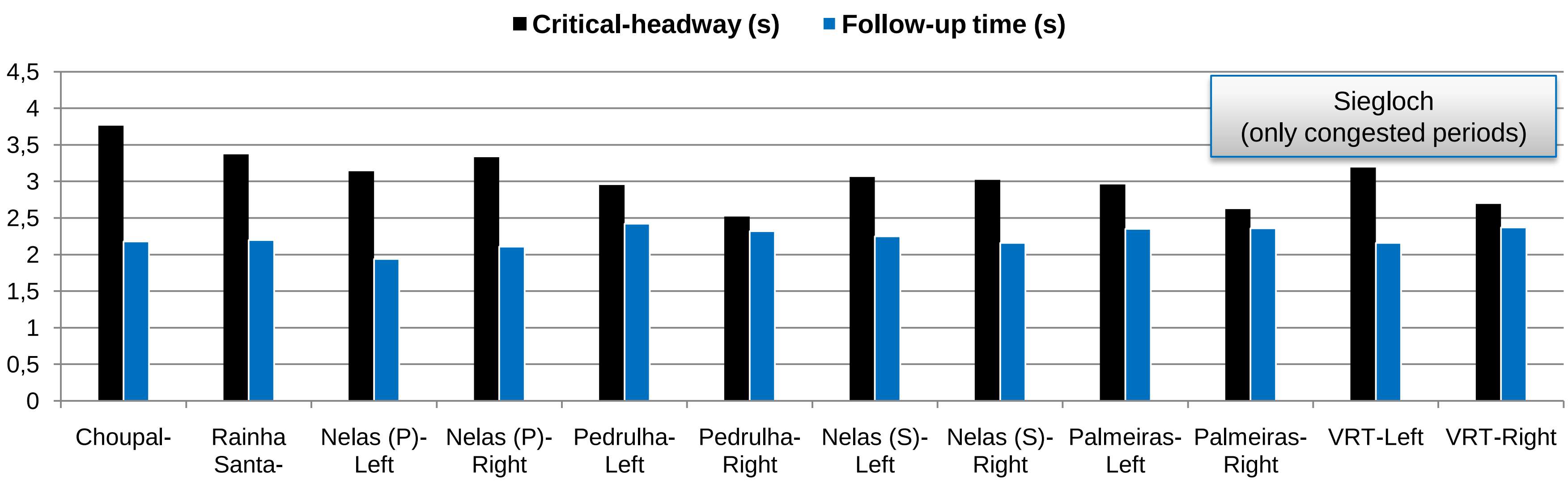



### Data collection: FHWA methodology

- Opposing traffic: inner + outer lanes (even at right lane entries, where there is no physical conflict between some movements)
- Siegloch method - 4s headway threshold used to identify congested periods

# Recent research



# Recent research

## Estimation of critical-headway and follow-up times

### Some conclusions

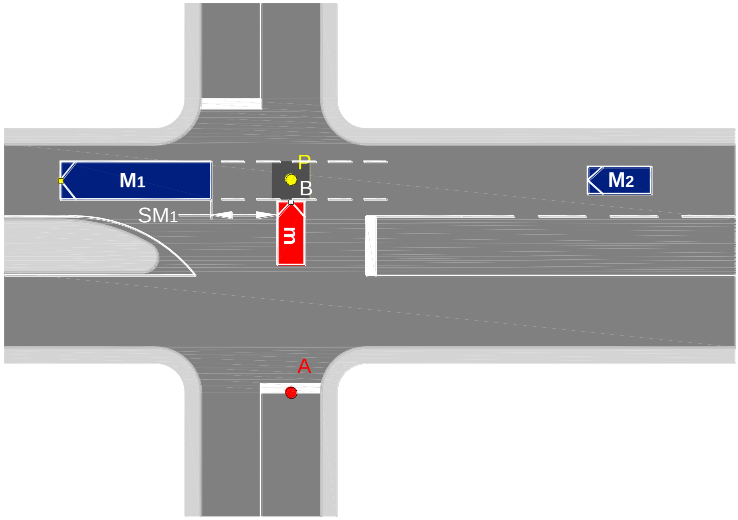
- At two-lane entries, critical headways is usually smaller at the right lane
- Wu's method is the one that provides the closer estimates to the Maximum Likelihood method
- Logit's method indicates that the waiting time decreases the critical headway
- Siegloch's method returns the lowest estimates
- The follow-up time is relatively uniform [2.0 – 2.5 s]

