National Technical University of Athens
School of Civil Engineering
Department of Transportation Planning and Engineering

Risk factors, driver behaviour and accident probability. The case of distracted driving.

Doctoral Dissertation

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Athens, August 2015

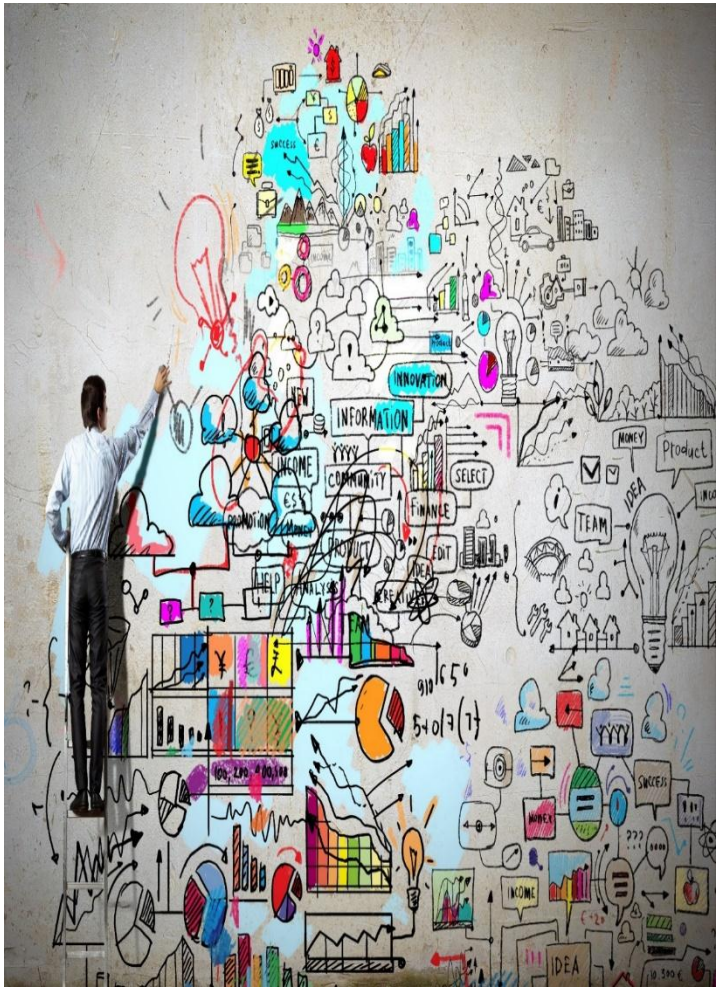
Objective

The analysis of the effect of road, traffic and driver risk factors on driver behaviour and accident probability at unexpected incidents, with particular focus on distracted driving

The development of risky driver profiles and road characteristics leading to increased possibility of driver error

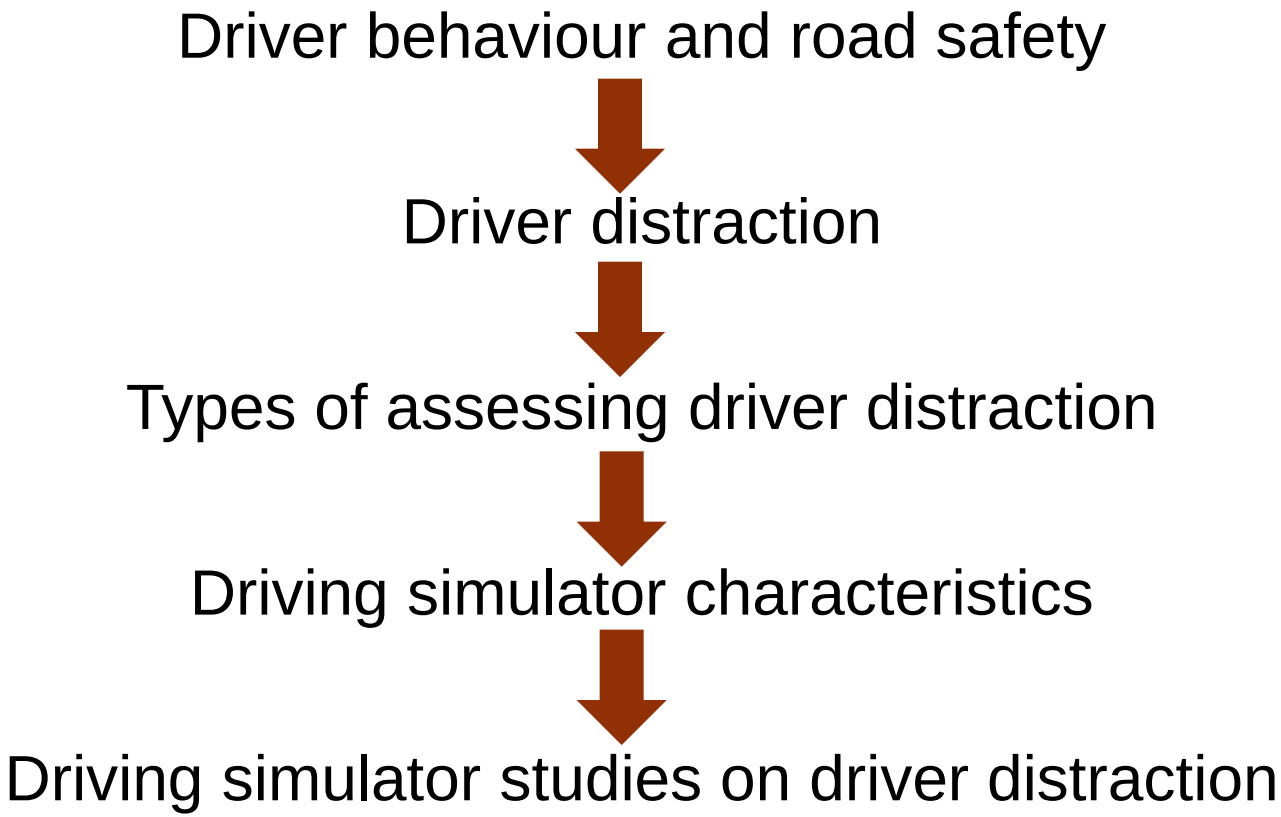
Methodological steps

- Literature review
- Methodological review
- Research questions
- Driving simulator experiment
- Statistical analysis
- Methodological contributions
- Key research findings
- Further research



Literature review

Several literature reviews were implemented in the following research topics:



Driver behaviour and road safety

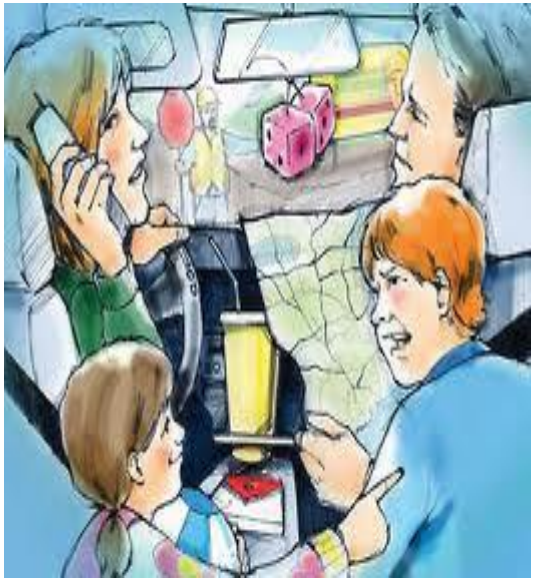
- **Human factors** are the basic causes in 65-95% of road accidents (Salmon et al., 2011).

- Human factors involve a large number of specific factors that may be considered as accident causes, including (Yannis et al., 2013):
  - **Driver injudicious action** (speeding, traffic violations etc.)
  - **Driver error or reaction** (loss of control, failure to keep safe distances, sudden braking etc.)
  - **Behaviour or inexperience** (aggressive driving, nervousness, uncertainty etc.)
  - **Driver distraction** (cell phone use, conversation with passenger etc.)
  - **Driver impairment** (alcohol, fatigue etc.)

Driver Distraction

- **Driver distraction** is generally defined as “a diversion of attention from driving, because the driver is temporarily focusing on an object, person, task or event not related to driving, which reduces the driver’s awareness, decision making ability and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes”

- Driver distraction may include four different types: **physical** distraction, **visual** distraction, auditory **distraction** and cognitive **distraction** (Ranney et al., 2000)



- Driver distraction factors can be subdivided into those that occur outside the vehicle (**external**) and those that occur inside the vehicle (**in-vehicle**).

Types of assessing driver distraction

The following **experiment types** of assessing driving behaviour and driver distraction exist (Papantoniou et al., 2015):

- Field tests
- Naturalistic driving experiments
- Driving simulator experiments
- In-depth accident investigation
- Stated preference surveys

Driving simulator characteristics

Driving simulators allow for the examination of a range of driving performance measures in a controlled, relatively realistic and safe driving environment

Advantages

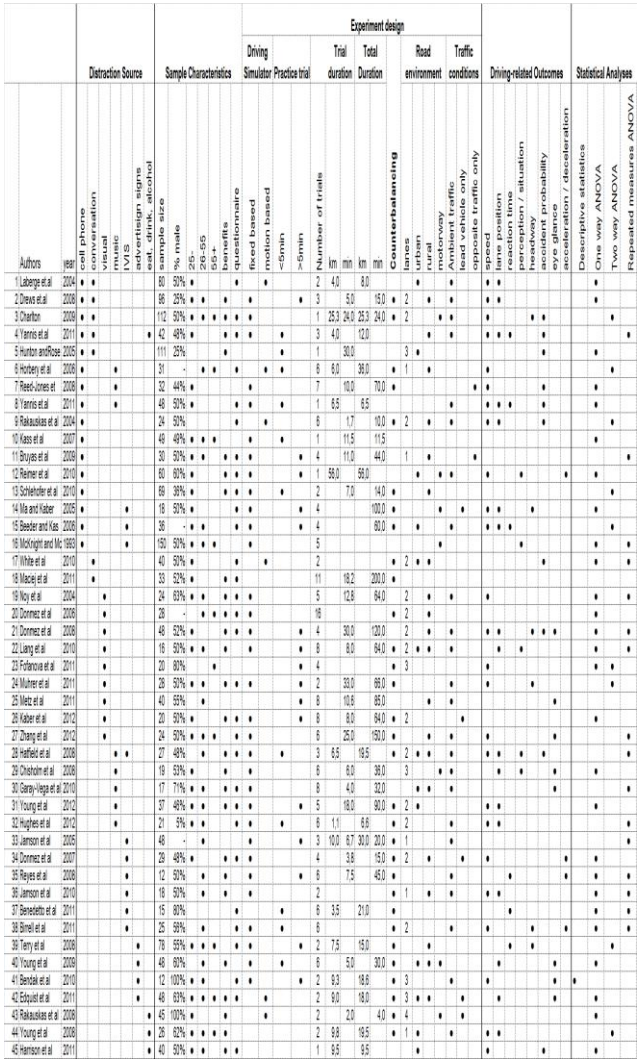
- safe environment
- greater experimental control
- large range of test conditions (e.g., night and day, weather conditions, road environments)

