Variables influencing driver speed
Safety on inter-city roads

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Summary

• I. Road infrastructure and driving task
• II. Drivers speed in traffic
• III. Part played by infrastructure factors in accident processes
• IV. What rationale for improving roads?
Design and ergonomics of roads (streets)

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Road infrastructure as an interface between Designers and Road Users

- The design of the infrastructure and the formulation of the traffic rules determine its use: choices made by the designers of the road system including road and traffic engineers and the legislators of the highway code (two faces: physical+organisational)

- The road infrastructure conveys a wealth of information that guides drivers’ activity and their interactions with others in situ
  - explicitly through devices such as road signs and road markings,
  - implicitly by means of the environmental context and road layout, for example.

Main design issues: compatibility between the choices made by designers and the drivers needs to achieve their objectives and perform their driving task efficiently and safely.

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Driving task definition

- “A situation in which a person has a problem to solve or a goal to achieve” by a succession of actions

- Three levels
  - Strategical (trip)
  - Tactical (manœuvre)
  - Operational (trajectory with longitudinal and lateral control)

- Characteristics
  - Multiplicity (multi-tasks and other road users)
  - Dynamism
  - Uncertainty

The prescribed (or formal) task

- The task to be carried out as conceived by the designer of the system and/or the safety manager.

- It sets out (more or less explicitly) a number of prescriptions, which are supposed to influence and to some extent guide driver activity (formal rules).

- In other words, the prescribed task defines the expected driving behaviour, what the driver should do (in terms of performance and/or procedures to follow).

The actual or redefined task

- What the driver actually does (activity), the demands and constraints that s/he effectively takes into account.

- Identifying the actual task calls for a detailed analysis of driver behaviour with the aim of determining exactly how drivers organise and perform the driving task (informal rules):
  - What their goals and intentions are,
  - What information they select from the environment,
  - What motives and criteria underlie their decision-making,
  - What regulating actions they take.
Model of analysis (Leplat, 1993)

Human error or to err is human

- Failure of planned action to achieve the desired end
- **Slips** (automatic behavior: capture of similar actions)
- **Errors or Mistakes** (conscious deliberations like misinterpreting the situations) due to
  - vagaries of human thoughts
  - social pressure
  - inappropriate physical structure
- **Violations** (deliberate behavior)
**Psychological research in the field of driving ergonomics**

- To describe and categorise driver behaviour (task completion) in situ (as safe or unsafe, legal or deviant...),

- To identify the internal factors (relating to the driver himself, such as his experience) and the external factors (the technical and social environment of driving) that account for this behaviour,

- To reveal the psychological processes (perceptual, cognitive, motivational,) that govern drivers’ activity.

**Psychological processes :** A simplified model of driver’s categorisation of the road situation and choice of regulating action

![Diagram](image-url)
Behavioral models

Behavior is determined by the combination of:
- internal knowledge
- external knowledge
- constraints

Minimize the amount of material to learn or the completeness or precision

The importance of predictive activity

In-depth accident studies have highlighted the problems associated with the temporal constraints underlying the occurrence of accidents and have confirmed the importance of predictive activity when driving (Malaterre, 1990; Van Elslande et al., 1998).

The disparities between drivers' expectations and predictions and the events that actually occur during their journeys seem to be a result of processing errors and a belated detection of critical situations, reducing the safety margin for resolving them.
Research orientations for designing roads

The malfunctions observed (lapses, errors, violations, conflicts, accidents) have led researchers to focus on identifying the factors and mechanisms at the root of these problems.

How the road infrastructure could support drivers’ activity

- “Positive guidance” (Allen and Lunenfeld, 1986)
- “Road readability” (Mazet, Dubois and Fleury, 1987)
- “Self-explaining roads” (Theeuwes and Godthelp, 1995)

How to structure the road network by adopting homogeneous and consistent design principles

How to identify the relevant infrastructure features likely to provide a clear picture of the functionality of the road space

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Road readability and the importance of expectation

- To help drivers to detect, identify and interpret current situations

- Given the dynamic nature of driving and the associated temporal constraints, to facilitate their anticipation of on-coming situations and the events that could occur.

