Cooperation in traffic simulation

Symposium Human Factors in Safe Road Design and Driving behaviour
Prof Dr Ir Bart van Arem

Overview

- Context
- The MIXIC generation
- Traffic simulation based on variable driver models
- Conclusion

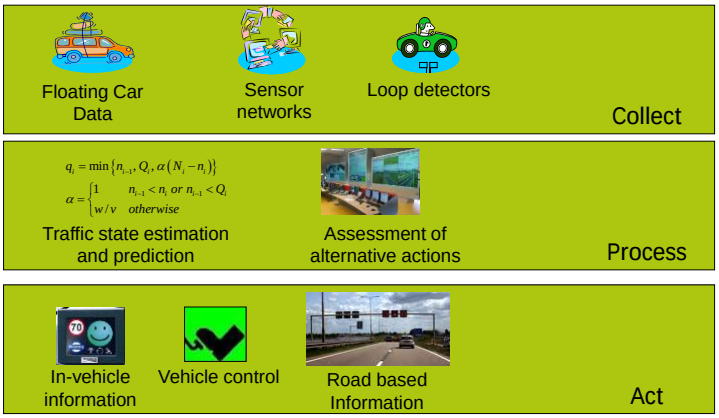
Toward Smart Mobility

TNO expects:

50% less congestion
25% less road fatalities
20% less pollution
10% less CO2

Bart van Arem, Ben Jansen & Martijn van Noort (2008), Slimmer en beter – de voordelen van intelligent verkeer, TNO rapport 2008-D-R0996/A, Delft, the Netherlands

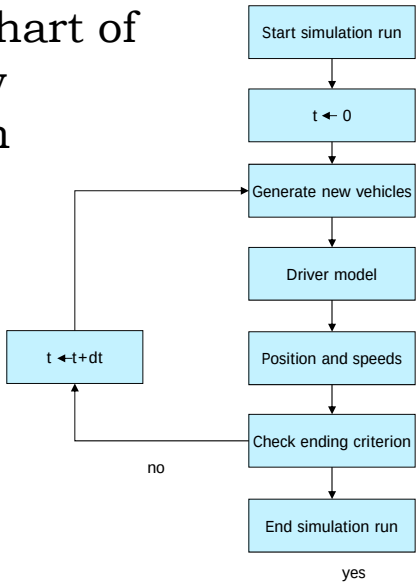
Many choices to make…



Microscopic traffic flow simulation

- Computer imitation of traffic flows based on hypothesized behaviour of driver-vehicle combinations
- Cheaper and safer than real-world pilots
- Useful to support design choices of new systems
- Realism limited by realism of hypothesized driver-vehicle combinations.

Generic flow chart of traffic flow simulation



Example of traffic flow simulation

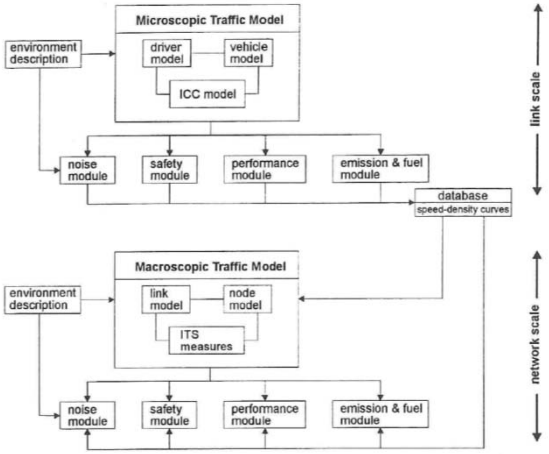
The MIXIC generation

- Develop instrument to evaluate ITS applications by computer simulation on traffic performance, safety, fuel consumption and emission

Bart van Arem, Richard van der Horst, Jeroen Hogema, Alexander de Vos (1993), The microscopic traffic simulation model MIXIC 1.0, TNO Institute for Human Factors, Report IZF C-53, Soesterberg, the Netherlands

