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GUIDELINE

for the application of the

HUMAN FACTORS EVALUATION TOOL

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1. ACKNOWLEDGMENT

In 2019 PIARC published the "Road Safety Evaluation Based on Human Factors Method" document [1], where the Human Factors Evaluation Tool (HFET) has been presented for the first time by PIARC. The document provides a wide overview of the main type of analysis currently used to improve network safety screening and to carry out specific site analyses. Moreover, it proposes a complementary evaluation procedure based on Human Factors. The instrument that may help the inspector to carry out such a procedure is the HFET. The tool has been developed by the PIARC Technical Committee "Safer Road Infrastructures" (2004-2014) with the great contribution of a German research team composed of human factors experts. The German team was mainly composed of Psychologists and Engineers and was coordinated by Sibylle Birth and Hans-Joachim Vollpracht.

As explained by PIARC [1], the HFET provides an instrument to carry out pro-active analysis accounting for Human Factors principles and to provide a numerical result at the end of the procedure, i.e. the Human Factors Evaluation Score (also Human Factors Score, HFS).

Before its publication, the tool was tested on different sites with positive results [1]. In 2020, the HFET was tested within a procedure, whose aim was to make a Network-wide Road Safety Assessment (NWRSA) as requested by the updated Directive 2008/96/CE [2]. The HFET has been applied to several road stretches, not just to distinct road segments alone [3]. The positive results have been confirmed; however, it appears sometimes difficult, even for trained inspectors, who use the tool for the first time, to correctly apply it, without a waste of time. This was due mainly because the understanding of the requirements was not always immediate, and because it must be understood how to apply the HFET to longer road stretches with different locations to analyze. From this, the decision to implement a guideline that can help inspectors in judging the Human Factors requirements using the HFET.

However, the present guideline is not a document that alone can lead to a correct Human Factors evaluation by all the practitioners who want to improve it. The inspectors must be experienced or at least, trained about the Human Factors principles.

Furthermore, along with this guideline, a new version of the tool is provided. The new version is an Excel file which provides some improvement to let an easier compilation. The structure of the requirements has been reorganized compared to the version presented by PIARC in 2019. A few requirements have been modified. The tool can now allow for the analysis of multiple locations within the same road segment.

Finally, the current guideline provides explanations about the use of the tool on a single road segment, but not on how to use it during a network screening. That means that a specific procedure should be considered to analyze the network including the HFET. However, if such a procedure requires the analysis of a road segment, then the HFET can be used on that segment.

2. INTRODUCTION

The Human Factors Evaluation Tool (HFET) was created starting from the branch of research, developed mainly in Germany, concerning the psychological and perceptual factors that link driving behavior to the shape of the road and the structure of the environment in which it develops.

It is certainly not a new concept that a well-designed road facility can guide drivers, helping them to choose the correct driving behavior to travel the road under safe conditions (self-explaining roads concept [4]). However, one of the most relevant aspects is not always considered when talking about road design and safety. This aspect is the road environment. To design safer self-explaining roads, we must refer not only to the road body itself, to the geometric components such as the horizontal alignment, vertical alignment, or cross-section type, but also to what develops beyond the road margins edges and how the overall picture of the road appears to the driver.

This is exactly the aim of the Human Factors Evaluation Tool. The tool provides an instrument that allows a quantification of the risk related to the human factors aspects. The tool is simple in its structure because is composed of three series of checklists. The requirements of all the checklists can be judged without detailed measurements. However, a road survey is required to fulfill the checklists, and the evaluator must be aware of the human factors principles to correctly judge the requirements presented in the checklists, thus they must be an experienced evaluator or at least a trained one.

The HFET is a tool that can be used to monitor and classify network safety (i.e. Network Safety Assessment) both "alone", and alongside the classical screening methods. For a complete safety analysis, it is always advisable to apply it complementarily to the other methodologies already used (such as accident analysis). The HFET is not able, nor is it born with this purpose, to identify all the possible risks of a road section or check whether a particular road section is designed according to regulatory standards, or not (especially as these standards may vary). Its purpose is to identify bad road configurations that can mislead the user, triggering the first event of a chain of events, which in the worst case, will lead to a crash occurrence. By way of example, a wrong barrier terminal can be a safety risk, but this feature is not considered by the HFET, which investigates which elements can trigger an accident and not what the final consequences are.

The HFET will give indications about the danger of a road, providing a safety level classification, but it does not aim to predict the number of accidents. It does not account for traffic. On one hand, this can be a limit, on the other hand, this allows its application even in the absence of such data and it gives a measure of the risk of the road, regardless of traffic flows.

The following guideline will explain how to correctly apply the tool while analyzing a single road segment. Specific procedures which include the use of the HFET (for example making a Network-wide Road Safety Assessment by the use of HFET) are not part of this guideline.

The purpose of the guideline is to provide some examples and clarify some specific situations that can be found while applying the HFET. Particularly, the purpose of the guideline can be summarised as:

- to provide useful references for carrying out future safety inspections;
- to obtain a greater level of objectivity in the performance of safety inspections by different inspectors;
- to transfer the experience gained during many applications after the first publication of the HFET;
- to explain how to use the digital version of the HFET (Excel file).

It must be underlined that, even if this guideline will provide information concerning human factors principles, the HFET must be used by a trained evaluator and the guideline is not sufficient to acquire all the required knowledge.

3. HFET AND HF PRINCIPLES

The HFET scope is to quantify the level of road safety concerning the accidents triggering factors related to the man-road interaction. It will analyze the road structure and its environment to understand how the whole configuration is perceived by the driver, what the driver expects from the road, and understand if risky conditions, which can surprise the driver, are present.

The application of the tool provides a numerical value which allows to define the risk level of a road stretch and to make a ranking. This numerical value is called the Human Factors Score (HFS).

As already introduced by PIARC [1] the HFET can be used both to:

- inspect network level (e.g. Network-wide Road Safety Assessment), after defining a specific procedure that includes the HFET;
- analyze a single site (e.g. high accident concentration section).

This analysis is based on the theory about Human Factors from PIARC [5], and all the aspects that will be analyzed, are grouped into three main groups of triggering factors, which are called "rules". These rules are here briefly summarised. Detailed information can be found in PIARC documents [5][6] [7].

Specific terms and acronyms are used in the document, which can be found in the Glossary of Terms and Definitions (paragraph 9).

The following three paragraphs provide an overview of the rationale behind the definition of the three Human Factor Rules and the main aspects included in the tool that concerns those rules. Experts in the field of Human Factors from PIARC may skip the following paragraphs.

3.1. First Rule of Human Factors: the 6-second rule

The perception and visibility of specific situations that require a change in driver's behavior must be evaluated. A driver must have enough time to see, perceive, understand, and react to such a situation. The main requirements are summarized in Table 1. The table is divided into two parts (1.1 and 1.2) which represent the two investigation topics. The first one, the *Moderation of Transitional Area*, specifically addresses the presence of enough visible distance to be advised, to see, to think about, and to react to a specific situation (Decision Sight Distance, DSD). The second one, *Perception and visibility*, focuses on how much a location is clear, even if visible. A potentially critical location could be in sight (you can draw a straight line linking the location to the point of view of the driver without encountering any obstacles), but the potentially critical location is not understandable, or even completely misleading. Both the two investigation topics are then divided into subsections with detailed requirements.

Table 1 – Requirements analyzed for the First Rule of HF

1.1 Moderation of Transitional Area
1.1.1 Visibility of the CHLs
1.2 Perception and Visibility
1.2.1 Visibility, perception, and identification of CHLs
1.2.2 Curves
1.2.3 At-grade intersections, driveways, and crossings visibility
1.2.4 Unmistakable right of way

The following figures show some examples of bad visibility and perception of some locations. Figure 1 shows three different locations that are not clear to the driver, even if no obstacle obstructs their visibility. The first one is an intersection where the main road goes straight forward, and the minor road on the left seems to be the main road. The central picture is taken 125 m ahead of an intersection, but the intersection is not perceivable, even if it is in front of the driver. The last picture shows a pedestrian crossing 50 m ahead and a bus stop 70 m ahead in a rural environment. These two elements are unexpected for such an environment, thus it is harder for the driver to understand them and they are not visible because of the geometrical and vertical alignment, the light, the position of the two elements, and the general composition of the visual framework.

Figure 1 – Examples of invisible or not clear potentially critical locations: left – the intersection where the main road goes straight [8]*, center – intersection not visible 125 m ahead* [8]*, right – pedestrian crossing not visible 50 m ahead.*

Figure 2 shows instead a sequence of consecutive pictures taken starting about 70 ahead of a driveway. The following is taken with a step of about 14 m (1 second with a speed of around 50 km/h). The sequence clearly shows the moment of a car entering the main road from a driveway on the right. The car is visible in the third picture only if you know where to search, otherwise, the driver will find a car crossing the road in front of them with about 35-25 m available to brake. Furthermore, a bus stop is present 10 meters ahead of the driveways and a pedestrian crossing is present 5 meters after the driveway. The problem is not only of a limited Stopping Sight Distance (SSD) but also that looking 70 m ahead of the driveway, the road shows no clues or instruction that can help the driver understand what is placed behind the curve. they can't foresee that some risky location that requires a change in their behavior is hiding there, then it will be a surprise. It must be noticed that even if the SSD is present at a specific location, a sudden breaking action can always be a risky maneuver for the driver and the other vehicles around.

Figure 2 – Sequence of photos approaching an "invisible" intersection, starting 70 m ahead of the intersection. The last photo is about 25 m before the intersection

3.2. Second Rule of Human Factors: the field of view rule

Driving is a task-based mainly on visual perception, and unfortunately, visual perception is not always by reality. Human limitations force the driver to acquire only some information from what they are facing, giving the brain the task of processing and elaborating such information to make a general and clear (in our opinion) framework of the situation. For this reason, the first information that is provided by the visual system must be true and clear, and the most necessary information should be the ones that catch the attention of the driver. Therefore, a safe road design must consider the composition of the field of view along its development. Table 2 shows the three investigation topics (2.1, 2.2, and 2.3) and the subsections analyzed for the Second Rule. The *Density and shape of the field of view* are strictly related to speed. It investigated if the road could be monotonous and involve drivers to accelerate. A higher density in the field of view will improve the perceived speed, inducing the driver to decelerate [9] [10]. Furthermore, also the geometrical design of the road will influence the monotony: a road with few short curves and many long straights is far more monotonous. The second investigation topic, *Elements in the lateral roadside environment support optimal lane keeping*, focuses on the characteristics of marginal elements to influence the ability of the driver to keep the lane trajectory. Also, the framing of the curve will be evaluated. A curve must be correctly perceived to drive safe on it and this can be managed not only by planimetric geometrical design but also by considering road margins. The last, D*epth of the field of view*, aims to identify misleading road development in front of the driver, which can create false expectations. Diverging or converging lines in the margins (e.g. safety barrier or trees line) can unconsciously induce the driver to follow their development because they are generally parallel to the lane, thus they are taken as a reference. This can cause you to not keep the right trajectory on the lane. Optical illusions, which are analyzed, can greatly influence driver expectations.