Disadvantages

- data generally include the effect of learning
- feeling of safety
- simulator sickness

Driving simulator studies on driver distraction

- Most experiments are based on **small samples**, limited to rural road environment and no explicit (if at all) simulation of ambient traffic
- Participants in almost all driving simulator experiments implemented a practice scenario, but no specific performance measures were used to assess the driver's **familiarization**
- No pattern could be identified as regards the selection of **number and duration of trials**
- In 30% of studies no **counterbalancing** in the different trials was reported



		Distraction Source						Sample Characteristics							Experiment design														Driving-related Outcomes									Statistical Analyses			
															Driving Simulator	Practice trial	Trial duration		Total Duration		Road environment			Traffic conditions																
Authors	year	cell phone	conversation	visual	music	SVS	road/sign signs	est. drink, alcohol	sample size	% male	25-	26-55	55+	benefits	questionnaire	fixed based	motion based	<5min	>5min	Number of trials	km	mn	km	mn	Counterbalancing	lanes	urban	rural	motorway	Ambient traffic	lead vehicle only	route traffic only	speed	lane position	reaction time	perception / situation	headway	accident probability	eye glance	acceleration / deceleration	Descriptive statistics	One way ANOVA	Two way ANOVA	Repeated measures ANOVA
1 Laberge et al	2004	•	•						80	59%	•					•				2	4.0		8.0				•					•	•									
2 Drews et al	2008	•	•						96	25%	•	•		•		•			•	3		5.0		15.0	•	2		•				•	•									
3 Charlton	2009	•	•						112	50%	•	•	•	•		•				1	25.3	24.0	25.3	24.0	•	2			•	•			•				•	•					
4 Yannis et al	2011	•	•					•	42	48%	•			•	•	•		•		3	4.0		12.0					•				•	•	•								•
5 Hurton and Rose	2005	•	•						111	25%				•				•		1	30.0					3	•									•						
6 Horberry et al	2006	•		•					31	-	•	•		•		•	•			6	6.0		36.0		•	1	•					•										
7 Reed-Jones et al	2006	•		•					32	44%	•				•					7		10.0		70.0	•							•	•									
8 Yannis et al	2011	•		•					48	50%	•				•	•		•		1	6.5		6.5					•				•	•	•								
9 Rakauskas et al	2004	•							24	50%					•		•			6		1.7		10.0	•	2		•				•	•									•
10 Kass et al	2007	•							48	48%	•	•	•		•		•			1		11.5		11.5																		
11 Bruyas et al	2009	•							30	50%	•	•		•	•				•	4		11.0		44.0		1		•			•											•
12 Reimer et al	2010	•							60	60%	•				•	•			•	1	56.0		56.0				•		•	•			•				•						
13 Schlehofer et al	2010	•							69	38%	•				•	•	•			2		7.0		14.0	•			•														
14 Ma and Kaber	2005	•					•		18	50%	•				•	•			•	4				100.0	•				•		•				•						
15 Beede and Kass	2006	•					•		36	-	•	•			•	•			•	4				60.0	•			•				•	•	•								
16 McKnight and Mc	1993	•					•		163	50%	•	•	•			•				5															•						
17 White et al	2010		•						40	50%	•				•		•			2						•	2	•	•							•						•
18 Macej et al	2011		•						33	52%	•				•	•	•			11		18.2		200.0	•																	
19 Noy et al	2004			•					24	63%	•	•		•	•	•				5		12.8		64.0		2		•				•	•									•
20 Donmez et al	2008			•					26	-		•	•	•	•	•				16					•	2	•														
21 Donmez et al	2008			•					48	52%	•			•	•	•			•	4		30.0		120.0		2		•	•				•	•		•	•					•
22 Liang et al	2010			•					16	50%	•	•		•		•			•	8		8.0		64.0	•	2	•	•					•		•							•
23 Fofanova et al	2011			•					20	80%			•						•	4						3															
24 Muhrer et al	2011			•					26	50%	•	•		•	•	•			•	2		33.0		66.0	•			•					•		•							•
25 Metz et al	2011			•					40	55%		•							•	8		10.6		85.0				•								•					
26 Kaber et al	2012			•					20	50%	•				•	•	•		•	8		8.0		64.0	•	2				•												
27 Zhang et al	2012			•					24	50%	•	•	•	•	•	•		•		6		25.0		150.0	•			•					•				•					•
28 Hatfield et al	2008				•	•			27	48%		•		•	•	•		•		3	6.5		19.5		•	2	•	•					•	•	•	•						•
29 Chisholm et al	2008				•				19	53%	•			•	•	•				6		6.0		38.0		3			•	•					•	•						
30 Garay-Vega et al	2010				•				17	71%	•	•		•	•	•				8		4.0		32.0				•	•							•						•
31 Young et al	2012				•				37	48%	•	•		•	•	•			•	5		18.0		90.0	•	2	•						•	•								
32 Hughes et al	2012				•				21	5%	•				•	•		•		6	1.1		6.6		•	2			•				•	•								•
33 Jamson et al	2005					•			48	-					•				•	3	10.0	6.7	30.0	20.0	•	1			•													•
34 Donmez et al	2007					•			29	48%	•			•	•	•				4		3.8		15.0	•	2	•			•			•					•				
35 Reyes et al	2008					•			12	50%	•			•	•			•		6		7.5		45.0	•								•	•				•				•
36 Jamson et al	2010					•			16	50%	•			•	•					2					•	1	•						•	•								•
37 Benedetto et al	2011					•			15	80%				•				•		6	3.5		21.0		•									•								•
38 Birrell et al	2011					•			25	56%	•			•	•	•		•		6					•	2			•				•		•			•				•
39 Terry et al	2008						•		78	55%	•	•	•	•	•	•			•	2	7.5		15.0		•		•							•	•								•
40 Young et al	2009						•		48	60%	•			•	•		•			6		5.0		30.0	•		•	•	•						•								
41 Bendak et al	2010						•		12	100%	•	•			•	•			•	2	9.3		18.6		•	3			•								•			•			
42 Edquist et al	2011						•		48	63%	•	•	•	•	•	•	•			2	9.0		18.0		•	3	•	•			•						•						
43 Rakauskas et al	2008							•	45	100%	•			•			•			2		2.0		4.0	•	4		•	•														
44 Young et al	2008							•	26	62%	•	•	•	•						2	9.8		19.5		•	1	•		•				•	•									
45 Harrison et al	2011							•	40	50%	•	•		•	•					1	9.5		9.5				•							•									

Methodological review

Two targeted literature reviews took place in order to investigate:

- the key **driving performance parameters** examined in driver distraction research
- the **statistical analyses implemented** in the scientific field of driver distraction

Driving performance parameters

- Driver distraction is a **multidimensional phenomenon** which means that no single driving performance measure can capture all effects of distraction

- A lot of different methods and **measures** exist for evaluating driving performance the most common of which include lateral control, longitudinal control, reaction time, gap acceptance, eye movement and workload measures

- The selection of the specific measures should be guided by the nature of the task examined as well as the specific **research questions**

Statistical analysis methods

- 5% of the examined studies perform only **descriptive statistics** tests aiming to gain general information regarding different performance measures
- In more than half of the examined studies the main statistical analysis is **repeated measures Anova**
- Latent model analysis and especially **structural equation models** have never been implemented in the field of driver distraction.

			Driving-related Outcomes								Statistical Analyses			
	Authors	year	speed	lane position	reaction time	perception / situation	headway	accident probability	eye glance	acceleration / deceleration	Descriptive statistics	One way ANOVA	Two way ANOVA	Repeated measures ANOVA
1	Laberge et.al	2004	•	•								•		
2	Drews et.al	2008	•	•								•		
3	Charlton	2009	•				•	•					•	
4	Yannis et.al	2011	•	•	•			•						•
5	Hunton andRose	2005						•				•		
6	Horbery et al	2006	•										•	
7	Reed-Jones et	2008	•					•				•		
8	Yannis et.al	2011	•	•	•			•				•		
9	Rakauskas et al	2004	•	•				•					•	
10	Kass et al	2007										•		
11	Bruyas et al	2009												•
12	Reimer et al	2010	•			•				•		•		
13	Schlehofer et al	2010											•	
14	Ma and Kaber	2005	•	•			•					•		
15	Beeder and Kas	2006	•	•	•								•	
16	McKnight and Mc	1993				•						•		•
17	White et al	2010						•				•		•
18	Maciej et al	2011												
19	Noy et al	2004	•									•		•
20	Donmez et al	2006									•	•		
21	Donmez et al	2008	•	•			•	•	•			•		•
22	Liang et al	2010		•		•						•		•
23	Fofanova et al	2011	•									•	•	
24	Muhrer et al	2011	•				•						•	
25	Metz et al	2011							•					
26	Kaber et al	2012										•		
27	Zhang et al	2012	•						•					•
28	Hatfield et al	2008	•	•		•		•						•
29	Chisholm et al	2008		•		•			•			•		
30	Garay-Vega et al	2010							•					•
31	Young et al	2012	•	•								•		
32	Hughes et al	2012	•	•										•
33	Jamson et al	2005												•
34	Donmez et al	2007	•							•		•		
35	Reyes et al	2008			•					•		•		•
36	Jamson et al	2010	•	•								•		•
37	Benedetto et al	2011			•							•		•
38	Birrell et al	2011	•				•			•		•		•
39	Terry et al	2008			•		•						•	
40	Young et al	2009		•					•			•		
41	Bendak et al	2010	•						•		•			
42	Edquist et al	2011		•					•			•		
43	Rakauskas et al	2008										•		
44	Young et al	2008	•	•									•	
45	Harrison et al	2011	•					•				•		

Research questions

1. Design and implementation of a simulator experiment aiming to deal with the majority of **limitations** that have been noted in the assessment of the examined simulator studies. The basic limitations found in the literature are the following:
   - Large and representative sample
   - Randomisation of trials
   - Adequate practice drive
   - Investigation of an optimum number of driving factors

2. Need to demonstrate a composite driving performance measure in order to examine driver distraction as a **multidimensional phenomenon**

3. Development and application of an **innovative statistical analysis methodology**

4. Estimation of the **combined effect** of distraction sources, driver as well as road and traffic environment characteristics directly on driving performance.

