# An evaluation of behaviour simulation modelling tools for urban intersection driving

**TRAIL Research School, Delft, November 2006**

**Authors**
**Drs. Nina Schaap, Prof. dr. ir. Bart van Arem**
Faculty of CTW, Centre for Transport Studies, Applications of Integrated Driver Assistance (AIDA), University of Twente

# Contents

# Abstract

Many traffic problems occur at urban intersections. Advanced Driver Assistance Systems (ADAS) are being developed to address these problems. Unfortunately, the effects of these systems cannot be deduced directly from observing normal driving behaviour, because adding a support system alters the complete driving task. Therefore, a model must be used to represent both normal intersection driving behaviour and interaction with ADAS. This model should incorporate the structure of the driving task. Five modelling tools have been reviewed. No single modelling tool was found to fully fit all our reviewing criteria. Nevertheless, we select a promising research approach based on a combination of different models, and in particular making use of an existing framework for Multi-Agent Systems.

# Keywords

# 1    Introduction

Many traffic problems are growing, mostly due to an increase in traffic volume. Traffic accidents for 2004 in the Netherlands are estimated to have cost the Dutch society over € 7.6 billion (SWOV, 2005a). Dutch congestion records show 10.5 million kilometres for the year of 2004, an increase of 12.7% compared to 2003 (Rijkswaterstaat, 2004). Finally, decreased driver comfort and increased pollution show that traffic problems are an important modern challenge. Research has so far primarily focused on the primary road network, but urban areas should also have high priority. This is especially true for urban intersections: not only do 38.5% of all traffic accidents leading to injuries occur on urban intersections (SWOV, 2005b), but these intersections are also the capacity bottlenecks of the urban road network. Furthermore, they are challenging to drivers because intersection driving is a very complex task.

## 1.1    Advanced Driver Assistance Systems

When trying to solve these complex problems, one could think of in-car information and support systems, in certain cases combined with infrastructure-based systems. These Advanced Driver Assistance Systems (ADAS) support the driver in his driving task. They are believed by many to be the necessary next step to safer and more efficient traffic and transport (e.g., ETSC, 2005; Lu et al., 2005; Benmimoun et al., 2005). With the support of these ADAS, drivers are supposed to handle conflict situations better and feel more comfortable when driving.

Many new concepts in driver support for intersections have been developed in the past few years. These concepts include, for instance, intelligent cooperative urban intersections, in which vehicles and the infrastructure exchange information (Mathias, 2005); peer-to-peer collision warning systems for vehicles outside each other's line-of-sight (Miller and Huang, 2002) or for turns across opposing lanes of traffic (Branz & Oechle, 2005); and systems for traffic management based on reservations for intersection crossing (Dresner & Stone, 2004).

Unfortunately, the real-life effects of ADAS can only be seen after the system has been implemented. On the one hand, many believe that traffic accidents will become less common and less severe with the help of ADAS. Some even estimate that the number of collisions will decrease by as much as 69% with an intersection collision warning system (Liu et al., 2005). On the other hand, some researchers dispute the extent of such positive effects, especially when ADAS are first implemented. For example, Janssen et al. (1995) believe that the introduction of automated support systems will lead to counterproductive behavioural adaptation before it could lead to any positive effects. They predict more risk-taking behaviour and decreased alertness in drivers, and increased accident severity. These predictions are supported by results from a driving simulator study with Intelligent Speed Adaptation (ISA), conducted by Comte (2000). She found that, for instance, drivers showed riskier behaviour when the ISA system was operational.

The uncertainty of ADAS effects is a serious drawback for their deployment. Therefore, we have to investigate carefully whether the concepts that have been developed will work, before we can fully commit to introducing them on the market. This can be done in a number of ways. Studying behavioural adaptation in a

simulation study is the first option. Unfortunately, this means that we need a new study for every new ADA system, with new participants every time. This is a costly and time-consuming way of testing new in-car systems. The second option is equipping an instrumented vehicle with the tested ADA system. This option is even more time-consuming and expensive, as it also requires the development of a physical built-in system. The third option is modelling driving behaviour, and running the computer-based model in combination with every new system. As this only requires a computer and one adequate model of driving behaviour, this is the more efficient option. We therefore chose to develop a behaviour simulation of intersection driving.