Table 2 – Requirements analyzed for the Second Rule of HF

2.1 Density and shape of the field of view
2.1.1 Monotony of road segment and surroundings
2.1.2 Long/far visible approaching sections before the CHL
2.2 Elements in the lateral roadside environment support optimal lane-keeping
2.2.1 Structures above the road
2.2.2 Presence of eye-catching objects
2.2.3 Illusion-free optical guidance
2.2.4 Carriageway width changes are well-delineated
2.2.5 Roadside objects appear to be vertical
2.2.6 Curve's framing
2.3 Depth of the field of view
2.3.1 Dominant eye-catching objects support the detection of CHL
2.3.2 Presence of optical illusion
2.3.3 The course of the road visible

Figure 3 and Figure 4 provide two clear examples of the possible influence of the field of view. The first image of Figure 3 shows a road that is not symmetrically centered in the space between the trees. Based on their previous experience on another road, where the space is generally symmetrically organized, a driver could take the two lines of the tree as a reference, causing a subconscious shift in the lane, moving in the position that they should have had if the road was centered within the trees. Furthermore, the monotony and the far long view to the horizon, induce drivers to speed up, searching for additional stimuli. The second image shows a reconstruction of the same road with an anomalous tree placed very close to the road, on the side where the distance from the tree line is greater. This element that comes out from the general picture of the road, catches the attention of the driver with a positive impact on speed because it moves the attention from the horizon to a point closer to the driver, but it can cause a severe shifting on the lane, because the tree appears as an obstacle.

Figure 3 – Left image: optical orientation to the horizon: distant focus and monotony decreased workload and caused subconscious acceleration. Furthermore, the road is not in the center of the space between the trees, and this can cause an unconscious shift in the lane. Right image: eye-catching objects reduce the optical orientation to the horizon but create a visual obstacle on the margin [11].

Figure 4 shows three images of the same curve. The first is an image from a satellite, while the second and the third are sequential photos approaching the curve from the northeast. The curve has been recently modified to increase its radius but the organization of the new field of view is extremely poor. The major field of view negative factors are: approaching the curve, the line of olive trees on the left interrupts, leaving a space in the outer margin of the curve, making its outer frame less distinguishable. The only reference, not visible from a distance, are the safety barrier and the chevrons, which unfortunately are not parallel to the road axis, giving the impression that a larger radius is present; then there is no visibility of the inner curve, and thus the only reference for the driver to estimate the curvature is the outside safety barrier and the outside lane markings, which are not parallel; finally, within the curve, the white bar on the outside shoulder create some ambiguous shapes that attract the attention of the driver and modify the picture of the road. All these features can cause a wrong reading of the curve and a wrong driving plan approaching the curve.

Figure 4 – Example of a critical curve, left - north oriented satellite view, right - photo approaching the curve from East. The curve is visible from a distance but not understandable. The field of view shows many problems: the barrier line follows a different trajectory from the road axis, and white markings along the shoulder create bad focus points and modify the perception of the road curvature (photos from Google Maps).

3.3. Third Rule of Human Factors: the logic rule

A road must have a logic sequence. Unconsciously the drivers adapt their driving to the road that they are experiencing, but this is done in some dozens of seconds or also some minutes [12]. The experience that the driver has about the road he/she has traveled builds his/her expectation of the future development of the road. If those expectations are violated, the drivers generally require time to adapt to a new behavior. If the passage from a required behavior (e.g. driving in a rural environment) to another required behavior (e.g. driving in an urban environment) is sudden and doesn't give the driver enough time to adapt, the driver could proceed with the old behavior that unsafe under the new conditions, or even make some sudden risky maneuvers. To analyze these aspects, five main areas will be investigated, which are presented in Table 3 (3.1, 3.2, 3.3, 3.4, and 3.5). The first, the *Change of road function*, deals mainly with the problem of the entrance to urban areas or areas that require a sudden change in the global driver behavior. This change can't be entrusted only by a vertical sign and the belief that the driver will follow the rule because sometimes drivers don't even notice they're breaking the law and that is because the road doesn't communicate any change. For this reason, particular attention should be used in such a situation to communicate to the driver with many visual clues that a new driving behavior is necessary. The second investigation topic, *Curse of the road supported by dominant eye-catching guidance*, investigates some elements that are present that give the impression to the driver that

their route is different from the real one. This could happen when some new road track is made, and it is still present some trace of the old track. The third, *Effects of pre-programmed habits and expectations*, account for road modifications that can surprise habitual drivers, for example changing the road that has the right of way or also, unexpected road course, such as a curve that is not in coherence with the previous curves (i.e., has a radius greatly smaller than the radii of preceding curves). The fourth investigation topic, the *Sudden increase of decision needs and overload of information processing capabilities*, instead considers the working load the driver must deal with. Multiple close potentially critical locations can provide too many points of interest and too much information for the drivers with the results that some information will be missed. The choice of information is only partially a conscious process. An unconscious and intuitive process provides the first filtering of what we see in front of us, but this process is limited and will identify only the more readable information. Some major problems occur if, near the overload of information, a decision must also be taken. The last investigation topic deals with the *Deficiencies in traffic control devices*. If a road would be a real self-explaining road, it probably would not require any signings, but signings are still a powerful instrument if used in the right way. This means that they must be readable and easily identifiable, and they must comply with the road type and the road development.

Table 3 - Requirements analyzed for the Third Rule of HF

3.1 Change of road's function
3.1.1 Visual clues reinforce changed road junction
3.2 Curse of the Road supported by dominant eye-catching guidance
3.2.1 The road's main direction is identifiable
3.3 Effects of pre-programmed Habits and Expectations
3.3.1 The CHL is expected
3.3.2 The road has been changed during the last 3 years
3.3.3 Road geometrical alignment conforms with driver expectations
3.3.4 Transition zones and Challenging Locations are visible, understandable, and progressively introduced
3.4 Sudden increase of decision needs and overload of information processing capabilities
3.4.1 Many sources of information are present at the same time
3.5 Deficiencies in Traffic Control Devices
3.5.1 Evaluation of traffic control devices

A couple of examples are shown in Figure 5 and Figure 6. In the first two couple of sketches representing a town entrance, are presented. The first couple shows a town entrance that is only signalized by the vertical sign, with no change in the road environment and alignment. The second couple shows instead a town entrance where other countermeasures have been taken to improve the perception of the change in the road function. In the latter case, the driver will understand better that a change is happening and will comply with the required behavior of the new road junction.

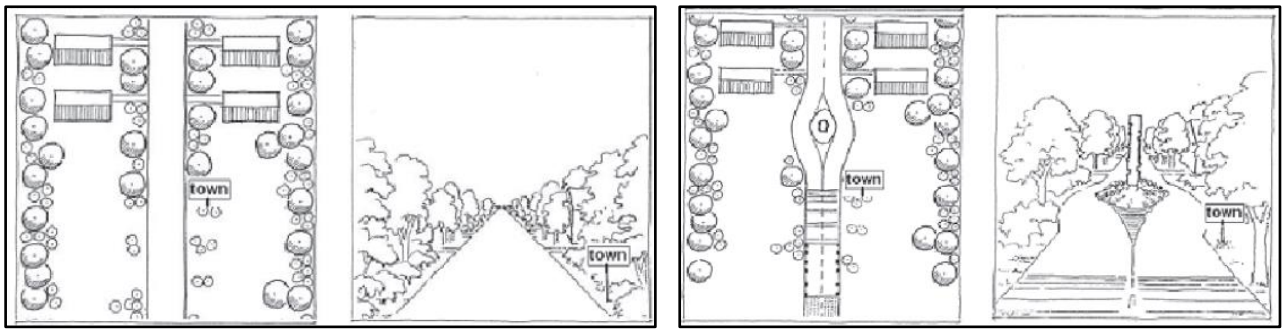


Figure 5 – Examples of change in road function with (right) and without (left) change in design and optical characteristics [13]

In Figure 6 two main problems are clearly shown: bad positioning of vertical signs and overload of information. These two conditions require the driver to study with attention all the signs, giving less attention to the road and causing also possible missing of information or misleading information.

Figure 6 – Bad positioning and overload of information provided by vertical signs.

4. THE INSPECTION TEAM

The application of the HFET requires a road survey. The survey must be carried out by a team of inspectors, called the inspection team. The inspectors belonging to the team must contribute to the fulfillment of the HFET.

The essential requirements of the inspection team are independence and qualification. The independence of the inspection team from the design, construction, and management process of the work is aimed at avoiding conditioning.

The qualification of the inspection team is essential for the process to be effective as the identification of road deficiencies and the attribution of those deficiencies to specific Human Factors aspects must be based on consolidated experience and practice in road safety engineering and Human Factors, particularly for the use of the HFET. The members of the inspection team should possess multidisciplinary skills and experience related to the application of the HFET but also related more generally to road design, traffic engineering, road engineering, traffic psychology, accident survey, and analysis. Furthermore, they must be at least trained on Human Factors principles.

It is recommended that only trained inspectors will be included in teams where at least one experienced inspector is present, for the first 2-3 inspections. After this period, they can be considered experienced inspectors.

The analysis of the road stretch using the HFET can be made also by a single inspector, however, is recommended that the inspection group is made up of several people as the exchange of ideas between different experts allows for the deepening of multiple points of view and greater objectivity in the process. It is suggested an inspection team of three people.

5. SITE INSPECTION

The site inspection (i.e., site survey) is structured as a typical road safety inspection road survey. This allows us to easily include the use of the HFET during a road safety inspection procedure.

5.1. General aspects

The following survey procedure can be applied for the analysis of road segments. The following steps characterize each inspection.

1. ***General survey***: the road is traveled at "normal speed", which is the speed that the driver would normally and spontaneously adopt on that road[1]; during this survey, the main road characteristics and issues are identified.
2. ***Detailed survey***: reduced speed driving or site inspection by foot. This survey is necessary only when detailed analysis is required at a specific site.
3. ***Night survey***: like the general survey but conducted at night; it allows for evaluation of specific site conditions at night.

5.2. Driving speed and detailed road analysis

The road stretch analyzed should be traveled at normal speed (***general survey***) and, if necessary, at reduced speed (***detailed survey***). During the ***general survey,*** the driver must try to forget to be an inspector. After the first driver has driven in both directions at "normal" speed (speed spontaneously chosen, taking care of road explicit information, e.g., speed limits, and implicit information, e.g., road configuration, but trying to not force itself to drive at reduced speed), is suggested to change at least one time the driver and make another driving following the previous criteria for the speed choice. This allows having a deeper insight into the perception of the road, with at least two different points of view and sensibilities. Of course, the second driver probably has already looked at the road as an inspector, but during their driving, they must try to drive spontaneously.

