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Driving speed model development using driving data obtained from smartphone sensors

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Scope

- **Development of driver speed models**
  - detailed driving data collected from smartphone sensors

- **Various driving behaviour parameters:**
  - harsh acceleration and deceleration events,
  - driving distance,
  - percentage of driving time per different road types, etc.
  - interaction between them
  - potentially serve as driving speed predictors

Background (1/2)

- **Road accidents increase**
  - human factors

- **Driving behaviour characteristics**
  - speeding
  - harsh braking/ acceleration/ cornering
  - seatbelt use
  - mobile phone use

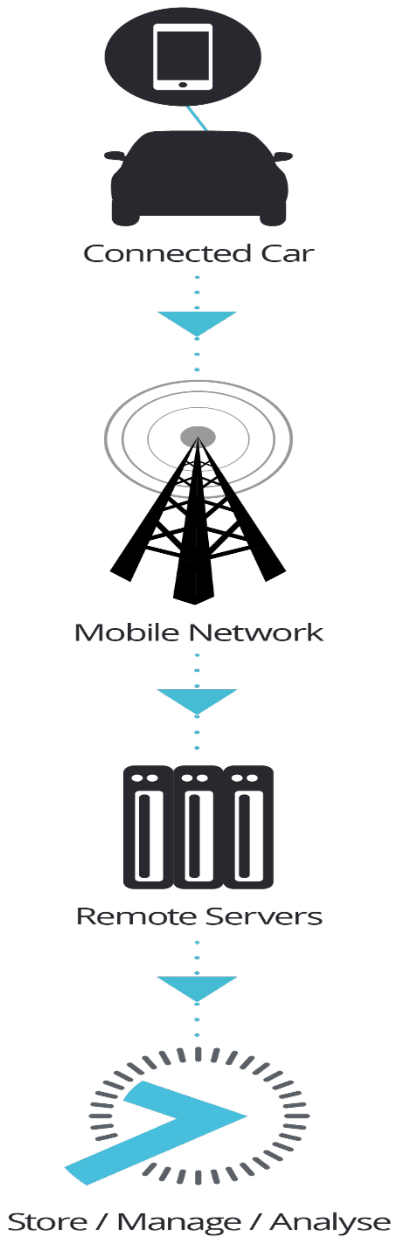
Background (2/2)

- **Data collection schemes**
  - DDR
  - drive Diagnostics (e.g. OBD-II)
  - smartphones

- **Data sources**
  - naturalistic driving experiments
  - driving simulator experiments
  - in-depth accident investigation

Smartphone data collection

- Data were provided by OSeven Telematics
- A mobile application to record user's driving behaviour (automatic start / stop)
- A variety of APIs is used to read mobile phone sensor data
- Data is transmitted from the mobile App to the central database
- Data are stored in a sophisticated database where they are managed and processed



Methodological approach (1/2)

- **Individual models** were developed to predict the average speed used by each driver:
  - in general conditions (on all road types) - Model 1
  - during less risky hours (on all road types) - Model 2
  - during risky hours (on any road type) - Model 3
  - on urban road (anytime of the day) - Model 4
  - on rural road (anytime of the day) - Model 5
  - on highway (anytime of the day) - Model 6

