Session 3 Infrastructure and behavior:
Effects of traffic infrastructure and road design on safe driving
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Accidents mainly occur by:

- Errors by road users
- Errors in the design

*Two approaches:*
- Prevent collisions (active safety)
- Reduce consequences (passive safety)

*Active safety:*
- Road design/infrastructure
- Vehicle characteristics
- Traffic System/Rules
- Road User

-> INTERACTION!
Traffic safety vs. traffic process
(Hydén, 1987)
Human as the measure of all things

Physical characteristics
- Senses (thresholds, differential, non-linear, etc.)
- Limited information-processing capacity
- The human is vulnerable

Psychological characteristics
- The human is not always able -> errors
- The human is not always willing -> violations
Driving seems so easy
(Lie, 2003)
Car driving: not just 1 task

- Continuous task (lane keeping)
- Planned actions (overtaking, turning)
- Sudden actions (braking lead vehicle)
- Changes in road environment (work zone)
- Finding your way (navigation)
Driving Task Hierarchy

- **Strategic level**
  - Route planning and route guidance (minutes-hours)

- **Manoeuvring level**
  - Interaction with road and other road users (seconds - minutes)

- **Control level**
  - Controlling speed and lane keeping (1/10 seconds - seconds)

(Alexander & Lunenfeld, 1986)
The human information processing cycle

**Perceiving** (mainly visual)
- Attention
- Detecting
  - top-down (task-related)
  - bottom-up (conspicuity)
- Interaction with expectancy!

**Processing**
- Recognition
- ‘Reading’
- Understand

**Decision-making**

**Act**
Task-performance (Rasmussen, 1985)

- **Knowledge-based** *(reasoned behaviour)*
  - Cognitive attention, interpretation, deductive reasoning,
    *(relatively much attention and time needed)*

- **Rule-based** *(habitual behaviour)*
  - Recognition of situation results in onset of a series of behaviours that fit *(selection costs some time, followed by ‘automatic’ execution)*

- **Skill-based** *(reflex behaviour)*
  - ‘automatically’, information results in efficient behaviour without cognitive control *(very fast)*
Modelling the driving task
Integral systems approach needed

› INFRASTRUCTURE
  › Road system (also including traffic operation+rules) design based on human capabilities and limitations
    (self-explaining, no signs needed to explain, people may only do it wrongly *on purpose*)

› VEHICLE
  › Supporting the driving task
  › Provide protection

› HUMAN
  › Well informed and trained
  › Controlled where necessary
### Advancing Sustainable Safety 2005-2020

**Sustainable Safe principle**

- **Functionality** of roads
- **Homogeneity** of masses and/or speed and direction
- **Recognition** of the road design and predictability of both road lay-out and road user behavior
- **Forgiveness** by the environment and by road users (for each other)
- **Status recognition** by the road user
Functional road categories

The design of a road must fit its function:

- **Flow function**
  - (Motorways, 100-120 km/h)

- **Distributor function**
  - (50-80 km/h roads, no slow traffic)

- **Access function**
  - (woonerfs, 30-60 km/h roads, mixture of all traffic)
# Sustainably safe road categories

<table>
<thead>
<tr>
<th>Essential Recognition Characteristics</th>
<th>Flow-road</th>
<th>Distributor road</th>
<th>Access road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed limit</td>
<td>120 km/h</td>
<td>100 km/h</td>
<td>80 km/h</td>
</tr>
<tr>
<td>Road sign</td>
<td>(ASW, G01)</td>
<td>(AW, G03)</td>
<td>no</td>
</tr>
<tr>
<td>Road side/edge marking</td>
<td>unbroken</td>
<td>unbroken</td>
<td>broken</td>
</tr>
<tr>
<td>Separation of driving directions</td>
<td>wide median or barrier</td>
<td>double axis marking with 'green' filling, or median</td>
<td>double axis marking (without filling), or median</td>
</tr>
</tbody>
</table>

**Rural area**
- Speed limits: 120/130 km/h, 100 km/h, 80 km/h, 60 km/h

**Built-up area**
- Speed limits: 50 km/h, 30 km/h
10 golden human factors rules to take the road user into account
Self Explaining Roads and Traffic System

The road and the traffic system should be designed according to the concept of Self Explaining Roads (SERs). This concept advocates a traffic environment that elicits safe behaviour simply by its design.

