The AKTA road pricing experiment in Copenhagen

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Outline

- Purpose, background and design of AKTA
- Experiences and conclusions
  - Experimental design and recruitment
  - General responses on pricing strategies
- Estimation of Route choice models (RP)
- SP-survey and model
  - Awareness of cost/length
  - Value of times
- Some later projects
- Conclusions

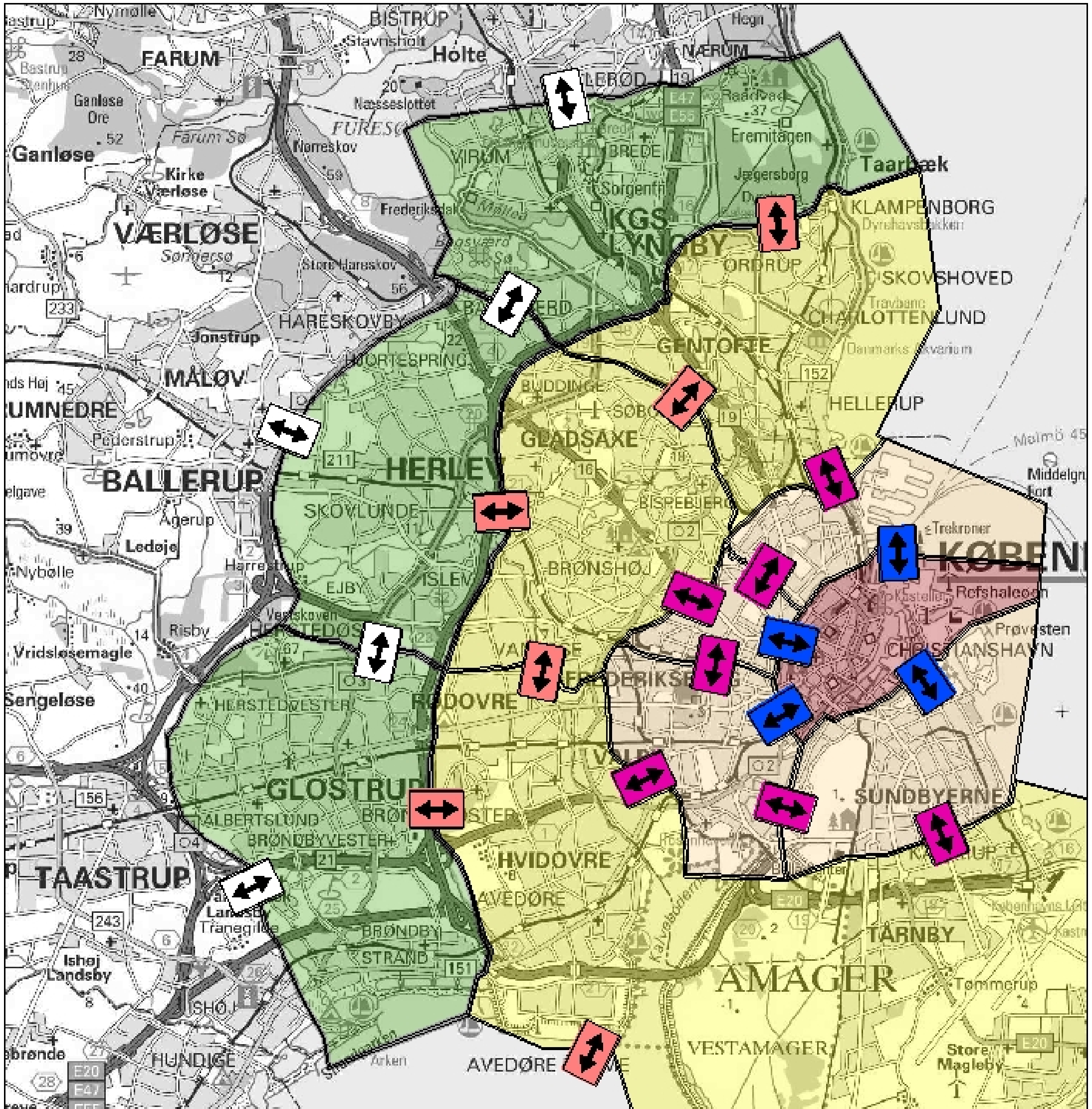
AKTA – purpose and background

- Part of EU project Progress
- 2000-2004
- At that time, the municipality of Copenhagen was very keen on establish a toll/road pricing system
- AKTA was lead by the Municipality
- I became involved during round 1

AKTA – experimental setup

- 200 + 200 + 100 car users try virtual road-pricing systems by a GPS-techniques
- Real money (total of 0-150 Euro, up to 1,000 Euro), 16-20 weeks
- In addition questionnaires, focus groups, background interviews (bigger sample)
- AKTA-SP on 200 participants before round 2 (+ 100 in 3. round)
  - Funded from other source

AKTA Pricing systems



AKTA Zonestructure

Low Km-Toll

Peakhour	Not peakhour
0.50 Kr/km	0.00 Kr/km
1.00 Kr/km	0.00 Kr/km
1.75 Kr/km	0.00 Kr/km
2.50 Kr/km	0.00 Kr/km

High Km-Toll

Peakhour	Not peakhour
1.00 Kr/km	0.50 Kr/km
2.00 Kr/km	1.00 Kr/km
3.50 Kr/km	1.75 Kr/km
5.00 Kr/km	2.50 Kr/km

Toll (kr.)

	Peakhour	Not peakhour
↔	2.00	1.00
↔	4.00	2.00
↔	8.00	4.00
↔	12.00	6.00

Pricing levels

- A Goal oriented scenario (internalisation of externalities) rejected
- Approximated by the high-level km. Toll
- Low level km.-Toll included due to political reasons
- Cordon-based system tested due to technological reasons
- High basic car-taxes in Denmark
- Marginal costs as in EU ~ 0.7 DKR/Km.

Recruitment

- Strong experiment
  - Physical installation in the car
  - Real money
  - Use of time for meetings, interviews, ...
  - Negative attitude to road pricing
- => Recruitment problems
  - 25,000 persons contacted by phone
  - 1,200 agreed to participate
  - 2x200 (+100) finally participated
- Representative of the population

The experimental design

- Factorial design
  - Income
  - Commuting pattern (location of residence and workplace)
  - Pricing system and control period
- All live or work in the pricing area
- 1-car households (in principle)
- All have a daily need for transport

Post survey, technical issues

- Experienced technical problems
  - 46% had experienced technical problems
  - 5% experienced discharged battery
  - 14% had a break down of unit
  - 5% experienced incorrectly pricing level
  - 5% at a given cross-section in time had a non-functioning unit
- However, usually solved fast and possible to compensate in the analysis

Saving strategies

- Some used illogical saving strategies (~10%)
- Some didn't change behaviour (~40-50%)
  - => Most of these had no reasonable alternative
- Groups at high km. Level changed behaviour most

Changes in behaviour (50%)