To develop this model, there are three steps that need to be taken. First, we need a thorough description of normal driving behaviour, including an explanation of the main internal processes (decision making, attention, perception) that are crucial in the task of driving. This description could be seen as a conceptual model of how a single driver would act on urban intersections. This description could then be put into a behaviour simulation model, build on the structure of the driving task. Using this structure as a base for modelling is important because it allows the model to be a full intersection driving model, and not merely a single subtask model. Second, we have to determine how adding a new system to the car alters the whole driving system, and thus the driving task. And after incorporating this behavioural adaptation into our simulation model, we can draw conclusions about its effects on traffic safety, traffic efficiency and other transport factors.

# 2       Modelling intersection driving

As will become apparent in the following sections, intersection driving is a very complex task. A valuable tool when describing and explaining such a complex task is a model. As a simplified representation of a task, a model can help in determining important behavioural factors such as timing, order and influence of internal processes. By using a computer simulation model, new concepts can be evaluated without introducing them into the real traffic network.

We need a conceptual model of driving behaviour before we can develop a behaviour simulation model of behavioural adaptation. Several types of conceptual models of driving exist, ranging from motivational models (e.g., Näätänen and Summala, 1976; Fuller, 2005) to extensive task descriptions (McKnight and Adams, 1970). A good overview of driver models and their history can be found in (Vogel, 2005), and therefore we will not explain all models in this paper. But however valuable these representations are as input for a model, they cannot serve as a complete model for the purpose at hand, or even as a guideline for developing such a model. The structure of the driving task is not included in any of these models, leaving the models at the level of single subtasks. Only by explaining the whole driving task can we determine the effects of ADAS on traffic safety, traffic efficiency and the environment.

## 1.2    Driving task hierarchy

Michon (1971) described driving as a hierarchical task with three layers: strategic, tactical and operational. At the strategic level, the driver sets his goal for the trip: route choices are made and the journey is planned. The tactical level is where the driver tries to get to these goals through manoeuvring the vehicle. Here, interaction

with other road users and the road layout takes place. An example of an action on this level is taking a right turn. On the operational level, the driver controls the vehicle. This includes steering, handling the clutch and the car controls.

The levels of the driving task always interact. In normal driving, this interaction takes place in a top-down, hierarchical manner. Before starting his trip, the driver decides he wants to go somewhere and thus defines his goals for the trip and the route to take (strategic). From this route and travel goals, decisions about desired speed, which exit to take and how to behave in relation to other road users can be inferred. These are all decisions about tactical level tasks. Obviously, the tasks on the tactical level influence operational tasks: turning left in a sharp bend entails turning the steering wheel far to the left, and slowing down. In this way, strategic (higher level) tasks determine tactical (middle level) tasks, which in turn influence operational (lower level) tasks.

Whereas top-down interaction happens continuously in normal driving, bottom-up influence takes place when the driving situation differs from the expectations of the driver. This can occur at all three levels of the driving tasks. For instance, route planning (a strategic task) can be changed by the fact that a street is blocked and the corresponding turn can not be made (tactical level task). Also, correcting the vehicle's movements on a slippery road (operational task) can influence tactical level tasks, such as keeping the proper distance to a car in front or going the correct way on an intersection. These two ways of interaction are especially important on urban intersections: all the levels come together.

Rasmussen's (1983) theory on performance control states that a task can be performed at three levels of control: the knowledge-based, rule-based and skill-based level. On the knowledge-based level, performing the task requires a lot of effort and attention. The next step to take has to be defined through feedback (closed-loop control) and reasoning. On the rule-based level, actions are performed in a more automated way. Once a rule is chosen and initiated, the related sequence of steps is performed without reasoning about it. This happens when the task or the environment becomes more familiar. Finally, when the task becomes very familiar, it is carried out completely automatically. One is then performing on the skill-based level. This distinction between task performance levels is very much linked to Michon's (1971) task hierarchy of driving. The more often a certain task is performed, and the simpler it is, the less mental effort it takes to perform the task. This means that this task will be performed more automatically. Lower level task hierarchy tasks such as steering or braking, are therefore often handled in a rule-based or skill-based way, at least for experienced drivers. Novice drivers may still need to think about every step of the task, and may therefore perform many tasks on a knowledge-based level for a certain amount of time.