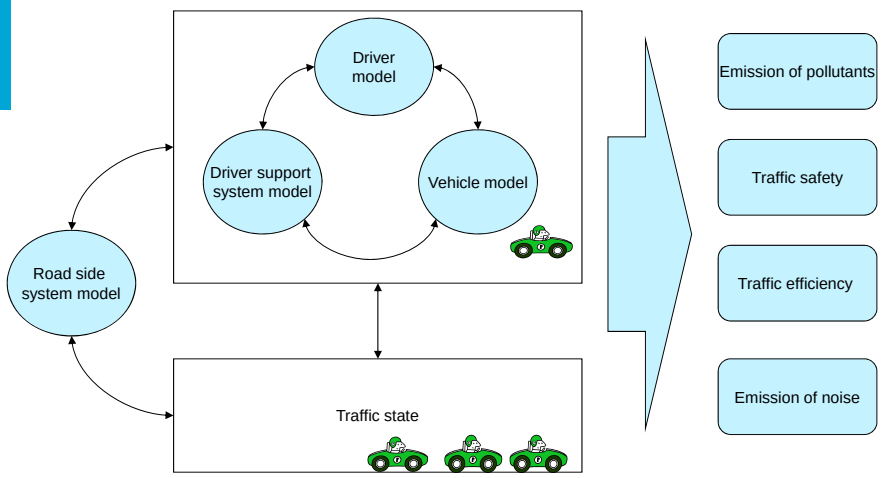
Richard van der Horst, Bart van Arem, Jeroen Hogema, Wiel Janssen, Ralph Kleuskens & Arie van Tol (1993), Randstad+ project Intelligent Traffic Systems: Definition phase and workplan, TNO Institute for Human Factors, Report IZF C-2, Soesterberg, the Netherlands

Model framework

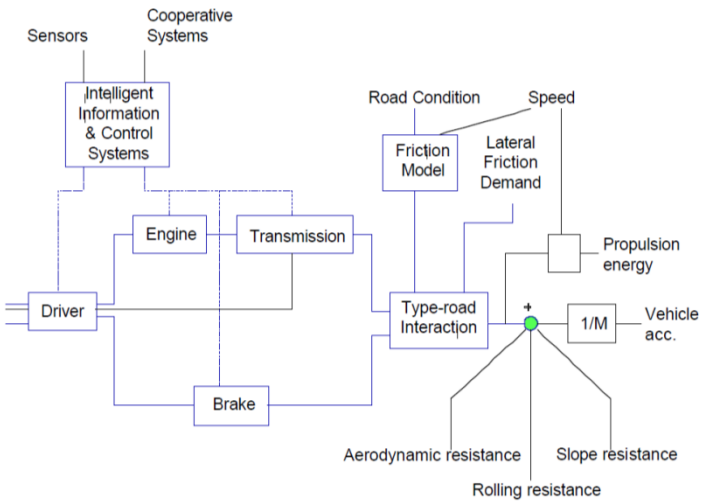


MIXIC framework

Object oriented, ANSI-C

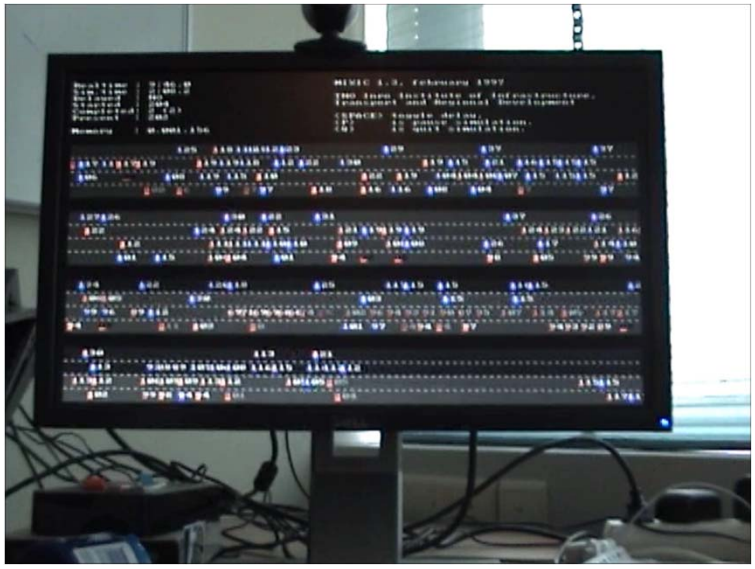


Vehicle model



Driver model features

- Car following (Helly including multi-anticipation)
- Free lane changing/mandatory lane changes (including gap forcing and courtesy)
- Perceptual thresholds (based on angular speed)
- Gear shifting, gas pedal and brake pedal modelling