1. Route choice
2. Kiss & Ride
3. Change of time of the trip (non-commuters)
4. Trip destination (leisure)
5. Cancelled trip (leisure, work home)
6. Little impact on commuting and mode choice

Saving strategies 1st round

Pricing levels	No saving	2nd period	1st period	Both periods	Total
Control + high km.	25 (60%)	8 (19%)	2 (5%)	7 (17%)	42
Control + Low km.	34 (63%)	12 (22%)	1 (2%)	7 (13%)	16
Control + cordon	6 (38%)	4 (25%)	-	6 (38%)	16
Low km. + high km.	9 (35%)	5 (19%)	1 (4%)	11 (42%)	26
Low km. + cordon	6 (35%)	-	-	11 (65%)	17
High km. + toll	13 (46%)	1 (4%)	-	14 (50%)	28

Saving strategies 2st round

Pricing levels	No saving	2nd period	1st period	Both periods	Total
Control + high km.	23 (69%)	7 (21%)	-	3 (9%)	33
Control + Low km.	13 (45%)	6 (21%)	1 (3%)	9 (31%)	29
Control + cordon	13 (48%)	12 (44%)	-	2 (8%)	27
Low km. + high km.	11 (39%)	5 (7%)	2 (7%)	13 (44%)	28
Low km. + cordon	12 (40%)	4 (13%)	2 (7%)	12 (40%)	30
High km. + toll	7 (30%)	1 (4%)	2 (9%)	13 (57%)	23

3. round (approx. 100 extra drivers)

- 3. round: money was paid (by check) after control period, invoice sent after pricing period. 1&2 savings are paid after the experiment
- More changes than in 1. & 2. round (about 80% reduced travel in 3. round, about 50% in 2. round)
- More impact in 3. round compared to 2., 75% confidence interval

Problems with the GPS-technology

- Much more problems than anticipated
  - Signals were lost (too few satellites, street valleys, atmospheric disturbances, ...).
    - 90% of trips lost signals
    - Often only for short period
    - 3% could not be recreated unambiguous
    - (46% experienced the technical problems)
  - Co-ordinate accuracy
  - Segmentation in trips
  - Specific cars
- Later experience show significant improvements of GPS-technology

Estimation of utility functions based on the experiment (RP-data)

- General discrete choice model:

$$U_i = \sum_j (\beta_j + \xi_j) X_{ji} + \varepsilon_i$$

- Road pricing case (one trip for one person):

$$U_R = V_R + \varepsilon_R =$$

$$\beta_c RoadPricing + \beta_l Length +$$

$$\beta_{tff} Time_{ff} + \beta_{tcon} Time_{con} + \sum_{a \in R} \varepsilon_a$$

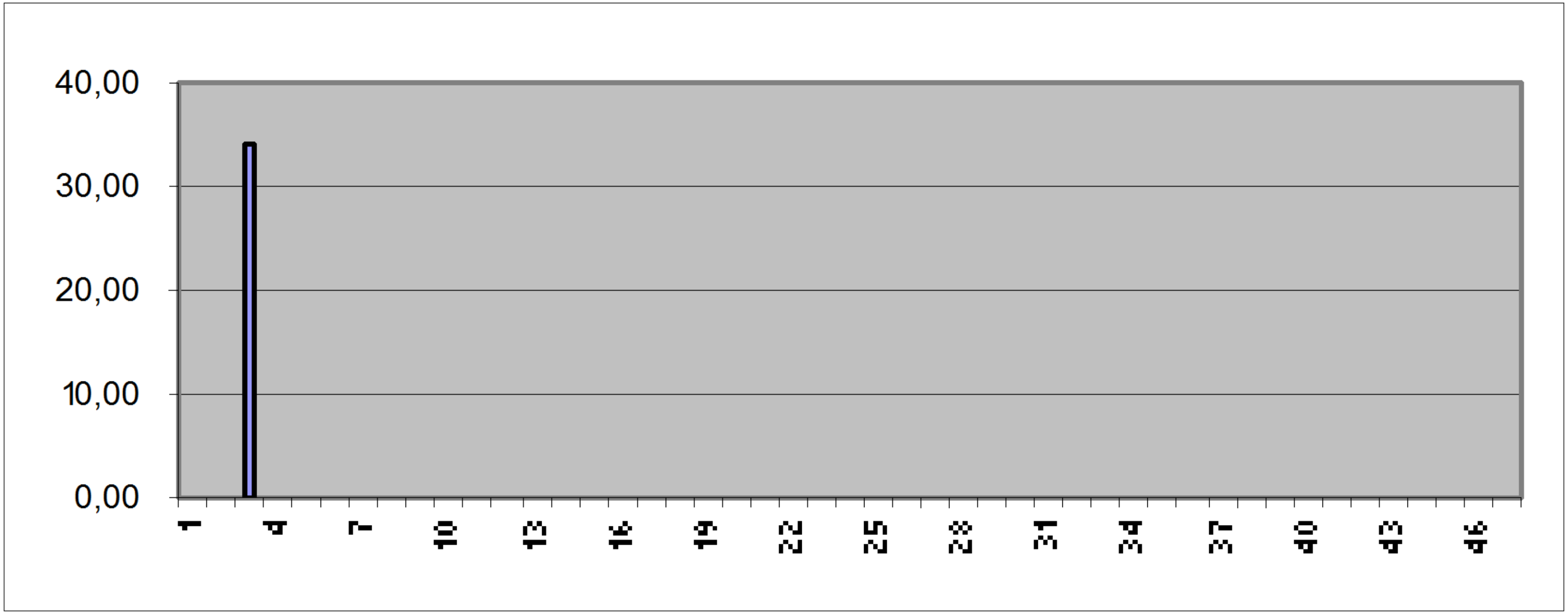
Estimation procedure

- For each trip (sum of coefficients=1)
  - Find the deterministic utility function with best fit (can be interval)
  - Can error term improve results?
- Then for each person
  - Analyse variation in coefficients, etc.
  - Find optimal utility function
- Then for all persons
  - Estimate overall utility function

Results, route choices

- Adding an error term does only improve model fit marginally
- A wide range of coefficients often provide the same fit for a specific trip
- 2/3 Persons with good fit to routes (small error-term) had small variations of preferences (for low as well as high VoT persons)
- 1/3 Persons with less good fit to routes had also much higher variation on VoT