# Recent research

## Estimation of critical-headway – microscopic model

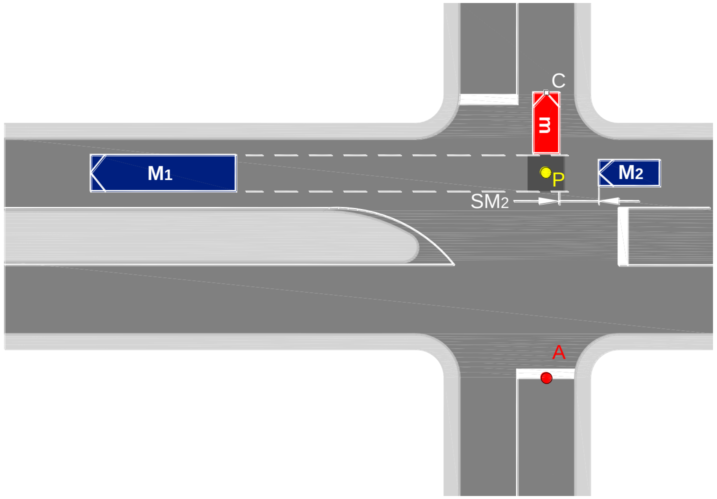
### Objectives

- Obtain critical-headway estimates to be used in analytic capacity models
- Should captures the interactions between the driver/vehicle dynamics and the intersection geometry
- Must be easily implemented in a spreadsheet




### Methodology

- Based on Gipps' equations to describe vehicle acceleration and car-following behavior
- Parameters calibrated  from video recordings

