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
Civil Transportation Enginner, MSc

Advisory board:
G. Yannis, Professor, NTUA
J. Golias, Professor, NTUA
E. Vlahogianni, Assistant Professor, NTUA

Athens, August 2015

Extended abstract

The objective of the present PhD thesis is the **analysis of the effect of road, traffic and driver risk factors on driver behaviour and accident probability**, with particular focus on distracted driving. For this purpose, a specially developed methodology is implemented which consists of **4 discrete steps**:

- The first step concerns a comprehensive literature review fully covering the research topics examined.
- In the second step a methodological review is taking place regarding driving performance measures and statistical analysis techniques.
- In the third step, a large driving simulator experiment is carefully designed and implemented.
- In the fourth step an advanced statistical analysis methodology is developed including four different types of analyses.

Beginning with the **first step**, an extensive literature review is carried out, investigating in a comprehensive way the research topics **topics** examined: driving behaviour, driver distraction and its assessment methods, driving simulator characteristics as well as driving simulator studies on driver distraction.

A major part of the literature review consisted of an exhaustive review on **driving simulator studies on driver distraction** indicating that although simulator studies on driver distraction provide useful insights into how driver, vehicle, and roadway characteristics influence distracted driving behaviour and safety, the design and implementation of such experiments is very often inconsistent and they do not always conform to experimental design principles. On the basis of the **comparative assessment** of these studies, it is found that at the majority of studies, the most common distraction sources examined are cell phone use, conversation with passengers and visual distraction, as well as their comparisons. Most experiments are based on very small samples, limited to rural road environment, with non-explicit (if at all) simulation of ambient traffic. No pattern could be identified as regards the selection of number and duration of trials. Moreover, it is a matter of some concern that often the size of the experiment is not adequately adjusted to the sample size in several studies.

The **second step** of the present PhD thesis concerns the choice of the methodological approach allowing to address in an innovative way the research challenges mentioned above. For this purpose, an additional targeted literature review took place in order to investigate the key driving performance measures examined in driver distraction research as well as the statistical analyses implemented in the scientific field of driver distraction.

Results indicate that while driver distraction is a **multidimensional phenomenon,** which means that no single driving performance measure can capture all effects of distraction and the selection of the examined measure should be guided by the nature of the task examined as well as the specific

research questions. However, in the literature different driving performance measures are examined in different studies, most often tackling only specific aspects of driving performance. Consequently, the need for a composite driving performance measure is demonstrated.

The **third step** concerns the design and implementation of a large driving simulator experiment, allowing to address the complex challenhges of this PhD thesis. All individual experiment parts are carefully designed and executed tackling the limitations and needs identified in similar driving simulator experiments reviewed in the previous chapters.

Within this framework, **95 participants** were asked to drive under different types of distraction (no distraction, conversation with passenger, cell phone use) in different road (urban/rural) and traffic conditions (high/low). Each participant aimed to complete 12 different driving trials, while in each trial, 2 unexpected incidents were scheduled to occur at fixed points along the drive. The above stages were designed on the basis of parameters and criteria shown to be important in the literature, as well as design principles that were appropriate for the research assumptions and objectives of the present research. After the driving simulator tasks, participants were asked to fill in two questionnaires. The first Questionnaire concerned their driving habits and their driving behaviour while the second was a Self-Assessment Questionnaire that covered aspects related to the driving simulator experience.

In the **fourth step**, the data collected from the driving simulator experiment and the respective questionnaires are analysed by means of an innovative statistical analysis method. The overall statistical method consists of four types of analyses.

- In the first analysis, the large size of the dataset makes the **descriptive analysis** of a large number of variables essential. Within this framework, an overview of all variables which are provided by the driving simulator is provided together with a correlation table. Then, several boxplots are presented investigating the effect of specific driving characteristics such as age, gender, area and traffic conditions on different distracted situations on selected driving performance measures.