Utility maximising person



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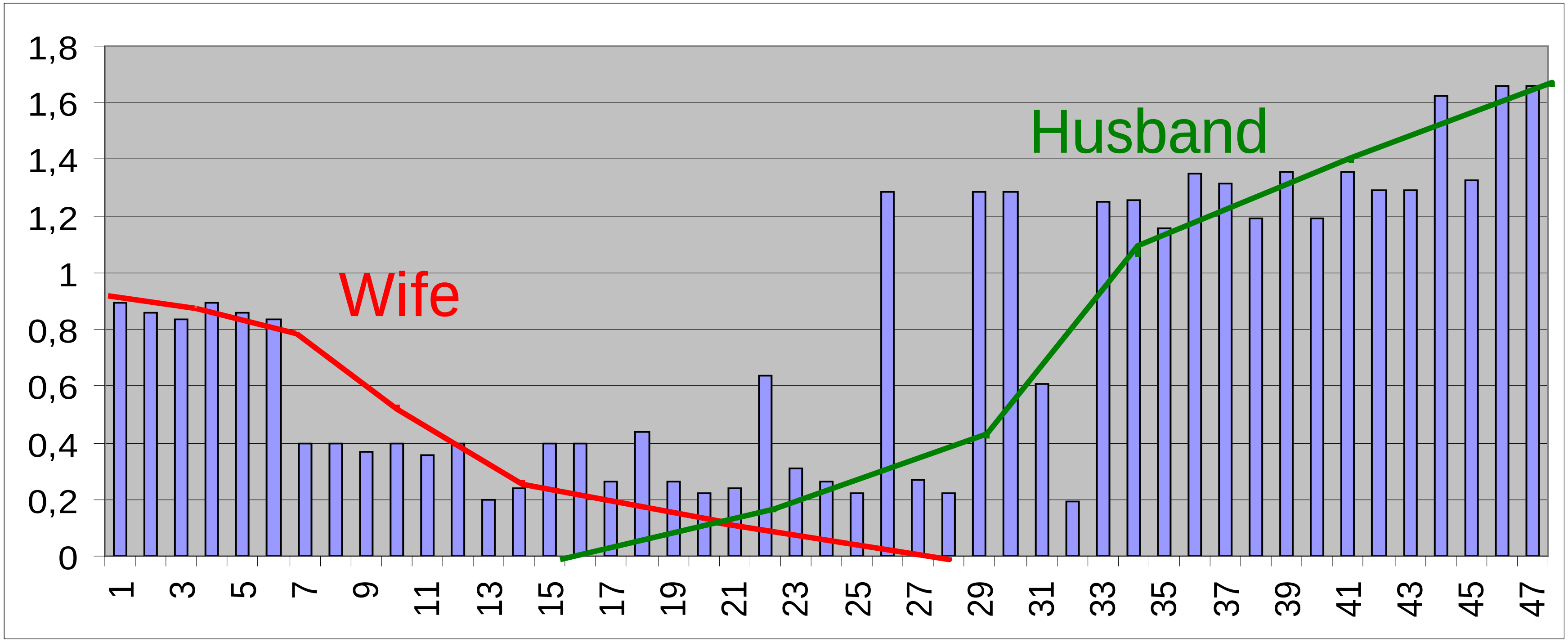
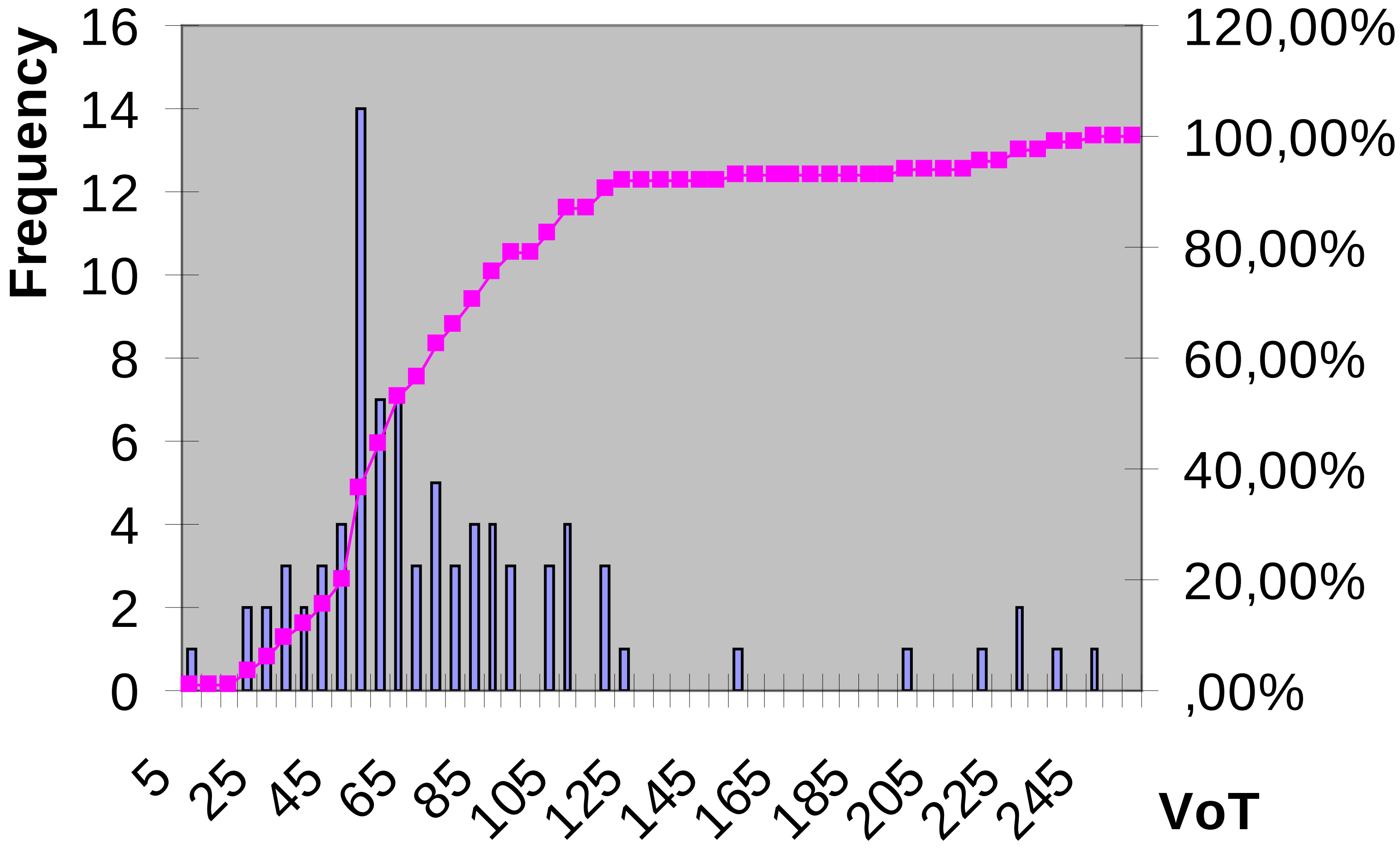
The most ”random” participant