Driving simulator experiment

A common simulator experiment in the framework of two research projects:

- **Distract** - Analysis of causes and impacts of driver distraction
- **DriverBrain** - Analysis of the performance of drivers with cerebral diseases

distrACT

driverBRAIN

An **interdisciplinary** research team:

- Dpt. of Transportation Planning and Engineering NTUA
- Dpt. of Neurology of the University of Athens Medical School, UoA
- Dpt. of Psychology, School of Philosophy, Pedagogy and Psychology, UoA

Department of Transportation Planning and Engineering, NTUA

Department of Neurology, Psychiatry and Social Medicine, UoA

Department of Psychology, UoA

Driving simulator characteristics

Technical characteristics

- Foerst Driving Simulator FPF
- 3 LCD wide screens 40”
- total angle view 170º
- driving position and support base

Driving simulator validation

- Research in order to compare the driving performance of young drivers in normal and simulation driving conditions
- 31 young drivers aged 20-30 participated in an experimental process including driving both in a driving simulator as well in real traffic conditions

<u>Results</u>

- Absolute values of drivers' performance vary between simulated and real driving conditions
- Relative differences remain mostly the same

Exclusion criteria

Driving criteria

- Have a valid driving license
- had driven for more than 3 years
- had driven more than 2500km during the last year
- had driven at least once a week during the last year
- had driven at least 10km/week during the last year

Neurological criteria

- not had important psychiatric history for psychosis
- not had any important kinetic disorder that prevent them from basic driving moves
- not had dizziness or nausea either as a driver or as a passenger
- not be pregnant
- not be an alcoholic or had any other drug addiction
- not had any important eye disorder that prevent him from driving safely
- not had any disease of the Central Nervous System

Design of experiment (1/2)

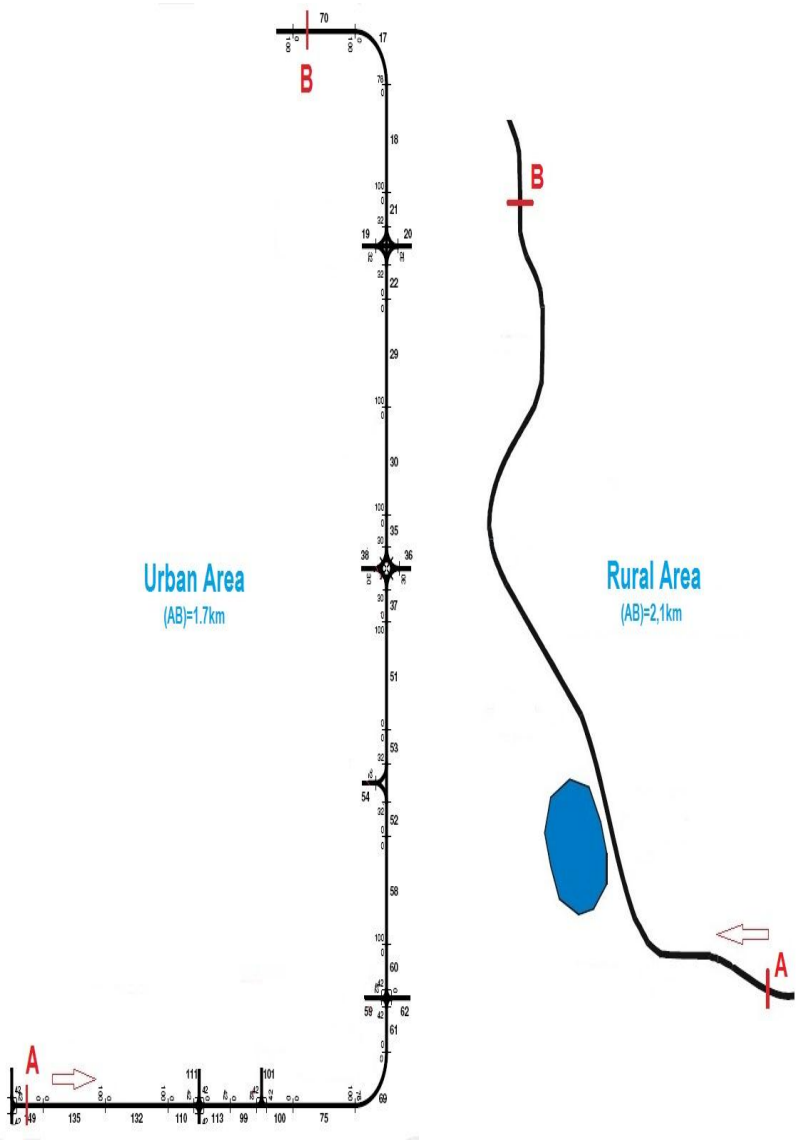
The design of the driving scenarios is a central component of the present PhD thesis and includes:

Area type

- Rural area
  2,1 km long, single carriageway and the lane width was 3m, with zero gradient and mild horizontal curves
- Urban area
  1,7km long, lane width 3,5m, separated by guardrails

Distraction conditions

- No distraction
- Cell phone use
- Conversation with the passenger



Design of experiment (2/2)

Traffic scenarios

- Low traffic
  Αντιστοιχεί σε μέσο κυκλοφοριακό φόρτο
  Q_L=300 vehicles/hour
- High traffic
  Αντιστοιχεί σε μέσο κυκλοφοριακό φόρτο
  Q_H=600 vehicles/hour

Unexpected incidents

- Child crossing the road
- Sudden appearance of an animal

Randomisation

- The purpose of randomisation is to remove bias and other sources of extraneous variation, which are not controllable

	Urban area		Rural area	
	Q_L	Q_H	Q_L	Q_H
No distraction	√	√	√	√
Cell phone use	√	√	√	√
Conversation with the passenger	√	√	√	√

Familiarisation

During the **familiarization** with the simulator, the participant practiced in:

- handling the simulator (starting, gears, wheel handling etc.)
- keeping the lateral position of the vehicle
- keeping stable speed, appropriate for the road environment
- Braking and immobilization of the vehicle

During this practice drive, two **unexpected incidents** took place.

The following criteria must be verified (there is **no time restriction**) before the participant moves on to the next phase of the experiment:

Procedure of experiment

Researcher – coordinator of the experiment:

- the oral briefing and the delivery of the instructions to the participant
- assisting the participant during their familiarization drive
- assisting the participant to fill in the Self-assessment and Memory questionnaire
- filling a checklist (see Annex) for the control of the experiment with any comments related to anything remarkable regarding the driving of the participant
- the monitoring for and handling of simulator sickness
- the accomplishment of the driving simulator experiment
- assisting the participant in any other issue

Researcher responsible for:

- performing the distraction tasks during the experiment: the conversation task and the phone call with the participant
- assisting for any other secondary issues during the experiment
- organizing the files generated from the participants' driving and editing statistically the data

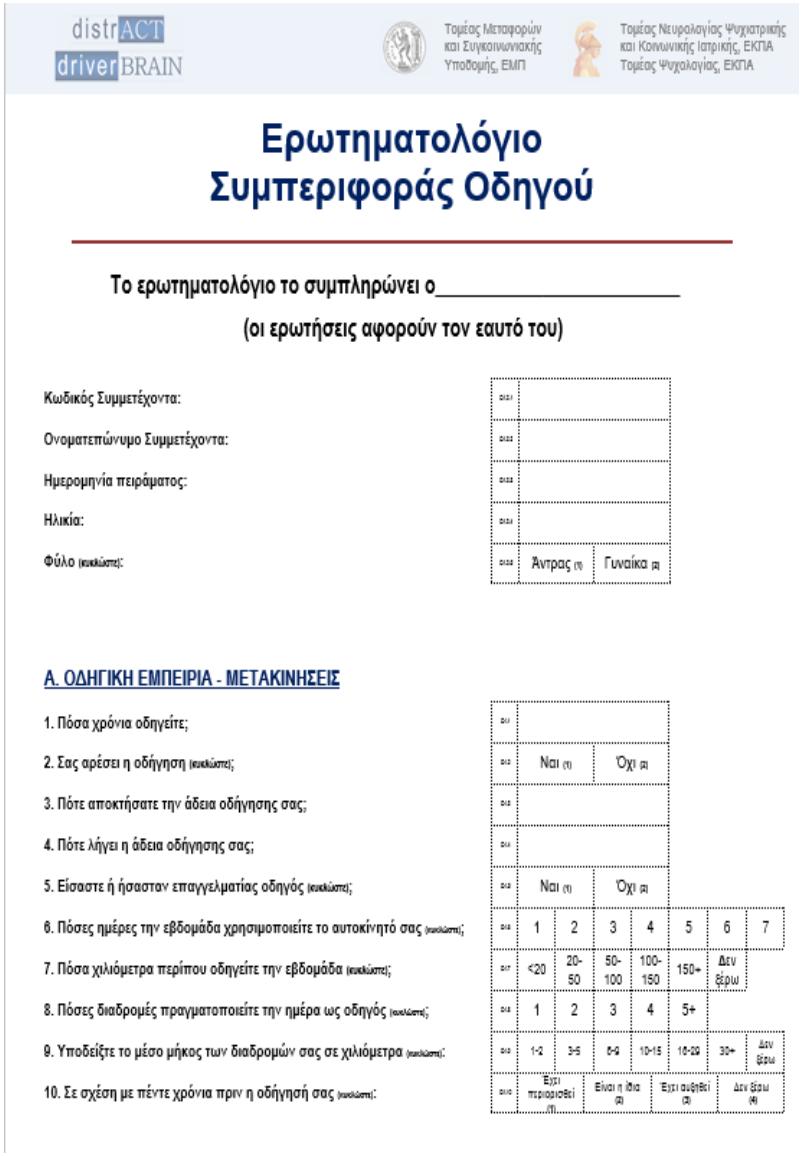
Questionnaires

Driving behaviour questionnaire

- Driving experience - car use
- Self -assessment of the older driver
- Distraction-related driving habits
- Emotions and behaviour of the driver
- Anger expression inventory during driving
- History of accidents, near misses, and traffic violations

Self-Assessment and memory questionnaire

- Memory
- Self assessment
- Driving skills



distrACT driverBRAIN

Τομέας Μεταφορών και Συγκοινωνιακής Υποδομής, ΕΜΠ

Τομέας Νευρολογίας Ψυχιατρικής και Κοινωνικής Ιατρικής, ΕΚΠΑ
Τομέας Ψυχολογίας, ΕΚΠΑ

Ερωτηματολόγιο Συμπεριφοράς Οδηγού

Το ερωτηματολόγιο το συμπληρώνει ο_____

(οι ερωτήσεις αφορούν τον εαυτό του)

Κωδικός Συμμετέχοντα:

Ονοματεπώνυμο Συμμετέχοντα:

Ημερομηνία πειράματος:

Ηλικία:

Φύλο (κυκλώστε): Άντρας (1) Γυναίκα (2)