Finally, three stages of information processing can be distinguished for the driving task (Theeuwes, 2001). These are selection, processing and action. The level of automation changes the type of information processing, but the three stages of information processing occur at all the hierarchical levels of the driving task. Together, these three types of defining the driving task constitute a 3-dimensional matrix in which all driving tasks can be organized. This matrix is depicted in Figure 1, after Theeuwes (2001).
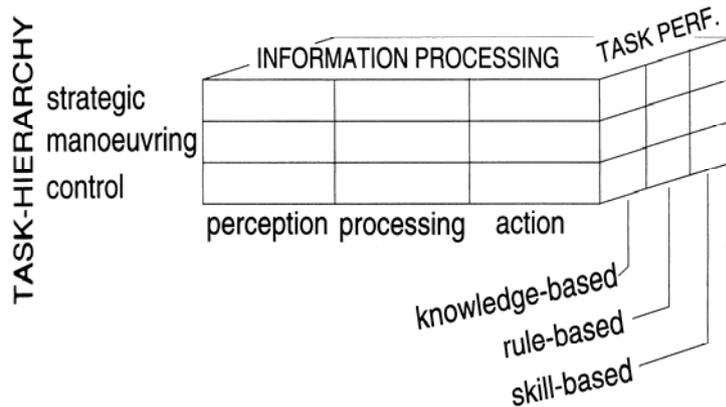
**Figure 1: Structure of the road user task in three dimensions (after Theeuwes, 2001)**

This three-dimensional structure of the driving task shows the complexity of intersection driving: all task levels, performance levels and information processing stages come together in this task. Route choice, interaction with the environment and handling the vehicle are all necessary at the same time in this situation, with some requiring more mental effort than others. As has been described before, all levels in this matrix also interact. Therefore, describing and explaining this task is a difficult but important goal in driving behaviour research.

The three different information processing tasks are an inherent part of behaviour modelling: perception, decision and action all play important roles in the final behaviour shown. Therefore, when describing the actions a driver performs, modelling perception and decision is also important. This requires a level of cognition to be put into the model. The level of automation can be modelled by the speed with which decisions and actions are performed. The task-hierarchy of driving can be seen as the actual structure of the driving task: all subtasks belong to a certain level of this hierarchy, and by interacting the final behaviour can be determined. Without describing this interaction, all models will stay on the level of describing single subtasks. The described structure of the driving task should therefore be used as a guideline for any comprehensive model of driving behaviour that intends to describe driving as a whole.

## 1.3    Existing simulation models for intersection driving

Our research is aimed at developing a driver model using existing modelling tools. We therefore highlight five modelling tools and their features, to see whether these tools fit our criteria.

The five modelling tools that we review here are selected because they are widely used, represent different levels of driving behaviour, or can be applied on different types of driving behaviour. We selected models that, in our judgment, together cover the wide range of intersection driving models. Unfortunately, no information was available about some commercially used models, such as some driving simulator software models. These were therefore not used in our review.

**Table 1: List of modelling tools reviewed in this paper**

| Model type | Description |
|---|---|
| Cognitive architecture | Cognitive models describe the cognitive processes that lead to the eventual driving behaviour. Some cognitive architectures also take into account the physical characteristics of human operators. An example of such an architecture is ACT-R, which can represent the perceptual, cognitive and motor actions of behaviour (Anderson & Lebiere, 1998). An ACT-R model uses production rules, factual information and a simulated world as input, and simulated driving behaviour as output. The driver model by Salvucci (in press) explains cognitive processes and takes into account physical constraints imposed on the human operator. |
| Driver module of a microscopic traffic simulation model | A microscopic traffic simulation is a tool that can model the performances of an entire network, showing driver-vehicle units as particles on the road network. The behaviour of these particles is set by behavioural rules, defining for instance car-following, lane-changing, and gap-acceptance behaviour. The microscopic traffic simulation model MIXIC (Van Arem, 1997) contains a detailed model of driver behaviour on highways. This model can be used independently to model and predict driving behaviour. |
| Hidden Markov Model | In a Hidden Markov Model, a prediction of driving behaviour is made from a chain of model states. The first phase consists of learning a large number of input-output relations: environmental factors and outcome behaviour. The Markov chains take certain values, representing the internal state of the actor. After this learning phase, the model can give the probabilities of different driving behaviour and actions, based on the input given to it. A Hidden Markov Model is a black box, giving minimal information about the internal processes constituting the final behaviour. A HMM driver model was described by Dapzol (2005). |
| Multi-agent system | In a Multi-Agent System (MAS), each object is represented by an agent, objects which are either static or acting. In the case of a driver model, these agents can represent cars, drivers, trees, roads etc. Some acting agents can together form greater objects: for instance, vehicle parts can be represented as individual agents with predefined behaviours. Together they can represent a complete car. All the agents in an environment together represent the driver, his behaviour and all objects surrounding him. <br> In MARS (Papp et al., 2003), a MAS architecture developed for driver modelling, the driving task is represented in four layers: the lower level (control), higher level (manoeuvring), strategic and navigation (together strategic) layer. The lower level layer controls the vehicle-unit. |
| Optimal control model | This model represents Human Machine Interaction (HMI) behaviour of the human operator, with feedback and open-loop control cycles (Hogema, in draft). Automatic processes occur without feedback loops; conscious decisions are made in a closed-loop control structure. This model proposes the action with the highest probability after a stochastic calculation. |

