Lane changing mysteries on behavior and modeling

21-09-14

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Lane changes

- Traffic operations
  - At capacity, we find a very unbalanced lane distribution
    (European rule: keep right unless overtaking – in UK: keep left unless overtaking...)
  - The interaction between car-following and lane-changing might produce instabilities and capacity restrictions
- Phenomena
  - Lane changes are the cause of stop-and-go waves
- Traffic management measures

Main difficulties

- Observation require space-time observations
- Only observed lane changes
- Three requirements
  - Not right in current lane
  - Better in other lane
  - Possibility to change lanes

This presentation

- Part 1: how often do people change lanes?
- Part 2: how to calibrate and validate LC models?
- Part 3: what should be in the models?

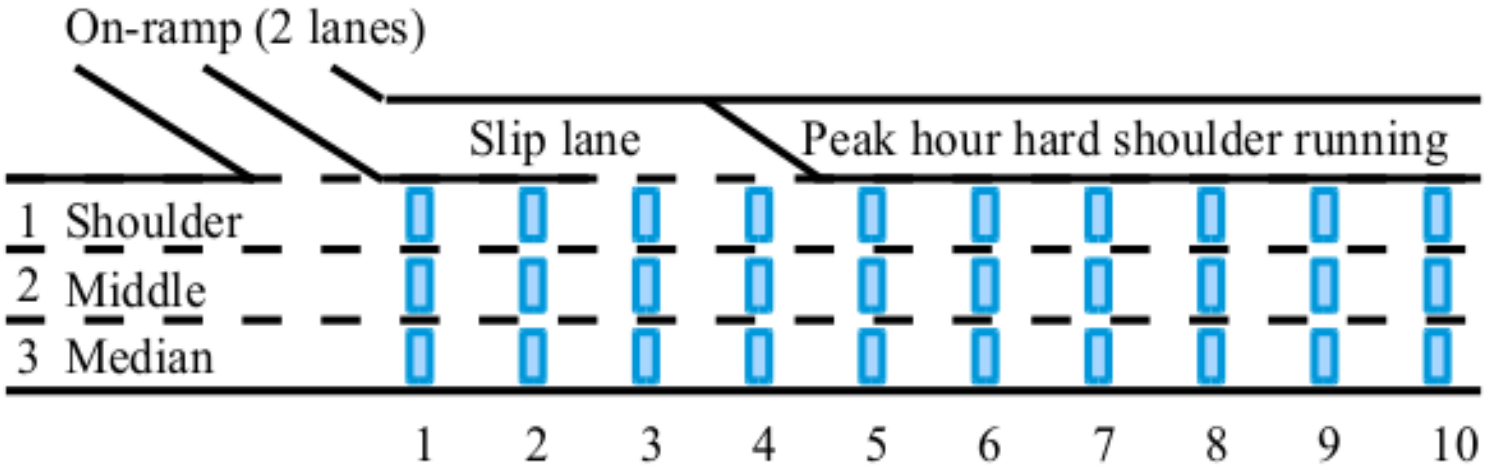
Part 1:
How often do people change lanes?

Study:

- Background
  - Discretionary LC <=> Mandatory LC

- Discretionary LC: from “slower” to “faster”
- Data needed: speeds, lane changes,
- Express as function of density,
  (density e.g. in veh/km)