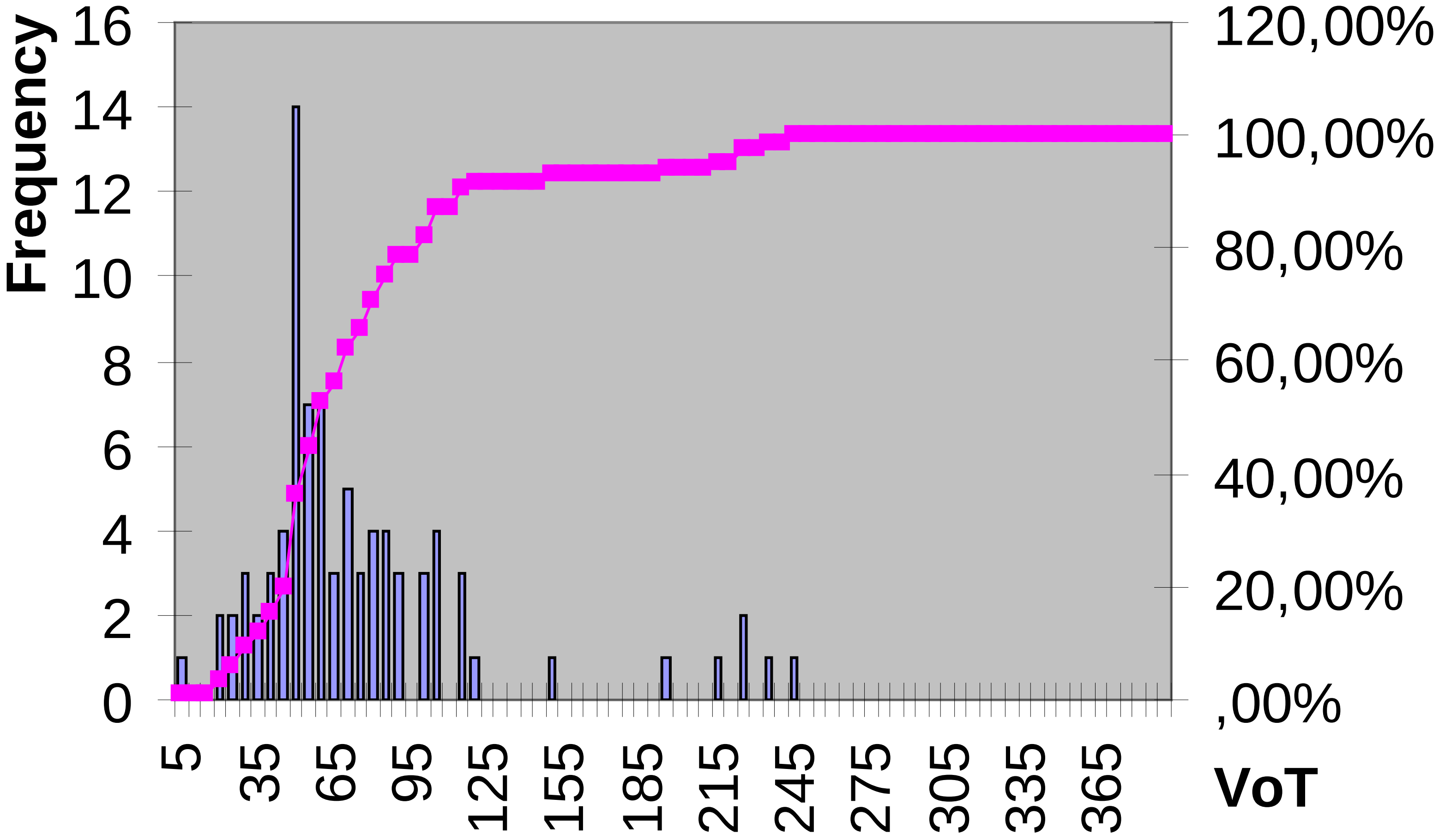


- Any rational explanation?