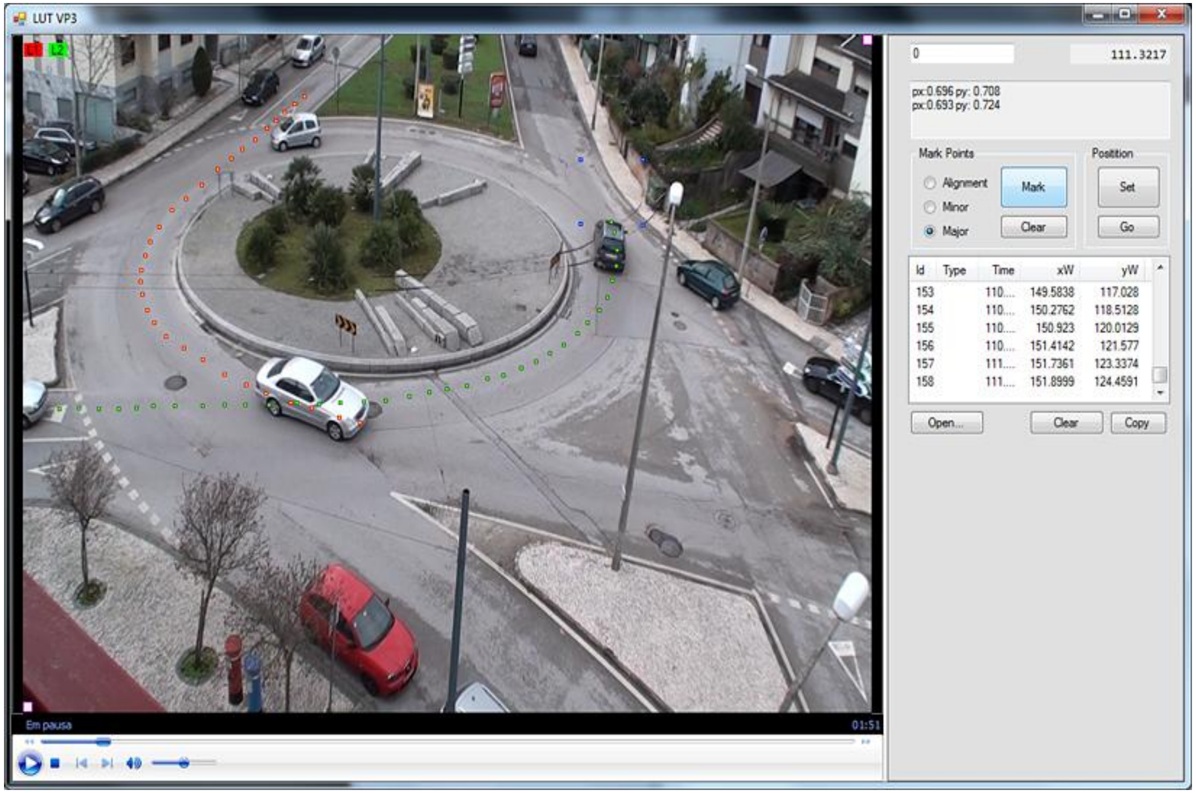


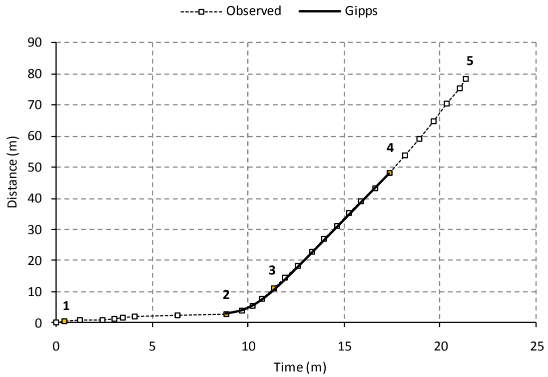
# Recent research

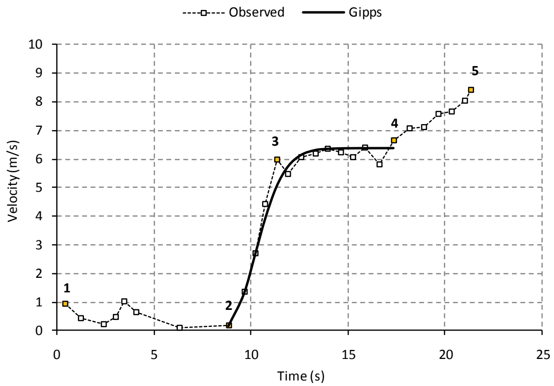
## Estimation of critical-headway – microscopic model

### Calibration

- Screen to World coordinates transformed using the DLT algorithm
- Safety margins and acceleration profiles extracted from video observations