Data – site 1

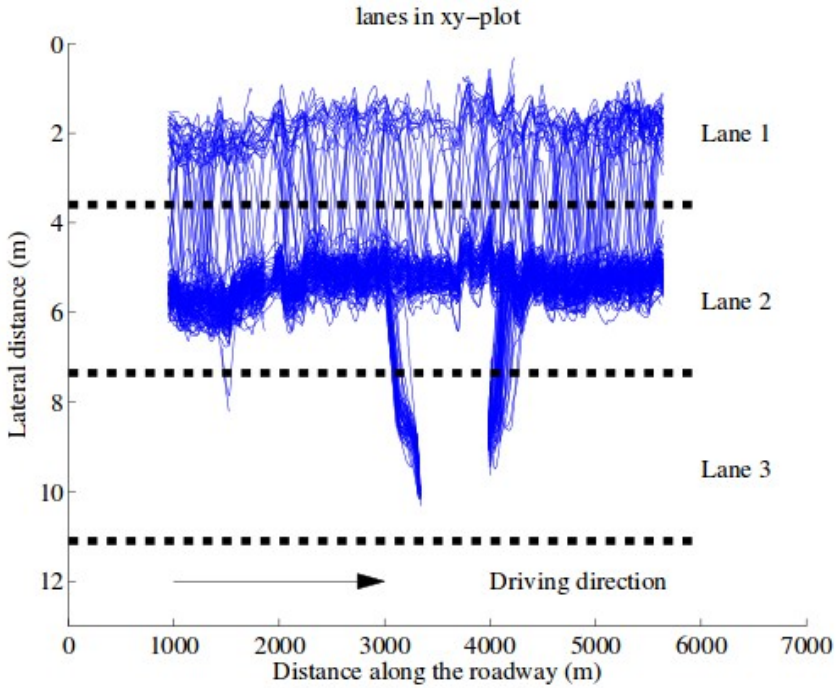


- Individual loop detector data
- 100 meter spacing
- => trajectories

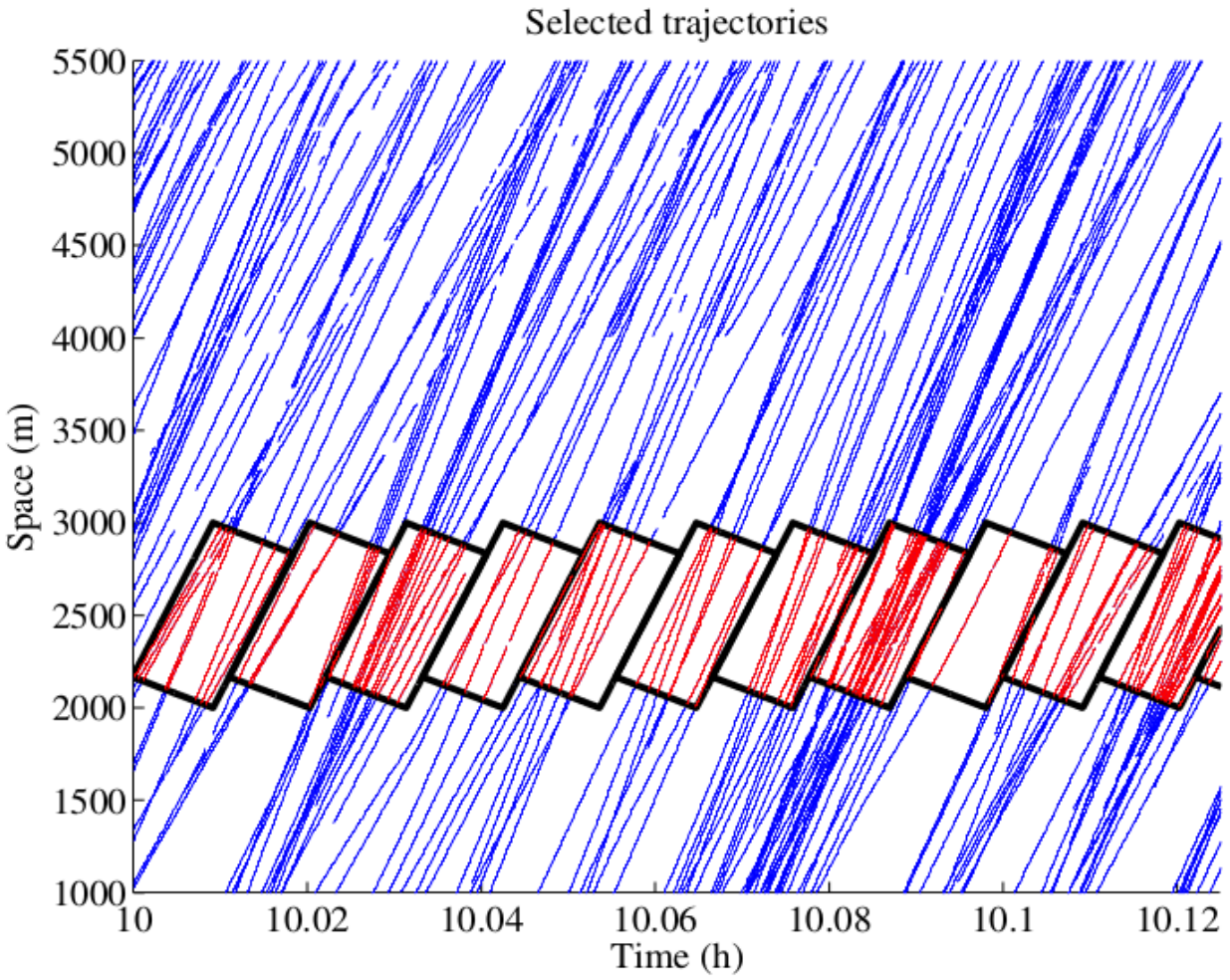
Data – site 2

- A270 freeway, the Netherlands
- 2-lane freeway
- 5 km video tracks (55 cameras),
- Uncongested conditions

