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Vehicle design

Human factors perspective

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Presentation 8

Agenda

1. Crash avoidance and crash protection – what can vehicle design contribute
2. What are main crash injury problems?
3. What happens in the crash and forces tolerated by human body
4. Crash protection measures
5. Crash avoidance measures
6. Problem of side effects
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9. Euro NCAP

1. Crash avoidance and crash protection – what can vehicle design contribute

Vehicle design, which **takes account of the behavioural and physical limitations of road users**, can address a range of risk factors **and help to reduce exposure to risk**, **crash involvement and crash injury severity**.

A review of the **effectiveness of casualty reduction** measures in the United Kingdom between 1980 and 1996 found that the **greatest contribution to casualty reduction was secondary safety or crash protection in vehicles**. This accounted for around 15% of the reduction, compared with 11% for drink-drive measures and 6.5% for road safety engineering measures.

The European Commission has stated that if all cars were designed to provide crash protection equivalent to that of **the best cars in the same class, half of all fatal and disabling injuries could be avoided.**

1. Crash avoidance and crash protection – what can vehicle design contribute

1. **Crash avoidance or primary safety**

Devices to **avoid** a crash e.g. daytime running lights, electronic stability control, intelligent speed adaptation, alcohol interlocks

2. **Crash protection or secondary safety or passive safety**

Protection **in the event of a crash** e.g. seat belts, airbags, front and side impact protection

As stated in the World Report on Road Traffic Injury Prevention "a traffic system **better adapted to the physical vulnerabilities of its users needs to be created with the use of more crash protective vehicles and roadsides**"

2. What are main crash injury problems?

The **main injury risks** for car occupants arise from the way vehicles interact with **each other and with the roadside**.

Car to car collisions are the single most frequent category of crash. For both fatally and seriously injured occupants**, frontal impacts** are the most important crash type followed by **side impacts**.

The head is the body area most frequently involved in life-threatening injury, followed in importance by **the chest and then the abdomen**.

Determinants of injury severity include:

- Restraint use
- Contact by occupant with the car 's interior, exacerbated by intrusion into the passenger compartment caused by the colliding vehicle or object
- Mismatch in terms of size and weight between vehicles involved in a crash
- Ejection from the vehicle
- Inadequate vehicle safety standards

2. What are main crash injury problems?

Pedestrians:

Research in Europe suggests that the majority of all fatally and seriously injured pedestrians are **hit by the front of a car**. **Lower-limb injury** is, in general, the most common form of pedestrian injury, **while head injury** is responsible for most pedestrian fatalities.

Motorized two-wheeler:

Tend to sustain multiple injuries in crashes, including to the head, chest and legs. The majority of the fatal injuries are **to the head**, despite helmet use.

Cyclists:

Head injuries are the major cause of death in around 75% of cyclist fatalities. Head or brain injury comprises about 50% of all younger hospitalised crash victims.

3. What happens in the crash and forces tolerated by human body

The tolerance of the **human body to kinetic forces** released in road traffic crashes is **limited**. Injury is broadly related to **the amount of kinetic energy applied to the human frame.**

Relationship between **crash forces** and **injury** is known for a number of **parts of the body** and types of injury for different categories of road user as well as for **different age groups.** *For example, a crash load applied to the chest of a young male may result in a bone fracture, but if applied to an elderly female, may produce a life-threatening injury.*

The energy of a crash is **related to the square of the velocity**, <u>so small increases in speed produce major increases in the risk of injury.</u>

3. What happens in the crash and forces tolerated by human body

The best-designed vehicle on the road today provides **crash protection currently up to 70km/h** for car occupants wearing seat belts in **frontal impacts and 50 km/h in side impacts**.