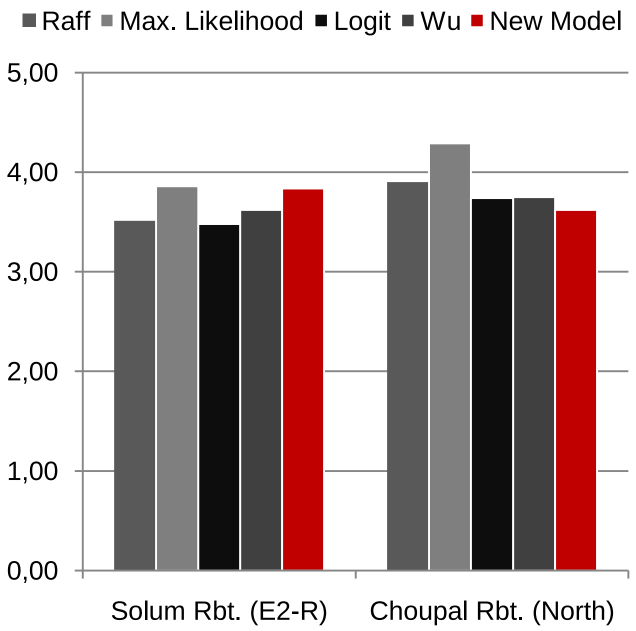



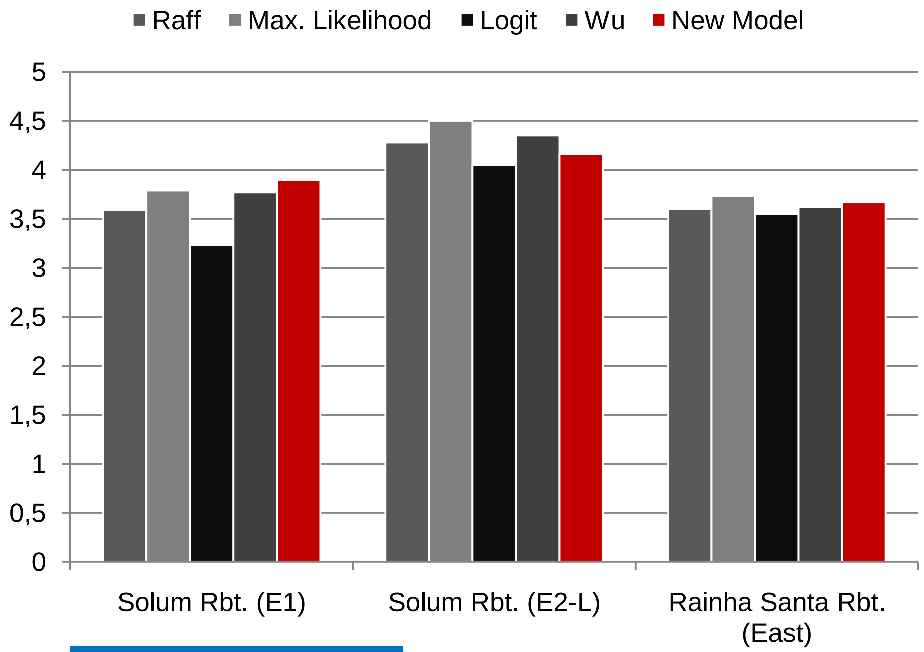
# Estimation of critical-headway – microscopic model

## Validation

- Comparison against conventional methods based on observations




**Merge movements**

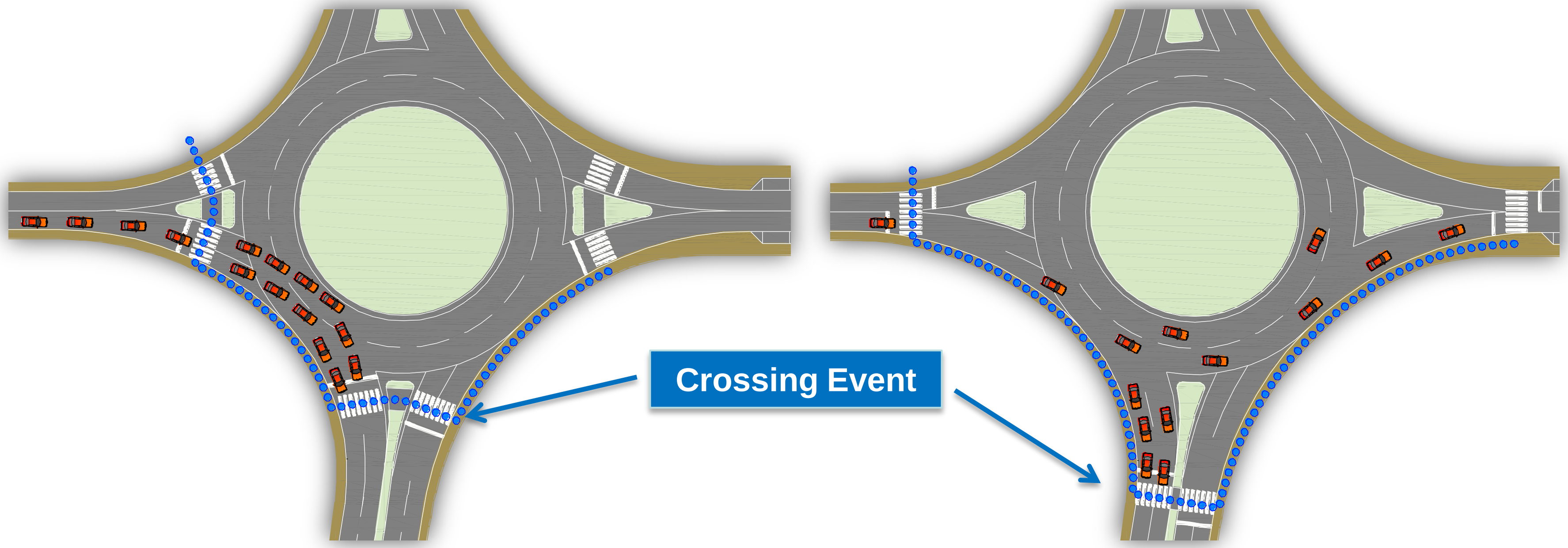



**Cross movements**

# Pedestrian effect on roundabout capacity

## Objectives

- Understand how a crosswalk located in a exit arm affects the roundabout performance (walking distance vs vehicle delays)
- Identify the preferable domain for a pelican crossing instead of a zebra crossing



