ASSOCIATION MONDIALE DE LA ROUTE
WORLD ROAD ASSOCIATION
ASOCIACIÓN MUNDIAL DE LA CARRETERA

LA GRANDE ARCHE
Paroi Sud - 5e étage
92055 La Défense Cedex - France

T +33 1 47 96 81 21
@ info@piarc.org
ω www.piarc.org

ROAD SAFETY MANUAL
A GUIDE FOR PRACTITIONERS !

PLANNING, DESIGN & OPERATION

DESIGNING FOR ROAD USERS

PIARC (World Road Association)

Version 2 - 30/09/2019

8. DESIGN FOR ROAD USER CHARACTERISTICS AND COMPLIANCE

KEY MESSAGES

- Human factors is a well-established scientific term in use since the 1930s by the safety community of man-machine-interaction. Human Factors is defined as those psychological and physiological threshold limit values that are verified as contributing to operational mistakes in machine and vehicle handling.
- Unless roads are designed and managed to take account of human factors, it is unlikely that a Safe System can be achieved.
- Speed management is a one key step towards creating a Safe System. Speeds are the result of road design and the resulting subconscious choices made by road users. Speed can be heavily influenced by the number of contrasts in the periphery of the field of view (e.g., by signs and markings), by the size of the visible road surface and the distance of the fixation point in the depth of the field of view.
- Two additional and until yet not systematically practiced key steps are the management of the field of view and the pre-programming of drivers expectations. That's why road engineers have to be trained in psychological basics of activity regulation (perception, cognitive processing and motor response).
- A skillful combination of design elements can create ‘self-explaining’ roads where appropriate actions, including speed choice, are obvious to road users. Self-explaining roads lead road users to behave in a way that road planners and designers expect, thereby resulting in low crash rates.
- In addition to road design, a range of techniques for directly influencing road user behaviour are available, including education, publicity and enforcement.
- Good practice in each of the above areas is now well-understood, and guides to good practice are available.

8.1 INTRODUCTION

THE CHALLENGE

Roads are provided to cater for the movement of people and resources between destinations, i.e. to provide for mobility and access. Particularly in LMICs, roadside trading and social interaction continues to be an essential third function for parts of the road network. In these countries, the benefits of setting aside areas of public space, where sociability rather than mobility is the priority, are being increasingly recognised. Mobility, accessibility, and commercial/social interaction are therefore the three key human uses that roads have to be designed and managed to serve.

Earlier chapters introduced the concepts of the Safe System, and of safe travel as a product, which requires certain actions to produce it. Safe products must match the needs, capacities and expectations of their human users and roads are no exception. This chapter outlines how to create a road system that takes account of human characteristics and meets Safe System requirements.

Human factors are a well-established scientific endeavour that has influenced developments in many areas of technology. Its application to road safety issues in a formal sense goes back to at least the 1930s (e.g. Forbes, 1939). Contemporary understanding of issues, such as the time it takes to perceive and detect any critical location that challenges the driver to adapt his driving programme and to make new decision, the desired luminance, size and contrast between objects and the background needed to resolve detail, and the rate that information is absorbed, should underpin key standards in road design. Other important demands for road design arise from the holistic perception of the road user within the road environment. From there essential design principles of "Gestalt" have to be included in the technical design considerations. This understanding of the laws of human perception and activity regulation that includes the decision-making capacity of the road user allows for the development of design and operational specifications for the road system. This includes elements such as:

- such as sight distance requirements
- lighting criteria
- design and dimensions of road signs, and
- spacing between successive decision points

By effectively do so, the road users can navigate the road system safely and comfortably. Since knowledge in Human Factors continues to evolve, many of its findings remain to be absorbed in technical standards and guidelines. This chapter seeks to introduce the concept of Human Factors, relate it to Safe System principles, and explain how Human Factors can be applied to create a safer road system. Human Factors is the **generic term** for those **psychological and physiological threshold limit values** which are verified as contributing to operational mistakes in machine and vehicle handling. It deals with general and stable subconscious reactions of common road users and excludes temporary individual reactions and conditions. From there can be derived essential conclusions for basic design principles that are until yet not well established in current national design guidelines (PIARC Report 2012R36EN).

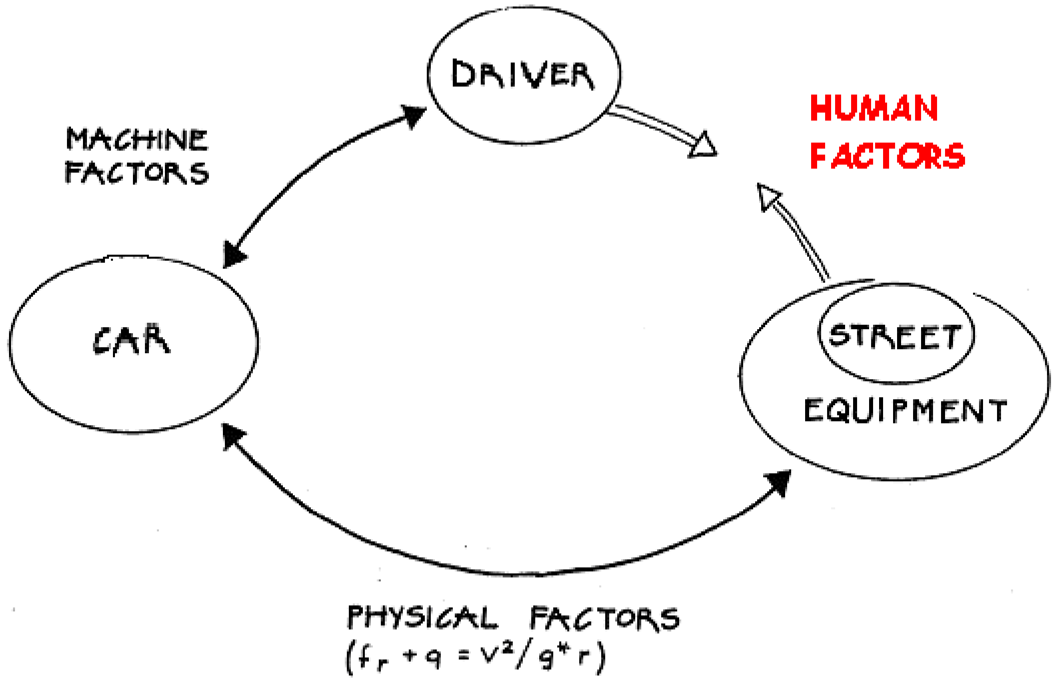

Figure 8.1 Human Factors in the system of road safety

In road safety, human factors is concerned with the interaction of human road users with the roadway system elements, including vehicles. The distinction is often made between unintended errors and disobedience of road rules. Unintended errors tend to occur when road users misperceive some aspect of the road system, they do not have enough time to react to changing situations, or they are confronted with unexpected situations. These issues and the means of remedying are discussed in Designing Infrastructure to Encourage Safe Behaviour.

Disobedience of the road rules often occurs when the road system does not adequately meet road users' needs, e.g. when there are long waiting times to cross at signalised pedestrian crossings. However, disobedience of the road rules may also occur when users do not understand what they are supposed to do or understand the benefits of compliance. This is particularly the case in LMICs as they rapidly motorise and upgrade their road networks. Disobedience may also occur because some road users believe they can gain a benefit (such as a faster journey or a more convenient parking or unloading spot) without incurring any penalty. These issues and some of the implications they have for infrastructure provision are discussed in Other Means of Encouraging Road Users to Behave According to the Rules

Human Factors is not the same as we commonly understand human behavior or human performance to be. So, the questions of personality traits like aggression, the will to violate traffic rules consciously or mistakes because of medication or age has to be regarded separately. From there can be derived essential conclusions for basic principles of driver's education, campaigns for influencing driving behavior and enforcement.

- Design measures to create a self-explaining and failure-forgiving road according to Human Factors needs of road users, are described in Chapter 8.2
- Measure of communication, education and enforcement including special warning signs and campaigns are described in Chapter 8.3

HUMAN FACTORS AND THE SAFE SYSTEM

Human Factors have a key role to play in achieving Safe System requirements.

Safe System principles require that no road users are killed or seriously injured. In an ideal system, collisions would not occur because the road is designed according to the needs of perception, cognitive processing and motor response for all the users. This is unlikely to be achieved as long as humans directly control vehicles and many roads are not designed consistent with the road users needs. Even with the advent of automonous and connect transportation human control is still likely for some time into the future.

Efforts should therefore be made to help road users perceive the road correctly and to make decisions about driving, riding or walking that are safe for themselves and other road users. Applying the Human Factors principles described in the remainder of this section should go some way to achieving a collision-free road network, but it must be recognised that improving guidance will not always succeed in preventing collisions. That being the case, space to correct mistakes should be provided where possible, e.g. by having lane widths that allow some manoeuvre space, providing sealed shoulders, or by having stop lines some metres in advance of the walkway on pedestrian crossings. Adequate recovery space will reduce the number and severity of impacts; however, it will not always succeed in preventing impacts. Therefore, the Safe System requires forgiving infrastructure and forgiving vehicles so that when collisions do occur, they will not result in fatalities or non-recoverable injuries.

KEY SOURCES ON HUMAN FACTORS AND ROAD DESIGN

The NCHRP report, Human Factors Guidelines for Road Systems (HFGRS) (Campbell et al., 2012) is a comprehensive source on Human Factors and road system design and management concerning the reaction time needs of road users. It is intended to supplement the primary design references and standards, so that designers who do not have an extensive Human Factors background will be better able to take account of road user reaction time capabilities and limitations in the application of these standards.