*It has been estimated that the Swedish traffic system as a whole probably **tolerates** speeds of between 30 and 60 km/h, **allows** use on most roads between 50 and 100km/h (through road speed limits) and **possibilities** of use (by engine capability) to more than 200 km/h.*

3. What happens in the crash and forces tolerated by human body

Newton's Third Law, states that *"For every action there is an equal and opposite reaction."*

In a frontal crash, the most common impact type, an unrestrained occupant continues to move forward at the pre-crash speed and hits the car structures with an impact speed approaching the pre-crash speed. Use of a seat belt or restraint helps to slow the occupant down in a crash by applying forces to the strong skeletal structures of the pelvis and rib cage; reducing the risk of major contact with the car structure and preventing ejection.

4. Crash protection measures

Vehicle **crash protection aims to keep the consequence of a crash to a minimum**. For car occupants, this means:

- Keeping the occupant in the vehicle during the crash
- Ensuring that the passenger compartment does not collapse
- Reducing the crash forces upon the occupants by slowing down the occupant or pedestrian over as long a distance as possible and spreading the loads as broadly as possible to reduce the effect of the impact forces
- Controlling the deceleration of the car

Restraint

Occupant restraint is the **single most important safety feature** in the car and most crash protective design is based on the premise that a seat belt will be used.

Over the last 10 years restraint systems fitted in many new cars feature seat belts, frontal air bags, as well as seat belt **pre-tensioning systems and belt force limiters** which have done much to enhance seat belt protection.

5. Crash avoidance measures

Does car colour influence road safety?

*Brightly coloured or light coloured vehicles are sometimes regarded as safer because they seem to be more visible but is this the case? While a small number of studies have started to explore this question the association between the colour of cars and their safety should be treated **with some caution**.*

For instance, if yellow cars were proven to be safer than other colours, it does not mean that safety would improve if all cars were yellow. It is the variation in colour, just as much as the colour itself that generates differences in safety.

6. Problem of side effects

The problem is **the technical view on systems that sometimes prevails**:

E.g., "This system enhances vision, I therefore see better and I will therefore be safer". During the years we have learned, however, that **such positive effects** are often not the outcome, **in reality**. The reason is that **human beings** - we - are no technical machines and often use any equipment **differently from what was planned or expected.**

We fiddle around, we compensate, we delegate responsibility, we take on secondary tasks that are forbidden, etc. I think that when we discuss vehicle design and vehicle equipment we should, as psychologists focus much on these **(non-wished-for) side effects** (Risser, 2014)

7. Intelligent Transport Systems (ITS)

Both at the **roadside** and in the **vehicle itself.**

Many of the current ITS applications are mainly **aimed at increasing comfort while driving and at improving accessibility.**

In addition, systems like the **alcolock and the seatbelt lock are being developed with the primary aim of road safety**.

There are also systems, such **as Advanced Cruise Control and Dynamic Route Information Panels**, that are not specifically intended to improve road safety, but that can have an effect.

7. Intelligent Transport Systems (ITS)

ITS categorized on *technical aspects:*

1. **vehicle** systems **without interaction** with data sources outside the vehicle;
2. **roadside** systems without interaction with data of individual vehicles;
3. systems that **allow for interaction** between individual vehicles and other data sources, such as between vehicles or between vehicle and roadside.

Categorized on *primary purpose:*

1. management of traffic flows;
2. driving comfort;
3. safety, subdivided into:
   a. systems that prevent unsafe traffic participation;
   b. systems that prevent unsafe actions while participating in traffic;
   c. systems that reduce injury severity

7. Intelligent Transport Systems (ITS)

Besides its primary purpose (e.g. driving comfort), an application **can** have positive or negative effects in other areas (e.g. traffic flow or road safety). In addition, it is sometimes possible that a particular safety ITS does **not have the desired effect because the driver, deliberately or unconsciously, adapts his/her behaviour** (behaviour adaptation).

Categorized on function:

1. purely informative systems;
2. warning systems;
3. physically intervening systems.

Generally, systems which **actively intervene** appear to be more effective than **systems which warn**, and these systems, in their turn, are more effective than **systems which only inform.**

7. Intelligent Transport Systems (ITS)

Which ITS are primarily aimed at road safety?