# 2    Model review

## 2. 1    Reviewing criteria

The ultimate purpose of our research is to develop a simulation model of intersection driving behaviour, which could be used to evaluate in-car systems and their consequences on traffic flow efficiency, traffic safety and the environment. The model may also be implemented in simulator software or in ADAS. Therefore, it needs to meet a number of constraints. To fully represent driving behaviour on intersections, all three levels - strategic, tactical and operational - of the driving task (Michon, 1971) should be incorporated into the model. These levels should also interact, as this is a very important aspect of intersection driving.

In order to evaluate the effects of a support system on the traffic network, the model has to be incorporated into a microscopic traffic simulation model. The calculation speed should therefore run in real-time. The model needs to explain the predicted behaviour, because we want to understand behavioural adaptation to ADAS. These constraints, and other model reviewing criteria, are listed in Table 2. Furthermore, in the review, the techniques that the model uses and the types of input and output will also be described.

**Table 2: Reviewing criteria and explanation**

| Model criteria | Explanation |
| --- | --- |
| Calculation speed | The model should run in real-time or faster. |
| Inherent limitations to human operator | The model should be able to represent the inherent limitations of human operators, such as errors, lapses and physical limitations. |
| Modelled (sub)tasks | The model should represent subtasks of intersection driving. |
| Workload/ attention level | Modelling workload and attention should be possible. |
| Explanatory capabilities | The model should not just show the outcome of calculations, but also give insight in constituting factors. |
| Modelled levels of driving task | All three levels of the driving task should be represented (Strategic, Tactical, Operational). |
| Interaction between levels of driving task | Interaction between the levels of the driving task should be represented |
| Model validation | To what extent and for which situations has the model been validated? |
| Traffic situation, or application flexibility | The model application should be urban intersections. If not, it should be adaptable to represent urban intersections. |
| Slow traffic | Does the model account for slow traffic (such as bicycles, pedestrians, etc)? |
| Interaction with ADAS | The model should interact with ADAS, or it should be possible to adapt the model to interact with ADAS. |
| Efficiency | Creating a valid intersection driving model might take substantially different amounts of work. This depends on the amount and contents of the assumptions that have been made in the architecture. |
| Stochastic | The mode should be stochastic, leading to (slightly) different outcomes in every run. |

## 2.2    Review of modelling tools

Table 3 shows to which extend our criteria apply to the five modelling tools. The rest of this section will describe the pros and cons of different tools, and will show the best tool for our intersection driving model.

**Table 3: Review of modelling tools and their features**

|  | ACT-R | HMM | MARS | MIXIC | OCM |
|---|---|---|---|---|---|
| *Calculation speed* | Calculation very fast, visualization often slower | Real-time | Calculation very fast, visuali-zation often slower | Real-time | Real-time |
| *Human limitations* | ++ Perceptual and motor limitations, distraction, errors and lapses | Unable to verify | + | + Motor and perception limitations. No errors and lapses | + |
| *Modelled actions* | Longitudinal / lateral control, curve negotiation, | Longitudinal control | Longitudinal control | Longitudinal / lateral control, free driving | Longitudinal / lateral control, free driving |
| *Workload/ attention* | ++ | - | - but optional | - | + |
| *Explanatory capabilities* | + | - | + | + | + |
| *Task levels** | S, T, O | T | S, T, O | T, O | O |
| *Level interaction* | + | - | + | - | - |
| *Validation* | + | + | - | + | + |
| *Application/ flexibility* | Highway, very flexible | Intersection, very flexible | Intersection, highway, very flexible | Highway, slightly flexible | Highway, slightly flexible |
| *Slow traffic* | - but optional | Unable to verify | - | - | - |
| *Interaction ADAS* | - but optional | - but optional | - but optional | + ACC | - but optional |
| *Interaction other road users* | - (visual module) | + but minimal | + but minimal | + but only on same carriageway | + |
| *Efficiency* | -- | + | - | - | -- |
| *Stochastic* | + | + | - but optional | - | + |