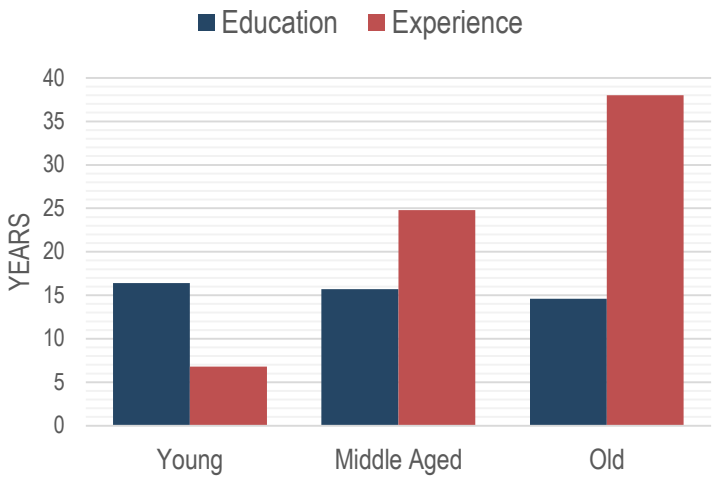
Α. ΟΔΗΓΙΚΗ ΕΜΠΕΙΡΙΑ - ΜΕΤΑΚΙΝΗΣΕΙΣ

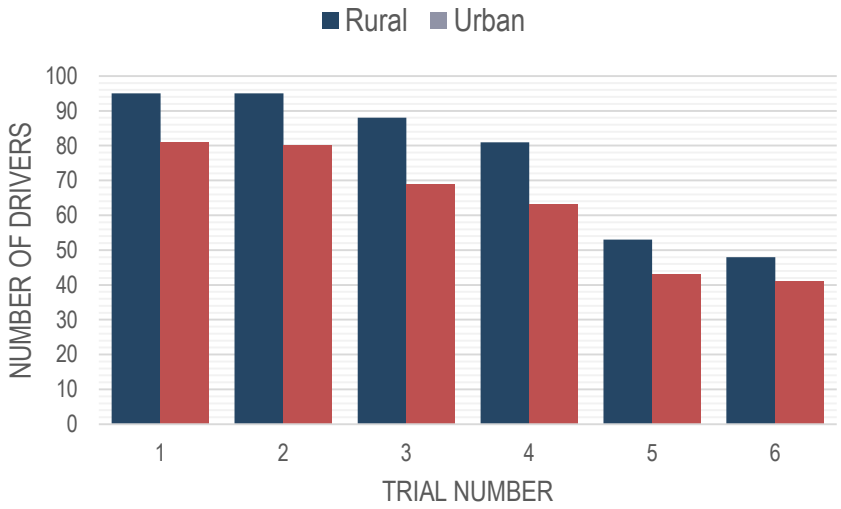
1. Πόσα χρόνια οδηγείτε;
2. Σας αρέσει η οδήγηση (κυκλώστε); Ναι (1) Όχι (2)
3. Πότε αποκτήσατε την άδεια οδήγησης σας;
4. Πότε λήγει η άδεια οδήγησης σας;
5. Είσαστε ή ήσασταν επαγγελματίας οδηγός (κυκλώστε); Ναι (1) Όχι (2)
6. Πόσες ημέρες την εβδομάδα χρησιμοποιείτε το αυτοκίνητό σας (κυκλώστε): 1 2 3 4 5 6 7
7. Πόσα χιλιόμετρα περίπου οδηγείτε την εβδομάδα (κυκλώστε): <20 20-50 50-100 100-150 150+ Δεν ξέρω
8. Πόσες διαδρομές πραγματοποιείτε την ημέρα ως οδηγός (κυκλώστε): 1 2 3 4 5+
9. Υποδείξτε το μέσο μήκος των διαδρομών σας σε χιλιόμετρα (κυκλώστε): 1-2 3-5 6-9 10-15 16-20 30+ Δεν ξέρω
10. Σε σχέση με πέντε χρόνια πριν η οδήγησή σας (κυκλώστε): Έχει περιορισθεί (1) Είναι η ίδια (2) Έχει αυξηθεί (3) Δεν ξέρω (4)

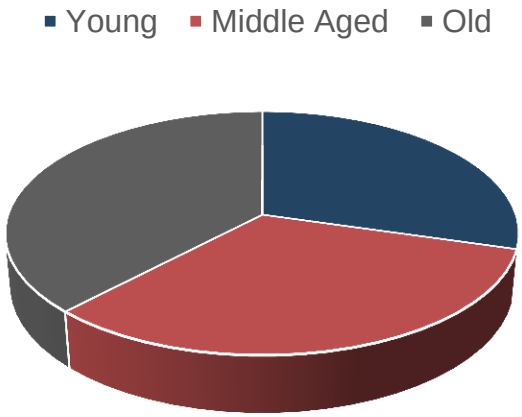
Sample characteristics

The sample of the analysis consists of **95 participants**

- 28 young drivers aged 18-34 years old
- 31 were middle aged drivers aged 35-54 years old
- 36 older driver aged 55-75 years old







Statistical analysis methodology

Data collected from the driving simulator experiment and the respective questionnaires are analysed by means of a **dedicated statistical analysis method**:

1. **Descriptive analysis**
   (correlation table, boxplots)

2. **Regression analysis**
   (6 general linear mixed models)

3. **Factor Analysis**
   (2 factor analysis)

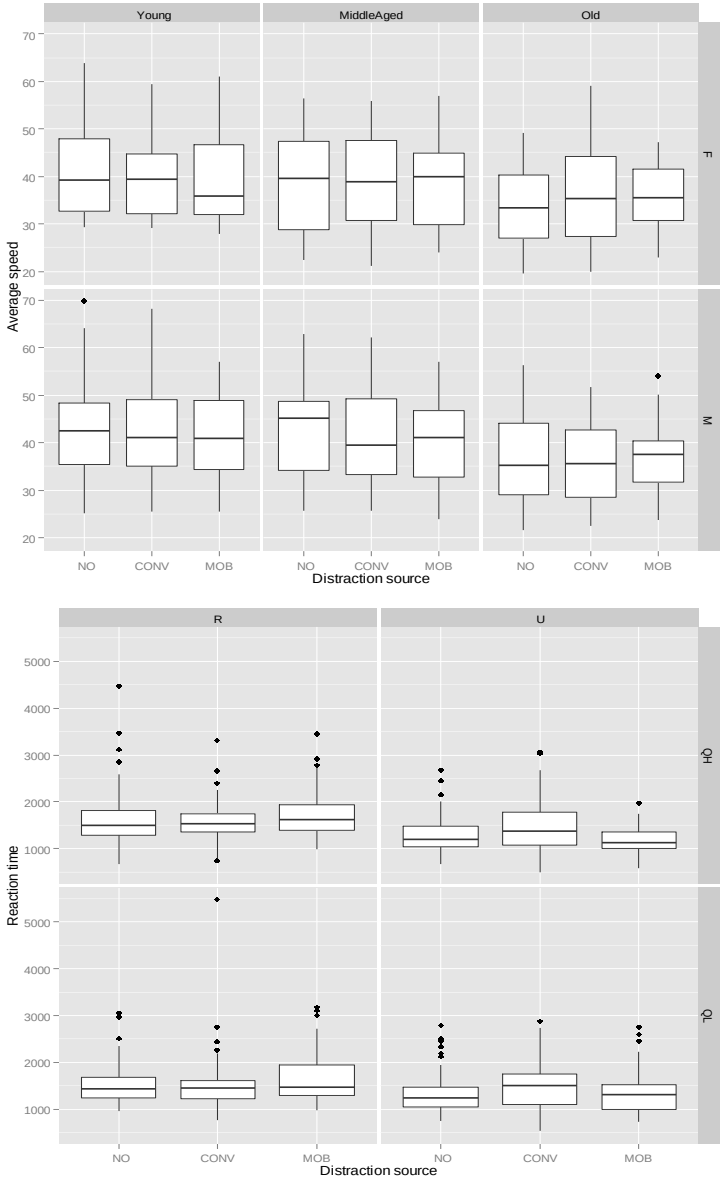
4. **Latent analysis**
   (4 structural equation models)

Descriptive analysis

- **Database** development
  - Type of variable
  - Min, max, average value

- Several **boxplots** are presented in order to explain the effect of specific driver, road and traffic parameters as well as the examined distraction sources on selected driving performance measures

- A **correlation table** is investigating any of a broad class of statistical relationships between driving simulator variables



Regression analysis

- Within the framework of regression analysis**, 6 general linear mixed models** are developed in order to identify several sets of explanatory variables that covary with specific driving performance measures of the driving simulator dataset.
- Average speed
- Reaction time
- Lateral position
- Average headway
- Speed variability
- Lateral position variability

Factor analysis

- Two factor analysis are developed in order to investigate which observed variables are most highly correlated with the common factors of **driving performance** and **driver error** and how many common factors are needed to give an adequate description of the data

- Regarding **driving performance**, 5 factors are best fitted in the specific database. The interpretation of the results revealed that the five factors are: lateral measures, speed measures, vehicle direction measures, headway as well as vehicle revolvation

- The variables that tend to explain better the "**Driver Error**" factor are: numbers of Outside Road Lines, Sudden Brakes and High Rounds per Minute

Structural Equation Models (1/2)

- Structural Equation Modeling is a very general, powerful **multivariate analysis** technique that includes several analysis methods

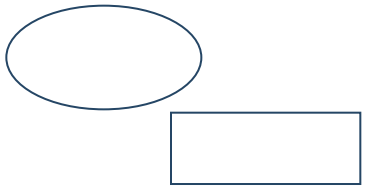
- SEM involves the evaluation of two models:

- **Measurement Model**
  - The part of the model that relates indicators to latent factors
  - The measurement model is the factor analytic part of SEM

- **Path model**
  - This is the part of the model that relates variable or factors to one another (prediction)
  - If no factors are in the model then only path model exists

Structural Equation Models (2/2)

Path diagram

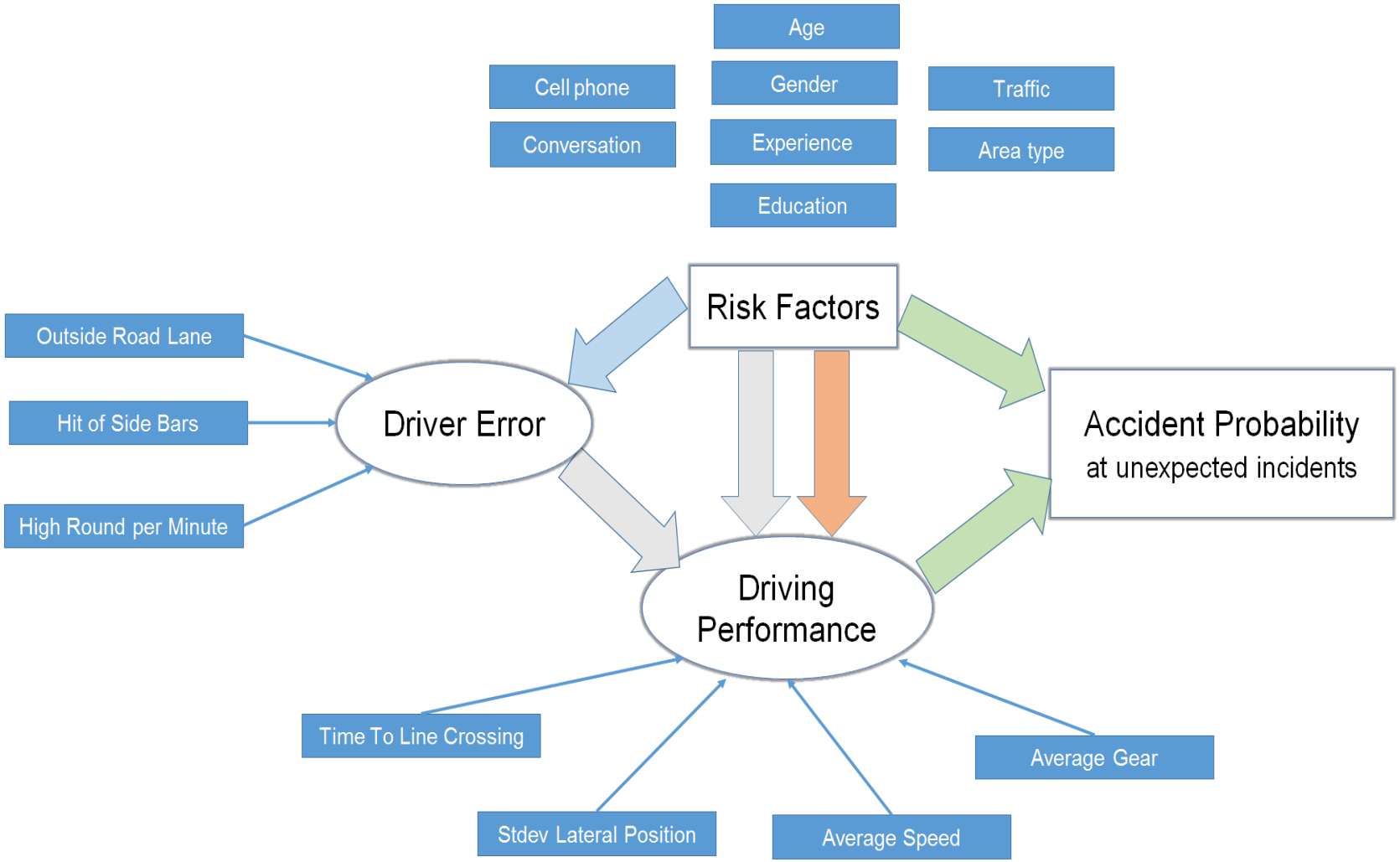


- Latent variables
- Observed variables
- Single-headed arrow →
  Regression Coefficient or factor loading
- Double headed arrow ↔
  Correlations