1. Systems that prevent unsafe traffic participation

An already well-known example of systems that prevent unsafe traffic participation, is the ***alcolock***. *Before drivers can start their car, they first have to take a breath test when an alcolock has been installed.*

The *seatbelt lock* *is based on the same principle: if the seatbelt is not fastened, the car will not start. Many cars already have a warning system.*

A step further than the above applications is the ***smart card,*** *which is a sort of individual starting permit. All sorts of data about the driver's fitness to drive can be stored on a smart card, such as information about the validity of the driving licence (vehicle type, licence suspension) and any restrictions for using the vehicle, for example in case of a graduated driving licence.*

7. Intelligent Transport Systems (ITS)

Which ITS are primarily aimed at road safety?

2. Systems that prevent unsafe situations or actions while driving

Systems that **offer support for vehicle control**, record and/or prevent deliberate and unintentional offences, offer support in observing, interpreting and predicting traffic situations, and react to a (temporarily) reduced fitness to drive.

Category	Name	Abbrev.	Intended effect
Vehicle control	Electronic Stability Control	ESC	Prevents a car skidding in a bend or when making a manoeuvre (autonomous system) ((See SWOV-Fact sheet Electronic Stability Control (ESC))
	Lane Departure Warning System	LDWS	Warns when crossing the road marking (via video in vehicle)
	Lane Keeping System	LKS	Intervenes when crossing the road marking (via video in car and servo-assisted steering)
Prevention of offences	Intelligent Speed Adaptation	ISA	Gives information about speed limit, warns of exceeding the limit, or intervenes when speeding (See SWOV Fact sheet *Intelligent Speed Assistance (ISA)*)
	Electronic Vehicle Identification	EVI	Locates and follows a vehicle in the network; can for instance be used for 100% chance of apprehension when speeding
	Electronic Data Recorder (black box)	EDR	Registers all sorts of driving behaviour. Can be used both for punishing (possibly linked to Automatic Policing) and rewarding (e.g. via insurance bonuses)
Support for observing, interpreting situations	Collision Avoidance System	CAS	Warns or intervenes when a (moving) object is detected in front of the vehicle (also pedestrians)
	Vehicle detection at intersections	--	Warns or intervenes when crossing traffic is detected
	Night time vision system	--	Improves night time vision, and thus timely detection of pedestrians/cyclists
Temporarily diminished fitness to drive	Fatigue Warning System (Distraction Warning System)	--	Detects deviations from normal brain activity, eye movements, or driving behaviour (e.g. in combination with smart card) and warns or intervenes

7. Intelligent Transport Systems (ITS)

Which ITS are primarily aimed at road safety?

3. Systems that reduce injury severity

One type of an injury reducing system is the so-called pre-crash sensing system that increases the effectiveness of passive safety instruments like seatbelt or airbag by calculating the collision angle, the collision speed and the size of the collision object just before an unavoidable crash. Furthermore, much European attention goes to *eCall, a system that speeds up the arrival of assistance at the crash location by automatically reporting the exact location.*

7. Intelligent Transport Systems (ITS)

Possible side effects of safety ITS

- ***Diminished attention level****. When driving tasks are – partly – replaced by ITS, the driver's attention for the driving task may decrease.*
- ***Information overload.*** *Road safety will benefit from an as low as possible mental burden on the driver. ITS should not lead to an overload of information. Therefore it is important to give the right information at the right moment, at the right place, for the right duration etc.*
- ***Incorrect interpretation of information.*** *The driver must be able to understand what the system does and what it wants to do. The wrong interpretation of information can have the opposite effect.*
- ***Overestimating the system.*** *The driver's expectations of a system must be realistic. The driver must not overestimate the system or rely on it too much.*
- ***Risk compensation.*** *If a particular measure reduces the risk, some people are inclined to take more risks in another way, resulting in a smaller net effect or, according to some, even reducing it to zero.*
- ***Effects on non-users.*** *Especially if not all vehicles are equipped with a certain ITS system, it is possible that some drivers without such a system anticipate the supposed behaviour of cars that do have that system. It is also possible that*

8. Elderly drivers and ITS

Which safety problems do elderly drivers encounter?