If necessary, driving at reduced speed can be performed if any specific locations require additional analysis. Thus, it is not mandatory to drive along the whole road at reduced speed, but only in the segment around the specific location that needs a detailed analysis. Reduced speed means about 30-40 km/h on rural highways and 60-70 km/h on motorways.

Finally, if some location requires additional analysis, the inspector can also choose to proceed by foot, taking photos of the location. During at least one of the driving at normal speed, a video must be made to ensure that the road can be easily virtually traveled again, both in day and night conditions.

[1] Please note that this means that the inspector is not forced to drive in accordance with the speed limits. This helps to highlight specific locations with some issues, where it is hard to comply with the speed limits.

5.3. Roles of the inspectors

The suggested number of inspectors in a team is three. During the driving, if three inspectors carry out the inspection, the role should be divided as follows:

- The first inspector is the driver. They will only consider the road and their driving, forcing them to not consider elements of the road as an inspector. they must consider their perception, expectation, and realization of expectation. they will tell their feeling so that all the impressions will be recorded in the video or noted by the other inspectors.
- The second inspector on the passenger seat will try to analyze the road environment exactly as an objective inspector, mainly focusing on single elements that it is known could unconsciously influence drivers. they will take notes about all those elements.
- The third inspector seated in the back seat will take notes of all the impressions by the driver and of some unconscious behavior of the driver (e.g. if the driver speeds up more than required).

The three inspectors will then exchange their roles. If fewer than three inspectors are present, then it will be considered only the role of the first and second inspectors (if they are two), or only the role of the first inspector (if only one inspector is carrying out the inspection). In the latter case, during the second driving, the inspector must judge the road as an inspector, thus it will make their comment while driving so that they will be recorded during the video.

While driving at reduced speed, all the inspectors will analyze the road environment as the second inspector did while traveling at "normal" speed.

All the notes taken, and the video recordings will allow proceeding with the identification of CHLs and the application of the tool.

6. USE OF THE HFET

The HFET is provided by three different checklists, one for each rule. The checklists will be compiled after the site inspection, considering the results of the site inspection (e.g., videos and notes). Each checklist must be applied to each CHL within the analyzed HFES. All the checklists and their meanings are described in detail in paragraph 7. Paragraph 7 describes the digital version of the HFET, but if the inspector prefers, the checklists can be extracted from the file and manually compiled.

6.1. Checklists' fulfillment

Each requirement must be judged for each CHL, considering the following voting values:

- "1": the requirement can be judged, and it is satisfied;
- "0": the requirement can be judged, and it is not satisfied;
- "na": "not analyzable", the requirement can't be judged for that specific CHL (e.g., requirements for a curve can't be judged for CHLs that are not curves).

Indication of how to judge each requirement is one of the objectives of this guideline. Specific indications are provided in paragraph 7, while a summary of the Evaluation Criteria, is provided in paragraph 8. It is essential to refer to paragraph 9 for the significance of the different acronyms.

Generally, when a requirement is only partially satisfied, then a "0" should be placed. Inspectors must not "be afraid" of voting "0". Evaluating a single requirement as "0" does not mean that the road segment must be burdened by many road accidents because of that specific condition. A road segment is risky when many of those HF requirements are not satisfied. It must be underlined that these conditions are triggering conditions, but generally, the driver will correct any starting error of perception. However, it is hard to correct more than one error or to understand that an error has been made if much negative information is provided by the road. A road segment will be considered risky using Human Factors when many requirements are not satisfied.

The reference condition to judge the requirement is daylight condition, if not diversely specified by the requirement itself. Furthermore, it is suggested to take notes and record any comments in the video while driving the night driving, because the video output in the night condition is generally darker than in reality.

Finally, the evaluation should be generally made by considering the whole HFES, not only the CHL and the area close to the CHL. The entire CHT must be considered to evaluate CHL. Specific situations are further described in paragraph 7.

After all the CHLs of the same HFES have been judged, the **Human Factors Score** (HFS) must be calculated. The HFS is calculated by summing up the numerical voting values ("1" and "0") and dividing the result by the number of requirements that have received a numerical voting value (i.e., the cells that didn't receive a "na" judgment), as showed in equation (1).

$$HFS = \frac{\sum_{i=1}^{n} RNVV_i}{\sum_{i=1}^{n} RTVV_i} \qquad (1)$$

Where:

HFS = Human Factor Score

i = number of the considered requirement;

n = total number of requirements;

RNVV = requirement's numerical voting value (1, 0);

RVVT = requirement's type of voting value, which is a Boolean value that assumes the value of 1 if true (the voting value is a numerical value, i.e., "1" or "0"), and the value of 0 if false (the voting value is not a numerical value, i.e., "na").

The calculation of the Human Factors Score must be made before each subsection for each CHL. Then the worst result of the HFS for each subsection must be identified within the results of all the CHLs, and the corresponding requirements' voting reported in an empty checklist. The result will be three checklists (one for each rule) fulfilled with the voting of the worst CHL for each subsection. All this procedure is automatic in the Excel file.

Then the HFS will be calculated for each investigation topic, each Human Factors rule, and considering all the requirements of all the checklists together. The latter results will provide the HFS of the whole HFES, while the "intermediate" scores of the investigation topics and the Human Factors rules, will provide information about the conditions of specific aspects. This could help in the definition of possible countermeasures.

Finally, the results of the HFS allow us to classify the HFES as having a low, medium, or high accident risk, based on the following criteria [1]:

- **Low risk**: HFS > 60%
- **Medium risk**: HFS $\geq$ 40% but $\leq$ 60%
- **High risk**: HFS < 40 %

7. HFET COMPOSITION

The HFET has been included in an Excel file to make it more practical. The Excel file is composed of seven different sheets:

- Segment Data
- DSD – A (Decision Sight Distance – A)
- DSD – B (Decision Sight Distance – B)
- First Rule
- Second Rule
- Third Rule
- Results

For each sheet, only light-yellow cells should be fulfilled.

First Rule, Second Rule, and Third Rule sheets are described in detail in paragraphs 7.3, 7.4, and 7.5. The descriptions of those sheets include soma figures and examples of specific cases. The provided examples are not exhaustive but help to make it clearer which are the parameters to be evaluated. The perception of the road derives from a series of continuous images and can't be summarized only by a photo. This must be always considered by the inspectors who are looking at this guideline. Examples of images are useful, but the description and significance of a requirement are the most important references. The numbering of the subparagraph enclosed in 7.3, 7.4, and 7.5, follows the numbering of the HFET sheets.

The Excel file allows to evaluation of a maximum of 10 different CHLs (or series of CHLs). After defining all the challenging locations in the Segment Datasheet, they will be automatically included in the DSD – A, DSD – B, First Rule, Second Rule, and Third Rule sheets. First Rule, Second Rule, and Third Rule sheets contain the "Clear Cells" button on the top left, which allows clearing all the cells in the sheet.

7.1. Segment Data

In the first sheet, the main data of the analyzed segment should be included. Inside the sheet, drop-down menus are included to facilitate the fulfillment.

The following entries are present:

Evaluation Segment ID: the ID (name) of the analyzed segment.

Road Name: the name of the road to which the segment belongs.

Direction: direction of travel, according to reference for distances. From the drop-down menu, it can be chosen within Increasing (ascending distances) or Decreasing (descending distances).

Reference for distances: it must be specified if the road km posts or some stretch-specific reference for distances were used.

Starting km: the starting point of the segment considering distances.

Ending km: ending point of the segment considering distances.

Inspection Date: when the on-road inspection has been carried out.

Compiling Date: when the Human Factor Evaluation Tool has been compiled.

Road Category: it is possible to choose between six road categories: motorway, rural highway, rural local, urban arterial, urban collector, and urban local. This category has been selected as representative of the many different road categories around the world.

HFES length: it represents the length of the HFES. It is automatically calculated.

Number of Challenging Locations (CHLs): number of the locations within the analyzed segment that will be considered in the application of the tool. Then, for each of the CHLs, it is possible to define which type of CHL is from a drop-down menu. It is possible to select "**Other (any location that potentially requires a change in driver behavior)"** from the drop-down menu if a specific location that the inspector wants to analyze can't be addressed by the elements in the previous list.

For each CHL it must be specified where it is located (i.e., Km posts), and if it is a single isolated location or is part of a series of consecutive locations of the same type. It is possible to have a CHL series if multiple consecutive locations of the same type are present and are within 50 meters from the previous (or following) one.

7.2. Decision Sight Distance (DSD)

Two different sheets are available to calculate the HFS for the DSD: DSD – A and DSD – B. DSD – A requires a higher detail of data, but it is the one suggested. If few data are available, then DSD – B should be considered.

- **DSD – A**

Based on the number of CHLs specified in segment Data, different cells will activate. The DSD-A is a completely automatic procedure. For each CHL (or a series of locations) the following features should be fulfilled:

Hard to identify: "Yes" if the location has some visibility problems, both because the visibility is partially obstructed, or because its configuration makes it difficult to be understood. Otherwise, put "No".

Available line of sight: the true line of sight in meters, should be placed here. Line of sight is present also if the location is only partially visible (in this case you should put "Yes" for the previous feature). To check the visibility of driveways, it should be considered the presence of a car waiting to enter the road, because an entering car is the most critical condition. Even a sudden braking maneuver from a car on the main road, which is searching for the driveway and seeing the driveway at the last moment, can be dangerous. However, if the car is searching for the driveway, its speed will be probably highly reduced. Moreover, it must be considered as an available line of sight the distance between the location and the first point from which the location is visible, considering the human sight limitation. To clarify

this statement, a zebra crossing at the end of a straight that is 500 m long, can't be visible at a distance of 500 m. It is suggested to check for those parameters during the site inspection or looking at the recording.

Speed: both the final speed and the approaching speed in km/h should be included. The final speed is the speed expected after the maneuver section, i.e., the speed required to correctly face the CHL, under the most critical conditions (e.g., a pedestrian crossing may require a stop from the vehicle, thus the speed will be set to 0). The approaching speed is the speed held by the driver before the maneuver section. If the approaching speed is not constant, an average value should be taken. The approaching speed can be taken as the measured V_{85} speed, or if not available, the V_{85} by formulas or the speed recorded during the inspection. Round the speed to the closer higher multiple of 5 km/h. The approaching speed is considered constant during the Response, Anticipation, and Advance Warning sections, thus if the speed changes during these sections, an average speed should be considered.

Deceleration data - Grade: if different grades are present, it is possible to account for it in the computation of the maneuver section (in number, not percentage). If no data are available, set the cell to 0.

Deceleration data – Average Friction Factor: if the longitudinal friction factor is known, it is possible to account for it in the computation of the maneuver section. If no data are available, set the cell to 0.37 [14].