Goodness-of-fit measures

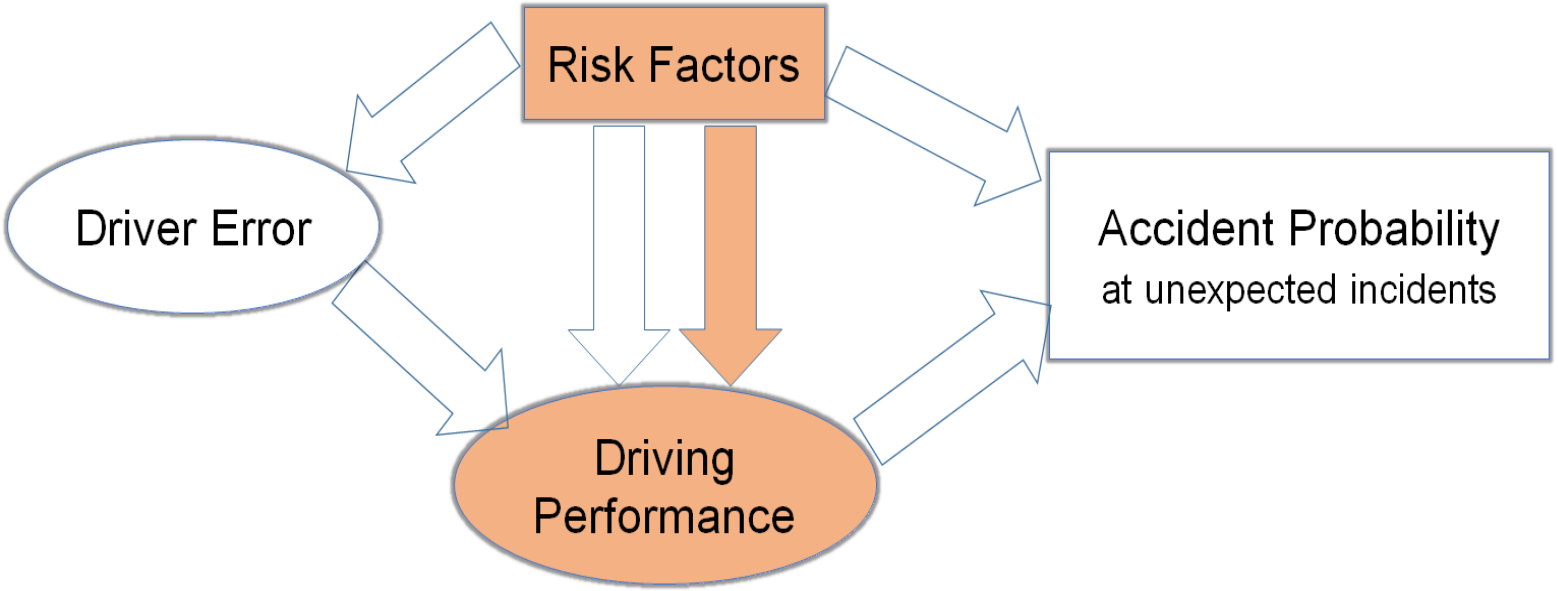
- Standardized Root Average Square Residual (SRMR) < 0,08
- Root Average Square Error of Approximation (RMSEA) < 0,08
- Comparative Fit Index (CFI) > 0,90
- Tucker Lewis Index (TLI) > 0,90

Latent analysis overview



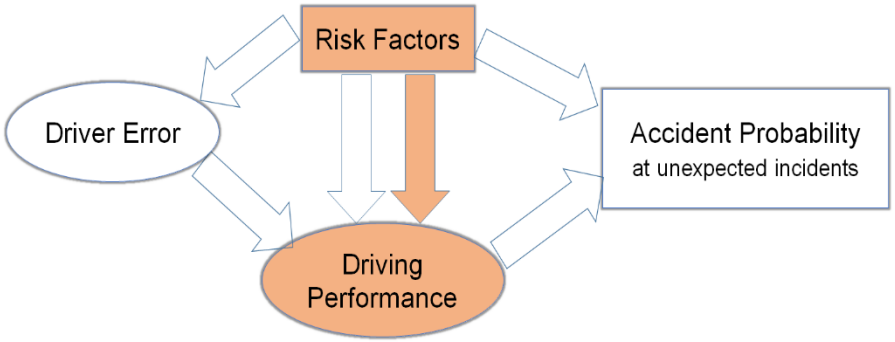
SEM regarding driving performance (1/3)

The latent variable reflects the underlying **driving performance** and the objective is the quantification of the impact of distraction, driver characteristics as well as road and traffic environment on driving performance

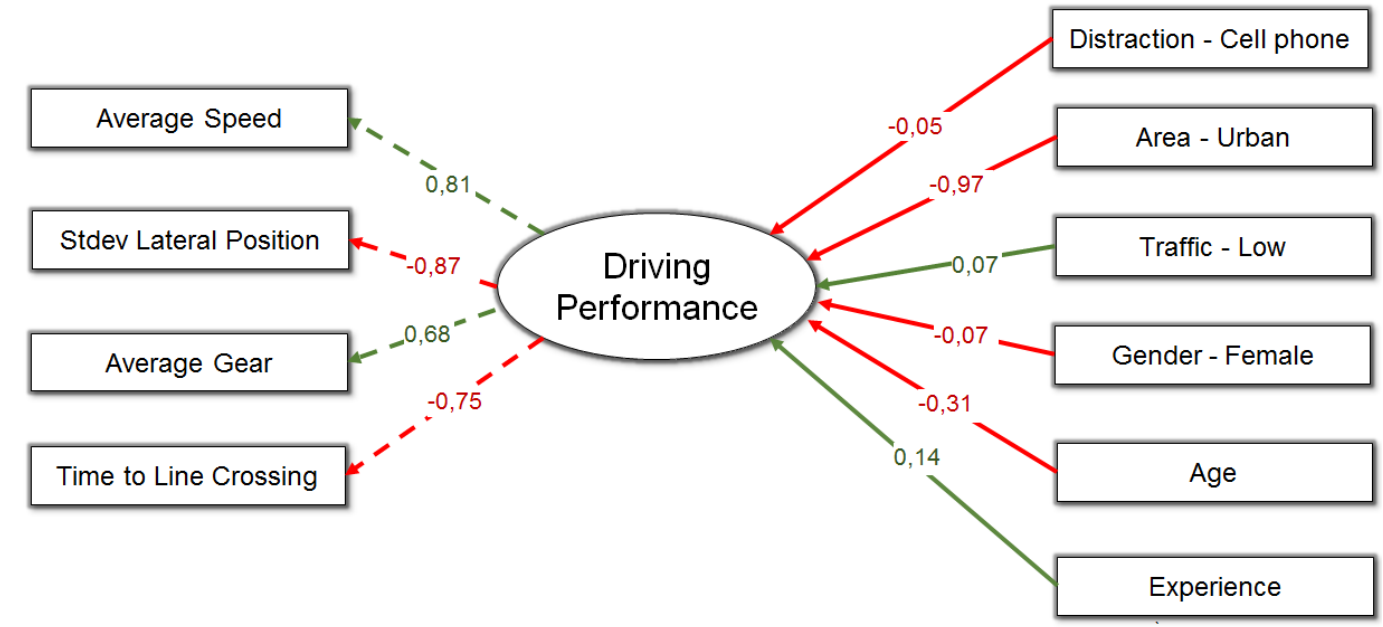


SEM regarding driving performance (2/3)

	Est.	Std.err	t value.	P(>|z|)
Latent Variable				
Driving Performance				
Average Speed	1,000	-	-	-
Stdev Lateral Position	-0,085	0,004	-23,909	0.000
Average Gear	0,048	0,002	21,887	0.000
Time to Line Crossing	-0,109	0,005	-19,972	0.000
Regressions				
Driving Performance				
Distraction – Cell phone	-1,099	0,342	-3,213	0.001
Area - Urban	-15,596	0,467	-33,410	0.000
Traffic - Low	1,123	0,285	3,943	0.000
Gender - Female	-1,154	0,303	-3,802	0.000
Age	-0,155	0,027	-5,755	0.000
Experience	0,083	0,032	2,630	0.009
Summary statistics				
Minimum Function Test	305,74			
Degrees of freedom	20			
Goodness of fit				
SRMR	0,061			
RMSEA	0,136			
CFI	0,867			
TLI	0,809			