Crash analyses show that, relatively speaking, elderly drivers (especially those of 75 years and older) are more frequently involved in crashes **when turning left at an intersection or while merging or exiting, for example on a motorway** (Davidse, 2004). Reasons:

a. having difficulty in judging whether other road users are **moving and how fast** they are approaching an intersection (poorer perception of movement);

b. **not noticing other road users** when merging and changing lanes (reduced peripheral vision and flexibility of neck and trunk);

c. **not noticing traffic signs** and **traffic lights** (greater difficulty in selecting relevant information);

d. **large increase in reaction time** as the traffic situation becomes more complex (slower information processing and decision making, more difficulty in dividing the attention, and worse performance under pressure of time).

8. Elderly drivers and ITS

Which ADAS are suitable for the difficulties of elderly driver?

ADAS which offer **assistance in the elderly motorist's traffic difficulties** and specifically take into account the underlying **functional limitations**, can contribute to a reduction in the elderly's crash involvement.

ADAS should have one or more of the following functionalities:

a. drawing attention to approaching traffic;
b. pointing out objects that are in the blind spot;
c. providing help in guiding the attention to relevant information;
d. providing prior knowledge about the next traffic situation.

For a long time now, there have been vehicle adaptations to compensate for motor functional limitations, such as a **decrease in muscle strength**. Examples of such systems are **servo-assisted steering**, an automatic gearbox, and adjustment of the force which is required to step on the brake or acceleration pedal. In

8. Elderly drivers and ITS

What should be given extra attention in ADAS use by the elderly?

If the goal of using ADAS is **the improvement of the safety** of (elderly) drivers, safer performance of the assisted task only is not sufficient. The **assistance must also not have any negative effects** on other elements of the driving task. Examples of negative side effects are an increase in the task load and the occurrence of behavioural adaptation.

Elderly drivers are **more sensitive to the effects of poorly designed ADAS** than younger drivers. In general, the elderly need more time to carry out secondary tasks while driving. That is why it is very important that the **design of the control panel of ADAS takes the capabilities and limitations of elderly drivers into account**.

9. Euro NCAP

Since 1996, the **Euro NCAP programme** has been **testing the (crash) safety of the most widely sold cars.**

The fact that consumers are familiar with the test results **encourages the car manufacturers to produce** cars that are often safer than is required by law.

Euro NCAP tests **the (secondary) crash safety for adult occupants, for child occupants and for pedestrians** as crash opponents.

Since 2009, points can also be earned for the presence of **devices for the prevention of crashes (primary safety)**, such as electronic stability control and speed limiters.

9. Euro NCAP

Euro NCAP **groups the cars in various model classes**, such as passenger car ('small and large'), multiple purpose vehicle (MPV; 'small and large'), SUV ('small and large'), sports car and pick-up truck.