In this sheet, the procedure to evaluate the visibility of each CHL is computed according to the following steps.

a. Definition of the time required by the Advance Warning Section, Anticipation Section, and Response Section. The time to consider may vary depending on the type of CHL and on the "Hard to identify" answer. Curves and Lane changes are considered "speed change" maneuvers and they require 3 seconds for all the above-mentioned sections. The other CHLs are considered "fast reduction" because they generally require a sudden maneuver to avoid the worst possible conditions. Sudden maneuvers rely more on quick reactions than on correct perception. For this reason, the Anticipation and Response sections for this type of CHLs are considered as 2 seconds. The Advanced Warning section is still set to 3 seconds. If the CHL is "hard to identify", then 1 second is added to the required time for each of the sections, with a maximum value of 3 seconds for the Anticipation and Response sections.
b. Calculation of the required length. The length required by each section is calculated using the motion equations. Advance Warning, Anticipation, and Response sections length is calculated considering a constant speed (equal to the approaching speed). The Maneuver section length is computed considering the space required to pass from approaching speed to the final speed, considering a uniform deceleration d that can be computed using Eq. 1 [14].

$$d = g \times (grade + f_l) \quad \text{Eq. 1}$$

Where:
d = uniform deceleration [m/s²]
g = gravity acceleration, 9.81 m/s²
grade = grade of the road, based on the user settings [decimal]
f_l = average longitudinal friction factor, based on the user settings [-]

c. Calculation of the cumulative length and comparison with the available line of sight. The cumulative length for each section is calculated by summing the required length to the cumulative length of the previous section (add 0 for the Maneuver section). The cumulative length is then compared with the available line of sight. If the cumulative length is equal or bigger, a 1 is set under the column "evaluation", otherwise a 0 is set.

- **DSD – B**

Based on the number of CHLs specified in Segment Data, different cells will activate. If the inspector chooses to use DSD-B instead of DSD-A, is because a manual fulfillment of the requirements is preferred by the inspector. For each CHL (or a series of locations) the following features should be manually fulfilled considering the attached table taken from PIARC [5]. The fulfillment of DSD – B is qualitatively and not as precise as DSD – A.

Speed: initial speed considered in the analyzed section (Advance Warning, Anticipation, Response, and Maneuver). Average qualitatively speed.

Length: length of the section (Advance Warning, Anticipation, Response, and Maneuver) obtained from the opposite tables (in the sheet).

Evaluation criteria: 1 = cumulative length higher or equal to the available line of sight, 0 = cumulative length lower than the available line of sight.

The cumulative length cells will be fulfilled automatically based on the procedure presented in DSD – A (point "c." of the list).

7.3. First Rule

The First Rule sheet (I Rule) is divided into two main investigation topics, and five subsections. The sheet requires to selection of the evaluation procedure used for the main investigation topic "Moderation of Transitional Area". This is possible from the dropdown menu in cell C1, where it is possible to select A (i.e., DSD – A) or B (i.e., DSD – B), according to the procedure chosen to evaluate the decision sight distance.

- **1.1 Moderation of Transitional Area**

This main investigation topic has been already evaluated by compiling the previous sheets. The cells will be automatically fulfilled based on the results obtained in DSD – A or DSD – B.

- **1.2 Perception and Visibility**

  - ***1.2.1 - Visibility, perception, and identification of the Challenging Locations***

a. The Challenging Location is obvious (at least in the anticipation section)

Since one point of the Anticipation Section, the CHL is visible and distinguishable. This means that it is possible to have a clear line of sight, but that it is also possible to recognize the CHL and easily understand its configuration. This must be distinguishable at least in the last part of the anticipation section (please note that this does not mean that the whole anticipation section must be present). Table 4 shows a couple of examples, one of two curves and one of two intersections, which help to understand when a visible location can be hard to understand. Images on the left show a not unclear configuration/development, while images on the right show two examples of clear configuration (development). The curves' example is quite simple to understand: the first curve is on a crest and even if it is possible to understand that it is a curve, defining its length and curvature is not easy. The first image in the second example shows a double intersection, explained also by the sign. It seems quite clear and visible, but the first visible left-turning lane is used to access the petrol station. The left-turning lane for the intersection is immediately after, and it is not distinguishable from the previous left-turning lane. This is not only a problem of correct visibility, but the main problem is also about expectations, however, the sight information provided doesn't help to make the situation clearer.

Evaluation criteria: if the CHL configuration is clear "1" should be put in, otherwise "0".

Table 4 – Examples for requirements 1.2.1.a.

Not clear configuration/development	Clear configuration/development
	
	

b. Visibility is not restricted by plants, terrain, buildings, traffic signs, control devices, roadside furniture, …)

Also, in this case, the CHL is visible, but some elements reduce the visibility. These elements can be plants, buildings, roadside furniture, traffic control devices, signs, and the terrain (i.e., embankments). An example is provided in Figure 7 where two driveways (private access) are present: one on the right side of the road and one on the left, immediately after the first. The first one is located immediately after the white advertisement panel. The panel, and the vegetation, reduce the visibility of a possible car waiting to enter the road (or entering the road). In the second access, a car is entering the main road. The car is not visible, even if visible. Because both the wall is close to the driveway and the tree on the right side of the road.

Evaluation criteria: if the visibility is not restricted "1" should be put in, otherwise "0".

Figure 7 - Example for requirements 1.2.1.b.

c. Roadside furniture/equipment and traffic control devices are visible and help to identify the CHL (traffic signs and signals, markings, safety barriers)

In many cases, CHLs are characterized by specific roadside furniture/equipment, such as traffic lights, chevrons, safety barriers, and markings, which help to clarify the configuration and development of such CHLs. In the two examples of Table 5, the image on the left shows a visible intersection, but not all the road furniture elements are visible. The intersection appears as a three-leg stop-controlled intersection where the drivers on the main road have priority (no stops required). That is not true, because the intersection is a signalized intersection. The traffic light is visible if searching for it, but it is hiding in the environment, so it is not visible. In the right image, a mirror highlighted with a white and red border catches the attention of the driver and informs the driver that a driveway is present. Without the colored boundary of the mirror, visible against the background, the driveway (and the mirror itself) would have been invisible.

Evaluation criteria: if roadside furniture is present and improves the identification of the CHL, the evaluation is "1", otherwise is "0" (not present or present but not helpful). If the CHL is obvious even without any furniture (rare case), "na" should be used.

Table 5 - Example for requirements 1.2.1.c.

Road furniture not visible	Road fuis rniture visible
	

d. Day: the luminance of road surface and traffic signs/markings is sufficient

It must be evaluated if the road surface and/or traffic signs are visible accounting for luminance. Bad luminance conditions can be present because of dirty or worn road signs and markings, or for the presence of shadows that reduce visibility. Figure 8 shows a curve where the luminance of the right margins is not good, thus the signs are not visible (they are also very old) finally, the overpass creates a "black hole", which hides the further development of the road.

Evaluation criteria: it would be probably not possible to evaluate the CHL under different daylights, so the inspector must judge if the conditions are good, in which case they will put "1", or bad, in which case they will put "0".

Figure 8 - Example for requirements 1.2.1.d.

e. Night: CHL is illuminated (not for curve), and the luminance of road surface and traffic signs/markings is sufficient, retroreflection of traffic signs/markings is sufficient

The visibility of signs, markings, and all other elements that help to understand the CHL must be visible at night. Thus, the luminance and retroreflection characteristics should be adequate. Furthermore, all CHLs except curves, should be illuminated at night, otherwise, they will be hard to see. Figure 9 shows a road stretch with very poor luminance and retroreflections of road markings and of some signs closer to the driver (on the right). A driveway is present on the left and an intersection on the right is 70 m above.

Evaluation criteria: if a CHL is illuminated (except curve) and all the road features (surfaces, signs, markings) are visible using luminance and retroreflection, put "1", otherwise "0". If the night evaluation can't be performed, put "na". Please note that the best way to make a night evaluation is to survey the road. Relying only on videos is not recommended, because the cameras have generally reduced performance at night.

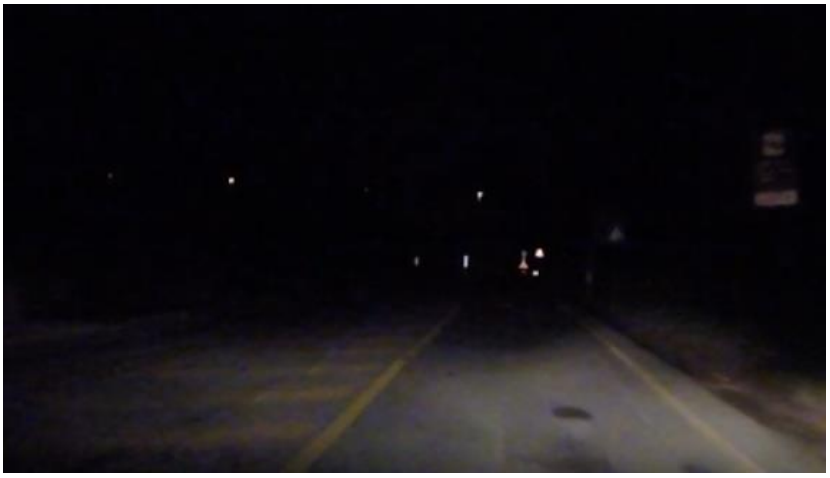


Figure 9 - Example for requirements 1.2.1.e.

- ***1.2.2 – Curves***

A specific focus should be made on curves because they present some peculiarities that should be addressed.

a. Curve is visible (at least 6 sec. ahead of the braking section)

The visibility has been already evaluated for generic CHL; however, the presence of this requirement stresses the importance of curve visibility. This means that if a curve is not visible at least 6 seconds ahead of the braking section (i.e., maneuver section), an even worse score will result at the end of the evaluation. The criteria to judge this requirement is the same as the DSD evaluations.

Evaluation criteria: if the curve is visible during the whole Anticipation and Response section (see the Moderation of Transitional Area main topic), then put "1", otherwise put "0".

b. Curve is not on/behind a crest

If a curve is on a crest, it will be only partially visible, and if after a crest, it will be probably not visible at all. Furthermore, a curve on a crest may lead the driver to misjudge the real curvature of the curve. Those conditions are quite clear; however, an example is provided in Figure 10. The figure shows an invisible curve immediately after a crest. Its presence is perceived only because of the chevrons.

Evaluation criteria: if a curve is on or behind a crest, "0" should be put in the evaluation, otherwise "1".

Figure 10 - Example for requirements 1.2.2.b.

c. Shoulder and marking of the outer curve are visible (at least in the response section)

Having a clear overview of the outer shoulder and marking helps to better understand the curve. This is the key to judging this condition. Shoulders and marking are hard to identify from a distance, for this reason, the condition must be satisfied at least in the response section. Figure 10 shows a good example of invisible shoulders and markings, while Figure 11 shows an example of poor outer delineation. This requirement must be judged also at night when road markings are required to provide strong guidance. Curves on crests often have poor visibility of shoulders and markings.

Evaluation criteria: if the shoulder and markings of the outer curve are not visible, then put "0", otherwise put "1".