- Then, in the framework of the explanatory analysis, the development of **regression models** takes place (general linear models and general linear mixed models) regarding key performance parameters such as average speed, reaction time of drivers at unexpected incidents, lateral position, average headway, speed variability, and lateral position variability. Such models are often used in driver distraction analysis in order to estimate the effect of distraction sources and driving characteristics on specific driving performance parameters and indirectly on driving behaviour and road safety.

- Then, **factor analysis** is implemented, as a first step towards the development of latent variables within the framework of the structural

equation models, regarding driving performance and driver errors in order to investigate which observed variables are most highly correlated with the common factors and how many common factors are needed to provide an adequate synthesis of the data.

- Finally in the fourth type of analysis, consisting as the central component of the statistical analysis of the present PhD thesis is taking place focusing to the development and application of structural equation models for the first time in the scientific field of driver distraction. Within the framework of latent analysis, a sequence of four **Structural Equation Models** is developed and applied aiming to investigate the quantification of the impact of driver distraction, driver characteristics as well as road and traffic environment directly on driving performance, driver errors, and accident probability at unexpected incidents.

  The sequence of the **four different structural equation models** developed is described graphically in the next figure (each colour represents a different SEM) and explained below:

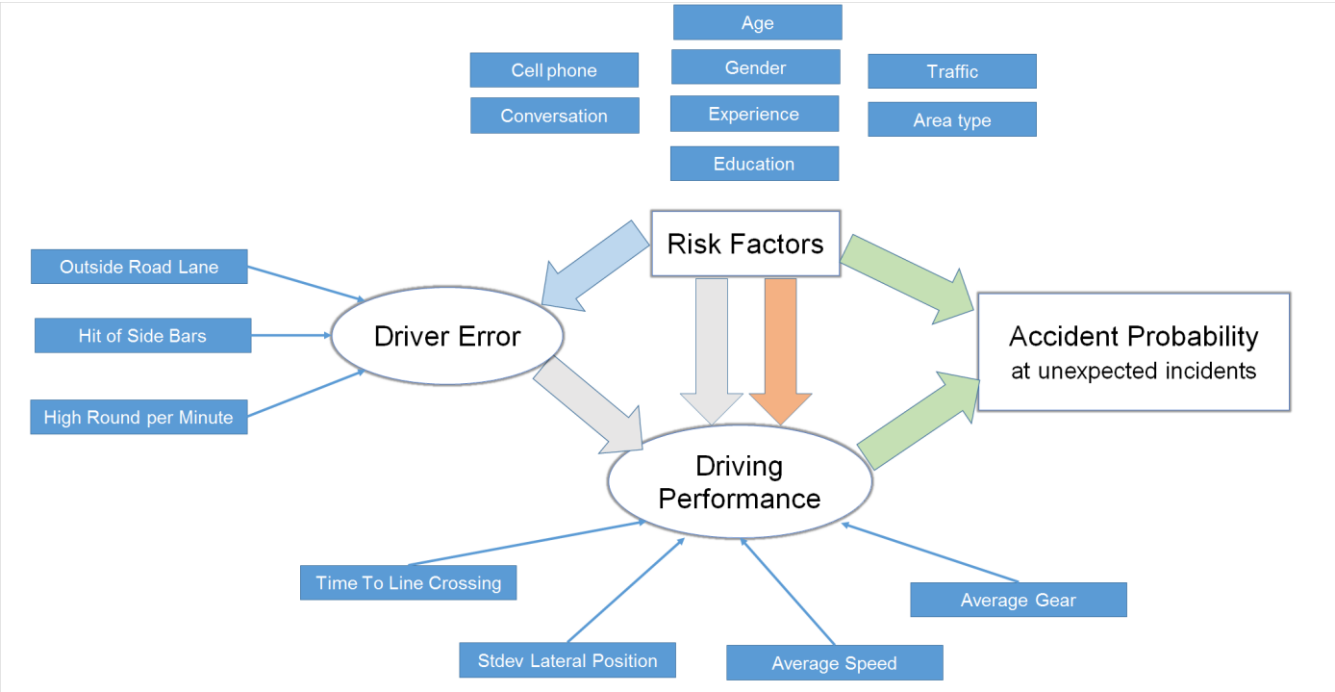

Figure 1 Graphical approach of latent analysis

- In the first SEM (orange arrow), 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.
- In the second SEM (blue arrow), 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 errors.
- In the third SEM (grey arrow), 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.