(a) Google maps

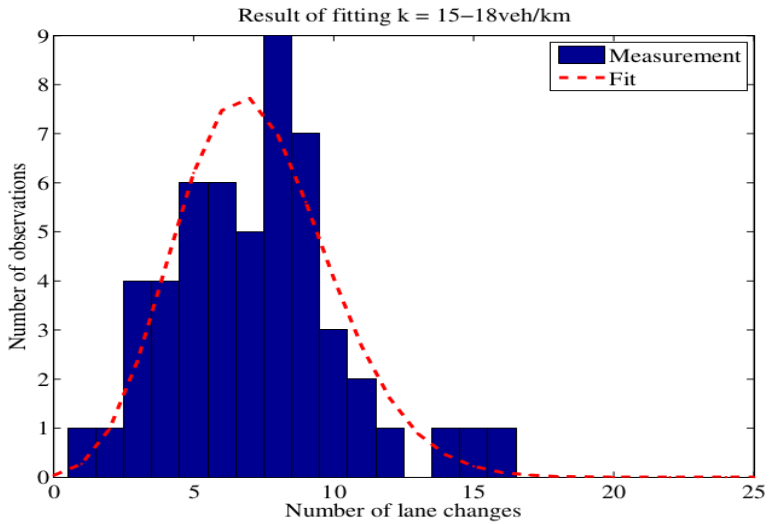


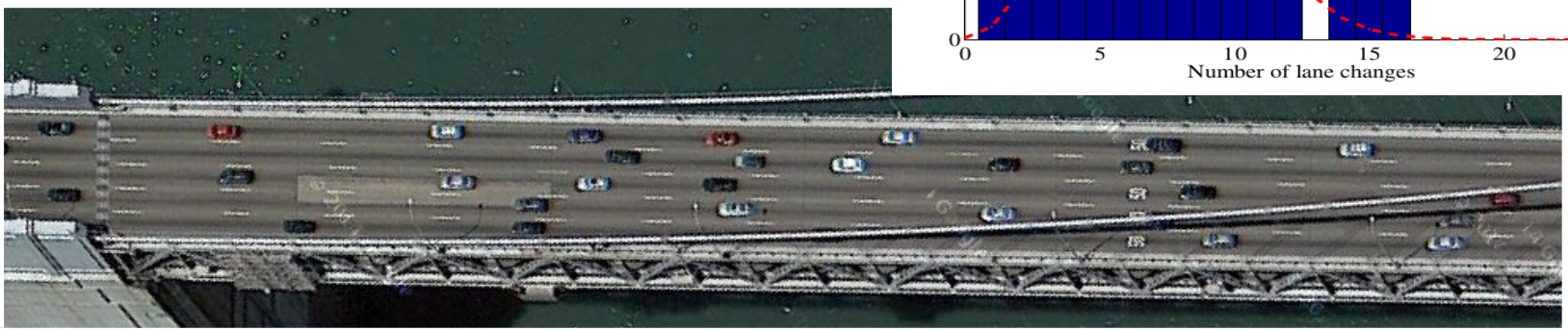
Scaling of the nr of lane changes



Data analysis

- Traffic state defined by density
- How many LC?
- Probabilistic:
  draw randomly,
  Poisson distribution of nr
- Fit the LC rate





Data analysis

- Traffic state defined by density
- How many LC?
- Probabilistic:
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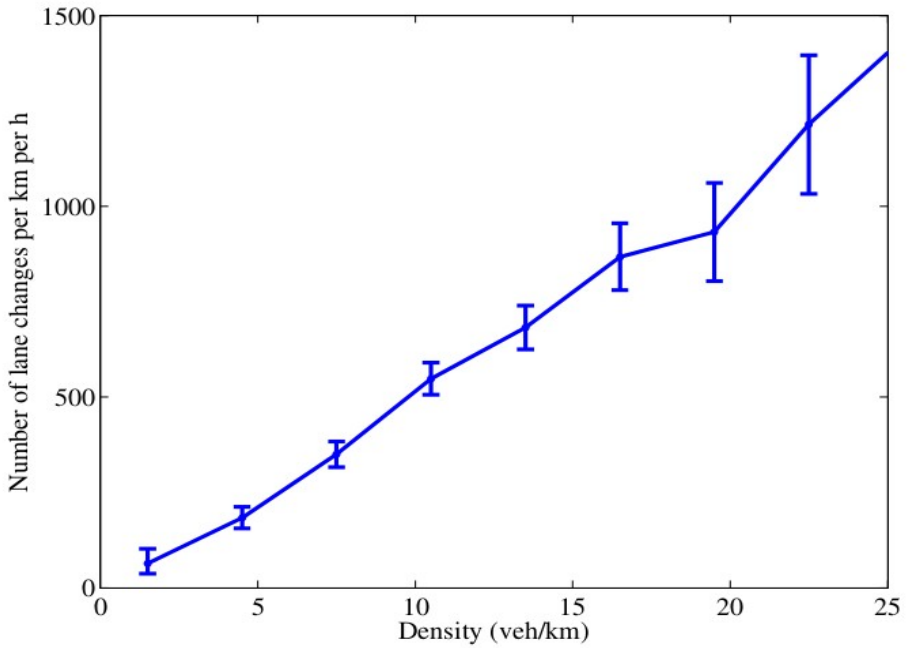
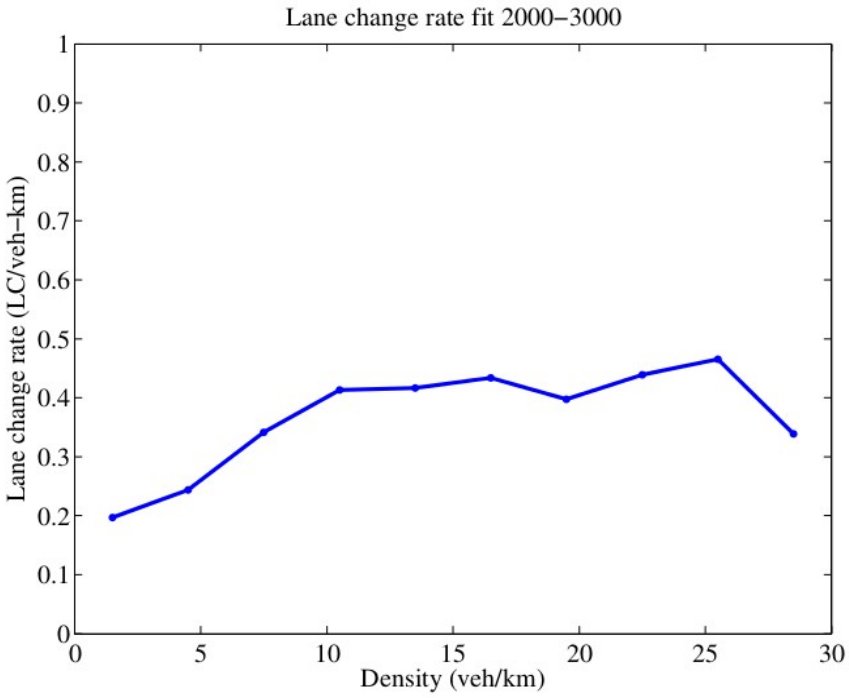
- Fit the LC rate
- Repeat for all density classes