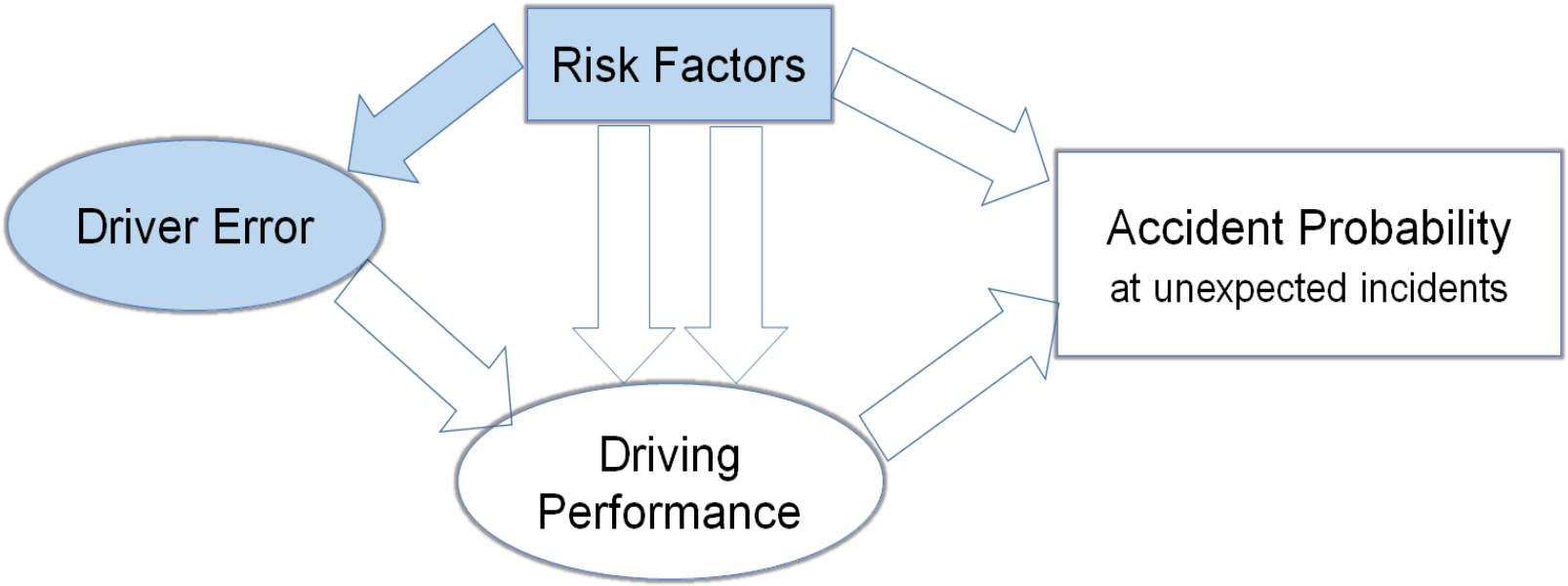
SEM regarding driving performance (3/3)



- The effect of **cell phone** on driving performance is definitely negative
- **Conversation with the passenger** does not has a statistically significant effect
- Risk factors that affect driving performance include driver characteristics (**age**, **gender**, driving **experience**), **area** type and **traffic conditions**

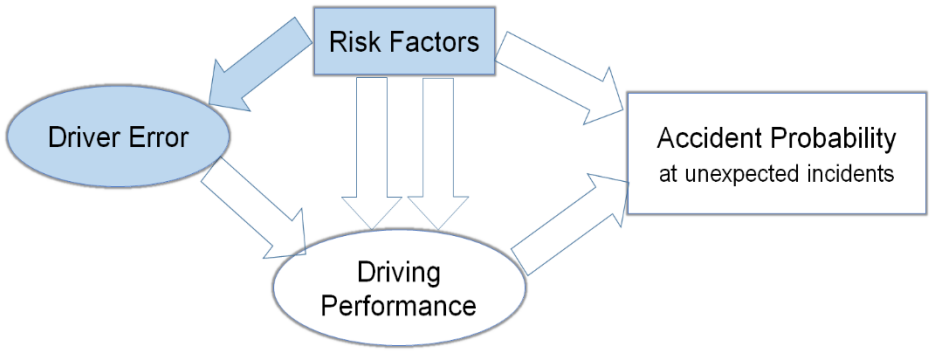
SEM regarding driver error (1/3)

The latent variable reflects the underlying **driver error** and the objective is the quantification of the impact of distraction, driver characteristics as well as road and traffic environment on driving error

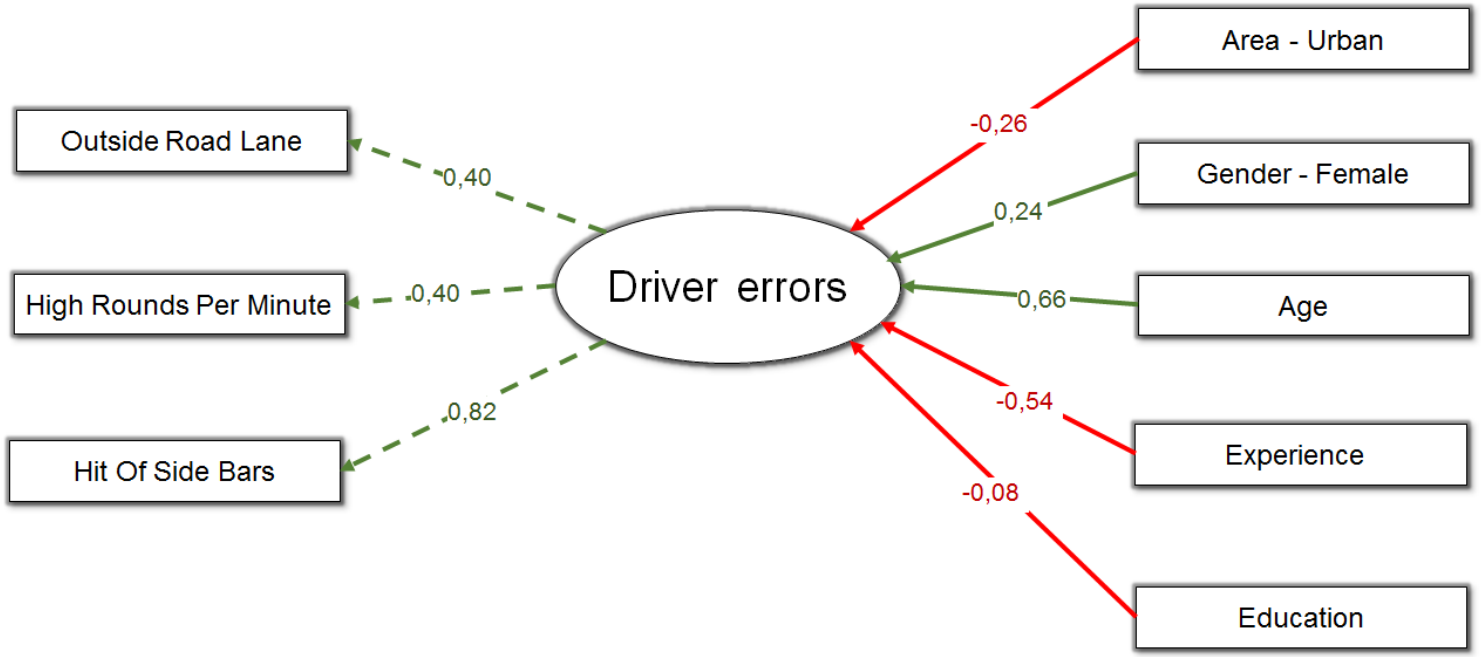


SEM regarding driver error (2/3)

	Est.	Std.err	t value.	P(>|z|)
Latent Variable				
Driving Error				
Hit Of Side Bars	1,000	-	-	-
Outside Road Lanes	0,741	0,257	2,887	0,004
High Rounds Per Minute	0,680	0,243	2,803	0,005
Regressions				
Driver Errors				
Gender - Female	0,359	0,076	4,739	0.000
Age	0,031	0,009	3,393	0.001
Area - Urban	-0,393	0,062	-6,383	0.000
Experience	-0,030	0,010	-3,050	0.002
Education	-0,021	0,010	-2,167	0.030
Summary statistics				
Minimum Function Test	62,19			
Degrees of freedom	10			
Goodness of fit				
SRMR	0,032			
RMSEA	0,096			
CFI	0,823			
TLI	0,682			



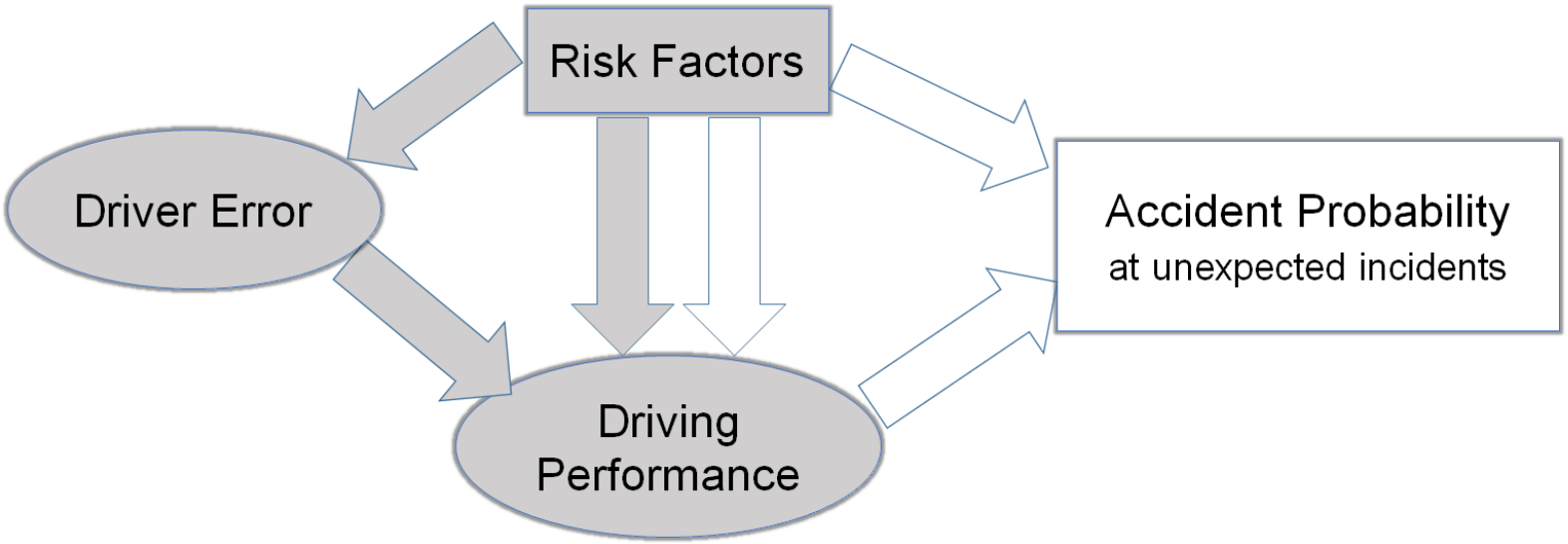
SEM regarding driver error (3/3)



- Neither conversing with a passenger nor talking on the cell phone has a statistical significant impact on driver error
- Risk factors that affect driver error include **gender**, **age**, **experience**, **education** and **area type**

SEM regarding driving performance and driver error (1/3)

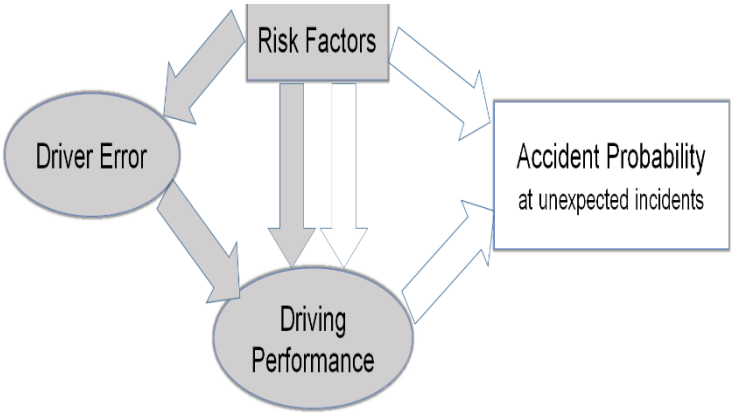
Two latent variables are created regarding driving performance and driver error while the objective of this analysis is the quantification of the impact of driving errors, distraction, driver characteristics as well as road and traffic environment on driving performance