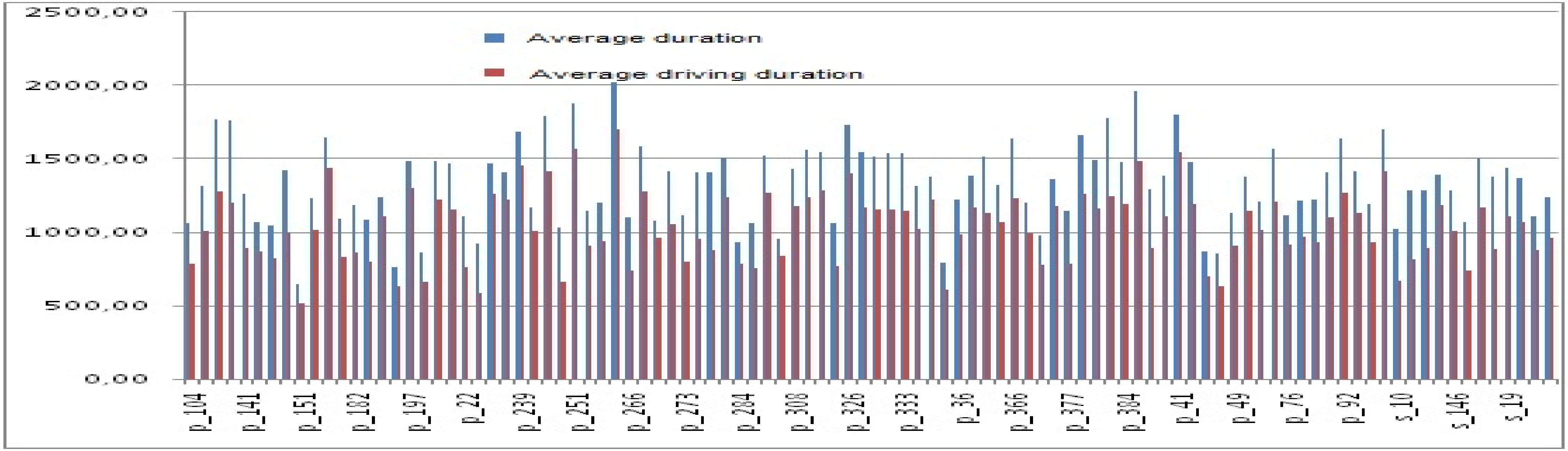
- **Linear regression** models
- The **original database** was modified and all data was changed per driver
- To avoid losing important information the **average/standard deviation** and minimum/maximum value was calculated for each variable

Methodological approach (2/2)

➤ Dependent variable:
- the average speed

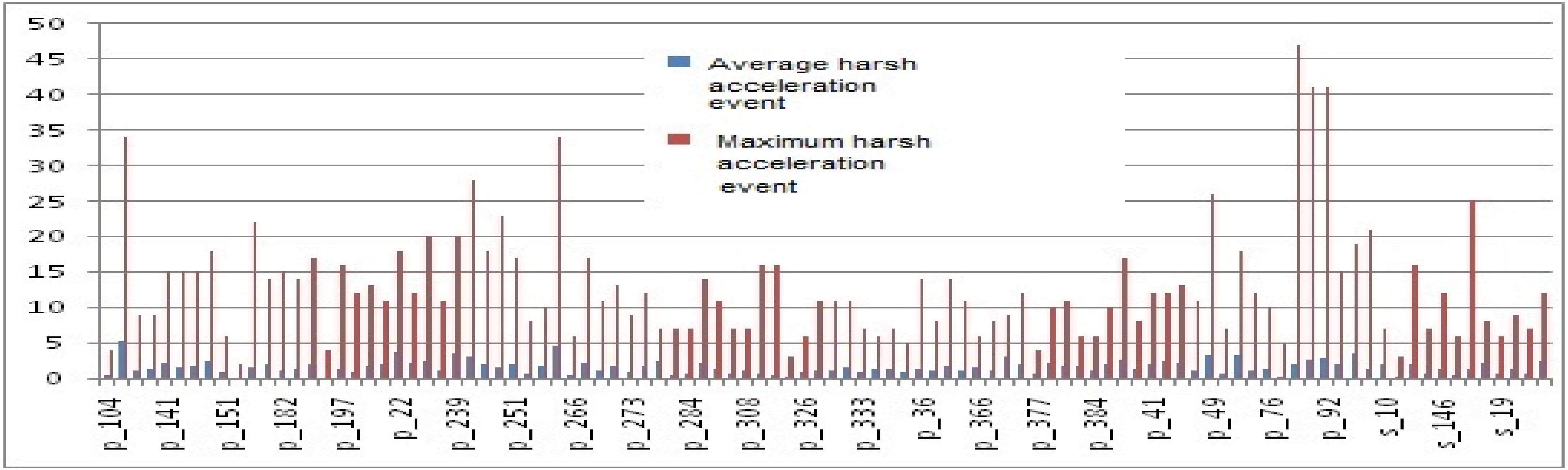
➤ Independent variables:
- the total distance driven in kilometers
- the average number of harsh accelerations
- standard deviation of mean deceleration
- the percentage of driving time in a highway
- standard deviation of mean acceleration
- average deceleration
- standard deviation of harsh cornering events
- the mobile phone use

Aggregated Statistics (1/4)