The World Road Association (PIARC) has published a Human Factors documents – Human Factors Principles of Spatial Perception for Safer Road Infrastructure (HFPSP) (PIARC, 2019). It is the most comprehensive approach to illustrate in a practical way the needs of road users for proper reaction time, for reliable guidance and stabilization of user's field of view and to pre-program user's expectations so that mistakes can be avoided by design. It is based on the state of the art of human sciences, especially on the Gestalt principles of the Gestalt psychology. Gestalt is the impression of content of perception that is clearly distinguishable from its background of scenery and the details of which are so integrated as to constitute a functional unit with properties not derived from the summation of its parts. It aligns well with Safe System principles and advocates a proactive approach to safety management, with the aim of designing roads so that crashes are unlikely. The HFPSP guide provides a powerful and convenient method for applying Human Factors principles to a wide range of situations that are likely to be encountered by drivers. It does not explicitly consider pedestrians or other vulnerable road users as active participants in the traffic system. However, the essential principles are also applicable to these road users, and the reader is encouraged to do so in cases where it is appropriate in their own practice. The Human factors guidelines for a safer man-road interface (PIARC, 2016). Human Factors concept presented in the guidelines highlights how road characteristics that influence a driver's or wrong driving actions. The guideline explains the relationship between several road characteristics that trigger wrong perception and therefore also wrong driving reactions, most of which happen subconsciously. The guideline containes detailed examples and sketches allow those using the guideline to gain an understanding between misleading and irritating road character-istics and operational mistakes. Better understandig the human factors relationship to road safety allows for an "on-the-spot" investigation of black spots or single vehicle accidents or in road safety inspections (RSI). This information is also very valuable in the planning and design processes in road safety audits (RSA).

These documents provide powerful and convenient methods for applying human factors principles to a wide range of situations that are likely to be encountered by drivers. The following illustration outlines the damage and prevention oriented accident approaches (Birth, Sieber and Staddt, 2004).

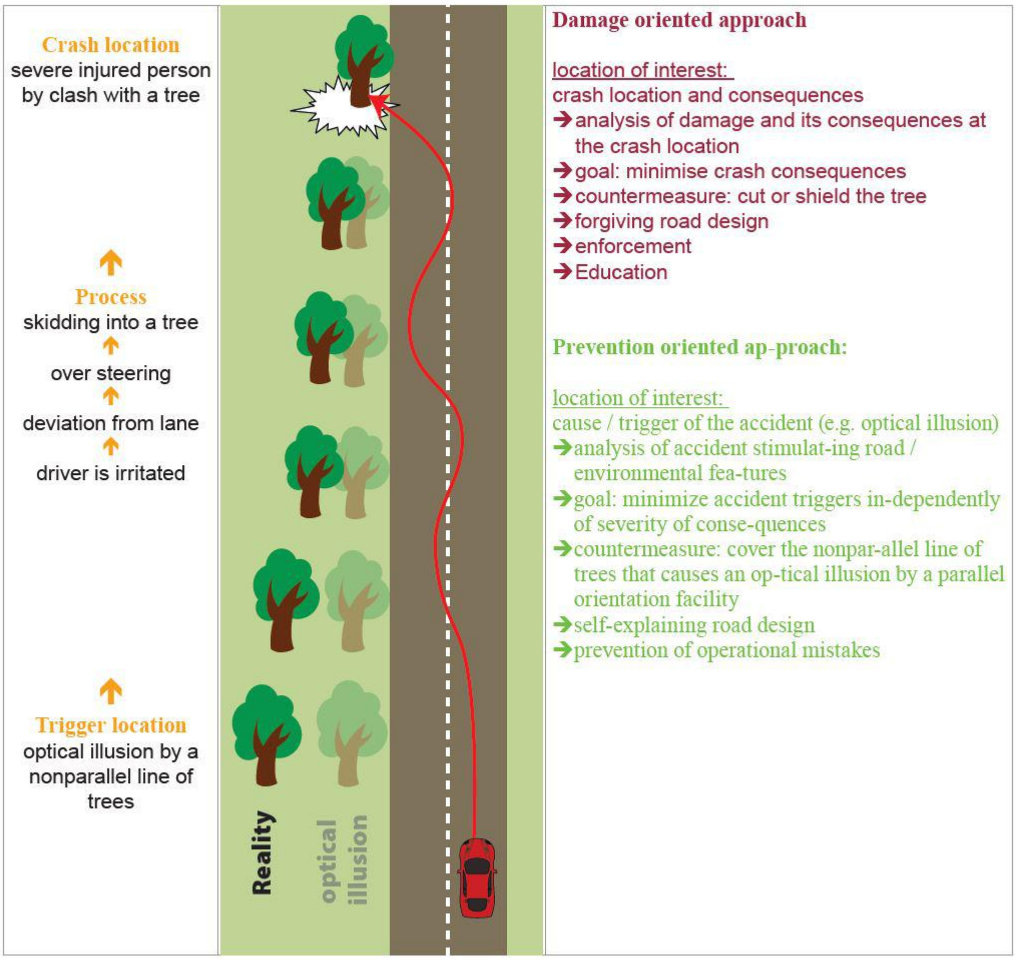

Figure 8.2 Damage and Prevention Oriented Accident Approaches

8.2 DESIGNING INFRASTRUCTURE TO ENCOURAGE SAFE BEHAVIOUR

THE BASICS: ROAD USER CAPACITIES AND BEHAVIOURS ACCORDING TO HUMAN FACTORS NEEDS

The demand of self-explaining design of Man-Machine Interfaces has produced a revolution in operating computers, machines and phones. The principles of an intuitive design that suggests users how they can use their mobiles or tablets reliably without further instruction are nowadays very common. In analogy to that, a self-explaining road design should be as intuitive as possible for the road user so that danger symbols, prohibition and requirement signs are not required any more in the Man-Road Interface. So, it is not only important to build up a clear system of road categories to inform the driver about the appropriate speed or to set speed limits. A road's Gestalt should provide a clear impression of how to drive and it should pre-program driver’s expectations so that they are never surprised or encouraged to take any risk. Out of the analysis of about 1.400 accidents spots and accident lines in Germany the most important mistakes that violate the principles of a self-explaining road design are presented.

The three Human Factors key requirements for a self-explaining design are discussed below.

HUMAN FACTORS REQUIREMENT NO.1: GIVE ROAD USERS ENOUGH TIME

The time it takes an average driver to adapt from one traffic situation to the next, or to adjust to new requirements, is much longer than what is stated in many current guidelines. Because humans are not constantly alert and searching for new information, they need more time. This is especially true when information is difficult to find or is unusual, or when the driver is confronted with complex decisions or when unusual manoeuvres are required. Instead of one or two second (simple "stimulus-reaction time") it takes the average driver at minimum 4-6 seconds to adapt to a new driving requirement ("anticipation-response time." PIARC Report 2012R36EN). At 100 km/h, the distance covered before the vehicle can be brought to a complete stop is up to 300 m, allowing for braking distance (note that this may take longer if braking is slow due to a wet road or other circumstances).

Figure 8.4 Intersection not visible 125 m ahead: unexpected braking and high speed cause of rear-end collisions (Source: Birth, Sieber, and Staadt, 2004

A user-friendly road will give drivers the necessary time to adapt to new and unexpected situations. It will give them the time they need to safely reorganise their driving program. That is why it is not enough to provide the driver with a reaction time of 2-3 seconds (Stopping Sight Distance, SSD, with manoeuvre section and response section). The design should also provide an anticipation section with a minimum 2-3 seconds to identify an unexpected or unusual situation with more complex decision demands (Decision Sight Distance, DSD). In situations that are more complex or involve higher speeds, it is recommended to have an advance warning section with proper signing and instructions.

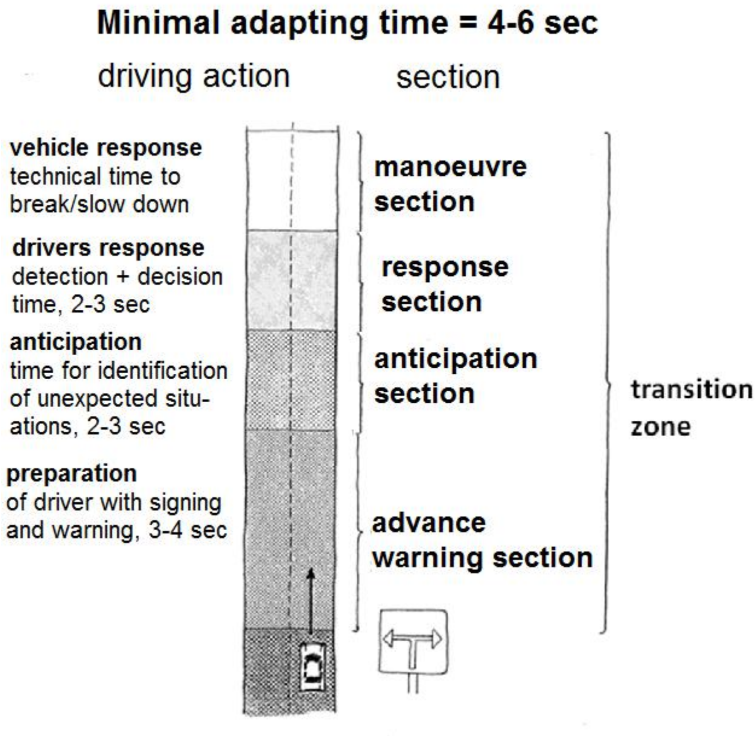

Figure 8.5 The six second requirement - Source: PIARC, 2015.

The usual ways to avoid this situation in practice are to:

- eliminate the problem by providing an unobstructed view of the critical locations. Remove visual obstacles such as crests, curves, vegetation and buildings prior to crticial locations. If useful, construct well detectable traffic islands;
- reduce the problem by implementing treatment that guide a driver's attention directly to the critical driving demand (if the problem cannot be eliminated) Use attention guiding clues such as coloured road surfaces, pavement markings, and other advisory treatments;
- minimise the problem, if attention cannot be drawn to the critical point warn road users by installing traffic control devices such as speed limits, pedestrian crossing facilities, road markings or signs to prevent overtaking.

Additional good solutions and best practise examples can be found in the PIARC Report (PIARC 2012b) "Human Factors in Road Design. Review of Design Standards in Nin Countries."