MIXIC applications

- Adaptive Cruise Control (1994)
- Fog warning (1996)
- Road trains (1996)
- Special lane for Intelligent Vehicles (1997)
- Energy friendly variable cruise control (1997)
- Cooperative following (1999)
- Cooperative merging (1999)
- External cruise control (2002)
- V2V communication Cartalk (2004)
- Chauffeur Assistant (2004)
- Cooperative Adaptive Cruise Control (2006)

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Traffic simulation based on variable driver behaviour

- Traffic simulation models assume constant driver behaviour
- In reality driver behaviour and driving style varies between
  - persons
  - locations
  - conditions
- Successful operation and acceptance of and behavioural response to ADAS and IVIS may depend on taking into account driver state

Hoogendoorn, R.G, B. van Arem, S.P. Hoogendoorn, K.A. Brookhuis, Applying the task-capability interface model to the Intelligent Driver Model in relation to Complexity, submitted to TRB Annual Meeting 2013.

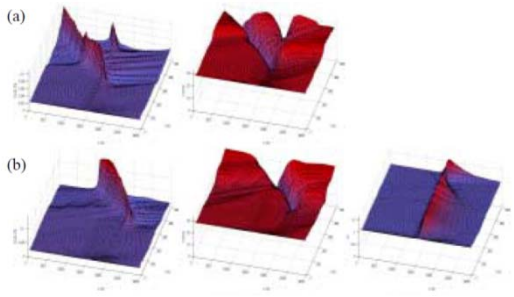
Pioneering work: variable driver based on gas kinetic modelling (2005)

$$\frac{\partial k}{\partial t}+\frac{\partial kV}{\partial x}=\left(\frac{dk}{dt}\right)_{discrete}$$

$$\underbrace{\frac{\partial kV}{\partial t}+\frac{\partial k\left(V^2+\Theta'(k)\right)}{\partial x}}_{convection}=\underbrace{k\langle v\rangle_{v,a}}_{continuous\ beh.}+\underbrace{\int_a\int_v v\left(\frac{d\rho}{dt}\right)_{discrete}dvda}_{discontinuous\ behaviour}$$

$$\underbrace{\frac{\partial kA}{\partial t}+\frac{\partial kAV}{\partial x}}_{convection}=\underbrace{k\langle a\rangle_{v,a}}_{continuous\ beh.}+\underbrace{\int_a\int_v a\left(\frac{d\rho}{dt}\right)_{discrete}dvda}_{discontinuous\ behaviour}$$

Speed (V), density (k) and alertness (A)



k v a

The Intelligent Driver Model

$$a(t)=a_{\max}\left[1-\left(\frac{v(t)}{v_0}\right)^{\delta}-\left(\frac{s^*\left(v(t),\Delta v(t)\right)}{\Delta x(t)}\right)^2\right]$$

$$s^*\left(v(t),\Delta v(t)\right)=s_0+v(t)T+\frac{v(t)\Delta v(t)}{2\sqrt{a_{\max}b_{\max}}}$$

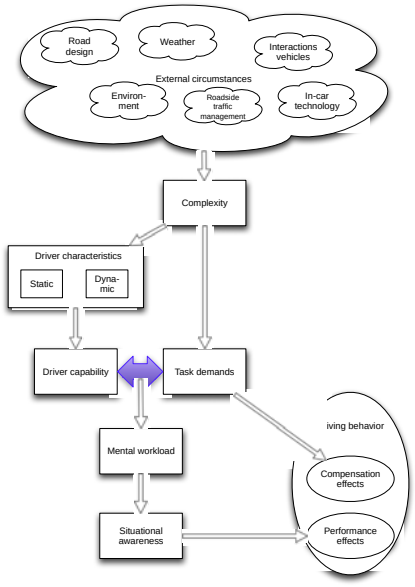
Parameters estimated from trajectory using log likelihood.

Assume *n* subtrajectories.

Goodness of fit will improve with increasing n
if driving style is indeed variable

Estimation results

	$N = 1$		$N = 10$		$N = 25$		$N = 100$	
Parameter	mean	std	mean	std	mean	std	mean	std
a	1.52	1.31	1.54	0.62	1.40	0.28	1.43	0.13
b	2.55	3.71	0.79	0.74	0.95	0.41	0.78	0.15
s_0	14.53	9.25	13.06	5.68	13.57	3.78	12.47	1.32
T	1.29	1.33	1.11	0.53	1.08	0.27	1.17	0.16
v_0	37.1	16.4	37.9	13.3	33.0	6.6	32.9	6.2