*Figure 2.1: Classifying a road as a motorway activates schemata about what to expect on this type of roads, how to behave and how other road users will behave.*
Resilience to Failure and Break-Down

One should take inadvertent aberration of the system or of the road user into account (principle of graceful degradation)

Figure 3.1: Schematic representation of the development of an accident (bold arrow) caused by latent errors and dangerous actions (in: Wegman & Aarts, 2006; free after Reason, 1990).
The Performance of Road Users: Hierarchical Task Levels

Driving takes place at three hierarchical task levels, viz. navigation, guidance, and control. For each level task load varies dependent on time and place. In road design one should take the distinction between these task levels into account.
Information carriers meet basic ergonomic principles

Take into account elementary characteristics of senses

› Perception thresholds
› Differential thresholds (Weber fraction)
› Adaptation (bright -> dark)
› Non-linear relationship between sensory intensity and awareness
› etc.

Information characteristics:

› Visibility (intensity, contrast)
› Legibility
› Recognition
› Comprehension
Individual Information Elements are Consistent and Uniform within their Context

Individual information elements should be mutually consistent and uniform within their context, don’t confuse the road user
Risk and Adverse Side Effects of Measures

When introducing particular measures it is likely that there are adverse side effects. The driver is an integral part of the traffic system and will adapt its behavior when necessary and possible. Any change within this system may lead to behavioral adaptation.
Interchange De Stok A58
Strategic level

- First information at 600 m, well below common practice
- Second pre-sign at 300 m
- At decision point: gantry
Manoeuvring level

- Preview, people expect continuation of motorway driving on A58
- Speed limit 100 km/h
Control level

- Curve radius 150 m
- Safe speed < 70 km/h
- Preview 4.5 s at 70 km/h, well below recommended 10 s for motorway driving
Speed-reducing measures 80 km-roads

Van der Horst & Bakker, 1994
Video observations of lateral placement

Question: Do people drive more to the centre of the road?
Passenger cars drive more to the right (10 cm)!
No difference in mutual lateral distance while passing

![Graph showing cumulative distribution of mutual lateral distance during passing of passenger cars. The graph compares control location (solid line) and experimental location (dotted line).](image)
Work-zones (contraflow-systems)

Commissioned by Dutch Ministry of Transport

Research question: What length is acceptable?

• safety
• comfort
• workload

Scenarios in driving simulator:

• two lane widths (2.50 - 2.75 m) up to 12 km
• with or without other traffic in adjacent lane (threat)
• two systems (3-1 / 4-0)
3-1 system
4-0 system
Results

▶ Test persons afraid to overtake heavy vehicles
▶ Proof for feelings of narrowness

• Behaviour for 3-1 system safer than for 4-0 system
• Wider lane width is more safe and comfortable
• > 4 km steering more strenuous and less accurate
• only 3-1 with 2.75m lane width acceptable up to 8 km
To conclude (1)

- People can learn things
- After learning – apply it uniformly on all roads
- *Uniformity* is one thing, making it *understandable* another
- Expectancy is stronger than reasoning
- Don’t expect too much background knowledge
- Design with the road users’ point of view in mind

If many people make errors, then the design is wrong!
To conclude (2)

› Consider road traffic as one system:
  › Road System (infrastructure - traffic operation + management - traffic rules – vehicle - human)

› Inform driver about road environment and its task difficulty to enable him/her to adapt driving behavior accordingly
  › -> no surprises
  › -> road design that meets drivers’ expectancy: SER (Self-Explaining Roads)

› Humans make errors/mistakes
  › -> forgiving road and environment
  › -> forgiving for each other

› Be aware of possible *behavioral adaptation* effects (+or -)