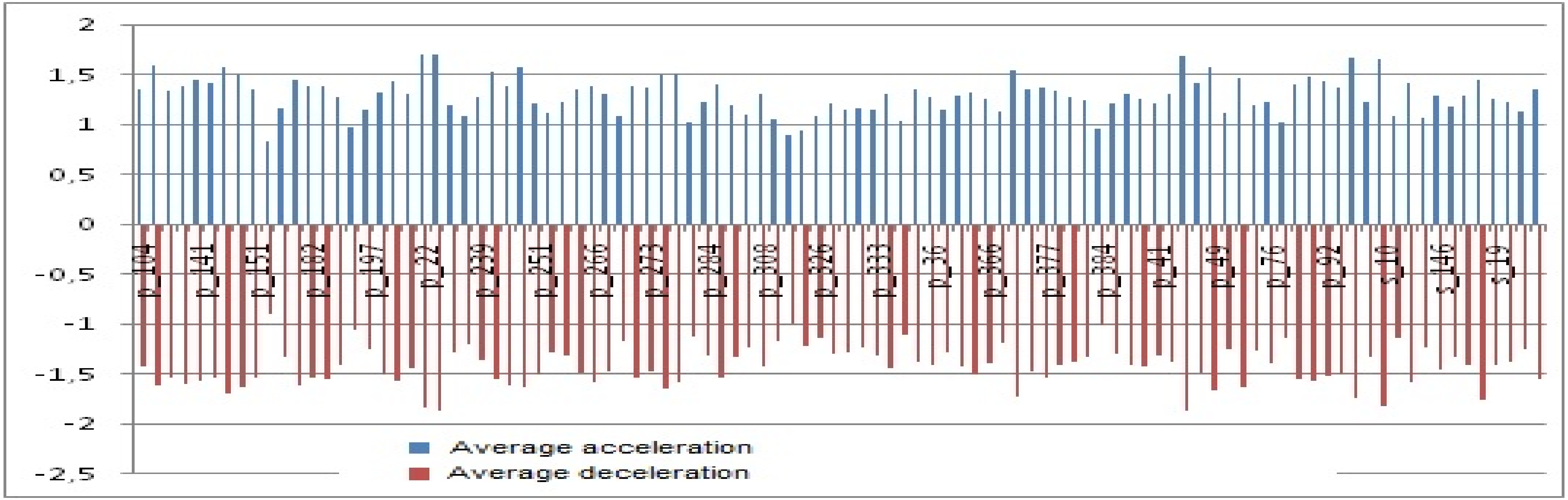
- The higher the difference between the average driving duration and the average duration, the more a driver drives during traffic congestion.
- The highest average duration and average driving duration per driver exist on urban roads and rural roads while on highways, the differences are much lower for all drivers.
- When driving on a highway a driver is rarely confronted with traffic congestion, in contrast to urban and rural roads.

Aggregated Statistics (2/4)