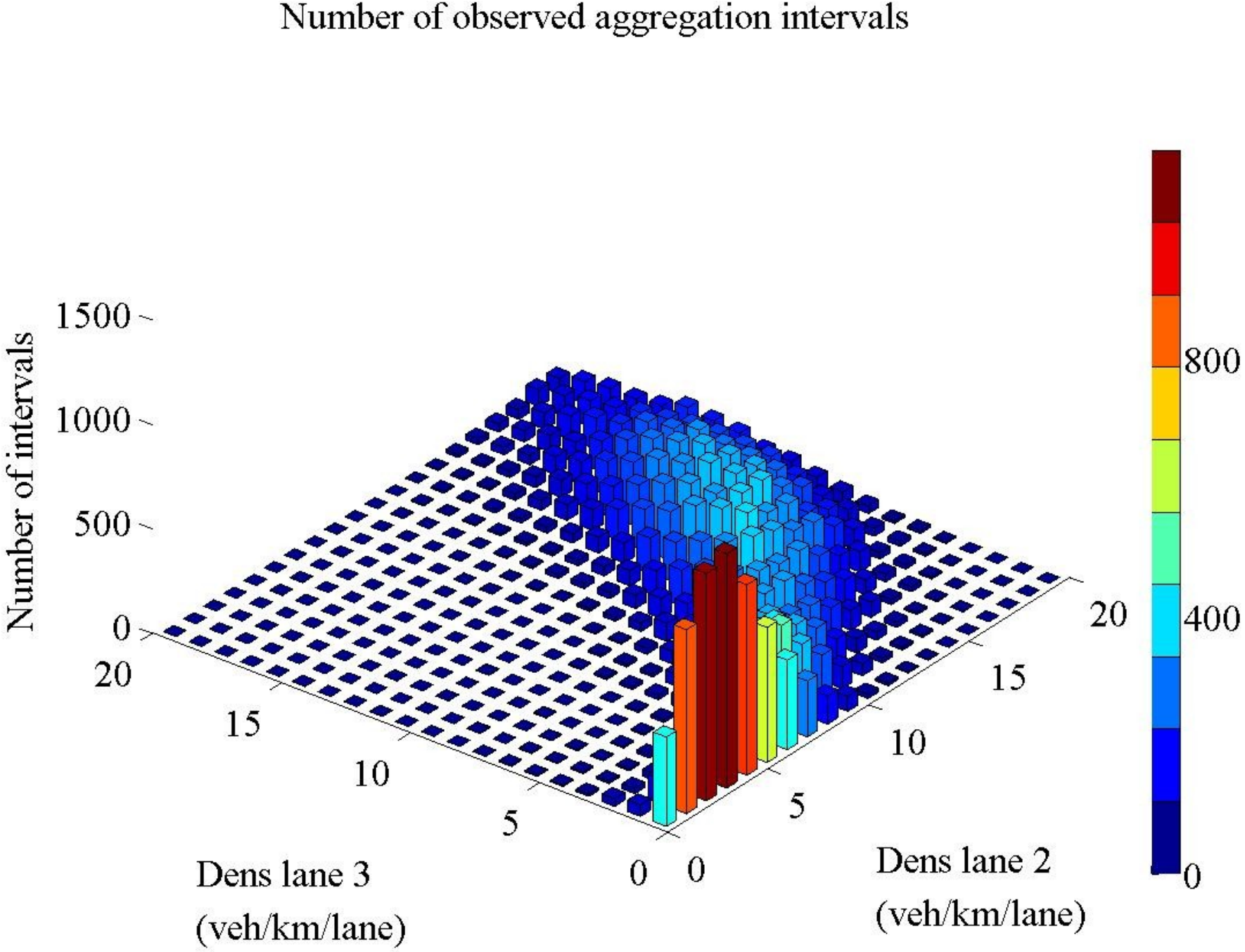
Data analysis

- Traffic state defined by density
- How many LC?
- Probabilistic:
  draw randomly,
  Poisson distribution of nr
- Fit the LC rate
- Repeat for all density classes
- Normalize to veh-km