Figure 11 - Example for requirements 1.2.2.c.

d. Visibility on the inner curve is not restricted

As proved by many studies, drivers search the inner curve to understand the curvature and plan the right maneuver to do. Therefore, a good sight of the inner curve is necessary. It must be judged if the visibility of the inner curve helps to understand the curve, and so, the visibility

before the maneuver section must be judged. Table 6 shows three images representing restricted visibility (top), partially restricted visibility (middle), and non-restricted visibility (bottom).

Evaluation criteria: if the visibility is restricted or partially restricted, "0" should be put in, otherwise "1".

Table 6 - Examples for requirements 1.2.2.d.

Restricted	
Partially Restricted	
Not restricted	

○ *1.2.3 – At-grade intersections, driveways, lane changes, and crossings visibility*

A specific focus should be made on at-grade intersections, driveways, crossings, and lane changes because they can be high-risk conflict points.

a. Priority traffic is visible (for at least 6 sec. ahead)

These conditions should be evaluated for vehicles coming from the minor road. The worst result should be considered. Signalized intersections and roundabouts must not be evaluated. In this case, the visibility triangle should be checked, considering the schemes in Figure 12. The distance "b" is calculated as the product of the average speed of the main road preceding the intersection (m/s) and the time (6 seconds). For the distance "a", the decision point can be set at 3 m from the end of the shoulder on the side of vehicle B [15]. These definitions provide useful indications, which serve as a reference during the analysis, however exact measurements are not necessary. It is suggested to make these evaluations on satellite maps, considering the visual inspection made during the survey. For pedestrian crossings the same principle may be used, considering the pedestrian is located two meters away from the carriageway (distance "a"), and a time of about 6 seconds to calculate distance "b".

Evaluation criteria: if the visibility is not present or reduced, put "0", otherwise put "1". If the intersection is a roundabout or a signalized intersection, put "na".

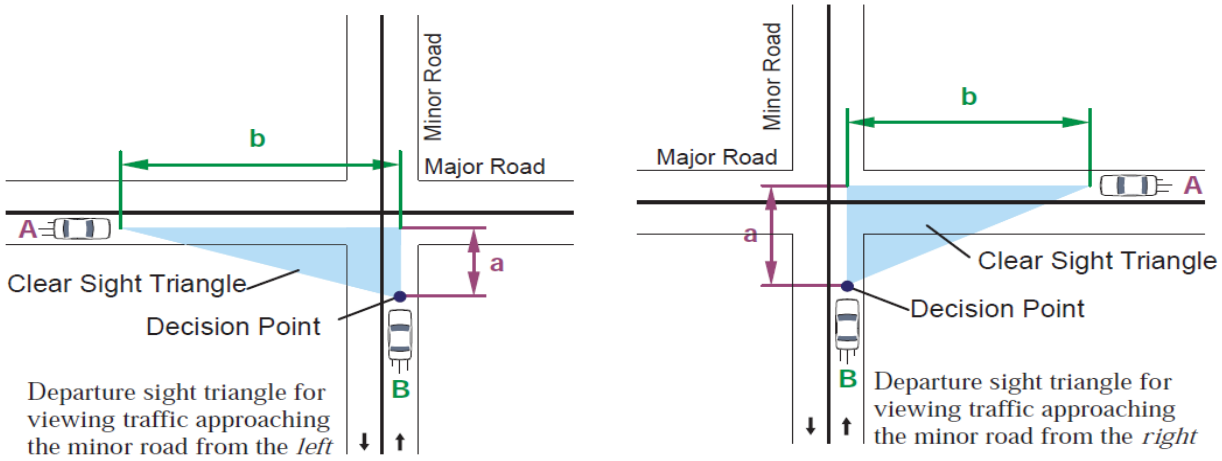


Figure 12 – Departure sight triangles [14]

b. The CHL is not on or behind a crest

The at-grade intersection, driveway, or crossing located on a crest or immediately behind a crest can be hard to see and understand. Furthermore, if also the minor road/driveway has a positive grade, it must be considered. A maximum grade can be considered as 3%. The higher grade increases the difficulties in seeing an approaching vehicle. However, the percentage is indicative, and the inspector must judge case by case depending on the road and road environment configuration.

Evaluation criteria: if the CHL is not on or behind a crest, "1" should be put in, otherwise "0". If the minor road or driveway has a positive grade (it can be assumed as reference >3%), then put "0".

c. CHL configuration is clear (at least in the anticipation section)

These conditions should be evaluated both coming from the main road and the minor road. The worst result should be considered. To have a clear configuration, the CHL (at-grade intersection, driveways, crossings) requires that the upcoming driver understands how to behave: if they had the priority, how many legs compose the intersection, and where they must go to follow the main road. This must be clear at least in the last part of the anticipation section (please note that this does not mean that the whole anticipation section must be present). This condition is the same as 1.2.1.a., except that it must also consider the point of view of the drivers coming from the minor road. Another example of a not-clear intersection is provided in Figure 13, where it is forbidden to go straight. A sign is present next to the traffic light on the top, but it doesn't catch the attention of the driver, and the visual configuration of the intersection, approaching the intersection, does not suggest any difference from a standard signalized intersection where it is possible to go straight.

Evaluation criteria: if the CHL configuration is clear "1" should be put in, otherwise "0".

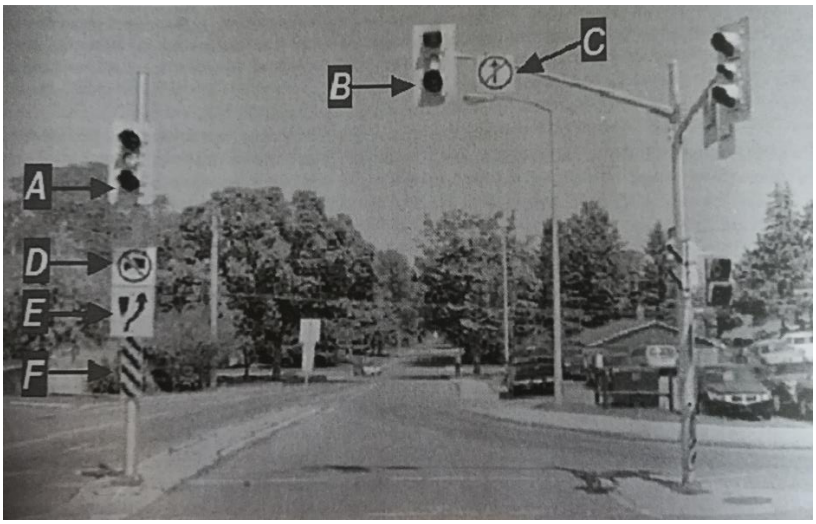


Figure 13 - Example for requirements 1.2.3.a. [12]

d. The CHL is not on or behind a curve

The at-grade intersection, driveway, or crossing located on a curve or immediately behind a curve can be hard to see and understand.

Evaluation criteria: if the CHL is not on or behind a curve, put "1", otherwise "0".

- ***1.2.4 – Unmistakable right of way***

Drivers should be clearly aware of who has the right of way. This subsection is applied only to driveways and at-grade intersections that are not signalized intersections. These conditions should be evaluated both coming from the main road and the minor road. The worst result should be considered. Driveways generally satisfy all these requirements. For signalized intersections, the following requirements must be judged as "na".

a. Road hierarchy is clear (at least in the response section)

This means that no mistake can be made by the driver evaluating the road hierarchy. It is clear which road is the main road and which one is the secondary road.

Evaluation criteria: if the road hierarchy is clear, put "1", otherwise "0".

b. Lay-out and/or surface of main and minor roads are not similar (e.g., color variations or different paving material, surface quality)

Even if much information is provided and it is quite easy to understand which is the main road and which is the secondary road, under some conditions driver can miss that information, relying only on automatic perception of the road environment. For this reason, the perception of a different road layout is crucial. Figure 14 provides an example of a well-signalized intersection, but which has slight differences in road layout (and which has bad geometrical configuration) and no difference in road surface. In this case, this requirement will be judged as "0".

Evaluation criteria: if the layout and the surface of the two roads are not similar, put "1", otherwise put "0".

Figure 14 - Example for requirements 1.2.4.b.

c. The minor road is not aligned with the main road

At-grade intersections, including roundabouts and signalized intersections, should be considered. It must be ensured that vehicles coming from the minor road must turn to enter the

main road and the roundabout (considering the roundabout, such a turn is related to the deviation angle and deflections [16]).

Evaluation criteria: if a turn maneuver is required to enter the main road from the minor road (or to enter a roundabout from the analyzed road), put "1", otherwise put "0".

7.4. Second Rule

The Second Rule sheet (II Rule) is divided into three main investigation topics and eleven subsections.

- **2.1 Density and shape of the field of view**

The following subsections concern all the aspects related to the density and shape of the field of view, which means the color contrast, the position, the layout, and the shapes of the road and its surroundings. The effects of the field of view influence mainly the automatic choice of speed. A reduced density of the field of view and a poor road layout, have a high influence on speed increase.

- ***2.1.1 - Monotony of road segment and surrounding***

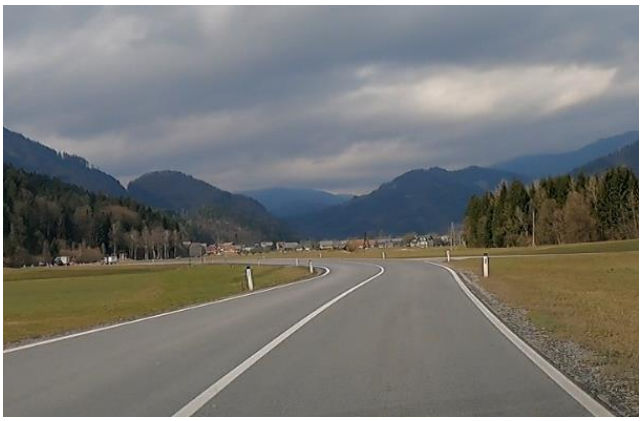
It must be evaluated if the density of different elements (plants, objects, buildings, signs, markings, road furniture) in the driver's field of view, is sufficient. Unfortunately, no instruments are available to measure such a density, neither a threshold has been defined, which indicates an optimal density of the field view. For this reason, the inspector must judge if the density is enough or not.

a. Diversified planting or buildings (variation in height, distance, ...)

It should be considered the number and the type of elements around the road: the greater the differences in height, distance, and size, the greater the beneficial effect. It is necessary to say that the color and color contrast should be mainly considered in the next requirement. This requirement must evaluate the road elements' diversity concerning shapes and dimensions. Table 7 provides some examples of high/medium diversity road environments, and low diversity road environments. The third examples of both columns are borderline cases. In the first case (left) the left margin of the road has clearly a low density, but the density is higher in the right margin. However, the dimensions of the plants are similar, and they are so close that it is hard to identify the shape. Furthermore, the big wall creates a sense of monotony. In this case, the road can be classified as low diversity. The image on the right shows a road that crosses some wood. On both sides, the trees have similar dimensions but are placed in a very random order, and when the leaves are present, the shape suddenly changes. In this case, the environment can be considered of high diversity. The inspector must judge the entire stretch preceding the CHL, using those examples only as a reference. they must try to make an overall evaluation, questioning themselves if the stretch is generally monotonous because of a poor diversification of the surrounding road elements.