- In the fourth SEM (green arrow), 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**.

The innovative outcome of the present PhD thesis consists of **four original scientific contributions** as presented here after (see figure 2). It should be noted that the first two scientific contributions refer to the methodological contribution of the research while the third and the fourth are the key research findings of this PhD. The four original scientific contributions are the following:

- A large and rigorous driving simulator experiment
- An innovative statistical analysis methodology introducing latent analysis in driving performance and traffic safety
- The estimation of the combined effect of driver distraction, road, traffic and driver risk factors on driving performance
- The development of a set of risky driving profiles regarding driver errors and accident probability at unexpected incidents

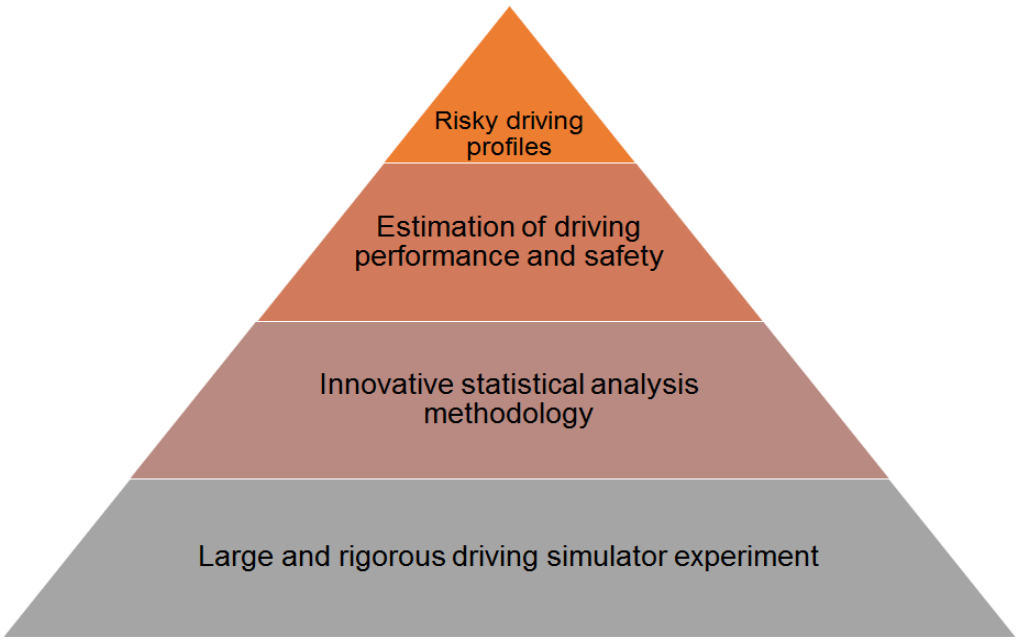

Figure 2 Four original scientific contributions of the PhD

The **first** scientific contribution concerns the design and implementation of **a large and rigorous driving simulator experiment** and consists the basis of the originality of the overall research**.** The design and implementation of this experiment is a central component of the present PhD thesis and it is based on all the respective literature reviews aiming to deal with the majority of

limitations that have been noted in the assessment of the examined simulator studies on driver distraction. 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