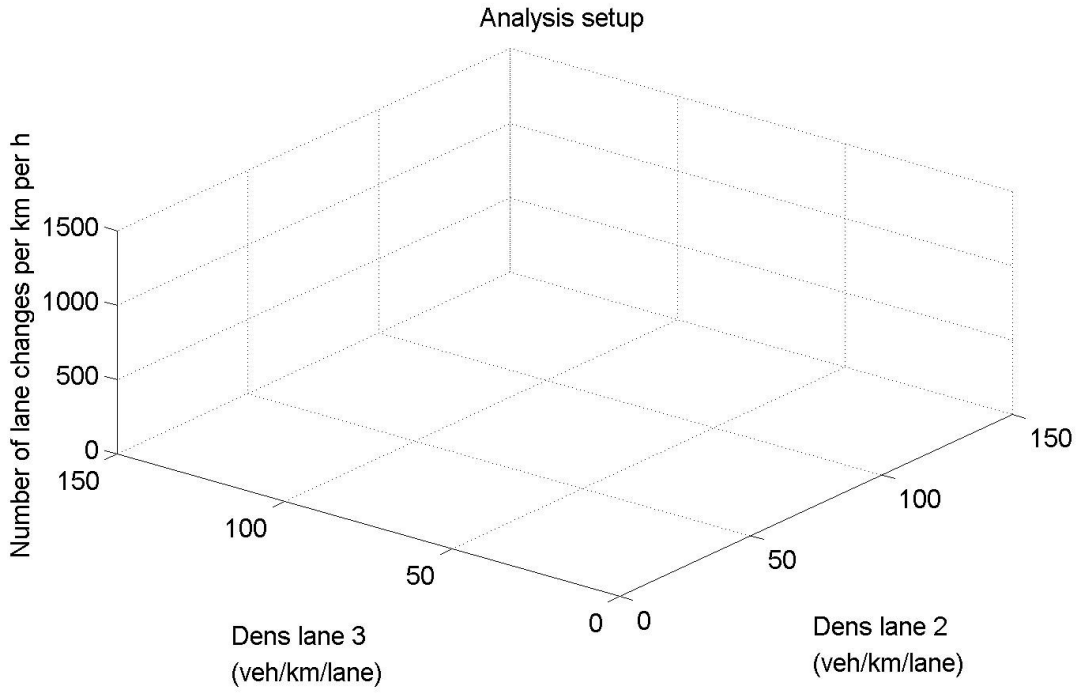
Lane specific

- Lane state expressed in density
- Relation between density of vehicles and the speed (Fundamental diagram per lane)
- For each lane separately
- Captures speed differences, gaps, densities, ...

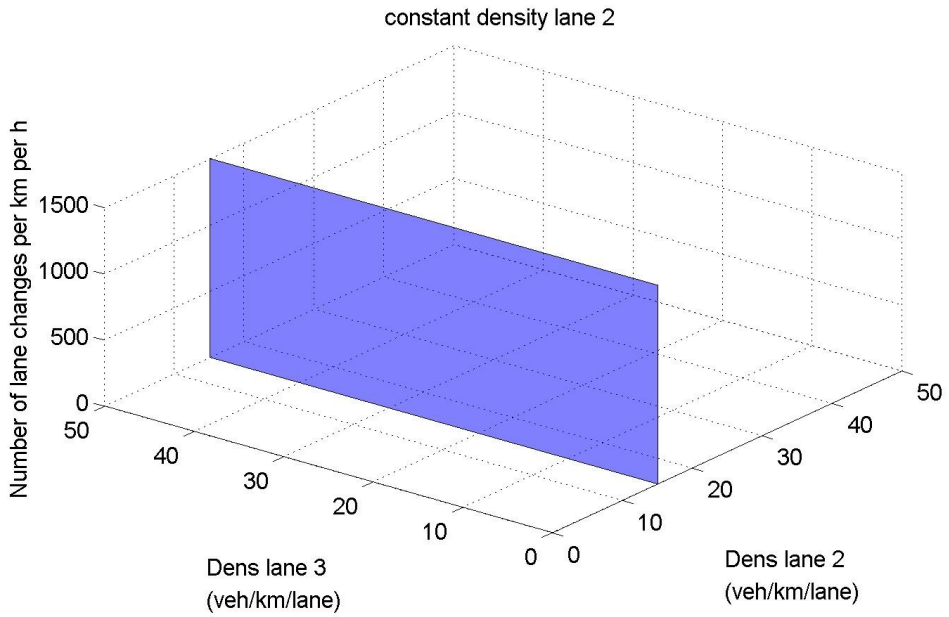

Number of observed aggregation intervals
Number of intervals
1500
1000
500
0
20
15
10
5
0
Dens lane 3
(veh/km/lane)
0
5
10
15
20
Dens lane 2
(veh/km/lane)
800
400
0