REQUIREMENT NO 2: THE ROAD MUST PROVIDE A SAFE FIELD OF VIEW

Monotonous, clouded, deceptive or distracting impressions affect the quality of driving. The road, together with its surrounding field, offers an integrated field of view. This can either stabilise or destabilise the driver; it can tire or stimulate them. It can also result in either increased or reduced speed. Speed, lane-keeping and reliability of direction are functions of the quality of the field of view.

A user-friendly road will give drivers a well-designed field of view with sufficient contrasts to increase alertness. It will provide good optical guiding and orienting facilities with symmetrical and orthogonal impression.

A good-quality field of view safeguards the driver and keeps him from drifting to the edge of the lane or even leaving it. Misleading eye-catching objects in the periphery of the field of view activate subconscious changes in direction. The most serious consequences arise from eye-catching objects that differ from the road axis. These lead in extreme cases to a horizontal swing of the complete field of view: The driver has the feeling that the road and its surroundings are moving while he is in an unmoved position. Such objects lead to gross mistakes in steering. At minimum they lead to disturbances in lane-keeping, though these can mostly be corrected (for this reason billboards near interurban roads that catch driver’s attention to a wrong direction should be forbidden like in Germany).

An experienced and Human Factors trained designer will avoid monotony in curvature and visual appearance. They will avoid optical illusions or misleading objects that destabilise drivers and negatively impact their driving and will take advantage of the optical perception to influence the driver's choice of speed.

Factors that are forming a safe field of view include the following characteristics:

a) Density of the field of view

The amount of information also influences driver’s speed. The term used for this is *density of the field of view*. It is a function of the number of objects that contrast with the background. The presence of very few contrasting objects leads to monotony as well as reduced performance and reactivity. To avoid monotony the driver subconsciously changes his driving activities in order to increase information input: he swerves, brakes or – in most cases – increases speed. Consequently, it is desirable to achieve an optimal level of bness and color-contrast (optical density) to support the correct choice of speed. That is why efficient speed management relies on changing bness and color contrasts to avoid subconscious speeding up.

Figure 8.6 Density of the field of view is low; monotonous and long straight-ahead section stimulate subconscious speeding up (Birth, et. al 2004)

b) Lateral space structure

It is proven, that the lateral field of view and its information provide the most important information to master the difficult task to hold balance on the road like on a balance beam.

If designers fail to take this fact into account, they may not make the prediction about how the finished design will influence lane-keeping. To hold balance on the road (as on the balance beam) drivers need a clear orthogonal orientation out of objects in their periphery. Orthogonal objects or structures calibrate the equilibrioception of road users that is needed for lane-tracking. Equilibrioception is the perception of the position of an organism in the space with the help of the eyes (visual system), ears (vestibular system) and the body's sense of where it is in space (proprioception). Structures over the road like bridges, advertising, signaling and toll facilities should be symmetrical, of equal height, and the angle of skew to the own road should be less than 15° from perpendicular.

It was found at accident spots that asymmetrical posts of a bridge or pitched bridges/advertisements confuse and disorientate drivers with regard to lane-keeping and result in run-off-road accidents.

Driving reliably through a curve also critically depends on the quality of the field of view and a clear distinguishable Gestalt of the curve. Best driving results are achieved when the driver has an unobstructed view over the inner curve and the outer curve has a closed optical framing that provides with its Gestalt a clear instruction that there is a curve at all. It provides also clear information about the sharpness of the curve.

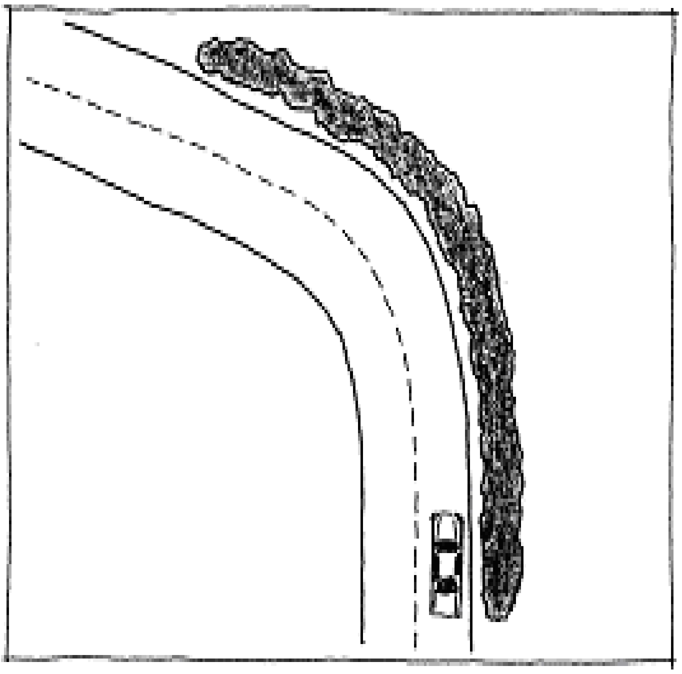

Figure 8.7 Complete frame of the outer curve and unobstructed view of the inner curve stabilise the driver (Birth, et. al, 2004)

c) Depth of the field of view

The driver orientates themselves in the environment that surrounds them. To estimate their position relative to the road and to their surrounding and to other drivers, they depend on their changes of position, the changing view axis and the changing points/lines of reference in the environment. The most serious consequences arise from eye-catching objects that differ from the road axis. These lead in extreme cases to a horizontal swing of the complete field of view.

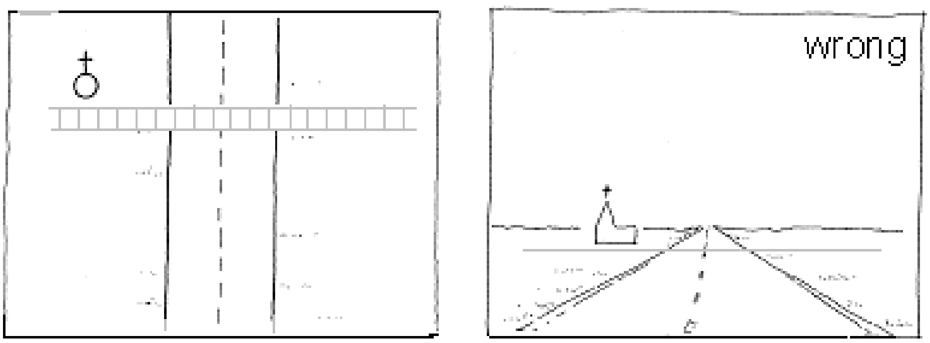

Figure 8.8 Depth of space structure: Dominant eye-catching object (church) in competition to a subdominant railway

crossing

All lateral orientation clues should be parallel to the road edge, regularly spaced and equally sized to stabilise lane-tracking. This is important for markings, hard shoulders, side strips, safety barriers, snow and wildlife fences, plantings, bicycle ridings and rescue paths and also for public maintenance roads. It was found at black spots that non-parallel orientation lines lead to the impression of prolonged (if lines are converging) or shortened (if lines are diverging) distances up to critical locations. Optical illusions cause subconscious swerving, sudden driving manoeuvres and technically “unexplainable” run-of road accidents. The word *illusion* comes from the Latin verb *illudere* meaning "to mock.” Illusions are the result of the complex information processing of the brain and the visual system that tricks us into perceiving something as different from what it actually is. Thus what we see does not correspond to physical reality.

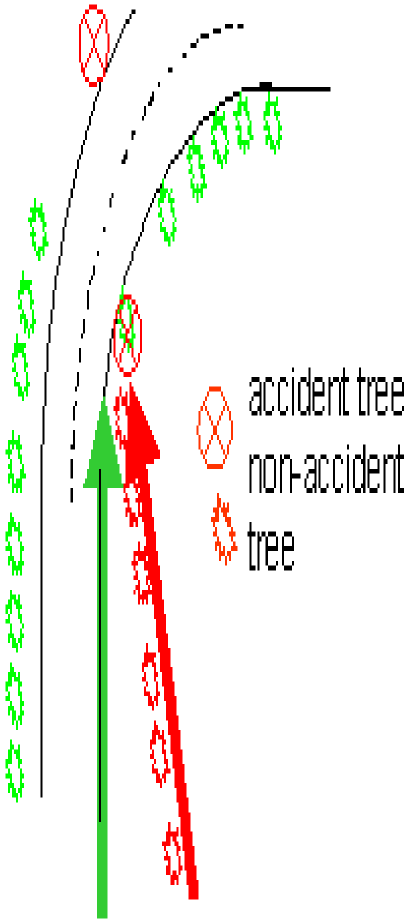

Figure 8.9 Distance Illusion at an accident point

These mistakes can be addressed by following measures:

- eliminate the problem by redesigning the road and its field of view: create sinuous “rhythmic” road alignment against monotony; create symmetry of superstructures by constructive measures, etc.
- correct the field of view (if the problem cannot be eliminated), e.g. by the use attention guiding eye-catching objects along the view axis, cover eye-catching objects that differ from the road axis, create a complete framing of outer curves, avoid visibility barriers in inner curves, cover non-parallel optical guiding lines that lead to optical illusions, etc.
- minimise the risk by warning road users (if satisfactory correction cannot be achieved) by installing traffic control devices such as speed limits, prohibiting overtaking or pedestrian crossing facilities.

Additional good solutions and best practise examples can be found in the PIARC’s Report (PIARC, 2012b)“Human Factors in Road Design. Review of Design Standards in nine Countries”.

REQUIREMENT NO 3: THE ROAD ENVIRONMENT MUST CORRESPOND WITH THE ROAD USERS’ PERCEPTION LOGIC

Drivers follow the road with an expectation and orientation logic formed by their experience and recent perceptions. These affect their actual perception and reactions.

The same principle applies when climbing stairs. After only a few steps the motion balance adjusts to the sequence of steps just perceived. In most cases, this is a subconscious process. However, if one step is of a different height, the motion balance will become considerably disordered - possibly resulting in a stumble or fall. Adjustment of driving programme on the road is similarly subconscious.