Evaluation criteria: if the requirement is satisfied, then put in "1", otherwise "0".

Table 7 - Examples for requirements 2.1.1.a.

Low diversity	High/medium diversity
	
	
	

b. Good light contrast and good color contrast in the environment

The previous requirement judged the shapes and dimensions of the elements in the road environment. By this requirement, the color and color contrast of such elements must be considered. The objective is the same, that is to understand if sufficient stimuli come from the environment. These stimuli must help to reduce the monotony and improve the perception of speed. Considering the previous example of Table 7 the first two images of the first column (low diversity), can be classified also as low color contrast, even if the road delineators (guideposts)

have good contrast against the background. However, they are the only color-contrasting objects, and they are small. The third image of the first column, provides a good contrast, however, this is due also to the sun's position and the effects of the shadows, otherwise, the green of the plants and the grey of the wall will be very uniform with no difference. These three cases must be considered to have a low color contrast. The images in the second column have a higher color contrast (medium contrast). In this case, the requirement can be considered as satisfied.

Evaluation criteria: if the requirement is satisfied, then put in "1", otherwise "0".

c. Road environment well structured (e.g., by fixation objects that attract the driver's attention, but do not distract)

Fixation objects are road elements that catch the attention of the driver, mainly because they seem to provide information to the driver (not necessarily about the road). Nevertheless, after the driver has understood the information or the type of information, they can decide to look elsewhere. A great example is advertising signs. The influence of such elements on the field of view density is positive, both because generally they are high color-contrasting objects, and because they are different in shape and size from the surroundings. Furthermore, they catch the attention of the driver away from the horizon, and this has been proven to have a positive influence on speed. However, these objects can also be a problem if the provided message is hard to read because they will increase the workload above the limit threshold or keep the attention of the driver away from the road for too long. If the object is very attractive and/or complex and forces the driver to keep their attention on it, it will become a distracting object. The latter negative possibilities are evaluated by other requirements. Table 8 shows one example of a road without any fixation object, and a road with some fixation objects. In the second example, the density of the field of view is improved and the driver will spontaneously reduce their speed.

Evaluation criteria: if no fixation objects are present, or the fixation objects are distracting objects, a "0" should be put in, otherwise "1".

Table 8 - Examples for requirements 2.1.1.c.

No or few relevant fixation objects	Relevant fixation objects

- ***2.1.2 - Long/far visible approaching sections before CHL***

  Monotony derives most from the density of the objects in the field of view and from the structure of the field of view. Furthermore, a continuous activity of the driver, e.g., steering and changing gear, helps to make them active, avoiding monotony.

a. Road environment well structured (e.g., by fixation objects that attract the driver's attention, but do not distract)

As stated in the previous requirement, fixation objects catch the attention of the driver close to the position of the driver itself and away from the horizon, with a positive effect on speed. However, it must be ensured that the fixation object does not become a distracting object.

Evaluation criteria: if no fixation objects are present, or the fixation objects are distracting objects, put "0", otherwise "1".

b. Road environment composed by a sinuous "rhythmic" alignment

A sinuous alignment helps to let the driver be active. A sinuous alignment leads to an increase in attentiveness and a decrease in speed. No specific parameters are presented to define an alignment as sinuous, but this kind of alignment has generally many curves in different directions, with short straight between one curve and another.

Evaluation criteria: if the road alignment can be considered as sinuous, put "1", otherwise "0".

c. Stretches are avoided where a "wider or longer" space is perceived

The perception of "available space" led the driver to speed up. Available space means a surface without obstacles. This kind of surface is both the surface outside the road, and the road itself. A large, paved carriageway with a large shoulder, leads the driver to accelerate, and the same effect is provided by long straight, or "open" road margins (with no trees, houses, or other elements of a certain size). In both cases, the road surface is big (in width or length). Figure 15 shows a road stretch where a wider space can be perceived because of the long visible straight, because of the plain fields on the left, and because of the bicycle path on the right that moves

away the line of trees from the road's right margin. If the line of trees isn't there, the space perceived will be even more.

Evaluation criteria: if no "wider or longer" space is perceived, put "1", otherwise "0".

Figure 15 - Example for requirements 2.1.1.c.

- **2.2 Elements in the lateral roadside environment support optimal lane-keeping**

Elements in the lateral field of view influence the speed, but also the lane keeping. When driving in an automatic way (control function, [17]), the brain unconsciously searches for information in the environment, linking it to the typical expected road environment. A typical road environment is characterized by some specific features like symmetry, verticality of marginal objects, and a continuous carriageway width. Furthermore, it has been proved that looking at an object while driving, provokes a shift towards that object. A clear and well-structured organization of the field of view would help to avoid lane-keeping errors.

- ***2.2.1 - Structures above the road***

Structures above the road (e.g., bridges and overpasses) can stabilize or destabilize the driver. Such structures are expected to be symmetrical in all planes (vertical and horizontal). If the structure is not symmetrical, it can mislead the driver, leading them to change the position in the lane and, in the worst case, leading them to leave the lane. If no overpasses/bridges are present, put "na" to all the following requirements.

a. They are of equal height

It should be considered if the backseats are of the same height, thus the grade of the bridge appears equal to 0. Figure 16 shows an example of two backseats of different heights. The real height of each backseat is not required, it must be judged how they are perceived, just with a visual check.

Evaluation criteria: if the backseats are not of equal height, put "0", otherwise "1".

Figure 16 - Example for requirements 2.2.1.a.

b. In the field of view, they are symmetrical to the road center

This means that the center of the road is also the center of the bridge. The presence of trees can improve or reduce the correct perception of the bridge. Also, in this case, it must be evaluated not the real position of the bridge, but what can be seen. Figure 17 shows a pedestrian overpass that is not symmetrical, while Figure 18 shows some sketches that exemplify a wrong asymmetrical bridge, a countermeasure taken to reduce the perceived asymmetry, and a symmetric bridge (from the top to the bottom).

Evaluation criteria: if an asymmetry is present, put "0", otherwise "1".

Figure 17 - Example for requirements 2.2.1.b., photo by Google Street View

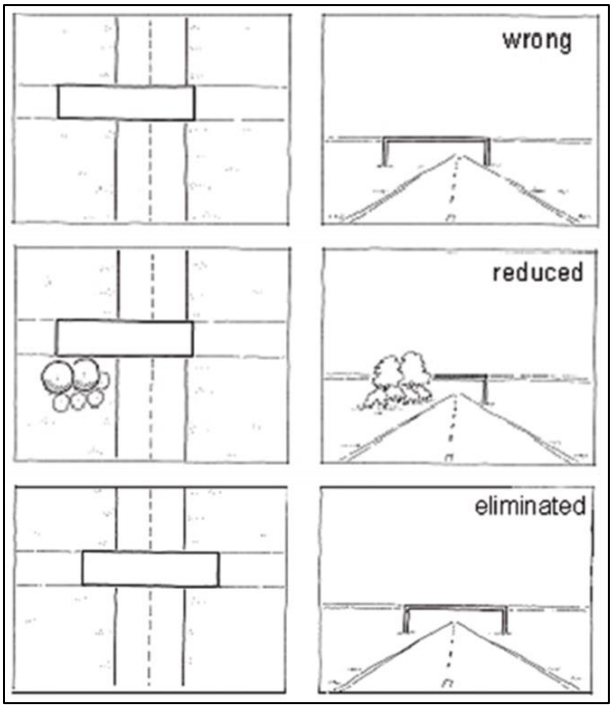


Figure 18 - Example for requirements 2.2.1.b., conceptual sketch [13]

c. In the horizontal plane, they are perpendicular to the road axis: skew angle less than 15°

The bridges/overpasses must cross the road perpendicularly. The maximum skew angle is 15°. This evaluation is made also looking at maps and satellite images. An example is provided in Figure 17, where the overpass axis is not perpendicular to the motorway axis.

Evaluation criteria: if the bridge is not perpendicular to the road, put "0", otherwise "1".

Figure 19 - Example for requirements 2.2.1.c., photo by Google Maps

2.2.2 - Presence of eye-catching objects

Eye-catching objects are those objects that continuously attract the attention of the driver because they are relevant in the field of view. A relevant eye-catching object can be a high color contrasting object, sharp or narrow shape with high brightness, moving objects, but also single isolated objects, which are very visible in the field of view. Focus on a point outside the road can reduce correct lane keeping, furthermore if the focus last for too many seconds and the objects it is not along the road axis, also the environment perception can be disturbed, because the focus point of the field of view is no more in the direction of travel. If no eye-catching objects are present along the analyzed segment, put "na" to all the following requirements.

a. Eye-catching objects do not 'disrupt' the continuity of lateral guidance clues

Lateral guidance is extremely important for lane-keeping. A single eye-catching object alone can disrupt the continuity of the lateral guidance. A single eye-catching can be also a sudden interruption of the guidance line. The three images of Figure 20 show one situation with no eye-catching objects (left image), one with an eye-catching object (middle image) that is a single tree alone, clearly visible, and out of the main tree line, and one with an eye-catching object (right image) represented by a hole of light in the tree line. In both cases (middle and right image) the eye-catching objects will influence the lane keeping. Eye-catchers can be considered also special road markings. If they help to focus the attention on the road and help the lane keeping, they must be considered as positive. One example is provided in Figure 21.

Evaluation criteria: if an eye-catching object is present and disrupts the continuity of the lateral guidance, put "0", if it is present, but doesn't disrupt such a continuity, put "1".

Figure 20 - Examples for requirements 2.2.2.a., [11]*, third image modified*

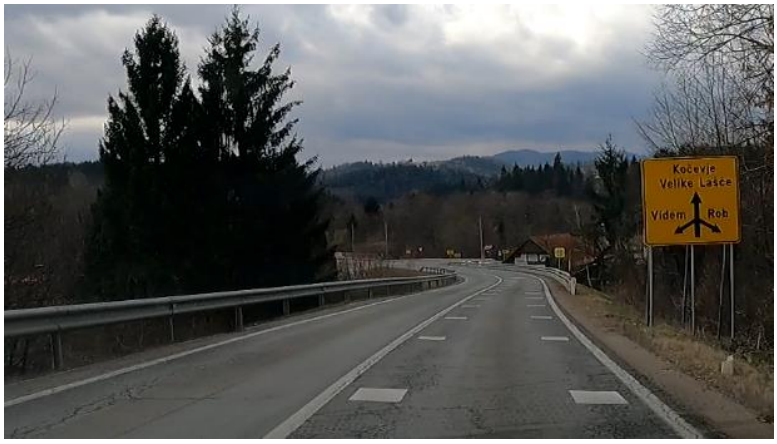


Figure 21 - Example for requirements 2.2.2.a.

b. Eye-catching objects are symmetrical with the road's centerline

Generally, eye-catching objects, when present, are not symmetrical to the road axis. However, if such a condition arises, the eye-catcher can stabilize the driving with a positive effect. In the case of eye-catchers like the ones shown in Figure 21, they can be considered as "symmetrical" because they stabilize the attention on the main lane.