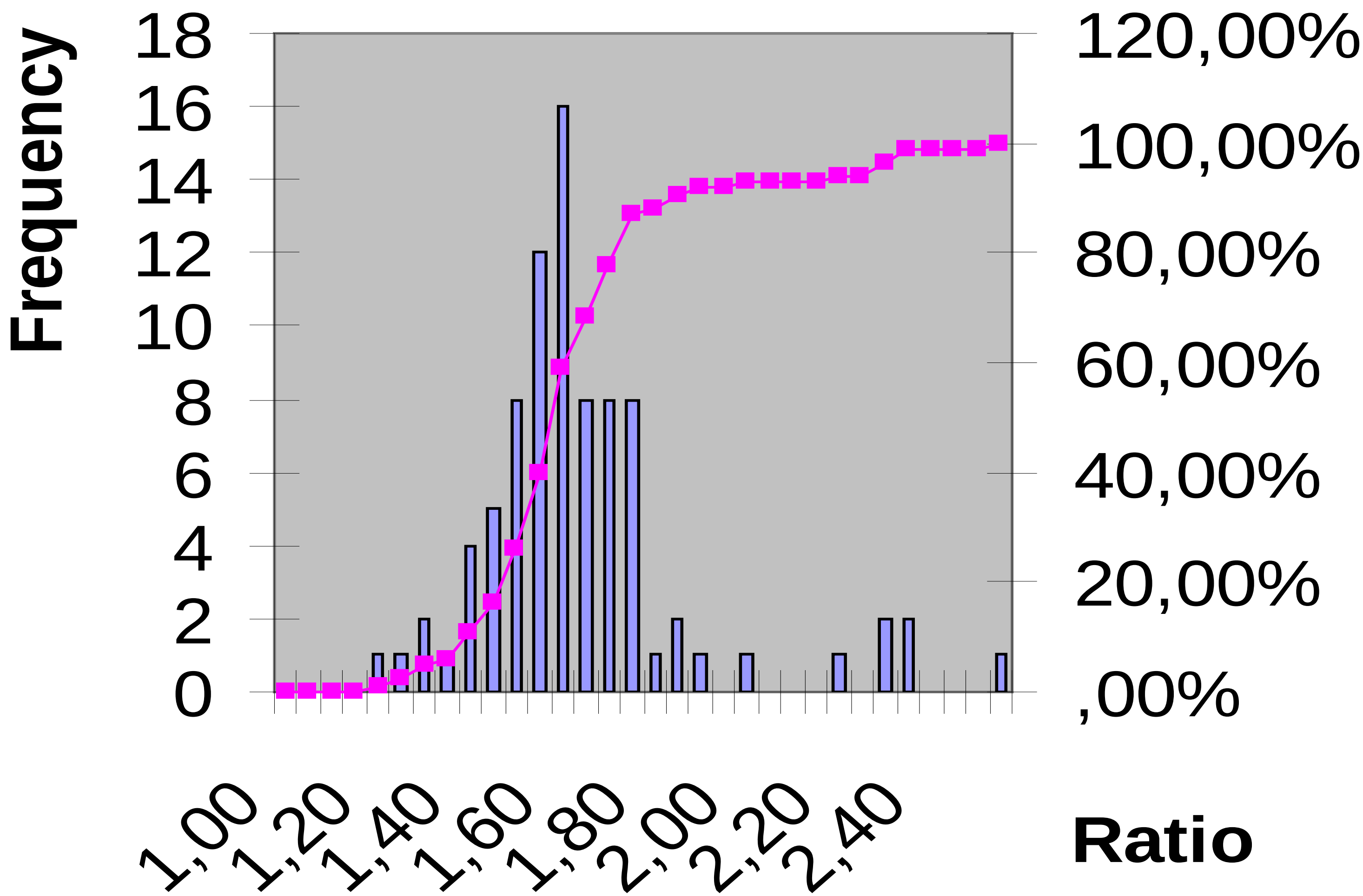
Distribution of Free Flow VoT



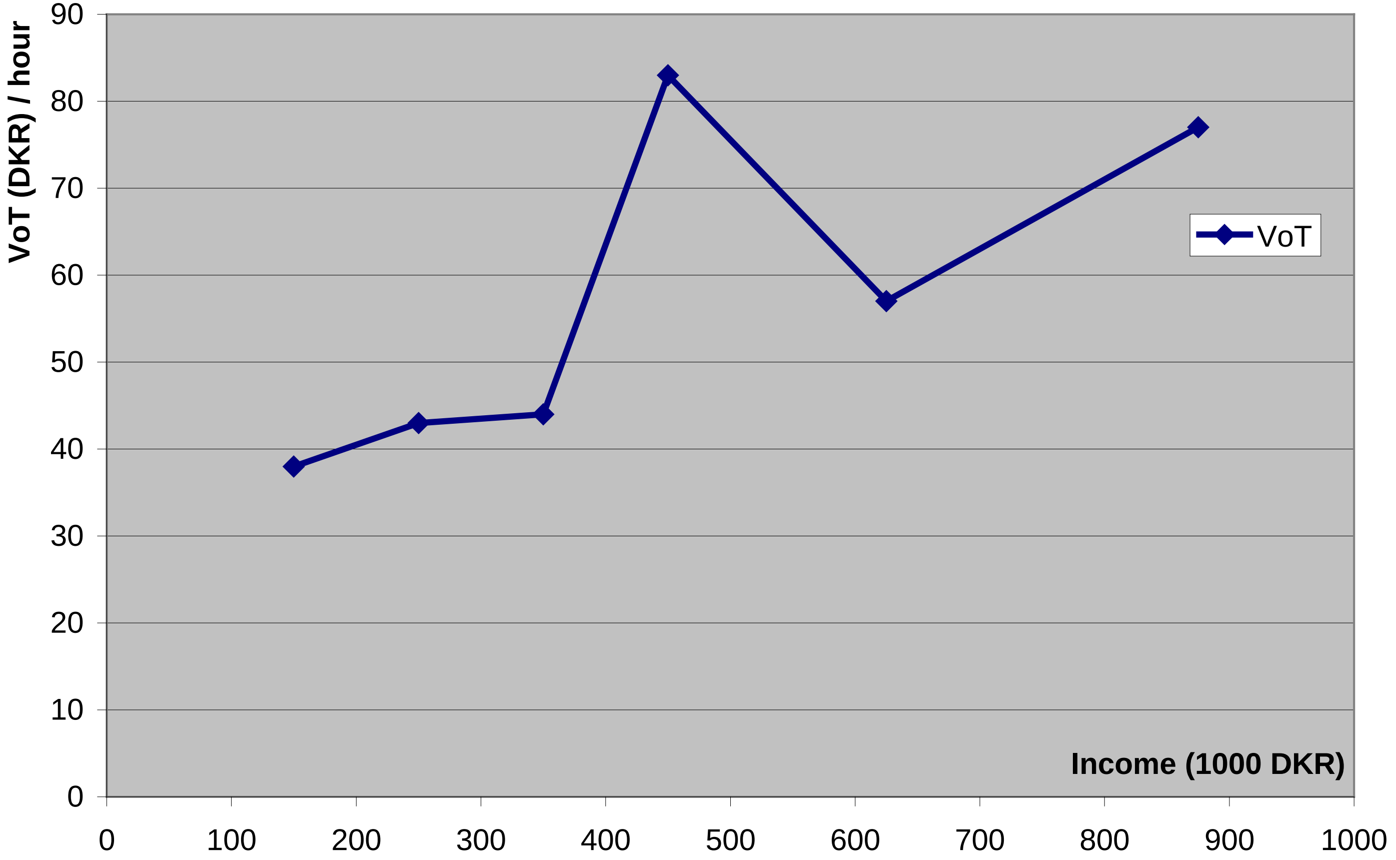
Distribution of Congestion VoT



Congestion over free flow VoT



Income effect



AKTA data – new model estimations

- VOT for free flow time and congested time:
  - Group (Base, Toll rings, Low km., High km)
  - Peak vs. off-peak period
  - Income (low, medium, high)
  - Demographics (gender, age, hh-size)
- VOT regression goodness-of-fit:
  - Free flow time: 0.725
  - Congested time: 0.844

Post AKTA models

	VOT free flow time		VOT congested time	
Parameter	Estimate	T-stat	Estimate	T-stat
Constant	89.27	(27.65)	97.08	(26.52)
Group Base	-	-	-	-
Group Toll	18.99	(9.20)	35.77	(15.29)
Group Low	13.59	(7.97)	21.43	(11.09)
Group High	30.86	(20.88)	60.35	(36.01)
Peak	21.60	(16.05)	63.27	(41.45)
Off-peak	-	-	-	-
Male	18.87	(14.42)	17.90	(12.06)
Female	-	-	-	-