The perception of the lane, the edge of the lane and the lane periphery produces a general sensual impression. Drivers react to these road elements with their actions, in the same way as the person climbing stairs reacts intuitively to the height, depth and width of the steps. Unexpected objects disturb the automatic sequence of operations, possibly causing the driver to “stumble”. After several critical seconds the disturbance can be handled. Therefore, planners and designers try to keep road characteristics flowing in a logical sequence. They should introduce inevitable changes as early and clearly as possible and exclude any sudden changes that would confuse the driver.

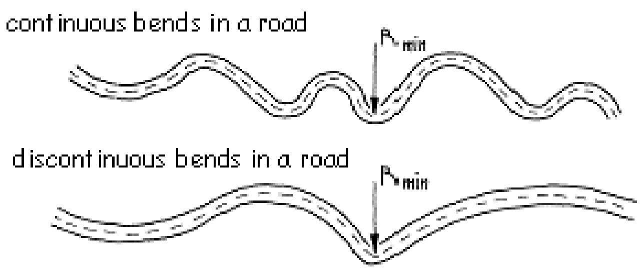

Figure 8.10 Continuous and discontinuous curves in a road

When choosing their speed, drivers rely on their previous and recent sensory impressions of the last driven 5-10 minutes. Breaking the consistency and the experienced logic of the design causes operational mistakes which can lead to driving mistakes and accidents.

This particularly applies to five situations:

a) Change of road function without corresponding change in design and optical characteristics (e.g. town entrance)

Drivers need to adapt their driving programme when entering a built-up urban area or when road functions changes significantly. They need to decrease speed and be more attentive as more decisions and reactions are required. Generally, there should be offered unambiguous visual clues to recognize the change of function, for instance by a horizontal swing of road’s course, optical sight barriers, planted central islands, special speed-reducing markings or a combination of these instructions. A clear guiding Gestalt hast to instruct the driver how to adapt the driving programme.

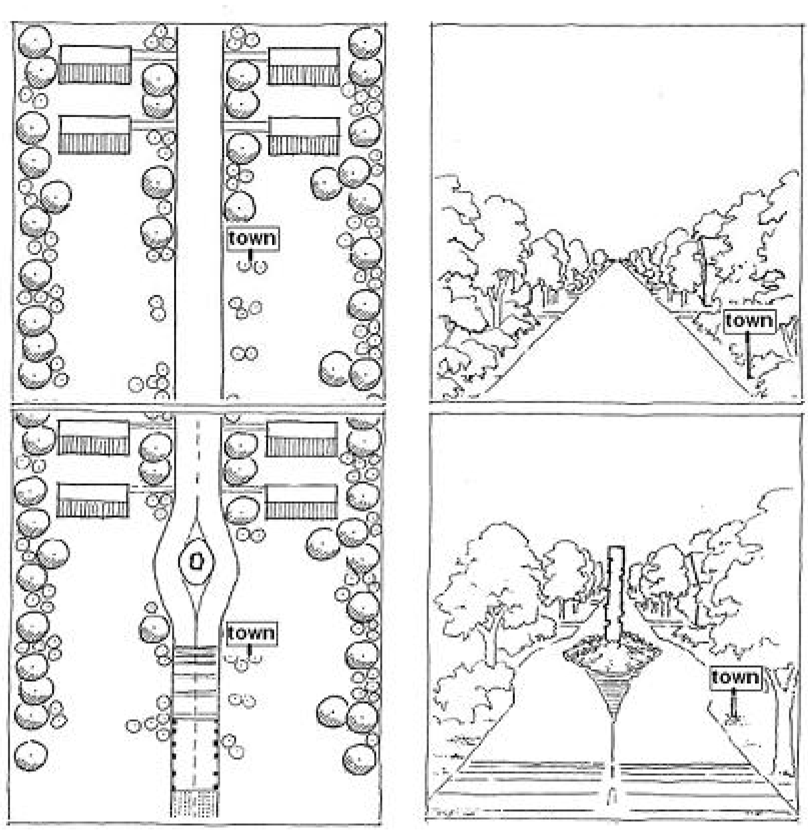

Figure 8.11 Visual Cues reinforce the changed road function and eye-catching objects reinforce the change (Birth, et. al, 2004)

b) Change of road’s direction is contrary to eye-catching objects in another direction (e.g. city by-pass dilemma)

Drivers need eye-catching objects to realize that there is a change in road's direction despite other dominant eye-catching orientation structures or objects. The change of direction has to be supported by covering the wrong view axis or optical misguiding.

It has been found at black spots that dominant eye-catching objects such as a line of trees, buildings or straight road sections impede the correct anticipation of a road’s course even though correct signing is present. Road characteristics that mislead spatial perception cause technically “unexplainable” accidents.

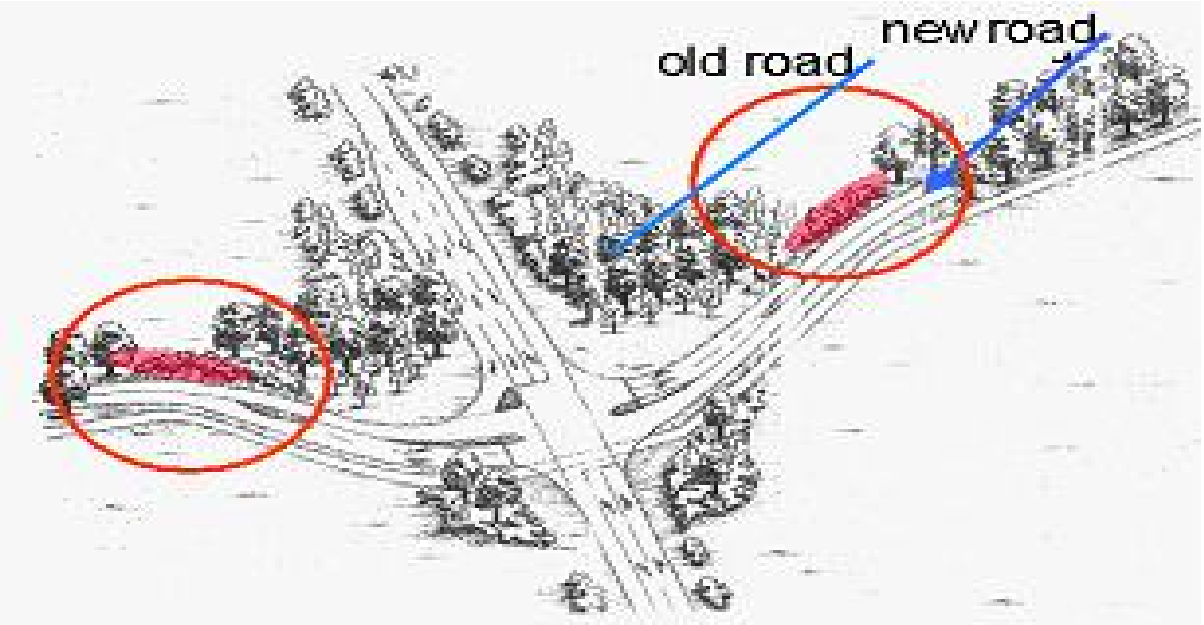

Figure 8.12 changed direction contrary to the old, dominant eye- catching view axis can be corrected by a planted embankment (Birth et. al, 2006)

c) Requirement for a new driving program recognised and changes are introduced to "re-programme" driving habits and expectations

Changing the -of-way or altering the course of the road - such as a new alignment will challenge driver's habits and expectations. Appropriate and timely signals or visual clues are required to inform the driver and provide an adequate time for correct anticipation. The required reaction could be significantly different from the habitual one! In order to avoid surprises, various design principles need to be considered.

It has been found at black spots that newly built intersections that are not introduced properly lead to incorrect anticipation of the situation and therefore to accidents even though correct signing is present

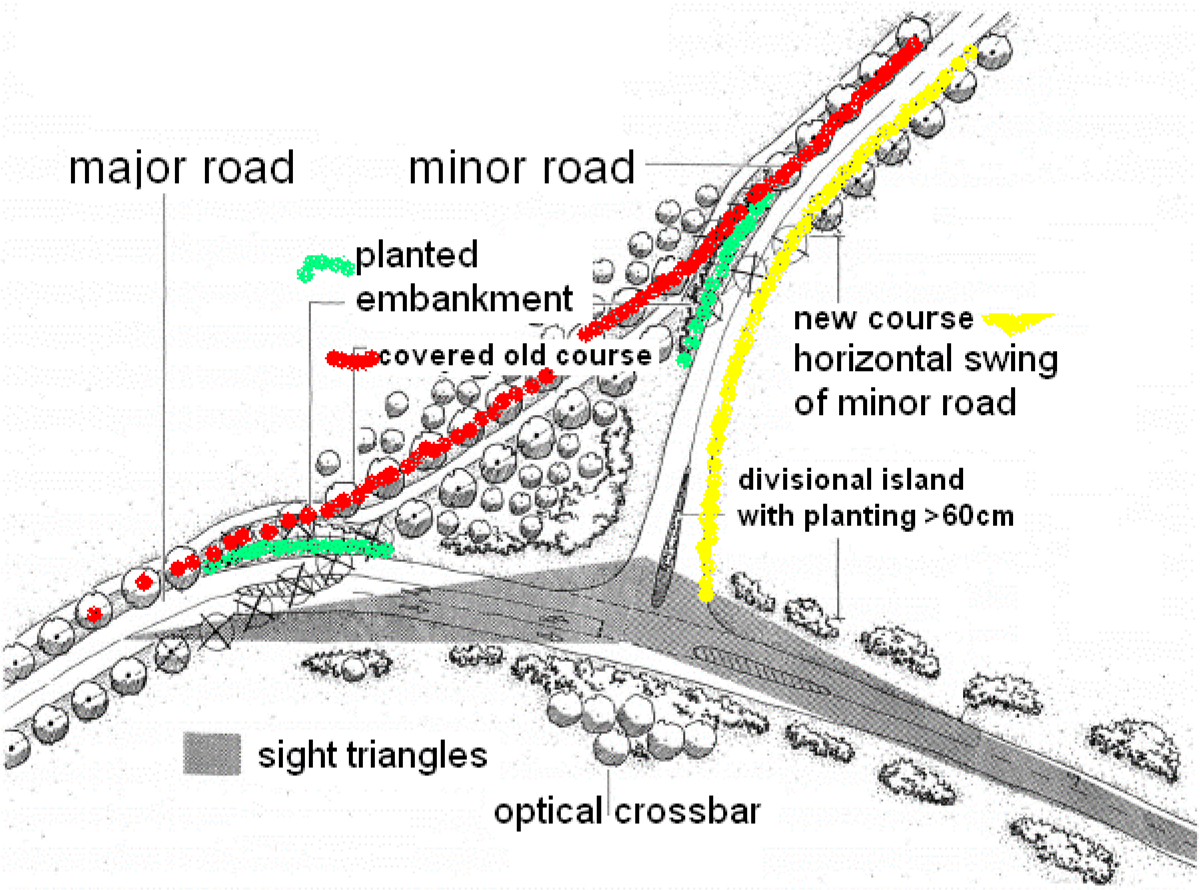

Figure 8.13 Example to re-programme a driving habit by a combination of design and optical guidance measures (Birth et. al, 2006)