The **second** original scientific contribution of the present PhD thesis concerns the development and application of an **innovative statistical analysis methodology**. More specifically, latent analysis through structural equation models is implemented for the first time in the field of driving performance and traffic safety. Latent analysis allowed an important scientific step forward from piecemeal analyses to a sound combined analysis of the interrelationship between risk factors (including driver distraction), driving performance, driver error and accident probability. For the purpose of this research, two latent variables were created: a) **driving performance** variable reflecting the underlying driving performance of the participants (on the basis of several observed driving measures such as average speed, lateral position variability, average gear, time to line crossing) and b) **driver errors** variable reflecting the driving errors of the participants (on the basis of variables indicating driving errors such as hit of side bars, outside road lanes, high rounds per minute.

The **third original scientific contribution** of the present PhD thesis concerns the estimation of the combined effect of distraction sources, driver as well as road and traffic environment characteristics directly on driving performance.

More specifically, the development and application of the two first structural equation models, allowed the quantification of impact of several risk factors directly on the latent variable which underlines driving performance. Within this analysis, results regarding the effect of driver distraction indicate the different effect on driving performance between cell phone use and conversation with the passenger.

Conversation with the passenger was not found to have a statistically significant effect proving that drivers do not change their overall performance significantly while conversing with a passenger compared to undistracted driving. This finding can be explained by the assumption that the passengers are able to follow the road and traffic conditions and the related workload of the driver and adjust their interventions (distraction) to the driver. On the other hand the effect of cell phone on the overall driving performance was proved to be negative indicating the crucial role of cell phone use on driver behaviour and accident probability.

The change on driving performance of drivers talking on the cell phone is based on two opposing reasons. Firstly, cell phone use while driving distracts drivers in several ways including physical distraction (the driver has to use

one hand in order to manipulate the telephone), visual distraction (cell phone use is consisted of prolonged and repeated glances to the cell phone) and cognitive distraction (involves lapses in attention when two mental tasks are performed at the same time). On the contrary, **compensatory distracted behaviour** is occurring which means that drivers while talking on the cell phone feel insecure and change their performance in order to counterbalance the distraction activity. Results confirm the initial hypothesis that the overall balance regarding the effect of cell phone use on driving performance and accident probability is negative.

Finally, the **fourth original scientific contribution** of the present PhD thesis concerns the development of certain risky driving profiles as resulted from the application of the two other latent models regarding **driver errors** as well as **accident probability** at unexpected incidents.

Regarding the effect of distraction on driving errors, neither conversing with a passenger nor talking on the cell phone were found to have a statistically significant impact on driver errors. Based on the finding of the present research the effect of driver characteristics as well as of area type is much higher than the effect of distraction on driving errors. Drivers in the framework of compensatory behaviour are more concentrated when being distracted and seem that they fall in less driving errors. Consequently, **the increased accident risk of distracted driver is due to other factors than their errors**; e.g. inability to cope with the errors of other drivers or other incidents maybe due to increased reaction time.

According to the second latent analysis, accident probability is estimated as the probability for the driver to have an accident at an unexpected incident. The findings of the present PhD thesis indicate that cell phone use has a statistically significant negative effect on accident probability demonstrating that drivers while talking on the cell phone find it difficult to handle an unexpected incident and as a result are more likely to get involved in an accident. This is probably explained by the fact that at unexpected incidents risk compensation strategies of the driver can not counterbalance the higher reaction time due to distraction. On the other hand, drivers (and passengers) self-regulate their driving performance better while conversing with a passenger and as a consequence react better and are less involved in accidents at unexpected incidents.

Summarising the findings from both structural equation models two risky driving profiles can be created as follows:

- **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.**

Overall, the proposed methodological approach and statistical techniques of the present research, are proved to significantly improve the potential of the analysis and provide new insights on driver behaviour and safety. The a**dded**

value of the methodology, through the consideration of latent variables and the implementation of structural equation models, is found to be useful and promising, revealing new patterns such as the estimation of the effect of risk factors directly on driving performance as well the creation of specific driving profiles.