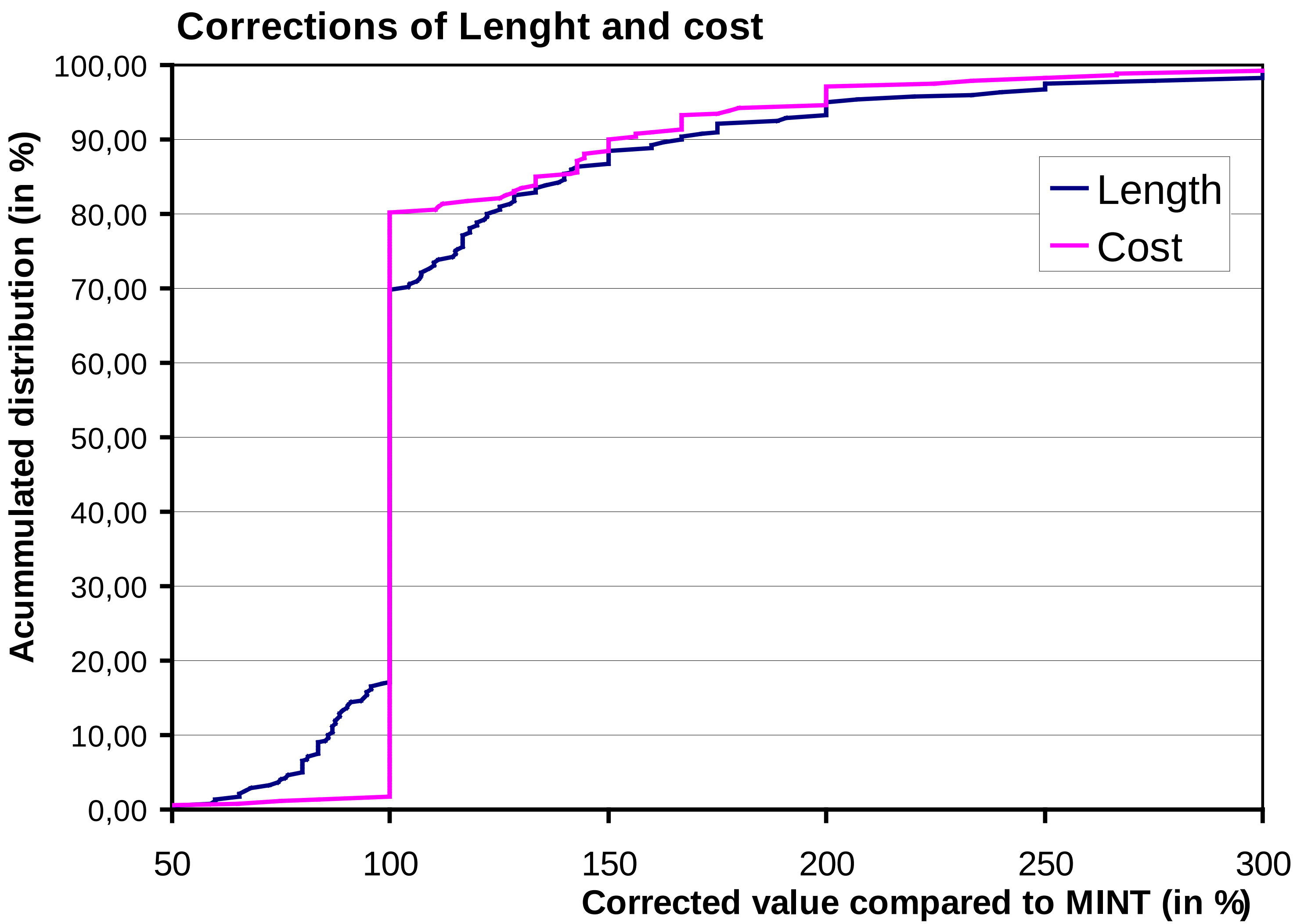
Post AKTA models

	VOT free flow time		VOT congested time	
Parameter	Estimate	T-stat	Estimate	T-stat
Age <30	-	-	-	-
Age 30-39	-13.22	(-5.33)	-7.52	(-2.68)
Age 40-49	-29.67	(-11.80)	-22.77	(-7.99)
Age 50-59	-36.32	(-14.66)	-28.55	(-10.16)
Age >59	-41.13	(-13.16)	-33.83	(-9.55)
Income low	-	-	-	-
Income medium	22.40	(15.77)	22.56	(14.01)
Income high	53.37	(26.00)	49.42	(21.23)
HH size	-14.60	(-29.19)	-13.91	(-24.53)

Main design of the SP-experiment Subset of AKTA Participants

1. Present transport behaviour, including a typical trip
2. Value of time experiment.
   - SP1 Length and SP2 cost based on typical trip
3. Time of day experiment
   - Length/cost based on typical trip
   - Only if an reasonable alternative exists
4. Road pricing experiment
   - SP5 Realistic alternative route is pinpointed by the respondent. Pricing level as in AKTA
5. Socio economic data