d) Driver's attention and ability to process information is limited

Driver’s attention and ability to process information is limited. Driving requires multiple tasks, such as control of lane tracking, anticipation and orientation as well as navigation. Drivers can focus on one piece of information at a time and multiple distractions or critical locations may result in an overload.

Too many decisions in too short time can overload the capacity for information processing and result in safety risks.

Figure 8.14 Three critical locations: maintenance point, starting a curve and exit road without transition and/or progressive information (150 m ahea) (Birth, et. al, 2006)

e) Deficiencies in traffic control devices

Due to higher traffic volumes, roads need to be equipped with traffic control devices for safety. Along with rules, traffic control devices organise the driving reactions of road users. Under all light conditions and within all optical backgrounds, traffic signs should be visible, legible and detectable. They should never be covered by plantings or other structures. That is because the effect of mimesis may make even b, oversized signs invisible to the driver. Mimesis, also mimicry is the ability of organisms to adapt their coats/skin completely to their background so that they can't be detected.

Figure 8.15 Three oversized chevron signs in red and white are not visible against the background in an accident curve (Birth, et. al, 2006)

Additional good solutions and best practise examples can be found in the PIARC's Report (PIARC, 2012b) "Human Factors in Road Design. Review of Design Standards in nine Countries".

The case study from Portugal, shows the use of low cost engineering measures and law enforcement to change driver behaviours.

CASE STUDY - Portugal: Perceptual treatment - Low Cost Engineering Measures on a dangerous trunk road

The case study describes the approach used in 1998 by the Circulation and Safety Division of the Portuguese Road Administration (JAE) to improve road safety on the interchanges of a single carriageway, two lane, trunk road that connected the Portuguese coastal area and Spain (route IP 5). In a first phase, Low Cost Engineering Measures (LCEM) were applied, to improve the road characteristics; in a second step, exceptionally intense and severe law enforcement actions were employed by the police, to improve driver behaviour. Read more (485 kb).

COMMUNICATION WITH ROAD USERS

Messages relating to regulatory requirements, warnings of hazards, directions, and other useful information can be conveyed to drivers and other road users by a number of means. These include:

- *signs* – static or changeable electronic signs, using words, pictograms or diagrams showing directions;
- *signals* – at intersections, pedestrian crossings, and railway level crossings, and which cater for particular vehicle types e.g. buses, bicycles, emergency vehicles;
- *road markings* – these are a highly intuitive way of conveying messages, such as the path to follow, areas to keep off, and points at which to stop;
- *delineation* – guide posts and retroreflective pavement markers have an important role to play in providing guidance in poor weather or at night. Pavement markers generally supplement the information provided by line marking.

The PIARC HFPSP guide discussed in Introduction includes actions to improve delineation or signage as possible remedial treatments for all of the three key requirements mentioned above, usually as a corrective measure to bring about a satisfactory resolution of the issue, or as a warning to indicate a potentially hazardous situation. Human factors considerations are critical in the design and provision of these treatments. The principal characteristics to be considered are:

- *Conspicuity* – is the sign easily noticed?
- *Size and position of devices in relation to the required decisions or actions* – e.g. Is the traffic control device sufficiently in advance of the required decision or driving action to allow the decision to be made or the driving action executed in an unhurried manner? These issues have to be considered at each site, initially by the road design team, and subsequently by the road manager during the road's operational life.
- *Visibility* – e.g. Does the design of the sign allow it to be easily read? Are signs or line markings faded or worn away so much that they are no longer effective? Are they still reflective at night? Checking and inspection to ensure visibility is a matter for the road manager. While physical measurements are the most reliable guide to the condition of traffic control devices, a well-managed programme of regular inspections by experienced personnel who are trained to make consistent assessments can be an acceptable basis for managing the condition of traffic control devices.
- *Comprehensibility* – e.g. Can the signs (especially symbol signs) be readily understood by road users? The design of nearly all signs is specified in the standards or guidelines of individual jurisdictions; some of these designs comply with worldwide practice, some have proved effective over a long period of time, and newer signs may have been subject to rigorous testing before they were included in the standard. Difficulties can arise when new signs are required to cover unusual situations and the proposed signs are not adequately tested on road users.
- *Credibility* – e.g. Are the messages they convey believable? This depends very much on how they are used in the local context. Overuse of signs can lead to them being widely disregarded. Consistency in the use of line marking, delineation and signing over lengths of road is essential in establishing the credibility of the system.

Note that a Safe System is not created solely by communication with road users. However, clear indications of the expected driving actions, especially speed choice and clear warning of hazards, can do much to reduce the number of collisions and to mitigate the severity of those that do occur. Therefore, signing that matches user's needs human factors make important contributions to achieving a Safe System. It will have a critical contribution to crash reduction on road systems that fall short of Safe System requirements.

The case study from Slovenia highlights the use of human factors in road design.

CASE STUDY - Slovenia: Safer way to school

In Slovenia, there is not yet a harmonized strategy and with that directive or guidance how to deal with school paths and vicinity of schools alongside roads (consequence of poor spatial planning and land use / urbanism), so Pilot project aim was to make and to introduce low cost solution, without construction intervention (prompt measures), using good practice and Human Factors knowledge in Road Design. The aim of the project was to implement safe(er) School and Kindergarten area on municipality road by introducing Human Factors in to the road (re)design. The pilot project could be used to learn (find potential defectiveness and find improvements), for further "best practice" implementations on Slovenian roads and background for legislative part (1st pillar) and potential guidance how to deal with those kind of problems (linear settlements and schools alongside roads). Read more (PDF, 2.235 kb).

SPEED MANAGEMENT

How speed management works from the point of Human Factors

Speed has a significant effect on safety – it influences accident severity and reduces the anticipation and response time available for a given sight distance . The correlation between accident severity and speed is well documented. Small changes in speed have a more significant effect on energy. So, it is not surprising that increased speed is considered as the biggest problem in road safety. Especially in the accident reports of the police increased or maladjusted speed is reported as the primary cause of accidents. But to be exact, speed is not the cause of an accident, but a moderating factor. In a lot of cases, inappropriate speed can be attributed to driver's spatial perception on the road environment. As explained in the PIARC HFPSP the chosen speed depends on the interaction of human information processing and decision making on one hand and features of the road and its environment on the other hand. Modern science shows that the choice of speed, as well as the choice of position on the road, is mostly a subconscious process.

Most of the variables of the Man-Road Interface relate to physiological and neuronal mechanisms and affect the speed subconsciously. The following variables influence drivers speed and fatigue and therefore can also be used for an effective speed and fatigue management:

1. The optical density of the field of view is a function of the number of objects that contrast with the background. A very small number of contrasting objects leads to monotony and both reduced performance and reactivity. To avoid monotony, the driver subconsciously changes his driving behaviour in order to increase information input: he swerves, brakes or – in most cases – increases speed. Consequently, it is desirable to achieve an optimal level of optical density to support the correct choice of speed and to avoid fatigue (Herberg and al, 1994).
2. Also, the curvature of the road influences speed. A sinuous swinging alignment leads to an increase in attentiveness and a decrease of speed (Richter and al, 1998). This can be explained by the increase of workload to steer the vehicle and an increase in information from the balance organs that react to the change of position and curve acceleration. So this feature also prevents the driver of fatigue that arises from a straight, monotonous road course.
3. Research also suggests that there is an optimal road width from a speed environment perspective. Drivers increase speed on very wide roads (>8,00m) and also on narrow roads (<7,50m). In Addition reaction times are best on roads within this range. (Zwielich and al, 2001). This is possible because the activation of driver's neuronal system has an optimum in this case and prevents him from task determined fatigue.
4. It is proofed that the visible amount of road's surface influences speed. It is a function of both dimensions: width and length of the road surface. The more of the surface that is visible – such as long straight sections or wide roads – the faster the driver will drive (Klebelsberg, 1963) (Cohen and al, 1997). In combination with all other findings above it suggests to realise a curvy design instead of a design with long straight sections and stretched curves. It allows also the conclusion that a broader road should have a higher curvature than a narrow road.
5. If the driver failed to identify a critical location that requires decreasing speed like a change of road's function, a crossing, or other demands is will drive of course with inappropriate speed. So maybe he was not able to perceive the need to slow down. In sum missing references from road and the road surrounding, optical illusions, misperceptions of curves, exits, crossings or other situations can be also cause for the inappropriate speed. This can be easily corrected with Human Factors design practice as described in PIARC HFPSP.

The following case studies from France, Italy, Singapore and Sweden all highlight different techniques and reasons for speed management.