Setup of analysis

- Separate densities in origin lane and destination lane

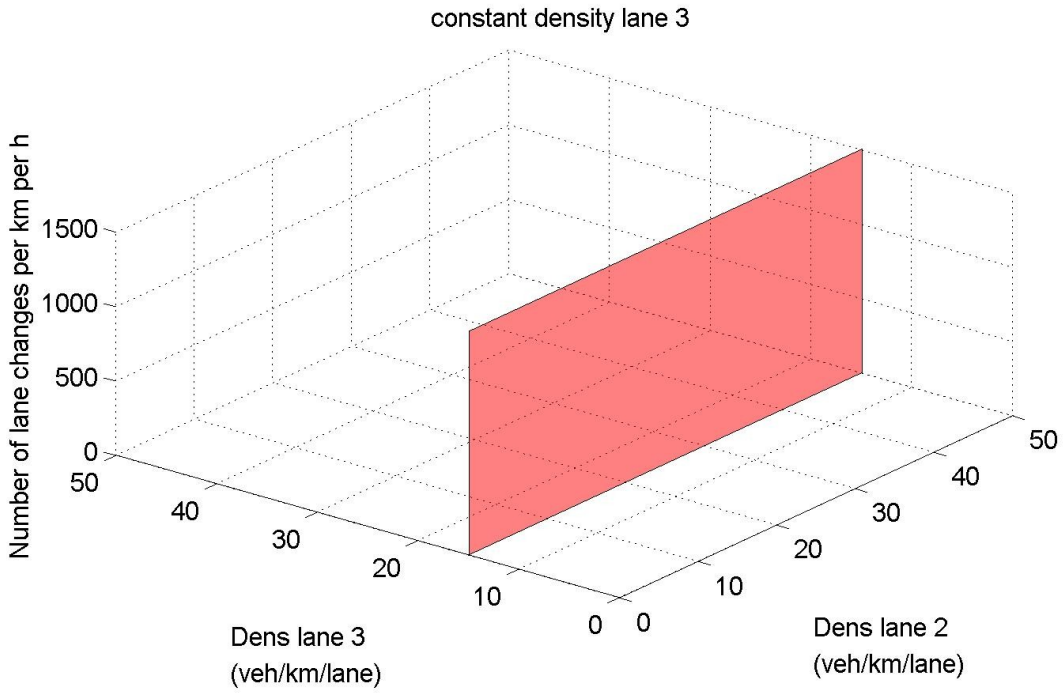


Guess – what is the influence of



- Consider lane changes from lane 2 to lane 3
- Constant density in lane 2
- Dependency of density in lane 3?

Guess – what is the influence of



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- Constant density in lane 3
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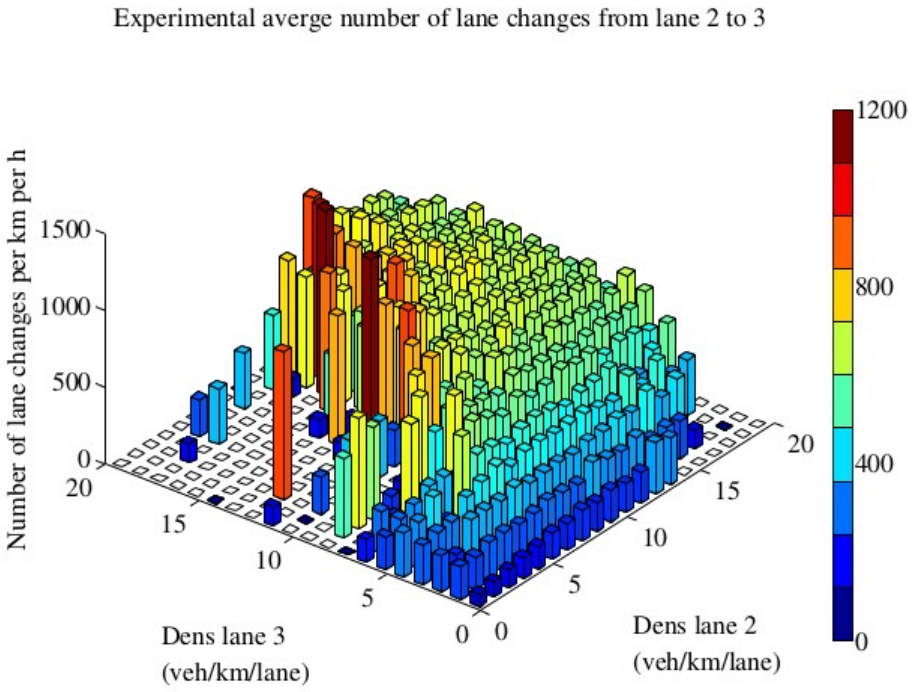
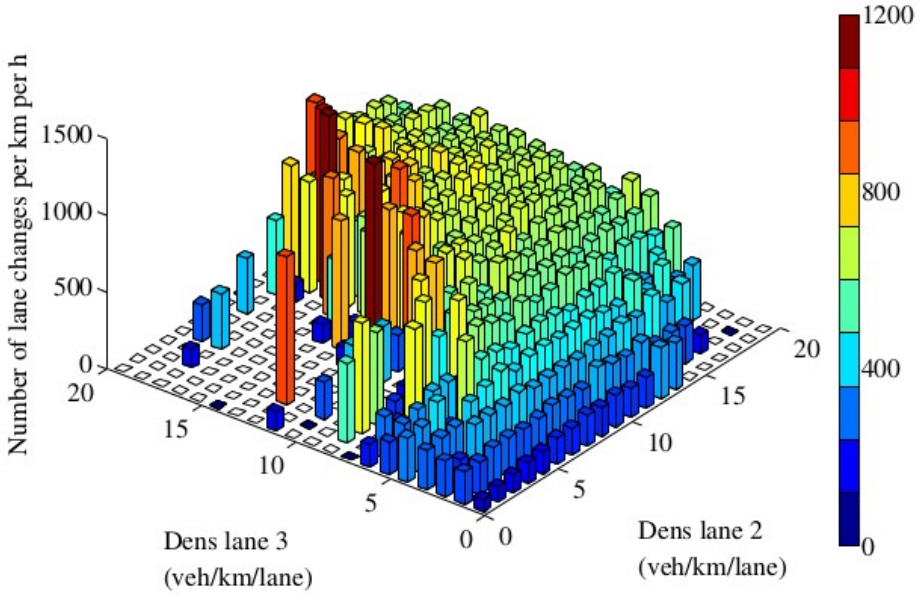
Dependencies?