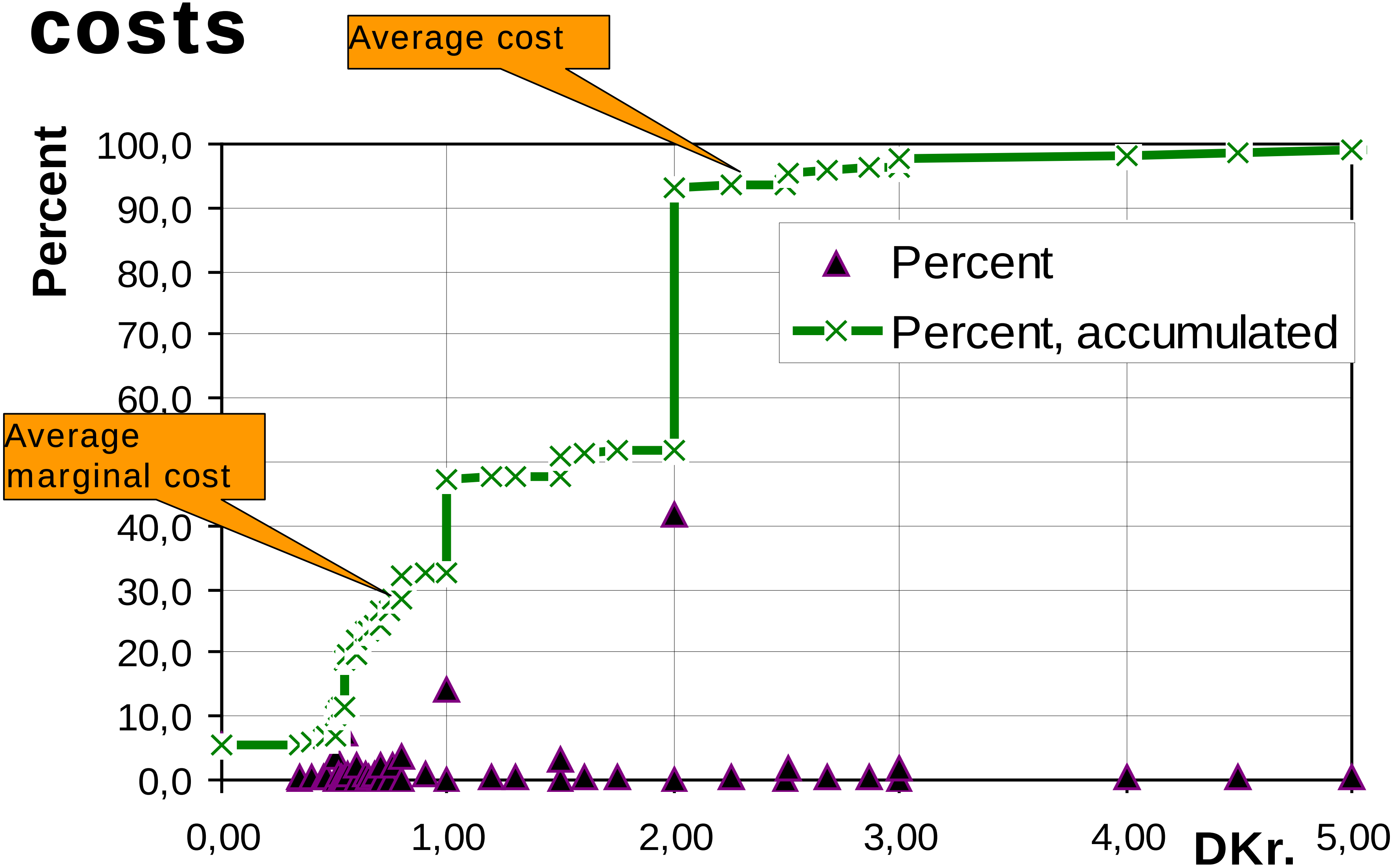
Accumulated distributions



Confirmation of cost-estimate

- MINT Estimation of length
  - 52 % agreed
- Estimation of cost
  - 81% agreed

Distribution of mentioned costs



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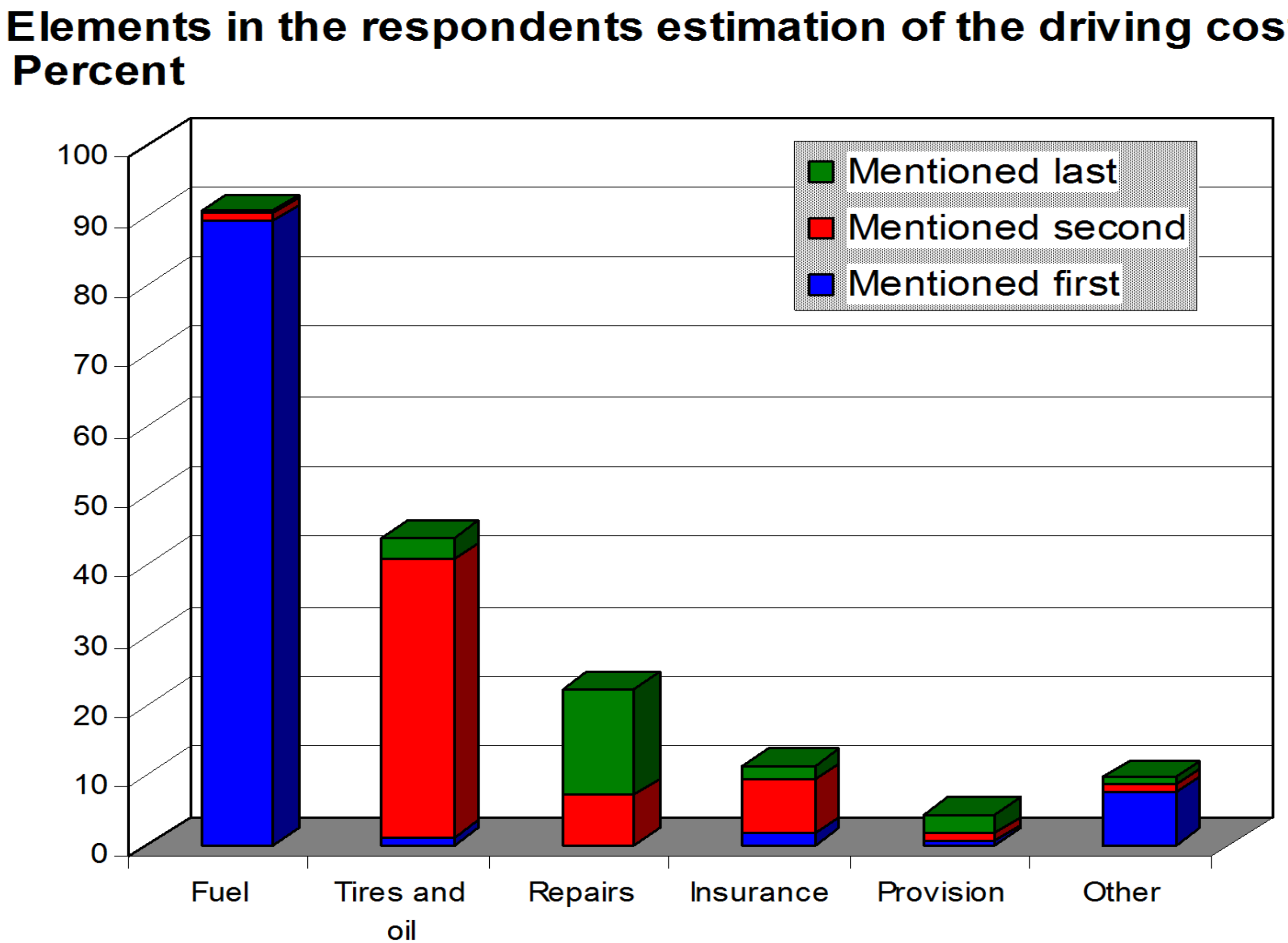
Estimation of costs



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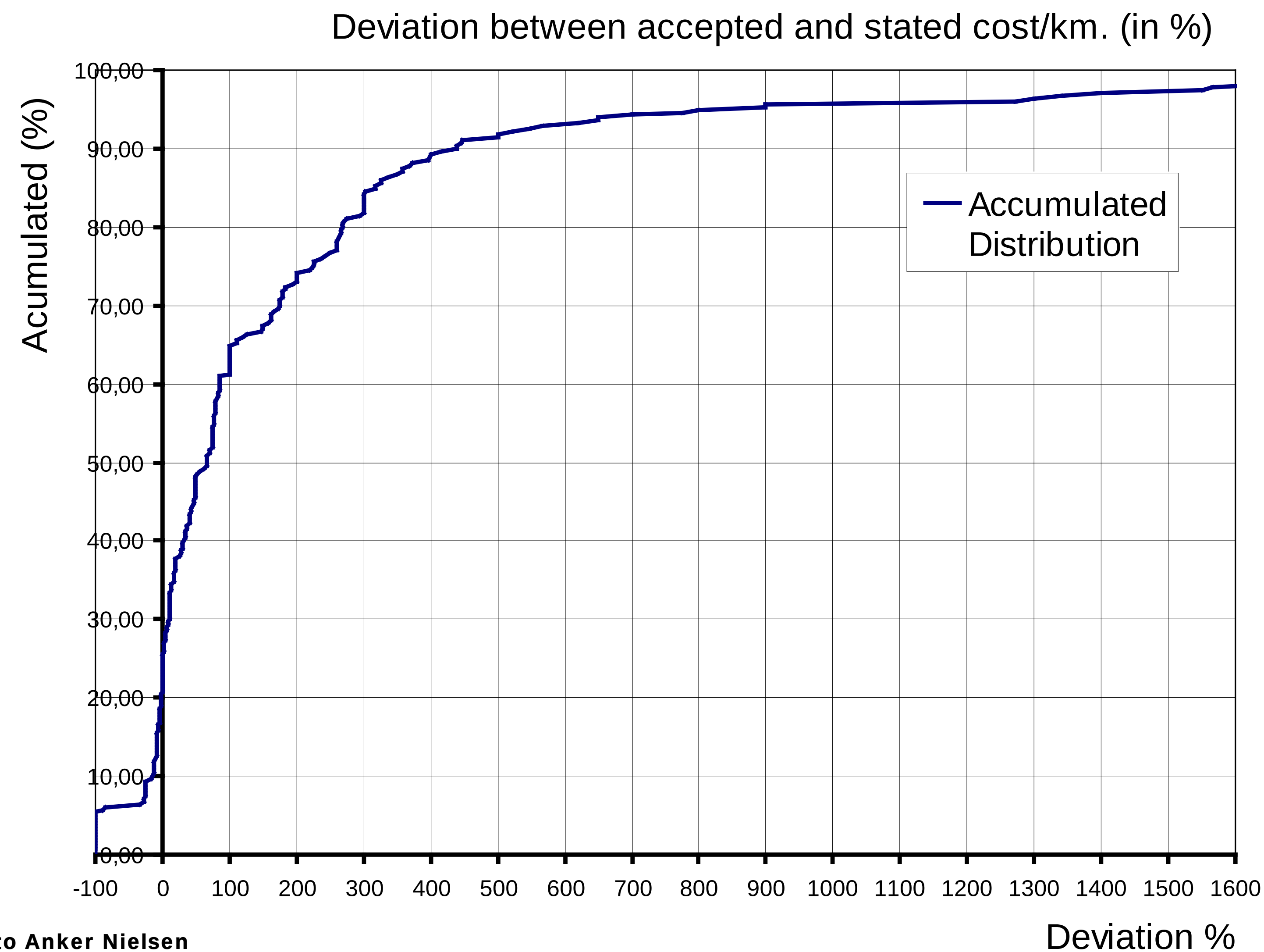
Confirmed total cost / length versus stated driving costs/km