CASE STUDY - France: Implementation of speed regulation system on highway A10

The highway A10 connects Paris and Bordeaux. During the holyday migrations, many usual traffic jams appeared in 2 areas: north of Orleans before the bifurcation of highways A10 and A71; and through the agglomeration of Tours. The objectives to implement a speed regulation system were: To improve traffic fluidity, to increase security, to reduce CO2 emissions. Read more (PDF, 337 kb).

CASE STUDY - Italy: Speed reduction schemes on urban collector roads

The case study describes a set of safety countermeasures in Via Pistoise (Rizenze, Italy), that is an urban collector road classified as a high accident concentration section. A detailed safety study has been undertaken to identify the possible applicable safety countermeasures. Accident analysis, road safety inspections and driving simulation studies were performed. The intervention to be implemented combines physical and perceptual treatments. Read more (PDF, 828 kb).

CASE STUDY - Singapore: Lower speed limit (40km/h) in Silver Zones

The case study covers the Silver Zone program implemented in Singapore since 2014. The program is designed to further enhance road safety of the elderly at large in the neighborhood precincts. Silver Zones aim to change the character of the street such that traffic movement is slowed down significantly and there will also be better walkability infrastructure to enhance road safety and first-and-last mile connectivity. Read more (1,177 kb).

CASE STUDY - Sweden: Bicycle passages and bicycle crossings

The project studies the consequence of a change in traffic law. In the 1st of September 2014 traffic law changed in Sweden. The change meant, among other things, that the concept of bicycle crossing was introduced and defined, with rules for the yield towards cyclists who are on or just traveling on a bicycle crossing, a new roads sign and requirements for local traffic regulations. In addition, it was stipulated that the traffic environment should be designed so it is not possible to drive vehicles at speeds higher than 30km/h. Read more (432 kb).

TRAFFIC CALMING

Traffic calming is the general term given to engineering techniques for encouraging lower speeds, and now includes a variety of well-documented treatments. The Institute of Transportation Engineers has a website that provides a comprehensive overview of traffic calming measures (ITE, 2013). Fact sheets are available for some of the most widely used types of devices, i.e.:

- devices that rely on vertical displacement – humps, flat-top platforms (speed tables), and raised platforms at intersections;
- devices that rely on lateral displacement – chicanes and mini-roundabouts (neighbourhood traffic circles);
- devices that rely on road narrowing – choke points and central islands;
- street closures.

The website also has links to areas dealing with other types of treatments such as curb extensions, refuge islands, raised crosswalks and rumble strips; and links to topics such as speed reduction, accident frequency reduction, and reductions in cut-through traffic movements. A report from the UK's Department for Transport provides a comprehensive summary of research on traffic calming (Department for Transport, 2007).

From the Human Factor point of view, they trigger the fixation in the nearer field of view and guide the attention to the places. Or they break the straight road axis and with this also the straight view axis that increases speed. In case of road narrowing the measures increase the difficulty of driver's task to hold the balance on a narrower road. That's why they have not only a physical, but first an optical stopping effect.

Traffic calming principles have been widely applied in the establishment of low-speed zones in residential areas. This concept originally emerged in the Netherlands as the 'woonerf' or 'living zone'; it has since been adopted in a number of countries under various forms. The key success factors are that the road network must carry low traffic volumes, the completed scheme must not be able to be traversed quickly, and the appearance of the streets should be changed.

In the UK, the first 20 mph zones produced substantial changes in speeds and crashes. A review found that the average speed reduction was approximately 14 km/h, the number of crashes fell by 60%, the number of crashes involving children fell by 70%, and the number of crashes involving cyclists fell by 29% (Webster & Mackie, 1996). Traffic flow within the zones fell by an average of 27%, and increased on the surrounding network by 12%. Despite this shift in traffic, there was little increase in crashes on these surrounding roads.

Combinations of treatments such as pavement markings, road narrowing, and signage have been used effectively to reduce the speeds through settlements. A report from the UK's DETR provides a comprehensive summary of research on traffic calming, including gateway treatments (Figure 8.4). Low-level gateway treatments were found to reduce speeds by less than 5 km/h; more substantial treatments by up to 11 km/h; and the most substantial treatments, which involved narrowing of the carriageway, by up to 16 km/h (DETR, 2007).

Makwasha and Turner (2013) found speed reductions associated with gateway treatments in New Zealand. Consistent with previous research, they found that speed reductions were greater at pinch point gateways where the roadway had been narrowed compared to gateways that consisted of signage alone. Consistent with speed reduction data, there was a 41% reduction in fatal and serious injuries at pinch point gateways, but small increases in crashes at the 'sign only' gateways. This agrees closely with earlier work by Taylor and Wheeler (2000) in the UK, which found a 43% reduction in fatal and serious injury crashes for gateway treatments alone, but reductions of 70% in these crashes when accompanied by downstream traffic calming treatments.

Figure 8.15 Threshold treatment with identity feature, median island, and vehicle activated speed feedback sign - Source: Dr Peter Cairney.

A detailed hypothetical example of how a gateway treatment might be provided is discussed in the PIARC HFPSP guide. Gateways are also used at the entry to lower-speed zones within urban areas. However, as speeds are generally low at these points anyway, their effectiveness can be hard to evaluate (DETR, 2007). The case study from Germany shows an example of bundling the motorized vehicles to help organize traffic flow.

CASE STUDY - Germany: Areal improvement of the quality of stay by bundling the motorized traffic

In this project a central square in Brandenburg an der Havel was redesigned into a three-arm junction. Brandenburg an der Havel is a city with about 71.000 inhabitants in the region Brandenburg in north-east Germany. The Nicolaiplatz is a triangular square with an important function for the local traffic, located in the city centre, nearby the historic city of Brandenburg an der Havel. The sums of the traffic volumes of all access roads to Nicolaiplatz are approximately:15.000 vehicles, 450 city busses, 360 trams, 500 cyclists (estimated) per 24 hours. Before the redesign, the function and geometry of Nicolaiplatz was significantly influenced by the traffic facilities before the remodeling (see picture 1). The Bus- and Tram stops were spread over the entire square and the whole traffic infrastructure was disordered and unclear for both, motor vehicle traffic and local public transport. Furthermore all facilities were outdated and not in a good condition. Read more (825 kb).

THE ROLE OF ROAD HIERARCHIES AND SELF-EXPLAINING ROADS

As mentioned in previous sections, road and traffic engineers have an effective array of techniques and devices available to provide information to the road user. If the basic road design creates a road environment and Gestalt that give consistent impressions on how to drive on that type of road the speed choice will be appropriate. This concept is generally referred to as a 'road hierarchy'.

'Self-explaining roads' require a holistic approach in designing the road system and its immediate surroundings to make the required driving actions obvious to the driver. The European Commission website (EC, no date) describes self-explaining roads in the following terms:

- The aim is that different classes of roads should be distinctive, and within in each class, features such as width of carriageway, road markings, signing, and use of street lighting would be consistent throughout the route. Drivers would perceive the type of road and "instinctively" know how to behave. The environment effectively provides a "label" for the particular type of road and there would thus be less need for separate traffic control devices such as additional traffic signs to regulate traffic behaviour.

Roads have different functions which require different traffic speeds and other driving actions, e.g. readiness to deal with cyclists and pedestrians (including young children). If these functions can be made explicit by the design and features of the road, it should be much easier to pre-programme the drivers to behave appropriately. A road that is truly self-explaining would make other aspects of driving demand obvious, such as which traffic stream should give way to another, when the driver is approaching an intersection or a curve, where pedestrians are likely to cross the road, and where the driver should position the vehicle to make a turn across a traffic stream. A self-explaining road would require few signs or line markings as the required driving actions would be conveyed intuitively by the way the road looks.

In the Netherlands, where the concept originated, four categories of road seem to be sufficient to cater for all needs (Theeuwes & Godthelp, 1995); these are:

- motorway,
- major inter-city roads,
- rural roads to connect residential areas to shopping and services,
- and woonerfs (or traffic-calmed residential zones).

Other countries may find that they need more categories to cover their full range of road types (e.g. rural access roads, urban collector roads). The important point is that roads can be designed to create different expectations about how road users should act on them.

A recent application of self-explaining roads principles in a suburb of Auckland, New Zealand demonstrates how appropriate design – in this case retrofitting an area with planting and other low cost measures – can pre-programme the driving actions. After implementation, average speeds were lower on local streets but unchanged on collector roads. In both cases, the variability of speeds was reduced after implementation (Charlton et al., 2010). On local roads, vehicle numbers were reduced, vehicle lane keeping was less consistent, and signalling was less frequent. Also, pedestrian numbers increased, and pedestrians were less constrained in their movement patterns; however, these changes were not evident on the collector roads (Mackie et al., 2013). The authors interpreted these changes as indicating that a more relaxed, informal environment had been created on the local streets, consistent with the objectives of the project. These changed driving actions were accompanied by a 30% drop in crashes and an 86% reduction in crash costs.

The implications of self-explaining roads are especially profound for LMICs. The evidence is that drivers pick up powerful messages about the appropriate way to drive from the cues in the environment.

Developments affecting parts of the road system that have customarily been used for social or commercial purposes should therefore be handled with particular care. If it is possible to retain the social or commercial function, then care should be taken to separate through traffic movements from the mixed activity area and ensure that a high-speed environment is not imposed on it. If it is not possible to retain the social and commercial functions, then a suitable alternative site for these activities should be found, and the new road facility which replaces the former mixed activity area should be clearly identifiable as primarily a traffic facility.

The case study from Hungary highlight the use of the "Rapid Way" narrow cross section.

Case Study - Hungary: Road design of "Rapid Way" narrow cross section

The case study describes the approach used in 1998 by the Circulation and Safety Division of the Portuguese Road Administration (JAE) to improve road safety on the interchanges of a single carriageway, two lane, trunk road that connected the Portuguese coastal area and Spain (route IP 5). In a first phase, Low Cost Engineering Measures (LCEM) were applied, to improve the road characteristics; in a second step, exceptionally intense and severe law enforcement actions were employed by the police, to improve driver behaviour. Read more (PDF, 241 kb).