- Given the collective nature of driving, to facilitate interactions between drivers and to ensure that the rules to be applied for solving potential conflicts are clear and easily understandable.

- Lastly, and in the longer term, reducing the variability of road infrastructure design should make it easier for drivers to learn its functionality and its use.

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Sustainable safety orientations (F. Wegman)

To structure the road network by adopting **homogeneous and consistent design principles**.

To identify the relevant infrastructure features likely to provide:
- **Clear picture of the Functionality of the road space** (through categorisation: roads, distributor roads, access roads)
- **Homogeneity of mass and/or speed and direction**
- **Predictability of road course and road user behaviour by a recognizable road design**

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Designing for prevention from D. Norman

- Put the required knowledge in the world rather than in the head (provide a good conceptual model)
- Simplify the structure of the task
- Keep the task much the same but provide mental aids
- Use technology to make visible what would be otherwise invisible (for improving feedback (immediate and obvious effect of action for control) and feedforwarding (anticipation, planning in the future) and the ability to keep control)
- Change the nature of the task
Designing for prevention from D. Norman (2)

• Narrow the gulf of execution and evaluation (distance between mental representation and state of the system). Make things visible
• Use the power of physical or artificial (cultural, semantic, logical) constraints to reduce the number of alternatives
• Prefer forcing functions rather than warning signals to prevent error (interlock, lockin, lockout barriers) and minimise the nuisance
• When all else fails, standardize the system (traffic signals). Form of cultural constraints.

Precautions

• Designing for special people (make things adjustable): aged (driver on motorways at dusk), handicapped
• The problem of focus: selective attention (fire escape). Trade-off: usability/safety (not to use)
• Eliminate one danger to create a second one
• Problem of communication and coordination between road users (groups working activity)
Complex situations

- The questions prompted by the identification of these preventive measures stem from **complex situations**, whose dimensions must be examined and taken into account when designing research studies, validating the results and formulating recommendations.

- **Open system**: Complex (/well structured) and tightly (/loosely) coupled system

- Applying a systemic approach (see, for example, Hale and Glendon, 1987) entails focusing on **interaction phenomena** between the driver(s) and the technical and organisational components of the system (vehicle, road infrastructure, legislation, traffic management,...) and hence **going beyond a simplified view of causality in analysing system malfunctions**.

- Reasons of accident into the mismatch between the variability of contexts and conditions and the variability of performances, rather than into the failures of actions

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Accidents are the result of some defective interaction in the system

Pierre van Eslande
Emergence

• Car-following model

\[ a_i(t + T^r) = \lambda = \frac{V_i(t + T^r) - x_i(t)}{V_i(t)} \frac{(V_i(t) - V_i(t))}{x_i(t) - x_i(t)} \]

Critical aspects of the driving task

Errors, incidents, conflicts and accidents = limits of drivers’ adaptation to their task

– It is thus important to understand the reasons for such deviations,
– To identify the conditions in which they are most likely to appear,
– To analyse the processes that could explain their occurrence.

Deviations are particularly common when drivers have to manage changes in road situations and pose serious problems that are known to have a significant impact on the reliability and safety of man-machine systems (Hale and Glendon, op. cit.; Leplat, op.cit.).

For the driver, these changes may be more or less predictable and more or less expected, depending on whether or not s/he has the knowledge and the information needed to detect and identify them as s/he drives along.

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Performance migration and rule violations

Amalberti

Rasmussen

Safety by constraint

Barriers, regulations, procedures, standardization, elimination

Individual, team, organisation (sharp end, blunt end)

Function

Success (accident free)

Slow drift, abrupt transition

Malfunction (root cause)

Safety is achieved by constraining performance

Failure (accidents, incidents)
Safety by management

- Individual, team, organisation (sharp end, blunt end)
- Physiological factors
- Psychological factors
- Social factors
- Organisational factors
- Environmental factors

Normal function (performance variability)

- "Amplify"  
Success (no accidents or incidents)

- "Dampen"  
Failure (accidents, incidents)

Performance variability is needed for normal functioning (successes)

Failures cannot be prevented by eliminating performance variability

Exemple

- Shared spaces
- Hans Monderman
Drivers’ speeds in traffic

Monitoring and control of driving speed = crucial subtask in driving

Speeding, which covers excessive speed (i.e. driving above the speed limits) as well as inappropriate speed (driving too fast for the prevailing conditions), is often a leading cause for many the road accidents

Speeding can be seen as a multidimensional issue,

- Sometimes unintentional (associated with perceptual errors or lack of knowledge)
- Sometimes deliberate (associated with negative attitudes towards speed regulation, under-estimation of the risk associated with speed, or suboptimal compromise between the various demands of the driving task).