Evaluation criteria: if more eye-catching objects are present and they are symmetrical with the road centerline, put "1", otherwise "0".

c. Eye-catching axis to eye-catching objects aligns with the road axis

If the eye-catching object is far away from the road the influence on the driving can be even more negative. The inspector must try to make a line (axis) between the point of view of the driver and the eye-catching object. If this line greatly diverges from the road axis, then the requirement is not satisfied. Obviously, the closer the driver is to the object, the wider the difference between the two axes. For this reason, the inspector must consider the influence of the eye-catching objects some dozens of meters before the objects. An indicative measure can be about 3 seconds before the eye-catching object. However, it must be considered the influence of the object also in the preceding part (up to the warning section). In this case, only objects that lay in the lateral road space are considered. Objects far away from the horizon are not considered (see the next main investigation topic). Considering the examples in Figure 20, the image in the middle illustrates an eye-catching object that is very close to the road margin, thus it can be considered as aligned. Instead, the third image shows an eye-catching object that is located many meters away from the road margin. In this case, the requirement is not satisfied.

Evaluation criteria: if an eye-catching object is present and the axis to eye-catching objects is aligned with the road axis, put "1", otherwise "0".

- ***2.2.3 - Illusion-free optical guidance***

Elements providing reference clues in the lateral space must be clear and not mislead the driver.

a. Lateral guidance clues/orientation lines are present and parallel

Continuous elements parallel to the road provide a strong reference to the driver. For this reason, the driver relies on them in both conscious and unconscious ways. Parallel lines are made by a continuous element (such as safety barriers) or by a series of similar discontinuous elements (such as a line of trees). Figure 22 shows a double example of diverging lateral guidance clues. Both the safety barrier and the noise barrier, which are generally parallel by standard design, are instead not parallel in that road segment. Particularly the noise barrier on the right is converging to the road, while the median barrier is diverging. Moreover, the space between the noise barrier and the median barrier is the same: only the shoulder widths and the carriageway position are changing. This may cause a shift in the lane. The shift can be even more critical if approaching a curve.

Evaluation criteria: if lateral guidance is present and parallel, put "1", if they are present but not parallel to the road axis put "0". If no reference clues are present, put "0".

Figure 22 - Examples for requirements 2.2.3.a., photo by Google Street View

b. Lateral guidance clues/orientation lines are consistently spaced and equally sized

Even if parallel, continuous elements on both sides of the road can have some difference in dimension or location or be present only on one side of the road. This may influence the driver's lane-keeping. A symmetrical composition of the field of view must be always considered. Table 9 shows two examples. The example on the left shows a line of big trees, which is present only on the left side of the road. In this case, the requirement is not satisfied. The example on the right shows a road without any relevant lateral guidance clue. A weak reference is provided by the road white road delineators, but it is not sufficient.

Evaluation criteria: if the lateral guidance clues are consistently spaced and equally organized considering together both sides of the road (searching for symmetry), put "1", otherwise put "0". If no, or very low-influencing reference clues are present, put "0".

Table 9 - Example for requirements 2.2.3.b., left photo by Google Street View

Asymmetrical lateral guidance clue	Absent lateral guidance clue
	

c. Lateral guidance clues/orientation lines are unambiguous

To be unambiguous means to be clear. Some lateral guidance may present some ambiguous parts, like trees of different shapes and sizes, non-regular organization, a development that is not continuous, and may suddenly change close to the CHL. All these factors make lateral guidance ambiguous. Figure 23 shows an example of an ambiguous margin. In the left margin, the embankment terminates and leaves place to some plants, which are not well organized: some are closer, and some are farther.

Evaluation criteria: if the lateral guidance clues are unambiguous put "1", otherwise put "0". If no, or very low-influencing reference clues are present, put "0".

Figure 23 - Example for requirements 2.2.3.c.

- ***2.2.4 - Carriageway width changes are well delineated***

a. Carriageway width reductions/increases are well delineated and visible (e.g., with the use of traffic control devices, markings, posts, …)

A change in the carriageway width influences the driver, surprising it. For this reason, when the carriageway significantly changes its width (an indicative measure is more than 50 cm), this

must be clear using markings, signs, and traffic control devices. Changes in curves must not be considered except if they are very big changes (more than 1 m).

Evaluation criteria: if a carriageway width change is present and well delineated, put "1", if present and not well delineated, put"0". If no carriageway change of width is present, put "na".

- ***2.2.5 - Roadside objects appear to be vertical***

a. Roadside objects appear to be vertical

Non-vertical objects have a high influence on the capacity of drivers to keep the lane. A clear example of non-vertical objects is provided in Figure 24. Such a condition is very common in windy areas.

Evaluation criteria: if all the objects along the road margins appear to be vertical, put "1", otherwise put"0". If no object is present, put 0.

Figure 24 - Example for requirements 2.2.4.a., photo by Pikist (https://www.pikist.com/free-photo-xawia)

- ***2.2.6 – Curve's framing***

Curves are crucial elements while driving. A good estimate of the length and radius of the curve leads the driver to plan the correct maneuver, choose the right trajectory, and choose the appropriate speed.

a. Lateral optical guidance frame of the outer curve is present and parallel

This requirement is the same as 2.2.3.a. but it considers only the outer frame of a curve. Table 10 provides two examples, both concerning non-parallel lateral optical guidance of the outer curve. In the first case the trees on the right margin are diverging from the road axis, while in the second, the trees on the right margin are converging. Another example is provided in Figure 22, where the safety barrier and the noise barrier are both not parallel to the road axis.

Evaluation criteria: if the CHL is not a curve, put "na". If lateral guidance is present and parallel, put "1", if it is present but not parallel to the road axis put "0". If any optical guidance is not present, put "0".

Table 10 - Examples for requirements 2.2.6.a.

Examples of non-parallel lateral optical guidance frames of the outer curve	
	

b. There are no gaps in the lateral guidance frame in the outer curve

This requirement requires that the lateral guidance frame in the outer curve is present and continuous. Figure 25 illustrates a curve with non-continuous lateral guidance. Both the trees and the safety barrier, which are the main lateral guidance in the outer curve, present a gap within the curve, because of the presence of a private access.

Evaluation criteria: if the CHL is not a curve, put "na". If the lateral guidance does not have any gap, put "1", otherwise put "0". If no lateral guidance frame in the outer curve is present, put "na".

Figure 25 - Example for requirements 2.2.6.b.

c. No obstructions to overview the inner curve

This requirement differentiates itself from 1.2.2.d, because it must be judged not only by the visibility of the inner curve approaching the curve but also within the curve. The visibility should be not reduced by any obstacle and the driver must have a clear overview of the curve, so that it can continuously make correct estimations about the curve's development and

curvature. In the example in Figure 25, the visibility of the inner curve is restricted (even more considering the opposite direction or travel). The overview of the inner curve must include a wider space than the visibility for the stopping sight distance. It must ensure that the curve, its radius, and its length are clear.

Evaluation criteria: if the CHL is not a curve, put "na". If the visibility in the inner curve is sufficient put "1", otherwise put "0".

d. Edge line markings in the outer and inner curves are present and visible

Edge line markings provide extremely useful optical guidance, especially in a curve. Therefore, those markings are strictly required. This condition should be evaluated mainly at night. The visibility should be checked at least at the end of the Anticipation section. Figure 26 provides an example of roads with poor road markings.

Evaluation criteria: if the CHL is not a curve, put "na". If the markings are present and clearly visible, put "1", otherwise put "0".

Figure 26 - Example for requirements 2.2.6.d.

- **2.3 Depth of the field of view**

While 2.2 aims to analyze in detail mainly the aspects related to the lateral field of view (e.g., marginal elements), 2.3 aims to analyze the effect of the depth of the field of view, focusing on the central part of the field of view, that is the foveal area. Information derived from the foveal area is the more accurate and they represent the focus of the driver and the part of the road image that is more important for him. For this reason, the information must be clear and must not mislead the driver.

- ***2.3.1 - Dominant eye-catching objects support the detection of Challenging Locations***

Similarly, to 2.2.2, eye-catching influence should be investigated. However, while 2.2.2 analyzes the influence of eye-catchers on lane-keeping, 2.3.1 analyzes the influence of those elements on the

correct comprehension of the road and the identification of other potentially critical locations. As specified in 2.2.2, a relevant eye-catching object can be a high color contrasting object, sharp or narrow shape with high brightness, moving objects, but also single isolated objects that are very visible in the field of view.

a. View axis to eye-catching objects aligns with the road axis

An eye-catching object that is not aligned with the road axis can lead to some lane-keeping mistakes, as explained in 2.2.2.c., but it can also distract the driver from the road course, delaying its analysis of the road course and so reducing the time they must change their driving program when required. Concerning this requirement, the inspector should consider mainly far eye-catchers, which are present in the central part of the field of view. In the example provided by Figure 27, an eye-catching house is present. Its brightness and its size attract the attention of the driver. A straight line links the driver to the building, but the road turns left, thus the two axes are not aligned. Moreover, even if the curve is perceivable, the eye-catcher attracts the eye when it moves closer to the area where the eye-catcher is, diverging the attention from the intersection (see next requirement).

Evaluation criteria: if an eye-catching object is present and the axis to eye-catching objects is aligned with the road axis, put "1", otherwise "0". If no eye-catching object is present, put "na".

Figure 27 - Example for requirements 2.3.1.a.

b. Eye-catching objects guide the view to the Challenging Location

The eye-catcher is located close to or on the same view axis as the Challenging Location and helps its identification. Furthermore, some eye-catchers may not be on the same view axis of the location but provide information about it and help to identify it. To this requirement, the horizon is considered an eye-catcher. This means that if a straight line to the horizon is present, and if no closer eye-catching objects are present, the gaze of the driver will be attracted by the horizon, reducing the possibility of identifying closer Challenging Locations. In Figure 27 the brightness of the house distracts the attention of the driver from the intersection. Figure 28 shows an example already used in 1.2.1.d., which has been modified by adding a high-color contrasting

frame to the mirror used to improve the visibility in a junction with a driveway. With this modification, the mirror has become an eye-catching object. Concerning the visibility of the Challenging Location, this is now improved, even if indirectly, because the secondary road is located on the right. Figure 29 shows instead an example of a bad eye-catcher. Analyzing the image on the left, the eye-catcher object is the overpass in the horizon. It is exactly located in the horizon, in the center of the field of view and it is a source of brightness. Driver's gaze is attracted by that area. This helps to identify the curve under the overpass; the driver will explore that curve trying to identify its configuration and its curvature. This is a good thing for the curve, but at the same time, two other Challenging Locations will "disappear". One is a pedestrian crossing close to the point where the photo has been taken, and one is an intersection between the crossing and the curve. The intersection is already hard to see because of the vegetation, but without any objects that attract the attention on it, it is even worse. Therefore, in this second example, the requirement is not satisfied. Please note that the pedestrian crossing's markings were totally consumed and deteriorated when the photo was taken (left image of Figure 29) thus the image has been modified to greatly improve their visibility. The image on the right of Figure 29 is taken closer to the intersection and it is provided to have an overlook of the road configuration. The pedestrian crossing is more visible, and the location of the intersection is visible because of the turning car. This second image is taken from Google Street View and is dated 5 years before the photo shown in the left image. Finally, it must be underlined that, under standard conditions, road markings should be white. The last example, provided by Figure 30, shows a road with no eye-catching objects. The eye-catcher, in this case, is the horizon because the road image is built in such a way that all the lines underline the vanishing point of the road. The gaze of the driver will focus there, completely ignoring that close to them there is a level crossing with the train rails.