Uncontrolled access and unplanned communities can also create uncertainty and potential hazards for all road users the report: Land use and Safety: an introduction to understanding how land use decisions impact safety of the transportation system discusses how land use (e.g., density, use, mix) and typical transportation factors (functional classification, context classification, transit availability, speed and access control/management can affect safety outcomes. The report provides examples of where and how land use and transportation decisions are made and explores several tools and techniques to improve safety in transportation and land use interactions.

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ROAD-BASED FATIGUE COUNTERMEASURES

Addressing road based fatigue is a key component of increasing road safety. Fatigue is well known to reduce and keep drivers from reacting to hazards. The outcome of this is the potential to increase crashes. In 2016 PIARC produced, The Role of Road Engineering in Combatting Driver Distraction and Fatigue Road Safety Risks. This important document highlights the problem with fatigue and distraction and outlines road safety countermeasure to combat this ongoing issue.

There is a clear distinction between fatigue, which occurs with time spent on a task, and drowsiness which varies according to the time of day and how much sleep a person has had. The terms are often used interchangeably as they often occur together and have similar debilitating effects on driving. A recent review for the UK Department for the Environment, Transport and the Regions (Jackson et al., 2011) concluded that fatigue affects driving skills in three ways:

- It increases the frequency of errors (e.g. the number of times a driver intrudes on a neighbouring lane).
- It increases the size of errors (e.g. the distance that a driver intrudes on a neighbouring lane).
- It increases the variability of errors (e.g. reduction in the amount of time a driver drives in the centre of the lane).
- It increases driver's tendency for subconscious speeding to get ensure a normal activity level of the central nervous system although the workload decreases because of monotony of the driving task

The most effective ways of managing fatigue for professional drivers appear to be through workplace fatigue management programmes, supported by programmes to ensure that drivers come to work well-rested by addressing lifestyle issues. But for common drivers in general the road design has to ensure that the basic Human Factors principles of managing speed are realised in road design.

Roberts and Turner (2008) identified specific areas where infrastructure-based countermeasures might be effective. These include:

REST AREAS

Opportunities to rest are likely to be beneficial. It is well-established that short periods of sleep can restore the performance of fatigued drivers. However, there is uncertainty about the location of these facilities in relation to high-risk sections of road, and about the best type of facilities to be provided at different locations.

MONOTONY REDUCTION TREATMENTS

Monotony reduction was thought to be worthwhile, but there was uncertainty about what type of monotony reduction would be effective because there is a lack of empirical and experimental data until yet. But it is well known that long straight roads without sufficient curvature are creating monotony based fatigue to drivers. Note that the PIARC HFPSP guide suggests the creation of 'sinuous, rhythmic road alignments' (i.e. gently winding roads) to counter monotony by providing a constantly changing visual field and an activation of the equlibrioception, especially the proprioceptive system. It also suggests that the number of bness and color contrasts in the lateral periphery of the field of view should be increased as also the fixation point should be limited in the nearer depth of the field of view (8.2.3). This can be achieved by changed height and kind of vegetation, special markings, colored pavements, changes of contrasts in the vertical scenery of buildings, in tunnels and similar optical countermeasures against monotony.

SIGNAGE AND ROAD MARKINGS

Signs and road markings increase the number of bness and color contrasts and are supportive against road triggered fatigue. They can also draw driver's attention to areas of high risk of fatigue crashes and advising of opportunities to rest at towns or rest areas were thought to have potential.

AUDIBLE LINE MARKINGS

Audible line markings are raised thermoplastic lines which create a whirring sound when driven over, alerting the driver that the vehicle is drifting onto the shoulder (when applied as an edge line) or across the centre of the road into the opposing lane (when applied as a centre line). These have proved to be highly effective in reducing crashes, but generally do not generate a sufficiently loud signal to be effective for trucks. In countries where there is widespread use of asphalt construction on rural roads, an equivalent treatment can be produced at lower cost by creating depressions in the asphalt by means of a special roller, or by milling grooves in the road surface. This is not possible when the road is of sprayed seal construction , which is typical of many roads in LMICs and HICs with low population densities. Audible line markings can also be applied to concrete roads, either by the application of thermoplastic markings or by milling grooves in the road surface.

BARRIERS AND CLEAR ZONES

If these other measures fail to prevent a fatigue-related incident, then barriers and/or clear zones at appropriate points have the potential to avoid serious injury.

KNOWING WHAT BEHAVIOURS ARE REQUIRED IN A PARTICULAR SITUATION

Even when road users have a good understanding of the road rules and traffic control devices, there may be situations or locations where they are unsure about the correct driving procedures. These situations generally arise in unfamiliar situations, e.g. when a site has unusual geometry, or where drivers find themselves sharing the road with unfamiliar things such as slow, oversize vehicles, or herds of animals being driven along the road. Ideally, a road user’s training and experience would have taught them to behave safely and wait until any unclear/unusual situation is resolved so that they can move or overtake safely. Over time, it would be hoped that situations with unusual or misleading geometry would be eliminated by the progressive treatment of hazardous locations as determined by crash records or risk analysis. In the meantime, care should be taken to ensure that correct guidance is given to all road users by means of signage, lighting, line marking and delineation. It is important to ensure that the package of guidance measures is properly understood, particularly if unfamiliar.

8.3 OTHER MEANS OF ENCOURAGING ROAD USERS TO BEHAVE ACCORDING TO THE RULES

ROAD USER NON-COMPLIANCE

In addressing non-compliance with rules, it is important to consider the specifics of each situation. There are many possible reasons why road users do not comply with the rules, and more than one of them may be relevant in any particular situation. These different reasons require different strategies to encourage greater compliance.

UNDERSTANDING REQUIRED BEHAVIOURS

It is possible that some road users may not understand what is required of them or what the appropriate behaviour is in certain situations. In some cases, this may even be the majority of drivers. This is particularly likely to be true of socially disadvantaged groups in the community, especially where literacy is an issue. It is also likely to be true of new situations; the case of the introduction of roundabouts in Australia and North America is a good example.

Depending on the situation, this can be remedied by actions such as:

- locally-based education campaigns to reduce problems at particular locations;
- jurisdiction-wide advertising and publicity to address system-wide issues.

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CREDIBILITY OF RULES AND PROCEDURES

Rules and procedures are unlikely to be followed if they do not appear to be credible to road users, e.g. pedestrian reluctance to comply with ‘do not walk’ signals at crossings during periods of low traffic flow, or reluctance of drivers to comply with roadwork speed limit signs when it is obvious that no roadwork is in progress. The risk is that road users may continue to act in this way when hazards are in fact present, so that pedestrians cross unexpectedly in front of motor vehicles at night, or drivers continue to drive above the limit when roadworks have recommenced. While it is difficult to apply countermeasures in the first situation, close attention to the management of the worksite (e.g. by covering up the speed limit signs at the end of the day’s work) goes a long way to help in the second situation.

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CUSTOMARY USES OF ROAD SPACE FOR OTHER THAN TRANSPORT

Many communities use the road space for purposes other than transport and in ways which conflict with road safety goals. In LMICs, roadside commerce is entrenched and is an important element in the economy. Street play has been a customary use of road space in many UK cities. Reducing speed limits in selected local areas in the UK to 20 mph (32 km/h), in conjunction with supporting traffic calming measures, has been very effective in reducing child pedestrian casualties. An early evaluation of these schemes indicated a 60% reduction in all injury crashes, and a 67% reduction in child injury crashes (Webster & Mackie, 1996). Creative solutions are called for in accommodating roadside commerce and increasing traffic flows in LMICs.

SOCIAL NORMS AND PEER PRESSURE

Apart from the official system of rules and regulations, the road safety culture of a community has a strong bearing on how road users behave and the resulting road safety outcomes. For example, peer pressure is an important mechanism for maintaining social norms or in some cases, engaging in behaviour that deviates from the norm.

AGE-RELATED CHANGES THROUGHOUT A PERSON’S LIFE-SPAN

The psychological and physical changes that people experience throughout their life-span have a profound influence on their ability to cope with the road system. If roads are to cater for the whole of the community, road designers and managers should have an awareness of the more salient age-related changes. Some of the main points are:

- Young children lack the cognitive abilities to interact with motor traffic. This is compounded by their small stature, making it difficult for them to see and be seen.
- Learner drivers are very safe while they are under supervision, but have a very high crash rate as soon as they begin solo driving. Swedish work shows that extending the period of supervised practice before

going solo reduced crashes in the first year of solo driving by 46% (Gregersen, 2000).
- As drivers grow older, physical and cognitive abilities may begin to decline. Older drivers can be supported to keep driving safely by means of adaptive aids and restrictions on driving, and by bigger and ber signs and markings. Older pedestrians may benefit from treatments such as extended crossing times at pedestrian signals, ber lighting, and improving surface evenness on footpaths.

SHORT-TERM IMPAIRMENT – INATTENTIVENESS, FATIGUE, ALCOHOL AND DRUGS

Short-term impairment can have disastrous effects on driving. Amongst the most frequent causes of impairment are:

- distraction;
- drowsiness;
- alcohol-affected driving;
- alcohol-affected pedestrians;
- drugs.

COPING WITH DISABILITY

Some forms of disability make it difficult for individuals to fully comply with road rules. Safe System principles require that drivers and riders be capable and proficient; and many jurisdictions have basic physical requirements which must be met before licences to drive or ride a motor vehicle are issued. The most widespread issue is eyesight, and elementary screening to ensure adequate visual acuity (clarity) at a specified distance is a usual part of the testing procedure. Few conditions prevent people from driving altogether, as many people with disabilities, even serious disabilities, are able to drive satisfactorily with the assistance of driving aids that help them overcome the limitations imposed by their disability. No such screening processes apply to pedestrians or cyclists. Many developed countries have anti-discrimination legislation that requires transport providers to ensure that disabilities do not impede access. On the road network, some treatments that are provided to meet these requirements are:

- audible signals at signalised pedestrian crossings;
- distinctive patterns on the footpath surface that can be felt by a mobility cane or through the sole of the foot;
- ramps or lifts to accommodate wheelchair users, including ramps at pedestrian crossing points set into the kerb.