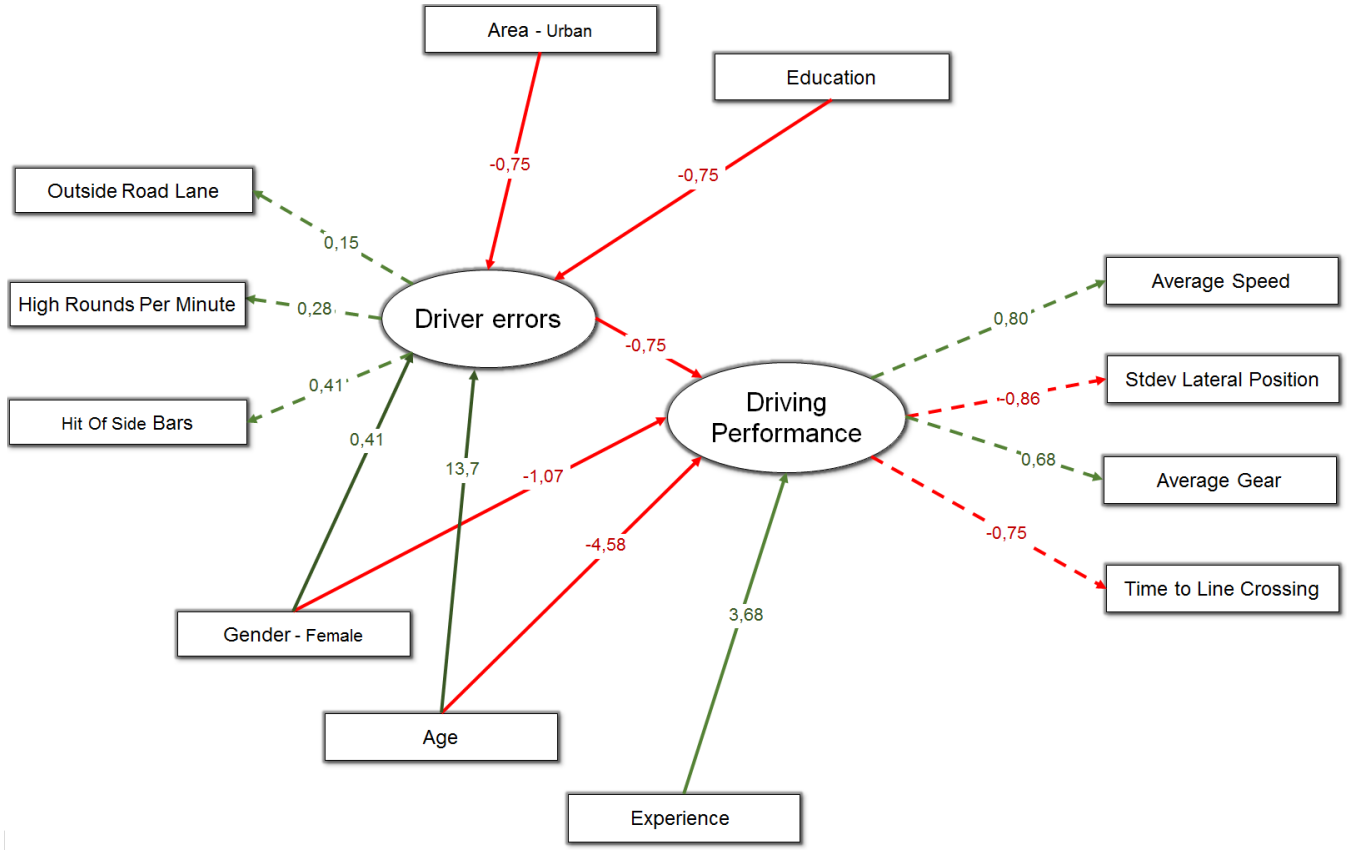
SEM regarding driving performance and driver error (2/3)

	Est.	Std.err	t value.	P(>|z|)
Latent Variable 1				
Driver Errors				
Hit Of Side Bars	1,000	-	-	-
Outside Road Lanes	0,547	0,214	2,559	0,010
High Rounds Per Minute	0,950	0,276	3,436	0,001
Latent Variable 2				
Driving Performance				
Average Speed	1,000	-	-	-
Stdev Lateral Position	-0,085	0,004	-23,117	0,000
Average Gear	0,049	0,002	22,043	0,000
Average TTL	-0,108	0,005	-20,114	0,000
Regression 1				
Driving Performance				
Driver Errors	-51,016	11,417	4,468	0.000
Gender – Female	-16,739	3,799	-4,407	0.000
Age	-2,244	0,681	-3,297	0.001
Experience	2,103	0,694	3,031	0.002
Regression 2				
Driver Errors				
Gender - Female	0,311	0,076	4,068	0.000
Age	0,042	0,010	4,125	0.000
Area - Urban	-0,300	0,068	-4,395	0.000
Experience	-0,040	0,011	-3,815	0.000
Education	0,004	0,001	3,174	0.002

Summary statistics	
Minimum Function Test	608,01
Degrees of freedom	40
Goodness of fit	
SRMR	0,088
RMSEA	0,158
CFI	0,793
TLI	0,711



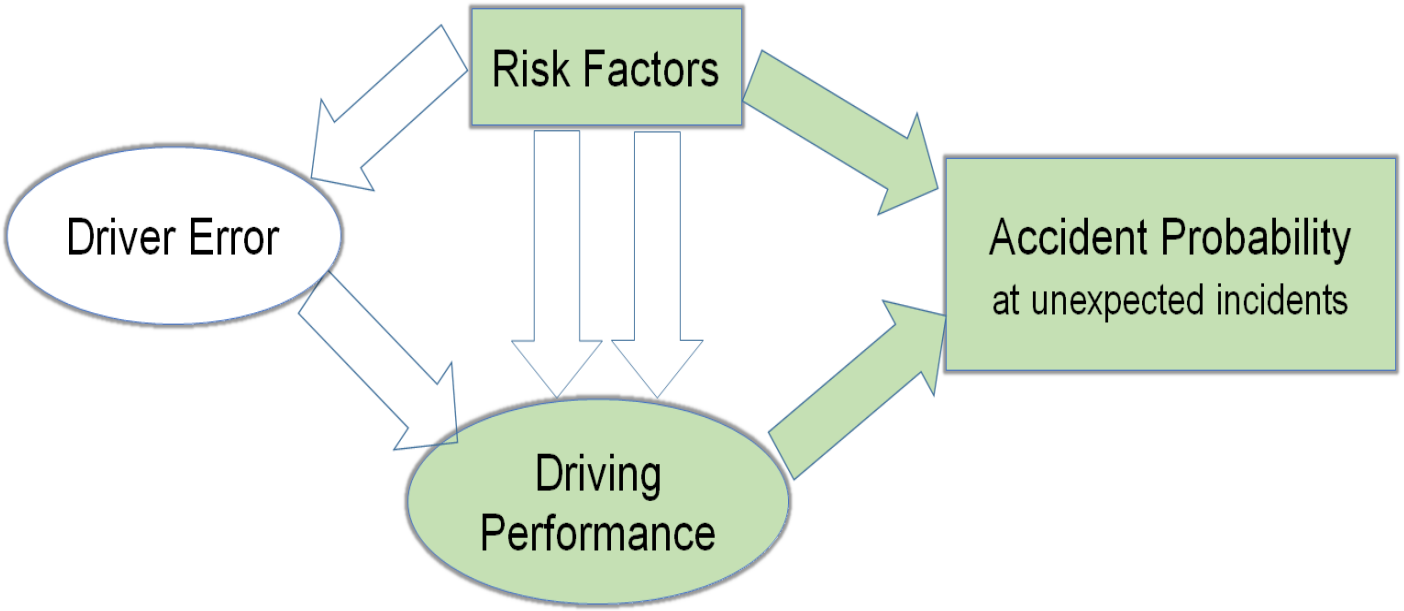
SEM regarding driving performance and driver error (3/3)



- Driver error is a crucial factor that negatively affects driving performance
- Neither **road characteristics** (area type, traffic conditions) nor the **distraction sources** examined (cell phone use, conversation with a passenger) have a significant impact on this model

SEM regarding accident probability (1/3)

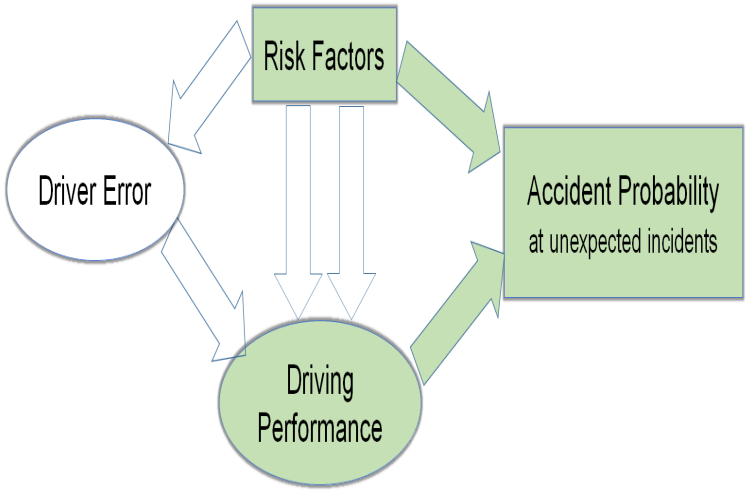
The latent variable reflects again the underlying driving performance of the participants and the objective is the quantification of the impact of driving performance, distraction, driver characteristics as well as road and traffic environment directly on **accident probability at unexpected incidents**