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Many research devoted to analysing factors influencing speed behaviour

- perceptual aspects of speed control
- cognitive and motivational aspects of speed control
- drivers’ representations, attitudes beliefs and norms with regard to driving speeds and the regulation or enforcement of speed limits

with a view to identifying ways of influencing driving speeds through various countermeasures such as:

- Design of road infrastructure
- Design of new driver support system
- Drivers’ training
- Design of safety campaigns
Variables influencing speed perception

- Role played by peripheral vision in estimating driving speeds (Salvatore, 1967 and 1968).

  Speeds are estimated more precisely in peripheral vision, but are underestimated in foveal vision.
  Influence of the size of the field of vision
  Example: speed under-estimation on wide roads that lack peripheral points of reference

- Role played by auditory information

  Speed under-estimation when the driver is deprived of these information (Evans, 1970; MacLane et Wierwille, 1975).
  Effect of the vehicle size on speed estimation (Mathews et Cousins, 1980):
  Example: reducing the noise in vehicle can cause under-estimation of driving speed

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Variables influencing speed perception

- Effects of speed changes (acceleration ou déceleration).

  The greater the deceleration, the greater the error in the estimation of a subsequent speed (Salvatore, 1967; Denton, 1967).
  The absolute error is greater after decelerating than after accelerating (Recarte et al., 2000).
  Example: Difficulties when managing « transitional situation », situations in which there is a need to adjust speed significantly (Saad, 1974).

- Speed adaptation associated with driving duration

  Reduction of speed sensation with duration of driving (Denton, 1972).
  The longer the exposure to an initial speed, the greater the adverse effect on drivers’ estimation of a lower subsequent speed (Shmidt et Tiffin, 1969).
  Example: leaving a motorway (slip road)

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Some infrastructure measures

Some studies have looked at the extent to which changes to road layout and design can offset perceptual factors.

Denton (1971) : by modifying the spatial structure of the road environment, it should be possible to compensate for speed adaptation mechanisms, notably at the approach to transitional situations.

Use of transverse marking patterns : Compared to a road with no markings, drivers who encountered the transverse markings made greater reductions in their speed.

This type of intervention was introduced under real conditions at approaches to driving situations where drivers are required to reduce speed, such as approaches to roundabouts, bends or motorway exit roads (see, for example, Denton, 1973; Helliar-Symons, 1981; Malaterre, 1977, Shinar et al., 1980; Taylor et al., 1995).

Assessments of such markings generally show that drivers reduce their speed, although it is not sure how long the effect lasts (Martens et al., 1997).

Some infrastructure measures

A more systematic investigation of various road markings and their combination was carried out by Goodley et al. (1999) within a research programme on the effectiveness of “Perceptual countermeasures to speeding” (PCM).

Perceptual countermeasures were defined as “manipulations of the road scene presented to the driver that can influence his or her subsequent behaviour”.

A series of simulator studies: speed effect of a representative sample of PCMs (using transverse, centreline or edge-line road markings) installed in either at the approach of transition zones or along roads involving continuous driving.

Impact of transverse markings on drivers' speed reduction at the approach of transitional zones

Peripheral transverse lines were also effective at reducing drivers' speed.