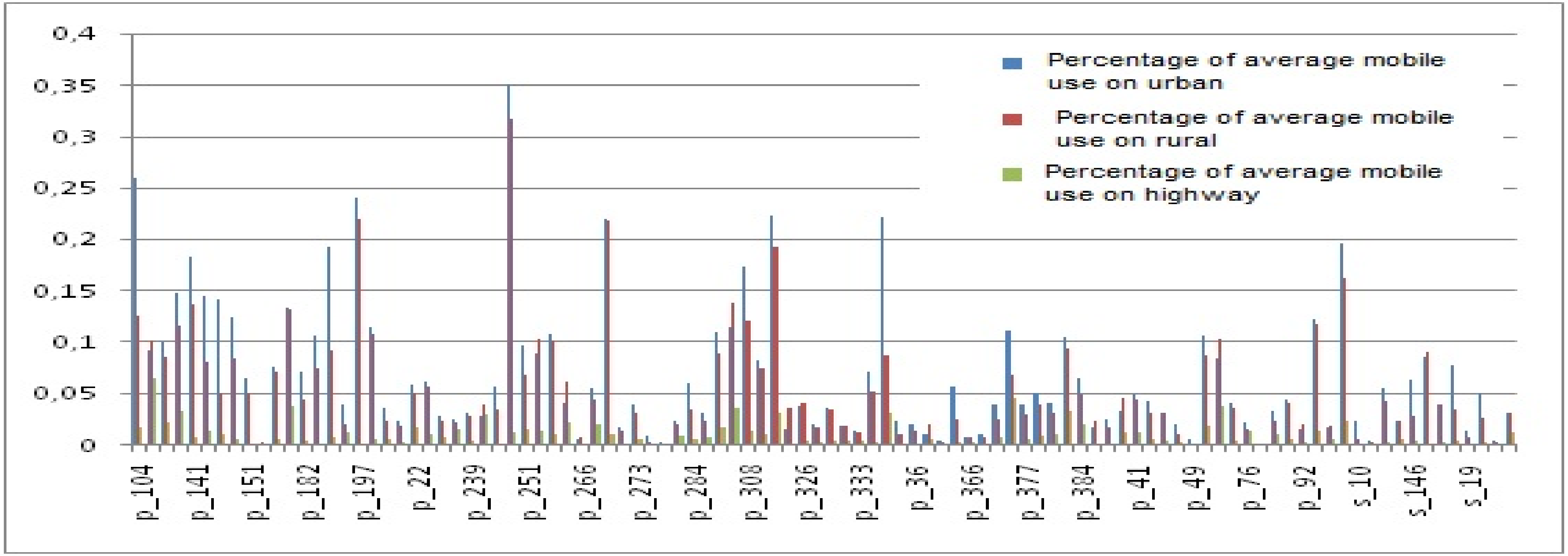
- Drivers with high average number of harsh acceleration events also have a high number of maximum harsh acceleration events per trip.
- The driver having the highest number of maximum harsh acceleration events, does not have the highest number of average harsh accelerations events.
- Drivers with the lowest number of maximum harsh acceleration events are those with the lowest number of average harsh acceleration events.

Aggregated Statistics (3/4)



- The average acceleration and deceleration for all drivers are approximately equal. Therefore, drivers who accelerate much, also decelerate much.
- On the other hand, the number of harsh acceleration events is higher than that of harsh deceleration events.

Aggregated Statistics (4/4)



Drivers use their mobile phone:

- more on urban roads, and less on motorways
- on average 20% on each move
- on moving more than 80%, while on other movements they did not use it at all

Summary table of the six model developed

Independent Variables	Model 1 (general model)				Model 2 (less risky hours)				Model 3 (risky hours)				Model 4 (urban road)				Model 5 (rural road)				Model 6 (highway road)			
	β_i	t	e_i	e_i^*	β_i	t	e_i	e_i^*	β_i	t	e_i	e_i^*	β_i	t	e_i	e_i^*	β_i	t	e_i	e_i^*	β_i	t	e_i	e_i^*
Constant	1,554	38,873			1,726	49,829			1,548	38,632			1,214	32,176			1,593	99,944			1,915	71,427		
av_distance	0.004	4,772	0.182	5,222	0	2,228	0.167	5,044	0.005	5,035	0.197	6,527	0.019	5,109	0.201	3,415	0.005	7,119	0.225	3,069	0	2,430	0.071	-9,555
ha	0.012	1,965	0.035	1	0.014	2,505	0.062	1,860	0.012	1,969	0.030	1									0.005	1,764	0.054	-7,253
av_dec_st_dev	0.255	3,803	0.194	5,579	0.070	1,769	0.033	1	-0.186	-4,586	0.194	6,412												
dr_dur_perc	-0.183	-4,502	-0.174	-4,994	-0.239	-5,533	-0.090	-2,707	0.253	3,671	-0.182	-6,006												
av_dec													-0.098	-4,816	0.293	4,991								
av_acc_st_dev													0.131	2,589	0.059	1	0.097	3,146	0.073	1	0.238	2,694	0.025	-3,324
hc																	-0.010	-3,648	-0.078	-1,063				
av_mu																					-0.336	-3,430	-0.007	1
correlation coefficient	0.569				0.564				0.575				0.369				0.372				0.354			
Dependent variable: The logarithm of the average speed																								