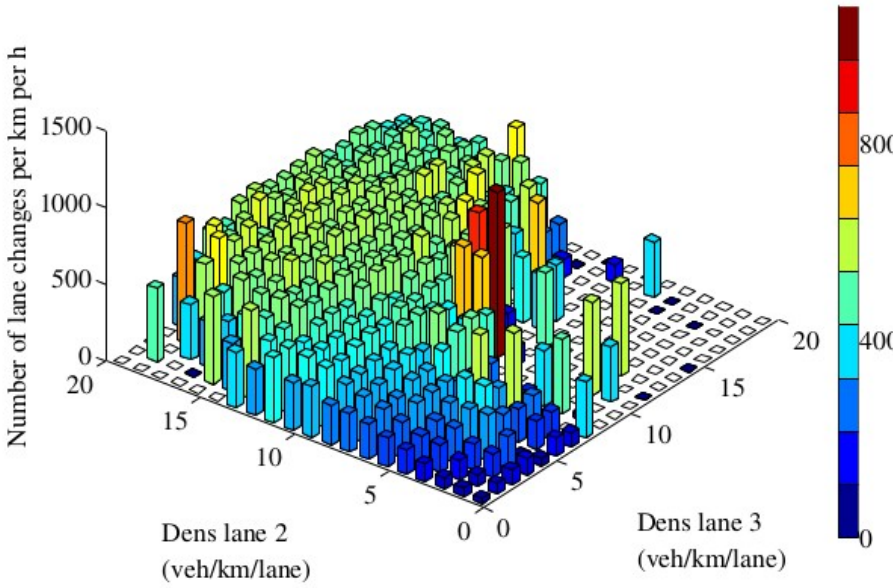


Dependencies?

Experimental averge number of lane changes from lane 2 to 3



Experimental averge number of lane changes from lane 3 to 2



Contributions

- Most constant number in LC:
  LC per veh km travelled

- Lane change models do not work as we expect
- Nr. *increases* as the density in the target lane increases

Explanations

- Future conditions not included (drivers anticipate)
- Lane changes are induced by lane changes from the target lane (place swapping), which occur more frequently with higher target lane density
- Separation origin lane density and target lane density artificial, and a result of the LC itself
- Daganzo's theory of slugs and rabbits:
  - fast drivers know that median lane is faster in the long run
  - they want to have a place there
  - higher densities make this desire higher (risk of not getting it)

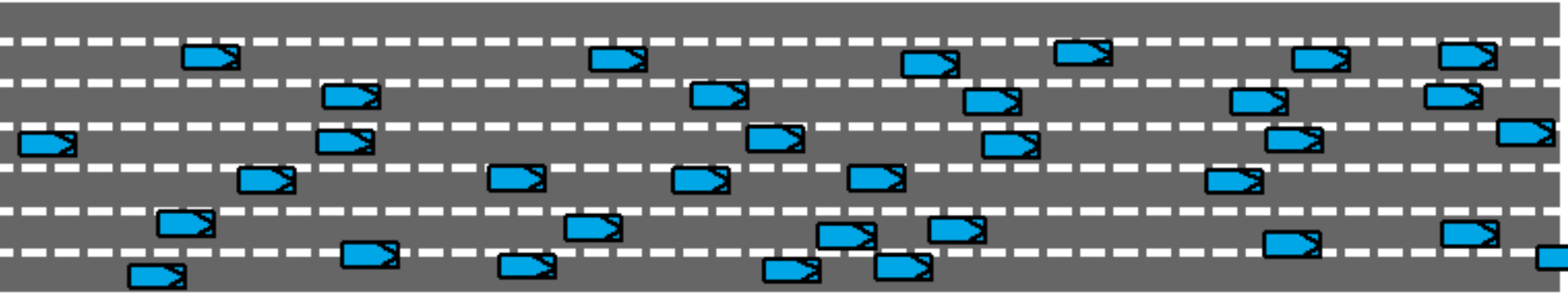
Part 2:
How to calibrate and validate lane change models?

Calibrating and validating LC models

- Lane changes are essential in motorway simulation
- Cause disturbances
- Lane use determines capacity
- Many car-following models, few LC models
- Calibration and validation is an issue for CF
- *Why not being done for LC models?*
- *Should we?*

How to calibrate

- Measure of performance
  - Number of lane changes?
  - Lane distributions?
  - Travel times?