Perceptual lane width narrowing is effective at reducing drivers' speed along roads with continuous driving.
Cognitive and motivational aspects of speed control

The cognitive and motivational aspects of speed choice include:

- The knowledge,
- The mental representations
- And the strategies

that drivers use to remain in control of a given driving situation and to adjust their speed to comply with

- “regulatory” requirements relating to speed limits
  - Acceptance of speed limitation
  - Margins of tolerance: magnitude and duration
- and/or “functional” requirements relating to road infrastructure characteristics and traffic conditions (Saad, 1983)
  - Perception and identification of functional constraints
  - Prediction of changes in situations

Drivers’ knowledge of speed limits in force

Several research studies suggest that there is confusion regarding the speed limits in force on certain sections of road:

- Hogg (1977): Correct responses varied from 99% to 19%, depending on the road scene, with factors such as width and alignment of the roads appearing to dominate drivers’ judgements.
- Cameron (1980): Between 18% and 32% of the drivers stopped by an interviewing team were unable to correctly identify the speed limit that applied on the stretch of road over which they had been travelling.
- Same tendencies observed by Carney (1986) and Stradling et al. (2003)

Hence, lack of knowledge about which speed limits apply can, in certain situations, account for the non-observance of speed limits in driving situations. Drivers’ judgements are sensitive to differences in the road environment. Depending on the characteristics of the environment, it is more or less easy for drivers to guess the speed limit in force.
Drivers’ attitudes and representations of the speed

Aberg et al. (1997) studied the same phenomenon in Sweden and in Denmark on eleven main roads traversing built-up areas with a speed limit of 50 Km/h, and then questioning drivers (both on the spot and by questionnaire).

In both countries, over 50% of drivers failed to respect speed limits despite most claiming to be in favour of compliance.

It was concluded that variables other than willingness to obey the law must influence observed speeds.

– Most drivers overestimate the speeds of other drivers
– As many drivers also state that they want to travel at the same speed as other road users, overestimation of the speed of other road users is probably one of the factors that accounts for speeding.
– The results also showed that drivers who were least negative towards speeding drove faster than other drivers.
– The drivers who thought that other road users were driving fast, or who wanted to drive like other road users, maintained a higher speed than other drivers.

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Synthesis

Studies that seek to identify the variables relating to infrastructure characteristics show that drivers make larger speed adjustments where the transitional situation is clearly of a functional nature, that is to say where the need to adjust the speed of their vehicle is sufficiently “obvious” to them.

- Formal notification of a transitional situation (signing) is not sufficient to induce appropriate speed behaviour if it does not correspond to the way in which the driver perceives and categorises the situation.
- Obvious discrepancies between the structural elements of the road environment and the speed limits in force reinforce inappropriate driving behaviour.

This suggests that it is important for road designers either to highlight the transitional situation visually or to incorporate structural constraints that clearly identify it as a change in relation to the previous situation.

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Synthesis

Studies examining the contribution of legal speed limits to speed behaviour show that drivers do not usually comply strictly with speed limits.

Drivers exceed speed limits to varying extents, depending on the driving context and their own characteristics.

Drivers’ attitudes to speed limits, the importance they attach to compliance with local traffic conditions, as well as their representations of the speeds of other road users, also account for the diversity of speed adjustments made by drivers.

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Part played by infrastructure factors in accident processes

- I.1 in the normal traffic situation
- I.2 in the pre-crash situation
- I.3 in the emergency situation
- I.4 in the crash situation

- Road alignment
  - horizontal (bends)
  - Vertical (slopes)
- Road or lane width
- Shoulder surface and width
- Road surface
- Road environment
- Lateral obstacles
- Signing
- Central and lateral markings
- Junction design
I.1 in the normal traffic situation

- The road user activity:
  - collecting information from the road and its environment
  - treating the information in order to build up a representation of the driving situation
  - controlling speed and trajectory of the vehicle
• The road features must help drivers
  - To exert this control adequately
  - To foresee any hazard that may occur

**How the road infrastructure could support drivers’ activity**
- “Positive guidance” (Allen and Lunenfeld, 1986)
- “Road readability” (Mazet, Dubois and Fleury, 1987)
- “Self-explaining roads” (Theeuwes and Godthelp, 1995)

What is the speed limit?
And the speed limit is …

Douala-Yaoundé (Cameroun)
Dr Joëlle TAMBEKOU, RSD, Cameroun
Dr Emmanuel Lagarde, INSERM, France
I.2 in the pre-crash situation

- The pre-crash situation is a breaking point in a road user movement

- Signing and marking indicate to the road-users the hazards they need to expect

- Road features should also help reduce potential encounters and therefore conflicts between road-users
Critical changes in the road infrastructure

Critical variations may occur due to a change in the road infrastructure that the driver could not anticipate in view of the road characteristics upstream of the change:

- For example, when the driver cannot anticipate the presence of a sharp bend and momentarily loses control of the vehicle,
- or when the driver does not expect to come across traffic lights and has to make a sudden stop.