Combining TCI and IDM

- Task demands [0,1]: $m_t(t)$
- Driver capability [0,1]: $m_c(t)$
- $m_d(t)=m_t(t)-m_c(t)$
  - *Negative: capability larger than demand* 
  - *Postitive: demand larger than capability* 
- Compensation: driver adapts behaviour toward restoring balance between demand and capability (in terms of goals)
- Performance: difference demand and capability affects quality of task execution

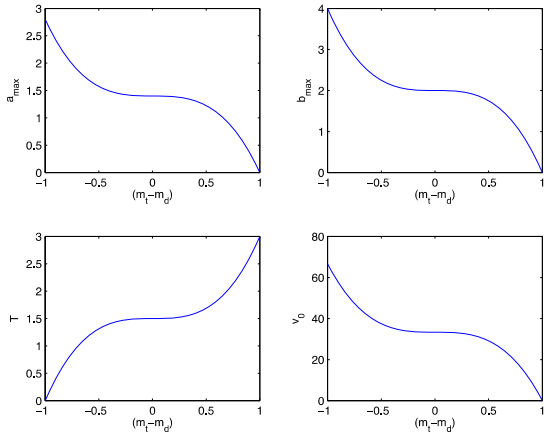
IDM including compensation and performance effects

$$a(t)=\left(1-m_p(t)\right)\left(\left(-m_d(t)^3 a_{\max}\right)+a_{\max}\right)\left[1-\left(\frac{v(t)}{\left(-m_d(t)^3 v_0\right)+v_0}\right)^{\delta}-\left(\frac{s^*\left(v(t),\Delta v(t)\right)}{\Delta x(t)}\right)^2\right]$$

$$s^*\left(v(t),\Delta v(t)\right)=s_0+v(t)\left(\left(m_d(t)^3 T\right)+T\right)+\frac{v(t)\Delta v(t)}{2\sqrt{\left(\left(-m_d(t)^3 a_{\max}\right)+a_{\max}\right)\left(\left(-m_d(t)^3 b_{\max}\right)+b_{\max}\right)}}$$

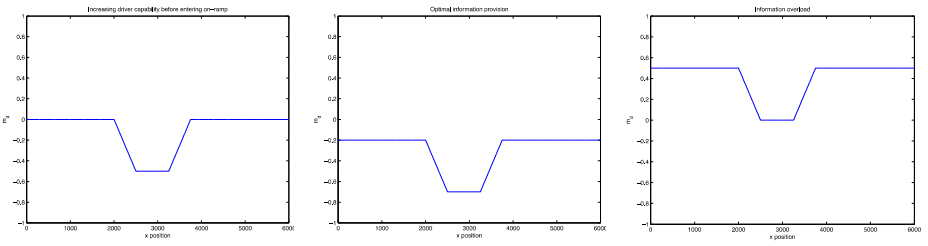
$$m_p(t)=-\left(\alpha m_d^2+\beta m_d+\gamma\right)$$

IDM including compensation and performance effects



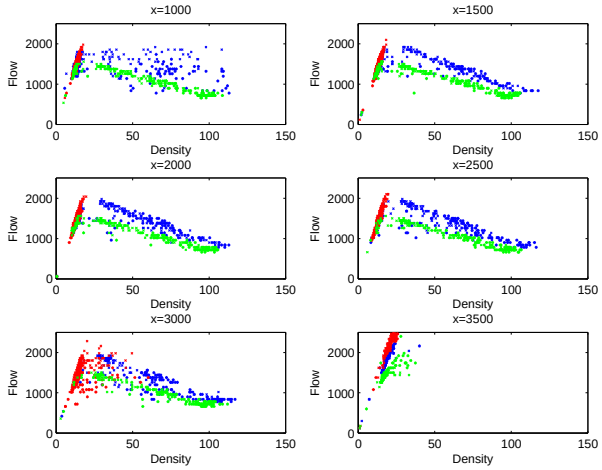
Application

- Traffic flow simulation using IDM
- On-ramp
- Three scenarios:



Increase driver cap. Optimal information Information overload

Results…



Blue: balanced demands/capabilities Red: optimal information Green: information overload

Conclusions

- A simulation model can never be better than its driver model
- Driver model major innovation in MIXIC

- Driving behaviour not constant
- Empirical evidence from trajectories
- Task demand and capability moderating a new generation of driver models
- Simulation results show plausible behaviour
- Future work: analysis and modelling task demand, capability, compensation and performance in relation to ADAS and IVIS.