* : <u>S</u>trategic, <u>T</u>actical, <u>O</u>perational

All the levels of the driving task are covered in the ACT-R model, and the interaction between these levels is also represented. ACT-R's application flexibility is high, because basically all types of human behaviour can be modelled with this architecture. However, a drawback of ACT-R is that the visual module may not (yet) be able to handle all the relevant visual information properly, especially in a complex environment such as a busy intersection. Because the model goes very deep into the cognitive processes, all aspects should be modelled very precisely. A limited visual

model is therefore not a good base for interaction modelling. Another drawback for using ACT-R is that every single cognitive step has to be modelled, and this goes beyond the aim of our research. We may use the strong points of ACT-R in certain subtasks.

The Hidden Markov Model classifies different types of behaviour, and can predict the probabilities of these types. This model is mostly used for recognition of tactical-level actions and driver motivation. Unfortunately, its internal state is unobservable, making the HMM a black box on many important aspects of driving behaviour. The cause of behaviour cannot be extracted from the model's behaviour, which makes it very difficult to predict behaviour with different parameters, such as driving with an in-car support system. This tool could possibly help with certain classification tasks that occur during driving.

MARS only has a minimal intersection driving model at this point: only longitudinal control is modelled, with no strategic level tasks. However, its high flexibility and "white box" approach allow for new models to be implemented. The different levels of the driving task are modelled independently, and can also interact with each other. Parameter settings can be used to model workload and attention levels and new agents can be added independently. Furthermore, in MARS it is possible to use sub-models to describe behavioural or physical aspects of certain objects in the environment. MARS is very suitable for making the driver model, with the use of different sub-models from different tools.

MIXIC's driver model has been validated for motorway driving. It consists of a longitudinal model, a lateral/ lane-change model and a model that simulates the interaction with driver support systems. However, its application to urban intersections has not been implemented to the level that our research requires. Its low flexibility does allow for an intersection driving model to be added. It can also not account for intrapersonal differences, which are very important in driving. The longitudinal and lateral control defined in MIXIC may be useful for our model.

Finally, the Optimal Control Model runs in real time and models driving on highways validly, but does not represent intersection driving. Its flexibility at this point is not high enough to change the model's application to urban intersections, mostly due to a number of assumptions that have been made regarding driving behaviour. Driving is seen as a stationary process in this model; this cannot apply to intersection driving. The Optimal Control Model determines the behaviour of an average driver, so interpersonal differences are not accounted for. It may be useful to use the control structure of the OCM in our driver model.

Overall, none of these models are fully capable of individually modelling intersection driving at this point. A combination of tools may be the solution. In the next section we will demonstrate how this combination could lead to a behaviour simulation model that can fully represent intersection driving, including the structure of the driving task.

## 2.3    Conclusion

Our review shows that currently, there is no known model that can fully represent driving behaviour with ITS on intersections individually. The approach that we

choose for our research is therefore based on a combination of different models and in particular making use of the MARS architecture. The structure of the driving task can easily be used in MARS, paving the road to a more complete model of intersection driving. By adding sub-models of different types to this framework and using the strong points of other modelling tools, we believe representing intersection driving behaviour in a valid way is possible.

MARS will be the overall environment that we use to build our model in. MARS is especially beneficial for representing the structure of the driving task, so that the "backbone" of our model is secured. Certain subtasks, such as route choice or turning behaviour, can be modelled more adequately in other modelling tools, as is described above. For instance: cognitive decisions can be modelled very precisely in ACT-R, and a representation of longitudinal control could be taken from the OCM or the MIXIC model. By linking these submodels to the MARS "umbrella", the model will not only incorporate the structure of the driving task but also the content of the different subtasks. The added value of our model will furthermore be the modelled interaction between the levels of the driving task.

# 3     Outlook

We have selected the optimal combination of modelling tools to model driving on urban intersections. The next step is to develop the model. It will focus specifically on the interaction between the levels of the driving task, because this is a crucial aspect of driving on urban intersections. The majority of driving behaviour models so far has had a certain subtask of driving as its focus. Our model can use these subtask models as input on the different levels, within the structure of the driving task that is included in MARS. We believe that our approach can take driving behaviour modelling to a next level.

# Acknowledgements

# References

Anderson, J. R., C. Lebiere (1998) *The atomic components of thought*, Mahwah, NJ: Erlbaum.

Arem, B. van, A. P. de Vos, M.J.W.A. Vanderschuren (1997) *The microscopic traffic simulation model MIXIC 1.3,* INRO-VVG 1997-02b, TNO Inro, Department of Traffic and Transport, Delft, the Netherlands, January 1997.