# Pedestrian effect on roundabout capacity

## Methodology

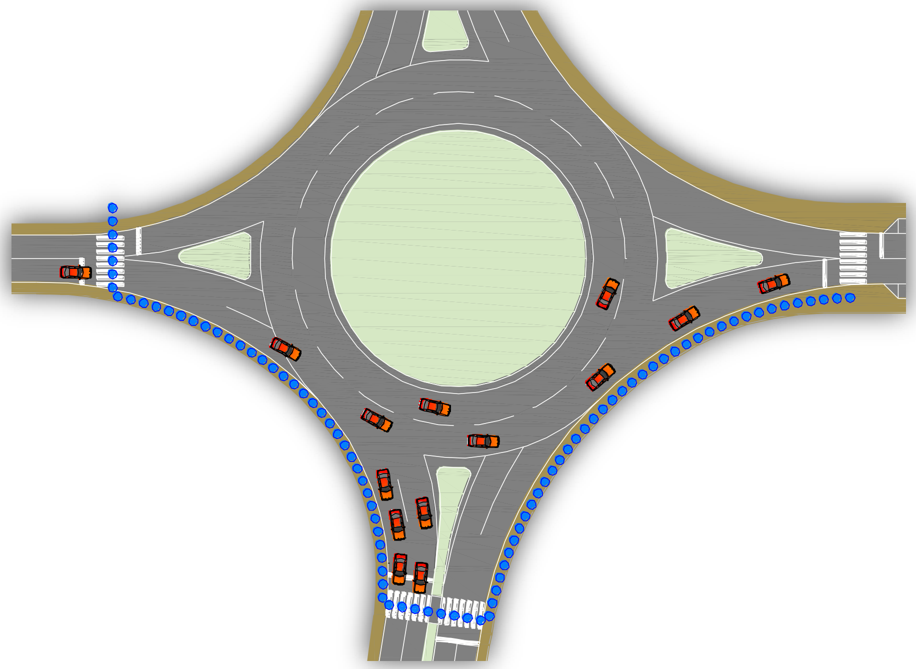
- The capacity of a roundabout without crosswalks was taken as reference
- Construction of an assessment matrix based on different levels of:
  - Traffic flow
  - Pedestrian flow
  - Crosswalk locations
  - Control type (zebra / pelican crossing)
- Comparative assessment of the different scenarios using a microscopic simulator (Paramics)

# Recent research

## Pedestrian effect on roundabout capacity

### Some conclusions

- The effect of pedestrian crossings fades as the distance between the crosswalk and the exit increases
- When N = 1 (aprox. 5 m), there is a reduction of the roundabout performance, even for low levels of traffic and pedestrians
- N = 3 (aprox. 15 m) seems to be a good starting number
- For extreme congestion levels, the pelican crossings perform better



# References


### Headway models

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### Effect of pedestrians on roundabout capacity

- Silva, A.B., Vasconcelos, A., 2009. Microsimulation applied to roundabout performance analysis: The effect of pedestrian crossings, Proc. of the *European Transport Conference 2009*, Leeuwenhorst Conference Centre, The Netherlands.

### Estimation of the critical headway and follow-up times

- Brilon, W., Koenig, R., Troutbeck, R.J., 1999. Useful estimation procedures for critical gaps. Transportation Research Part A: Policy and Practice 33, 161-186.
- Wu, N., 2006. A new model for estimating critical gap and its distribution at unsignalized intersections based on the equilibrium of probabilities, Proceeding of the 5th International Symposium on Highway Capacity and Quality of Service, Yokohama, Japan.

### Capacity model

- Hagring, O., 1998. A further generalization of Tanner's formula. Transportation Research Part B: Methodological 32, 423-429.

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# State of the Art

STOCKHOLM ROUNDABOUT DESIGN AND CAPACITY SEMINAR , 1ST JULY

# Thank You

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