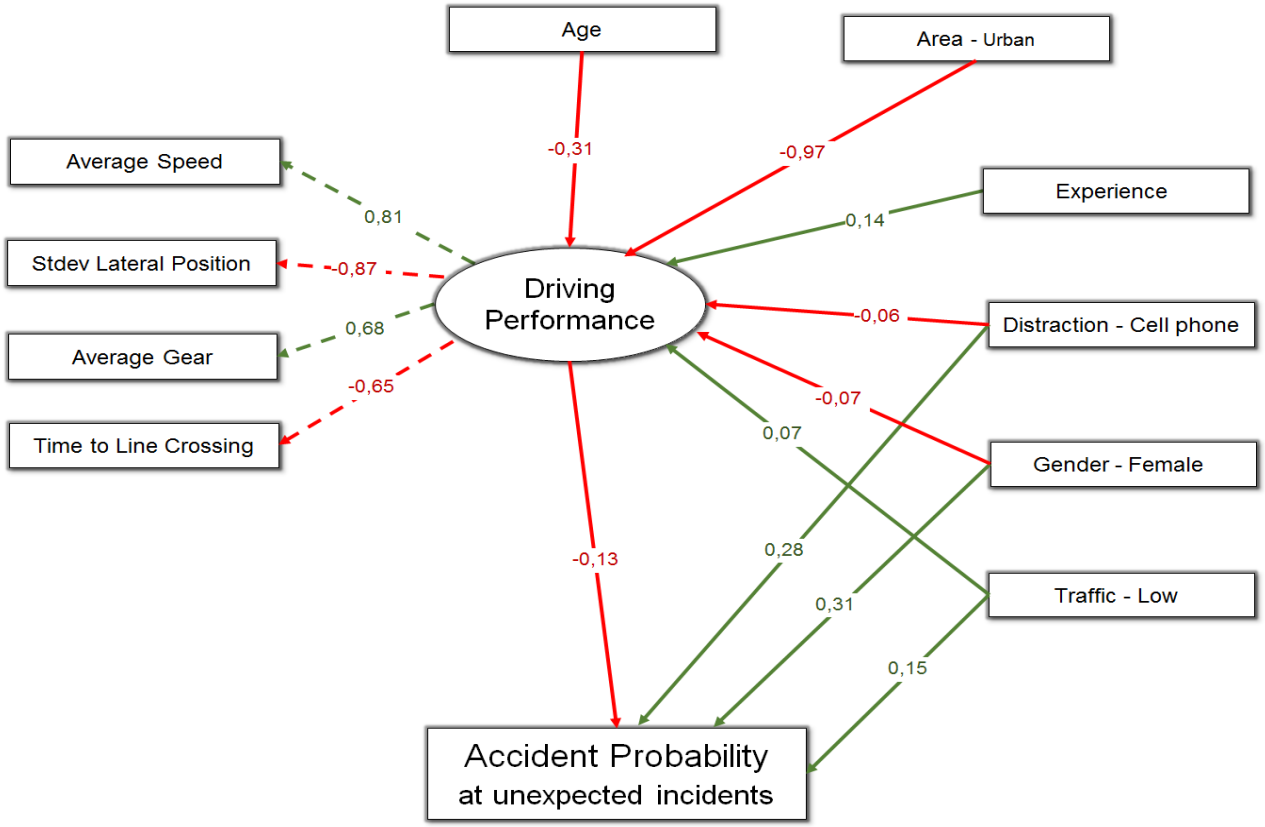
SEM regarding accident probability (2/3)

	Est.	Std.err	t value.	P(>|z|)
Latent Variable				
Driving Performance				
Average Speed	1,000	-	-	-
Stdev Lateral Position	-0,085	0,004	-23,803	0.000
Average Gear	0,048	0,002	21,836	0.000
Average TTL	-0,109	0,005	-20,046	0.000
Regression				
Accident				
Driving Performance	-0,007	0,002	-3,119	0.002
Gender - Female	0,074	0,034	2,198	0.028
Traffic – Low	0,104	0,033	3,142	0.002
Distraction – Cell phone	0,081	0,033	2,463	0.014
Regression				
Driving Performance				
Gender - Female	-1,147	0,307	-3,737	0.000
Area - Urban	-15,614	0,468	-33,386	0.000
Distraction – Cell phone	-1,099	0,343	-3,208	0.001
Traffic - Low	1,131	0,286	3,956	0.000
Age	-0,156	0,028	-5,593	0.000
Experience	0,083	0,032	2,557	0.011

Summary statistics	
Minimum Function Test	352,62
Degrees of freedom	31
Goodness of fit	
SRMR	0,061
RMSEA	0,136
CFI	0,867
TLI	0,807

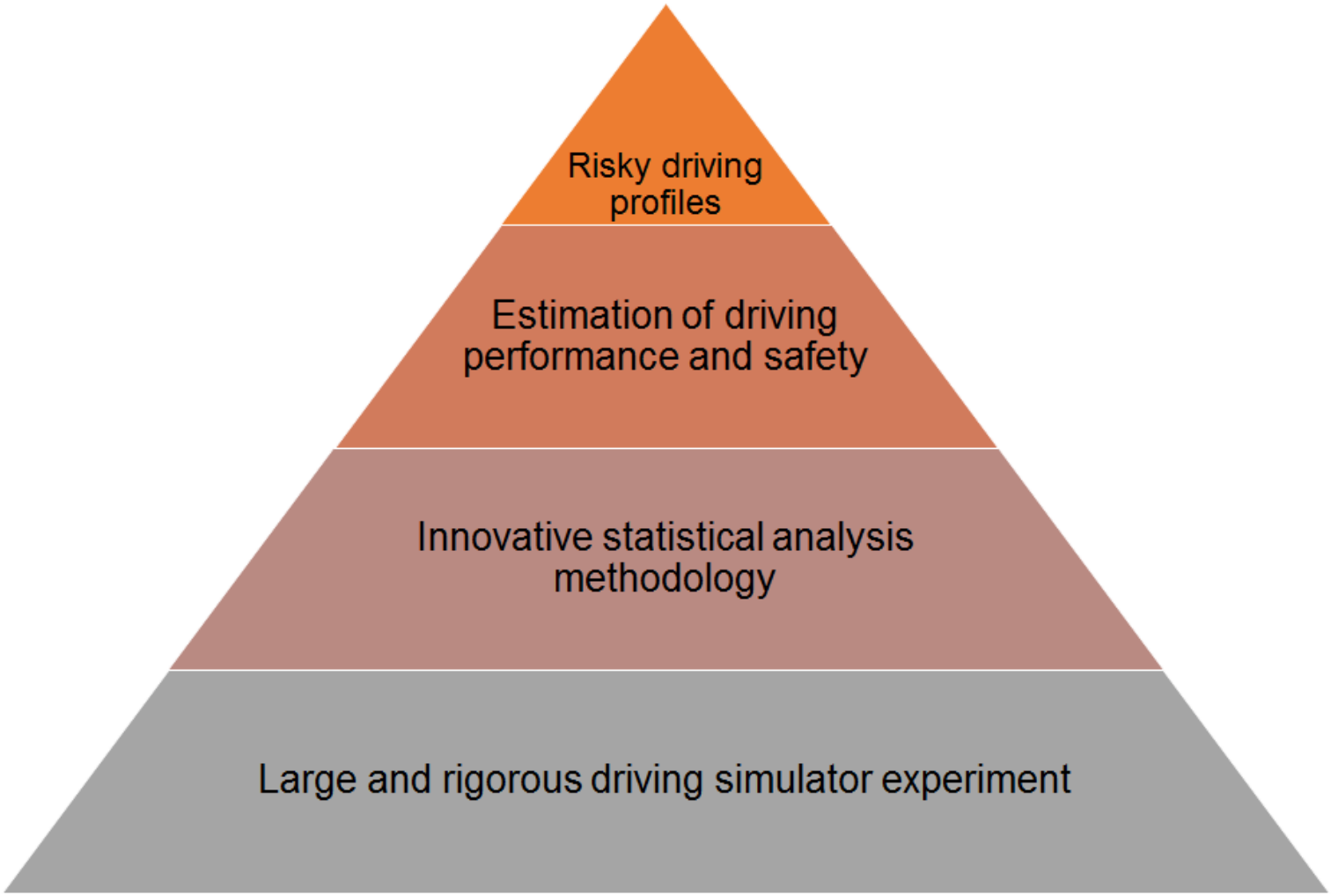


SEM regarding accident probability (3/3)



- **Cell phone** use has a negative effect on accident probability
- Drivers self-regulate their driving performance better while conversing with a passenger
- **Female** drivers at **low traffic** are more prone to accidents at unexpected incidents

Scientific contributions



Methodological contributions (1/2)

Design and implementation of a large and rigorous driving simulator experiment

The basic limitations found in the literature that the present experiment tackled are the following:

- Large and representative sample
- Randomisation of trials
- Adequate practice drive
- Investigation of an optimum number of driving factors

Methodological contributions (2/2)

- Development and application of an **innovative** statistical analysis methodology
- **Latent analysis** through Structural Equation models is implemented for the first time in the field of driving performance and traffic safety
- Estimation of the **combined effect** of distraction sources, driver as well as road and traffic environment characteristics directly on driving performance

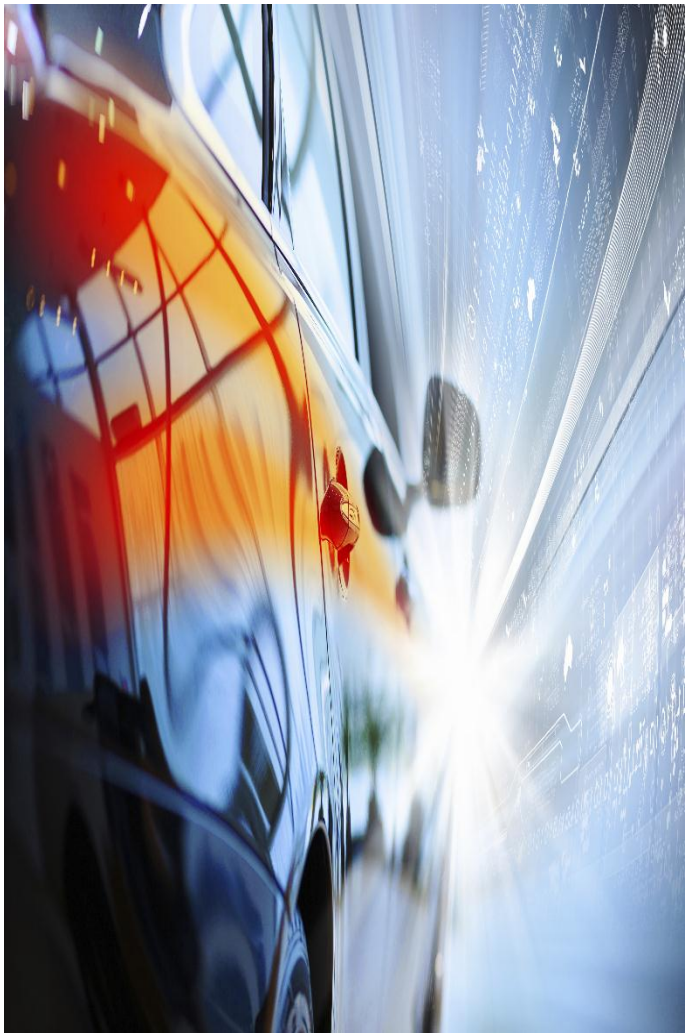
Key research findings (1/2)

- Results regarding the effect of **driver distraction** indicate the different effect on driving performance between cell phone use and conversation with the passenger
- **Driver characteristics** play the most crucial role in driving performance (gender, age, experience)
- Driving performance is worst in urban areas and high traffic conditions probably due to the complex **driving environment**

Key research findings (2/2)

Development of risky driver profiles regarding driver error and accident probability at unexpected incident. Results indicate that:

- more likely to commit driving errors are **young or old female drivers at urban areas**
- more likely to be involved in an accident at an unexpected incident are **female drivers in low traffic conditions while talking on the cell phone**



Further research

- Investigation of the effect of other parameters such as **alcohol**, **fatigue** etc. on driving performance through latent analysis
- Development of Structural Equation Model on different experimental methods (**Naturalistic experiments, field test etc.**)
- Further investigation of the parameters that affect the **compensatory** behaviour of the driver
- Investigation of different **types of cell phone** use such as a hands-free, bluetooth, typing an sms etc.)

National Technical University of Athens
School of Civil Engineering
Department of Transportation Planning and Engineering

Risk factors, driver behaviour and accident probability. The case of distracted driving.

Doctoral Dissertation

Panagiotis Papantoniou

Athens, August 2015