Benmimoun, A., J. Chen, D. Neunzig, D. Suzuki, Y. Kato (2005) Specification and Assessment of Different Intersection Assistance Concepts Based on IVC (Inter-Vehicle-Communication) and RVC (Roadside-Vehicle-Communication), *Proceedings 12th World congress on ITS*, San Francisco, USA.

Branz, W., F. Oechle (2005) Intersection assistance: collision avoidance system for turns across opposing lanes of traffic, *The 5th European Congress and Exhibition on Intelligent Transport Systems and Services*. Hanover.

Comte, S. L. (2000) New systems: new behaviour? *Transportation Research Part F (3)*, pp. 95-111.

Dapzol, N. (2005) Driver's behaviour modelling using the Hidden Markov Model formalism, *ECTRI Young researchers seminar*, The Hague, the Netherlands.

Dresner, K. and P. Stone (2004). Multi agent traffic management: a reservation-based intersection control mechanism, *Proceedings of AAMAS*, New York, USA. July 19-23, 2004.

ETSC (2005) *In-car enforcement technologies today*. Position paper of the European Transport Safety Council. [http://www.etsc.be].

Fuller, R. (2005) Towards a general theory of driver behaviour, *Accident Analysis and Prevention (37)*, pp. 461-472.

Hogema, J. (in draft). *IRVIN Driver Models,* Report TNO The Netherlands.

Janssen, W., M. Wierda, R. van der Horst (1995) Automation and the future of car driving, *Safety Science 19*, pp. 237-244.

Liu, Y., Ü. Özgüner, E. Ekicim (2005) Performance evaluation of intersection warning system using a vehicle traffic and wireless simulator**,** *Proceedings IEEE Intelligent Vehicles Symposium*, Las Vegas, USA.

Lu, M., K. Wevers, E. Bekiaris (2005) Comparative analysis of traffic safety effects: ADAS and telematics versus road infrastructure design, *Proceedings 12$^{th}$ World congress on ITS*, San Francisco, USA.

Mathias, P. (2005) The intelligent cooperative intersection as part of urban traffic control systems, *Proceedings 12$^{th}$ World congress on ITS*, San Francisco, USA.

McKnight, A.J., B.B. Adams (1970) *Driver education task analysis. Volume 1: Task Descriptions,* Technical Report, Department of Transportation, National Highway Safety Bureau.

Michon, J.A. (1971) *Psychonomie onderweg,* Inaugural speech at University of Groningen. November 2, 1971.

Michon, J.A. (1985) A critical view of driver behavior models: What do we know, what should we do? L. Evans and R.C. Schwing (Eds.) *Human Behavior and Traffic Safety*. New York: Plenum Press; 1985.

Miller, R., Q. Huang (2002) An adaptive peer-to-peer collision warning system, *Proceedings Vehicle Technology Conference*, Birmingham, Alabama, USA.

Näätänen, R., H. Summala (1976) *Road user behaviour and traffic accidents,* Amsterdam, New York: North-Holland/ American Elsevier.

Papp, Z., K. Labibes, T. Thean, M. van Elk (2003) Multi-agent based HIL simulator with high fidelity virtual sensors, *Proceedings IEEE Intelligent Vehicles Symposium*, Columbus, Ohio, USA.

Rasmussen, J. (1983) Skills, rules and knowledge: signals, signs and other distinctions in human performance models, *IEEE Transactions on systems, man & cybernetics (13)*, pp. 257-266.

Rijkswaterstaat (2004) *Filemonitor 2004*. Ministerie van Verkeer en Waterstaat, Directoraat Generaal Rijkswaterstaat, Adviesdienst Verkeer en Vervoer.

Salvucci, D. D. (in press) Modeling driver behavior in a cognitive architecture, in: *Human Factors*.

SWOV (2005a). *Factsheet Kosten verkeersonveiligheid,* [http://www.swov.nl/rapport/Factsheets/Factsheet_Kosten_verkeersonveiligheid.pdf]

SWOV (2005b) *Letselongevallen registratie, tijdreeksen op basis van BRON,* Kennisbank SWOV, [http://www.swov.nl/nl/kennisbank/index.htm].

Theeuwes, J. (2001) Chapter 13: the effects of road design on driving, *Barjonet, Pierre-Emanual (ed). Traffic Psychology Today,* Boston: Kluwer Academic Publishers, pp. 241-263