Model

- Three base requirements
- 1) Desire for higher speed (binary, f 1)
- 2) Higher speed in other lane (linear with speed difference, f 2)
- 3) Availability of gap (speed dependent, f 3)
- All need to be fulfilled, so multiply for probability
- Besides: rest probability (α)

$$P(\text{lane change}) = \alpha\left(f_1 * f_2 * f_3\right) + \left(1 - \alpha\right)$$

Probabilistic model

- Probability for a lane change given conditions
- Count the number of occasions where the model is right
- Likelihood: how likely is the observed result given the model prediction?
- L=P1 x P2 x … x Pn
- Optimize parameters of the model to observe likelihood (or log-likelihood for simplicity)

Validation definitions

- L=P1 x P2 x … x Pn

1) Values of parameters more or less right
2) Values of parameters equal for calibration set and validation set
3) Good enough for purpose

Validation results (1)

Values of parameters more or less right

	Var	microscopic avg	microscopic stdev	macroscopic avg	macroscopic stdev
Reconsider time	τ	16s	1.2s	12.1s	0.4s
Explanation by variables	α	0.915	0.006	0.927	0.004
Critical TTC	κ_0	4.0s	0.4s		
Critical gap	g_0	4.0s	0.2s		

Validation results (2)

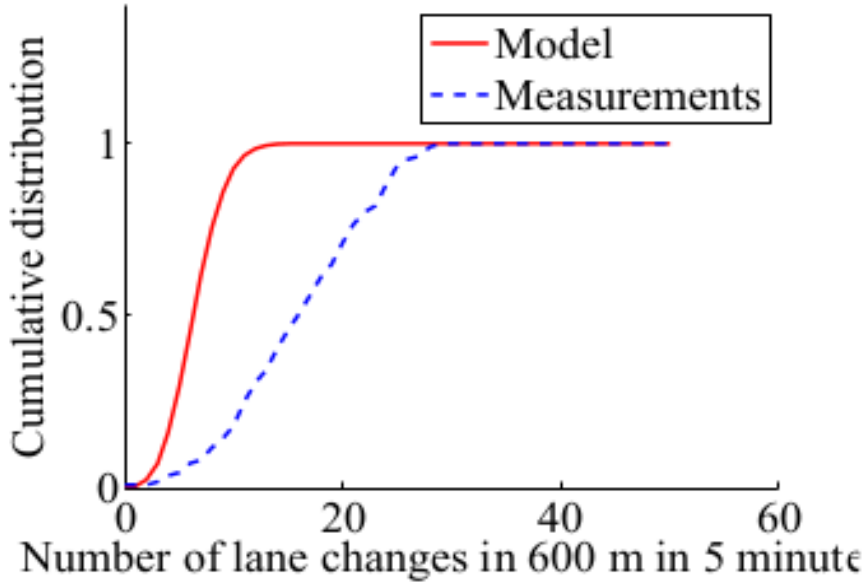
Values of parameters equal for calibration set and validation set

Level	Calibration			Valid	
	$\mathcal{L}$	Nr	Norm		Norm.
Micro	9.7E4	2.1E6	3.1E4	1.8E6	3.6E-2
Macro	2277		1.46	1802	1214	1.48

They are

Validation result (3)

Good enough for purpose



(a) Distribution of lane changes in bin $4< k_i <6$ (density in the origin lane) veh/km/lane and $4< k_j <6$ (density in the target lane) veh/km/lane

Interpretation of likelihood

Log-likelihood → likelihood → mean probability

L=P1 x P2 x … x Pn

Assuming equal P
(probability to have the right number of LC)

P=0,035 => 3,5% right to be correct

Zero order model (no lane changes): 5,8 %!

Conclusions

- Probabilisitic models are difficult to cal/val
- Likelihoods make most sense
- No proper interpretation for likelihood
- RMSE sensible alternative to check where the model is wrong
- Validation needed according to proposed purpose

Part 3:
What should be in lane change models?

Observing driver behaviour

- Check how people are driving
- Difficulties in observing cases where LC is not made

Findings

- Everyone considers himself a “normal” driver
- Mayor differences!
- 4 main strategies:
  - Speed leading
  - Speed leading with overtaking
  - Lane leading
  - Traffic leading

- **Others?**

Summary and conclusions

Conclusions

- Ballpark estimate 0,5 per veh km, or 0,3 per veh mile
- Keep right except when overtaking does not hold
- Driver's behavior is much more complicated, leading to completely different patterns
- Current models do not capture these effects
- A LC model should be tested on its working, not on a number

Questions

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Plaese pass by:
McLaughin 416F

This research is sponsored by COST action Multitude and NWO projects:
- How traffic jams start
- There is plenty of room in the other lane

Publications

Part 1:
Knoop, V.L., Hoogendoorn, S.P., Siomi, Y., and Buisson, Ch., (2012)
Quantifying the Number of Lane Changes in Traffic: Empirical Analysis,
Transportation Research Records No. 2278, Pages 31-41
Part 2:
Knoop, V.L., and Buisson, Ch., (in press)
Calibration and Validation of Probabilistic Discretionary Lane-Change Models,
Transactions on Intelligent Transportation Systems
Part 3:
Knoop, V.L. Keyvan-Ekbatani, M., and Daamen, W. (submitted)
Hidden Strategies of Driving Behavior at Freeways