Estimation of Value of time
- Utility functions

- General discrete choice model:

$$U_i = \sum_j \beta_j X_j + \varepsilon_i \quad , \quad \beta_j = \beta_j' + \xi_{(j)}$$

- Road pricing case:

$$U_i = \beta_c Cost + \beta_{tff} Time_{ff} + \beta_{tcon} Time_{con} + \varepsilon_i$$

- Derived Value of Time $VoT_{ff} = \beta_{tff} / \beta_c$

- Cost $Cost = DrivingCost_{(DKR/km.)} \cdot length$

Different VoT estimates, MNL
- Due to Questions and a priori assumptions

- Accepted Cost versus time
  - Route choice experiment
    - FF=27 / CNG=43 DKK/h
  - Road pricing experiment
    - FF=32 / CNG=51 DKK/h

Very low values

- Length versus time
  - Standard variable cost (0,55 DKK/km.)
    - MINT Length: FF=67 / CNG=103 DKK/h
    - Corrected length: FF=70 / CNG=113 DKK/h

Values close to RP/GPS

  - Respondents' cost/km. estimate and corrected length
    - FF= 159 / CNG=235 DKK/h

Very high values

Adding Error Components

- Improve model drastically
- Large heterogeneities were found
- VoT's changed to some extent

AKTA field experiment versus SP

- AKTA RP-experiment
  - 73 DKK FF time
  - 119 DKK CC time
- MNL SP with length/time experiment, marginal cost (fuel = 8,5 DKK/l, 12 km./l => 0,7 DKK/km.), and corrected length
  - 90 DKK FF time
  - 144 DKK CC time
- EC SP, simulated VoT
  - 108 DKK FF time
  - 131 DKK CC time
- Cost/time underestimate with about 66%

Conclusions of comparing RP and SP

- The RP Experiment was perceived as realistic
  - But some acted illogical none-the-less
  - Third round with true cash increased the behavioural changes
- Behavioural models can be estimated on GPS-data
- SP: The design affect the results
  - Length/time and marginal cost equal reasonable well values from the field experiment
  - Respondents have little and strongly biased knowledge on cost of car driving
- Large heterogeneities were found in both RP and SP
- Some income effect in RP
- SP tends to underestimate the impacts compared to RP

More recent GPS-data in Cph

- ACTUM research project
  - Personal lockers, household-based interview
  - Test of equipment important
  - One day traditional interview in parallel
    - Proved underreporting of short trips/small errands in the traditional survey
  - Trip, errand and mode detection
- Used for route choice estimation
  - Car drivers
  - Bicycle route choice
- Estimation of activity-based model
  - DaySIM

Bicycle project

- Bicycle route choices
- Speed profiles

Sund&Bælt project

- Technology test for pricing/tolling, 2017
- Martina Zabic
  - mz@transport.dtu.dk
  - mza@SBF.DK
- Not reported (NDA)
- Still large differences og GPS quality
  - Between suppliers
  - Between cars

Present test of smartphone-based data collection at DTU

- Functional requirements
- Possible approaches
  - Commercial product for transport surveys
  - Cooperation agreement with standard product (e.g. MMM)
  - Build on general tracking software (Google, HERE)
    - Seems to have quite advanced learning mechanisms
  - Use open source (e.g. Univ. Minnesota http://daynamica.umn.edu/)
  - New in-house open source code

Purpose / expected benefits

- Some of the interviews in the national transport survey (1000 interviews/month)
  - Choose between SmartPhone, www or telephone
  - Ad hoc extra surveys
- Tackle underreporting of short trips/small errands
- Potentially smaller response burden, and less data processing work
- Register route choice (all modes)
- Potentially longer period than one day interview / panel data
- Use information on travel times, travel time variability and congestion
  - Not only cars, but also bicycles

Functional requirements

- Battery use versus registration quality
  - Some suppliers seems to loose short trips due to slow startup of unit / low registration frequency (hibernate issue)
- Embedded map matching improve quality of mode detection dramatically
  - Map matching is needed anyway at some stage anyways for route choice analysis
- Combination of GPS and other censors (acceleration, etc.) improve quality of mode detection and usability
- Differences on quality of detection of intermediate stops/errands and purpose of activities
  - Seem to be very simplistic methods
  - Large potential for use statistical methods and machine learning for within and between person learning
- Differences on ease of use of user interphase

Mode detection with and without map matching

- T.K. Rasmussen et al. / Computers, Environment and Urban Systems (2015)

Table 4
The results of the mode identification when using *Algorithm 1 without map matching* (compared to reported mode use).

Algorithm	Observed							
	Walk	Bicycle	Bus	Car	Rail	Non-trips		Confidence rate
Walk	180	11	2	2	–	117		57.7%
Bicycle	2	114	–	6	–	16		82.6%
Bus	–	–	28	–	–	–		100.0%
Car	4	8	7	156	1	41		71.9%
Rail	3	–	–	–	33	2		86.8%
Other	3	1	–	3	–	1		–
Total	192	134	37	167	34	177		69.2%
Success rate	93.8%	85.1%	75.7%	93.4%	97.1%	–	90.6%	

Table 5
The results of the mode identification when using *Algorithm 2 with map matching* (compared to reported mode use).

Algorithm	Observed							
	Walk	Bicycle	Bus	Car	Rail	Non-trips		Confidence rate
Walk	75	5	1	1	–	3		88.2%
Bicycle	1	100	–	5	–	–		94.3%
Bus	–	–	29	–	–	–		100.0%
Car	1	7	7	151	1	4		88.3%
Rail	–	–	–	–	33	–		100.0%
Other	1	1	–	1	–	–		–
Total	78	113	37	158	34	7		90.9%
Total (all)	192	134	37	167	34	–		
Success rate	96.2%	88.5%	78.4%	95.6%	97.1%	–	92.4%	
Success rate (all)	39.1%	74.6%	78.4%	90.4%	97.1%	–	(68.8%)	

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