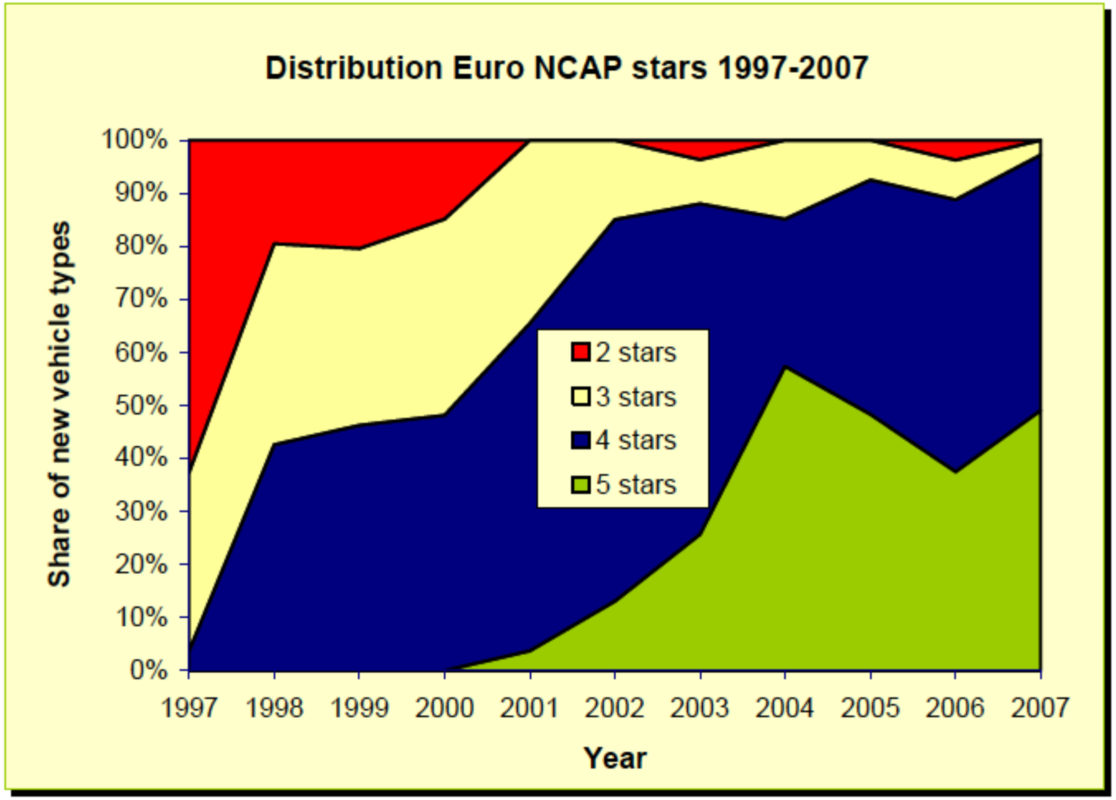
Test parts of Euro NCAP

Group 1 (36 points) **Adult occupants**	**Group 2** (49 points) **Child occupants**	**Group 3** (36 points) **Pedestrians**	**Group 4** (7 points) **Safety devices**
• Frontal impact • Side impact • Against pole • Whiplash	• Frontal and side impact • Use of child restraint • Appropriateness car	• Adult head and child head on bonnet • Adult lower leg against bumper • Adult upper leg against bumper and bonnet	• Seat belt reminder • Electronic stability control • Speed limiter

9. Euro NCAP

The final assessment was expressed in the **number of stars earned.**

Through the years, the share of cars with four or five stars has increased considerably. In 1997 circa 5% of the tested cars earned four stars and none of the tested cars earned five stars. Ten years later, in 2007, circa 95% of the cars earned four or five stars (see *Graph).*



9. Euro NCAP

BUT:

Due to both **mass and rigidity**, safety for the **occupants increases** with vehicle mass, whereas safety for the occupants of the **crash opponent car decreases** with vehicle mass (Berends, 2009).

The number of stars gives **good insight into the safety within the same model** and size class, but not between the various classes.

The trend to make **cars smaller and more lightweight** for reasons of environmental targets.

It is **more effective for road safety to prevent crashes** than to reduce the severity of injuries of car occupants in crashes (Ablaßmeier et al., 2007). The attention paid by Euro NCAP to **primary safety devices**, such as an ESC-system, is therefore positive.

Thank you for listening!

Based on:

SWOV Fact sheet – Euro NCAP, a safety tool (2010)
SWOV Fact sheet – The elderly and Intelligent Transport Systems (ITS) (2010)
SWOV Fact sheet – Intelligent Transport Systems (ITS) and road safety (2010)
EU road safety observatory (http://ec.europa.eu/transport/road_safety/specialist)