ACHIEVING BETTER COMPLIANCE

Achieving better compliance with legal requirements and established driving procedures can be considered under the four broad headings below. Each section concludes with a brief consideration of how the infrastructure can be used or adapted to support the activity discussed in the section.

EDUCATION

Road safety education is generally considered to relate to programmes delivered in school.

The European Community (EC) ROSE25 project (Road Safety Education in all 25 EU Member States) involved workshops and consultations throughout the EC membership, culminating in a booklet which summarises the essential elements of good practice in road safety education. It focuses on face-to-face interactions with school age children. The key emphasis of road safety education should be on:

- promotion of knowledge and understanding of traffic rules and situations;
- improvement of skills through training and experience;

- strengthening and/or changing attitudes towards risk awareness, personal safety and the safety of other road users;
- following the ten key steps to the successful implementation of road safety education that are outlined in the document (Rose 25, 2005).

Although training and education should prepare drivers to ‘expect the unexpected’, there is a limit to which this can be achieved, and it is clearly not possible to train drivers to deal with unexpected situations. The best solution is therefore to minimise the number of non-standard situations through progressive improvements to the network, and apply self-explaining roads principles as widely as possible, and thus ensure that the PIARC Human Factor Guideline’s three rules are followed in all situations.

DRIVER AND RIDER TRAINING AND TESTING

Driver and motorcycle rider training refers specifically to the process of preparing people for their ‘careers’ as drivers or riders. This entails not only mastering basic car control skills and a working knowledge of road rules and procedures, but the all-important skill of ‘reading the road’ and anticipating the actions of other road users. Road User Non Compliance in Other Means of Encouraging Road users to Behave According to the Rules cited work which showed that the more supervised driving practice a learner driver had, the safer they were after they began to drive solo. Many jurisdictions have introduced, or are about to introduce, requirements for extended supervised driving practice before taking a practical driving test.

A review of road safety measures in the European Community countries recommended reinforcing formal driver training by encouraging accompanied driving, and making advice and information available to the accompanying drivers to help them maximise their effectiveness (SUPREME, 2007). Good practice in driver and rider testing involves test drives or rides over nominated routes, which include all or most of the critical situations that the licensing authority deems are necessary to demonstrate competence, and that are assessed as being approximately equal in terms of their difficulty for test candidates. Licensing authorities should consult with road managers when identifying test routes to ensure that they choose appropriate routes that do not cause undue interference with other traffic or expose candidates or testing officers to avoidable risk.

ENCOURAGEMENT

Road authorities engage in publicity campaigns for a variety of reasons. The PIARC publication Best Practices for Road Safety Campaigns (PIARC, 2012a) provides an overview of this area, based on a literature review linked to a survey of selected PIARC members. The key messages relating to the delivery of campaigns are:

- Behaviour change is a long-term commitment.
- Integration of publicity campaigns with other activities, such as enforcement, adds to effectiveness.
- It is important to clearly identify the audience and tailor the message to address the dynamics of the particular behaviour in question.
- Choosing the correct medium to reach the target audience is essential; with age being the most important factor determining media habits.
- Fear appeals need to be used with caution as they may be dismissed when they do not accord with personal experience.
- Evaluation is essential and should be considered as an integral part of the campaign plan.

Roadside advertising space should be available for the display of safety messages, either by having some roadside advertising space reserved for this purpose or through the purchase of space at commercial rates. Where available, consideration should be given to the limited use of variable message signs to display safety messages that are appropriate to the time and place, e.g. displaying drink driving reminders in the early evening on weekends when many drivers and riders are heading out for the evening.

ENFORCEMENT

A good general source on enforcement appears to be the European Transport Safety Council's (ETSC) publication, Traffic Law Enforcement across the EU: Tackling the Three Main Killers on Europe's Roads (ETSC, 2011). This is a compendium of best practice, based on member countries' experience. A comprehensive set of recommendations is provided for tackling each of the three main killers – speeding, drink driving and non-use of seatbelts – as well as general guidance on planning, target setting, and general principles of effective enforcement.

Much progress has been made with automated enforcement in recent years, in particular with speed enforcement. Significant changes in behavior has occurred where automatic enforcement has been vigorously applied. Where necessary, space should be created to allow enforcement operations to be conducted where they are likely to have a major deterrent effect. The raised lay-bys provided on UK motorways for speed enforcement are a good example. Positioning of speed cameras or other automated devices needs to be carefully considered to coordinate with other infrastructure where possible (e.g. positioning point to point speed cameras on existing gantries).

8.4 ENSURING APPLICATION IN PRACTICE

Human Factors issues are not as well catered for as they should be on most of the world's roads, including those in HICs. A number of major in-depth crash investigations were carried out in the 1960s and 1970s that implied that driving actions carried out by the road user as the main contributing factor in most crashes. More recently, it has come to be understood that many of these driving mistakes were as much due to deficiencies in the road system as to failings on the part of the driver. These included crashes due to inadequate sight distance, poor lighting at critical points, poor transition zones, insufficient management of the field of view as well as misguiding drivers expectations and road surfaces that provided less friction than the driver was expecting.

HICs may therefore have a large backlog of road deficiencies to rectify to ensure that Human Factors needs of users are adequately integrated in their design standards and the practice to treat black spots and black lines across their networks. The same is likely to be true for LMICs. However, the road system cannot be brought up to standard unless the basic design tools – the road design standards and guidelines – take account of these issues. The PIARC study (PIARC, 2012b; PIARC, 2016) suggests that there is a long way to go before this can be achieved.

An expert Human Factors group examined the design standards from nine HICs and LMICs from across the world and systematically compared the advice and procedures in each standard with the specific Human Factors requirements which arise from the three Human Factors requirements described in the PIARC HFPSP guide (**see** Section 8.2). Requirement No.1, giving the driver sufficient time to react, was best catered for, with the specific driver needs being fully discussed in 49% of cases. Requirement No. 2, ensuring the road provides a safe field of view, was least well catered for, the specific needs being fully discussed in only 9% of cases. Requirement No. 3, that the road matches the road users' expectations, was fully discussed in 34% of cases.

It therefore appears that much work remains to be done to bring the world's design standards up to a level where Human Factors issues are fully addressed and to bring the thinking of designers along with them. Case studies from Canada and Iran present Road Safety Audits.

CASE STUDY – Canada: Recreational Lakeside Re-development Project (Feasibility State Road Safety Audit)

This case study example presents the results of a feasibility stage RSA that was conducted for a community in British Columbia, Canada. The project involved the review of a conceptual design of a lakefront area to improve the mix of transportation modes, access requirements and traffic management to better serve the citizens of the community and the many tourists that frequent the area. Read more (281kb).

CASE STUDY – Iran: Case Study Road Safety Audit Report of Qom-Garmsar Freeway (Pre-Opening Stage RSA)

This case study example presents the results obtained from a road safety audit project for the Qom-Garmsar Freeway. The RSA was a Pre-Opening RSA, completed before the freeway is opened to confirm that the facility provided would provide an acceptable safety performance based on the road signs and markings, safety equipment and police checkpoints. Read more (273 kb).

PATHWAY TO EFFECTIVE DESIGN FOR ROAD USER CHARACTERISTICS AND COMPLIANCE

GETTING STARTED

- Establish design standards and guidelines that incorporate established knowledge of Human Factors.
- Where design standards already exist, review standards to ensure that current understanding of Human Factors is fully integrated with the needs of transition and reaction time, the management of the field of view and a reliable pre-programming of driver's expectations.
- Provide training for design, road operations and road management staff in Human Factors and Safe System principles, supported by Human Factors guidelines.
- Provide basic training for police and other enforcement officers in the Safe System and evidence-based enforcement principles and methods.
- Prepare a manual on signs and line markings which covers most of the frequently encountered situations, drawing on experience and examples from elsewhere.
- Obtain general agreement about the importance of speed management in achieving Safe System outcomes.
- Establish road rules that are easy to understand and are consistent with driver expectations.

MAKING PROGRESS

- Application of standards and guidelines to the design of new facilities and upgrading of old facilities.
- Creation of self-explaining roads that are matched to their function.
- Hazardous spot/road section treatment according to human factors principles
- Establishment of standards for assets, both for new assets and for assets in-service based on road users' ability to cope with different levels of asset condition; e.g. road surface characteristics, sign and road marking condition.
- Establishment of effective school education programmes to teach appropriate road use, tailored to the needs of individual age groups; priority should be given to child pedestrian training in elementary schools.
- Establishment of effective publicity programmes to address clearly defined behaviours, targeted at the key groups at risk; these programs should be designed to prepare road users for and to reinforce enforcement
- Revise training and testing procedures for new drivers along graduated licensing lines.
- Establishment of enforcement programmes addressed at specific high-risk behaviours, guided by intelligence on where and when it occurs.
- Ensure increased compliance with line markings, sign and signal controls.
- Ensure increased seatbelt wearing; and reduced drink driving, fatigued driving and speeding.

CONSOLIDATING ACTIVITY

- Achieving consistency in design standards, signage and pavement markings across the road network.
- Training road safety auditors in Human Factors principles, and application of these principles to road safety audits.
- Extension of self-explaining roads across the network.
- Continual progress towards a road system that meets Safe System requirements.
- Comprehensive testing of new types of treatments before installation and evaluation after installation.
- Creation of a comprehensive inventory of road assets and their condition, accompanied by a programme to ensure all assets are kept up to the established standards.

- Maintenance of age-appropriate road safety programmes throughout the pre-school and school years to develop safe pedestrian behaviour and prepare for later road use.
- Maintenance of effective publicity programmes in response to fluctuating patterns of high-risk behaviours to coordinate with enforcement activity.
- Maintenance of high levels of enforcement.
- Ensure that non-compliance with line markings, sign and signal controls is a rare exception.
- Non-wearing of seatbelts, fatigued driving, drink driving and high-level speeding should be reduced to very low levels and moderate speeding is reduced.

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