These critical variations are often related to "coherency" problems in the sequencing of different types of road environment (Fleury, 1988).

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Managing changes in road situations

For instance, some research shows that when crossing intersections, drivers may take time to become aware of conflicts with other drivers, or display a certain inertia in the regulating actions they take (Monseur and Malaterre, 1969; Saad et al., 1990).

Factors associated with the features of the road environment (disparity between the functional characteristics of an intersection and the regulations governing it, or the visual aspect of the intersection), as well as factors related to driver characteristics (general experience or specific experience of the site), have been identified as the causes of these problems.

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In a curve

- Putting in specific chevron signs as well as markings are cost effective countermeasures
- If larger financial means are available, it is recommended to flatten the curve (increase the radius)

Exemples
Self-explaining roads? By X. Cocu

Critical changes / behaviour of other road users

Critical variations may also be related to the behaviour of other road users, when the action they take unexpectedly interferes with the tasks the driver is performing or planning to perform.

Different elements could be at the root of these problems, such as

- the application of contradictory systems of rules by the different participants in a situation,
- the lack of communication between users,
- or a failure to understand another driver's behaviour or intentions.

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1.3 in the emergency situation

- The road must « forgive »
- In particular, shoulders should provide sufficient space:
  - to make it possible to avoid frontal collisions
  - to return to normal trajectory after a car has encroached
  - To be used by non-motorized traffic (pre-crash situation)

Width of the carriageway and of shoulders

- Accident rates decrease with increases in lane and shoulder width
- Optimal carriageway and shoulder width depends upon traffic volumes and road alignment
FIGURE 3-1 Cross section design features and terms.

FIGURE 3-2 Normalized relationship between accidents and lane and shoulder conditions (2).
I.4 in the crash situation

• The trajectory may end by:
  - a lateral or frontal collision with obstacles
  - a rollover
• Through secondary safety measures, reduce the severity of injuries by
  - clearing the road sides
  - removing hard obstacles
  - protecting vehicles against them through restraint systems (guardrails or barriers)
• Exits from carriageway are described by two features:
  - exit angle (in average 6 degrees)
  - Exit attitude (in line with the previous trajectory or sideways)
• In general, maximizing clear-zone width (up to ten metres) is the best solution to reduce accident severity

- Mounting fragilized lamp-poles, utility poles
- relocating signs and poles
- installing gardrails
improve secondary safety
III. What rationale for improving roads?

• When accident risk is high at some road stretches, undertake corrective action, whatever the traffic volumes.
• When accident risk is moderate on parts of the road network with high traffic volumes, general upgrading should be considered.
• SafetyNet (2009) Roads, web text

A critical issue: Behavioural Adaptation

Mainly used to signal unexpected or unanticipated behavioural changes that appear in response to the introduction of a change in the traffic system and which may (more or less) jeopardise its expected safety benefits.

Behavioural adaptation may be an immediate response to the change introduced in the traffic system or may only appear after a long time period.

Although behavioural adaptation is a widely acknowledged phenomenon, the factors likely to explain it and the processes underlying its occurrence (in time and space) and are not clearly established.

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**Behavioural adaptation**

Several variables have been suggested as factors likely to induce the occurrence of a behavioural response, such as:

- the drivers’ perception of the change introduced in the traffic system: does the change directly influence the way the driving task is performed, does the change alter the drivers’ subjective safety?
- the degree of freedom that the change allows drivers: is there any opportunity for drivers to change their behaviour?
- the presence of competitive motives for changing behaviour, and so on (OECD, 1990).

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- The retro-active influence of road improvement on safety and risk should be controlled of accident
- Better roads induce higher speed which, in turn, lead to higher numbers of accidents
- Any safety measure on roads and their environment should thus be completed by some educative action addressing the road-users concerned