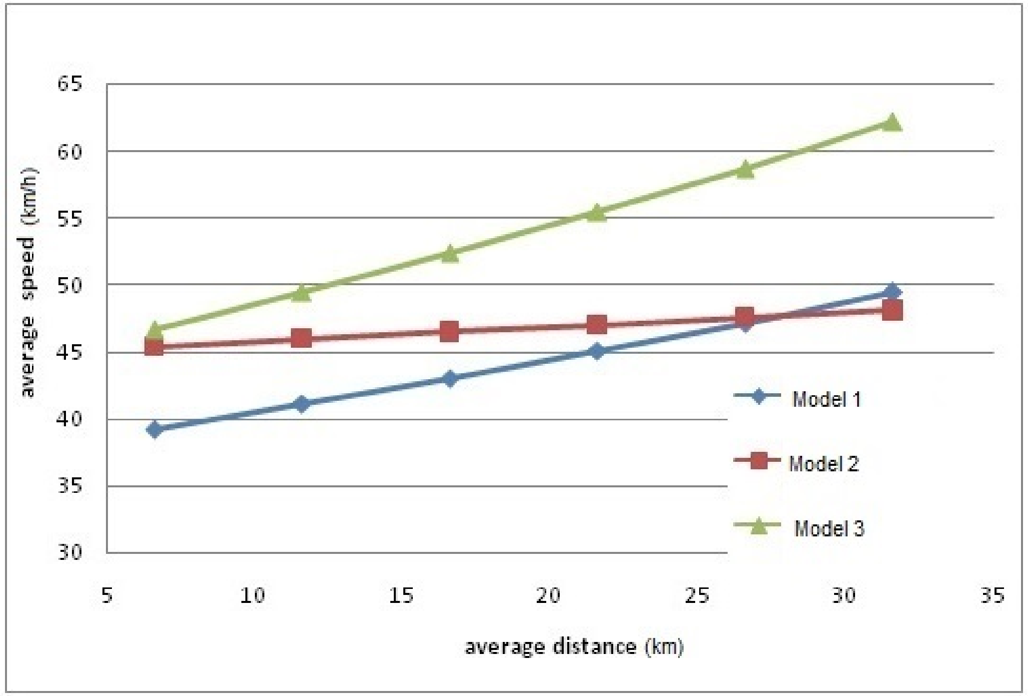
Relevant influence of the models' variables

Independent Variables	Relevant influence		
	Model 1 (general model)	Model 2 (less risky hours)	Model 3 (risky hours)
av_distance	1.090	1.000	1.182
ha	1.152	2.036	1.000
av_dec_st_dev	5.872	1.000	5.858
dr_dur_perc	1.942	1.000	2.027

- The 'average number of harsh accelerations' affects the average speed 2 times more for the model that predicts average speed outside the critical hours of the other two models
- The average of the total distance traveled by the driver affects the logarithm of the average speed for all models almost the same

- The 'average deceleration standard deviation' affects 5.85 times more the general predictive model and model within the critical hours relative to the off-peak model
- 'Percents' driving time' rate affects the average speed 2 times more for the general predictive model and the model within the critical hours relative to the off-peak hours model

Sensitivity analysis



Sensitivity analysis for average speed to average distance

➢ Observed:

- increase in all models
- within critical times the speed has the highest rate of growth and beyond the slower pace
- for long distances lower speeds are presented outside the critical hours
- for short distances lower speeds are presented in the general model
- at 27 km the average speed is the same for the models outside the critical hours and for the general model

Results

- All models include the **total distance** as independent variable and have a parameter related to acceleration

- All findings **confirm the results found in literature** so far

- The general model as well as the models for both the periods inside and outside the risky hours period include the **same variables**

Conclusions (1/2)

- Drivers who tend to **accelerate and decelerate harshly and often**, are also those who are finally driving over the speed limits.
- It is found that drivers who drive longer **distances**, are also driving faster.
- Driving time seems only to affect the **driver's speed** and not the overall **driving behavior**.
- Drivers who tend to **accelerate harshly often also tend to decelerate harshly often**. Perhaps this is due to the drivers attempt to stop within a relatively short distance

Conclusions (2/2)

- The mileage of a driver is found to be critical for the prediction of the average driving speed and is included in all models as one of the most influential variable

- For all drivers, larger driving variations occur during urban and interurban roads and much less on motorways. This is probably because there are no traffic lights on motorways to cause delays.

- Drivers are more likely to use their mobile phone on urban roads and much less on motorways. This is probably because drivers drives at lower speed on urban roads and stop more frequently.

Future research

- **Collect more information** on drivers such as demographics and/ or mental conditions while driving

- **Include more factors** in the analysis, such as vehicle characteristics and road condition

- **Examination** of traffic conditions

- **Larger sample**, especially for models by road type

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