Evaluation criteria: if an eye-catching object is present and guides the view to the Challenging Location without distracting from other locations, then put "1", otherwise "0". If no eye-catching object is present, put "na".

Figure 28 – Example 1 for requirements 2.3.1.b., modified photo

Figure 29 – Example 2 for requirements 2.3.1.b., right photo from Google Street View

Figure 30 - Example 3 for requirements 2.3.1.b., photo by Jiri Landa (PIARC)

- ***2.3.2 - Presence of optical illusion***

Optical illusions may play an important role in the capacity of the driver to judge the situation and choose the correct driving program. Optical illusion may communicate to the driver information that differs from reality.

a. Distance illusion avoided

Distance illusions influence the perception of distances. They are greatly due to non-parallel lateral guidance orientation lines (converging or diverging lines), but also to a change in the size of elements composing the lateral guidance orientation line (e.g., a line of tree of decreasing height creates the illusion that the line is longer than the reality). The difference between 2.2.3.a. requirement and this requirement is that the first investigates the influence on lane keeping and thus the lateral field of view is analyzed (the elements of the lateral field of view are generally closer to the driver), while the second investigates the perception of the driver of the further development of the road, thus it considers mostly the central part of the field of view. Figure 31 shows three draft examples of a road with a converging hedge (top), a converging hedge a parallel fence (middle), and a parallel hedge (bottom). In the top image, the requirement is not

satisfied, while in the bottom image, it is satisfied. The situation illustrated in the middle image must be judged by the inspector. If overall the parallel element has a higher influence and the perception is correct, then the requirement is satisfied, otherwise not.

Evaluation criteria: if a parallel reference clue is present and a distance illusion is avoided, put "1". If a parallel reference clue is present and a distance illusion is not avoided, or a parallel reference clue is not present, put "0".

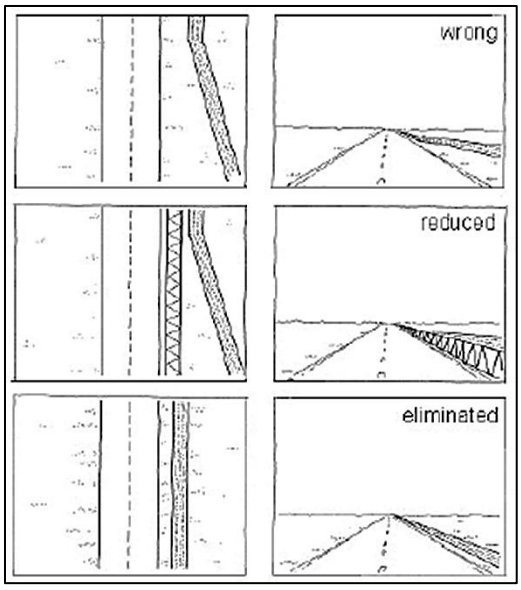


Figure 31 - Example for requirements 2.3.2.a., conceptual sketch [13]

b. Perspective illusion avoided

Perspective illusions are very rare and are due to specific planimetric and altimetric alignment so that an incorrect perspective is perceived. This illusion is often improved when marginal elements such as road safety barriers are present. A typical example is due to a double sharp curve of opposite directions. In such a case an oncoming vehicle can be perceived as travelling in the same lane as the driver. The same may occur in a curved crest, as depicted in Figure 32.

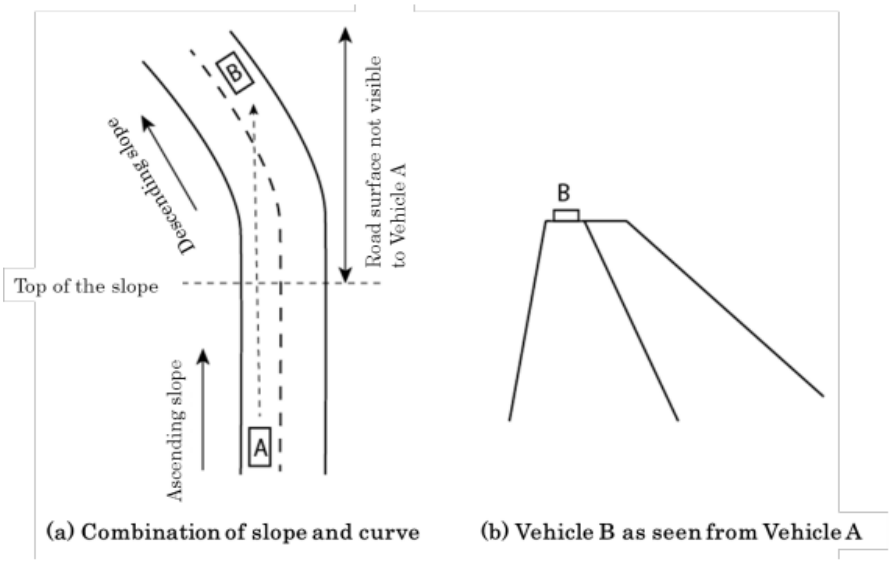


Figure 32 – Wrong perception of vehicle position after the crest. The example is from Japan [18] *and thus considers the left-driving condition.*

Evaluation criteria: if a double curve is present and if a perspective illusion is present, put "0", otherwise if a double curve is present but there isn't a perspective illusion, put "1". If no double curve is present, put "na".

c. Curve illusion avoided

This requirement must be analyzed only when the CHL is a curve. Curve illusions are due to wrong planimetric and altimetric coordination such as a curve on a crest or in a sag. Curve illusion drastically modifies the perception of the curvature of the curve. Consequently, curve illusion can also be due to not parallel frame of the outer and inner curve. This requirement stacks with 2.2.6.a., if present. It is something more than a simple non-parallel lateral guidance, but something that distorts the curve perception. Figure 10 is an example of a curve on a crest. Even if the chevrons are present, it is impossible to estimate the curve only from them.

Evaluation criteria: if a curve illusion is present, put "0", otherwise put "1". If the CHL is not a curve, put "na".

d. At night signs do not give wrong expectations of road direction

This can be evaluated only in night conditions. Under night conditions, vertical signs and other retroreflecting devices can be seen from a higher distance than the road surface. For this reason, they are taken as reference by the driver to understand how the road will develop. Consequently, these road elements must inform the driver about the right path to follow and not be misleading (i.e., suggesting to the driver that the road has a path different than the real one).

Evaluation criteria: if retroreflecting elements are present and help the driver to understand the real course of the road, put "1", if they are present and give the wrong expectation to the driver put "0", otherwise put "na".

e. Estimation of speed and distances supported by reference cues at CHL

Reference cues are generally specific road devices used to manage speed. Other elements that can help estimation of speed and have not been set for this scope, are rare. They are generally high-color contrasting elements placed immediately outside the shoulder or markings along the road surface. The example in Figure 33 shows the so-called "shark teeth", which is a typical traffic calming countermeasure, which improves the readability of the distance and of the speed (they also reduce the perceived lane width). Such types of reference cues are generally used for short stretches preceding the CHL.

Evaluation criteria: if speeding is a problem for that specific CHL and such cues are not present, put "0". If they are present put "1", otherwise put "na".

Figure 33 - Example for requirements 2.3.2.a., [19]

f. Negative slope is visually well-perceived

Drivers generally involuntary speed up on stretches with a negative speed unless the negative slope is well perceived. In this case, drivers tend to control their speed. Negative slopes that are difficult to perceive are due to stretches with no reference cues on the road margins, such as empty plains and tunnels. On the other hand, even if the slope is not negative but the perception of a negative slope is present, drivers keep attention to their speed.

Evaluation criteria: if reference cues on the road margins suggest to the driver that they are driving a negative slope stretch, put "1", otherwise if a negative slope is present and not perceivable put "0". If a negative slope is not present and no reference cues are present, put "na".

- ***2.3.3 – The course of the road is clearly visible***

A clear overview of the road and its development it's crucial both to not surprise the driver, and to decide the right action to take (such as deciding to make an overtaking maneuver).

a. Driver provided with good optical guidance of the road that is consistent with their expectations

In this case, the "image" of the road must be judged in its totality (Gestalt theory), understanding if the global image of the road and its surroundings may lead to misjudging the road's right development. Table 11 shows a series of three images taken 80 m, 60 m, and 30 m before a curve. The main road follows the curve, turning right, however, a motorway ramp is clearly visible in front of the driver, and it may appear to be the main road. The road course is not clear. Furthermore, the judged CHL must be highlighted from the optical guidance.

Evaluation criteria: if the optical guidance/road image provides the right expectation about road development and the presence of the CHL, put "1", otherwise "0".

Table 11 - Examples for requirements 2.3.3.a.

View 80 m ahead of the curve	
View 60 m ahead of the curve	
View 30 m ahead of the curve	

b. Overtaking maneuver is possible under safe condition

Overtaking possibilities must be granted and the stretch where this is allowed, must be clear and without risk. To evaluate if the overtaking distance is sufficient, it can be considered the distance traveled in 18-20 seconds, considering the maximum speed of the stretch ([20], [14]). Furthermore, where overtaking maneuvers are allowed, no locations should be present. Also, crossings and driveways should be avoided. Considering the example provided by Figure 31, a driver entering from the driveway on the right, may look only for cars in the closer lane, if they want to enter it and go that direction. A driver in the opposite lane who decides to pass another vehicle may start their maneuver because they do not see any oncoming vehicles, and a crash may occur. The same can happen if considering two vehicles coming from the direction where

the photo was taken, and a car coming from the driveway, that wants to reach the left lane. In this case, the overtaking maneuver is allowed, but not under safe conditions.

Evaluation criteria: if overtaking maneuvers are allowed and are possible under safe conditions, put "1", otherwise put "0", even if in that stretch the overtaking maneuver is clearly unachievable.

Figure 34 - Example for requirements 2.3.3.b.

c. If not, there were sufficient overtaking opportunities under safe conditions in the last 5 minutes

This requirement is linked to the preceding one. If the driver is not provided with sufficient overtaking opportunities, the risk of a forbidden maneuver under unsafe conditions increases. For this reason, if the analyzed stretch does not provide sufficient overtaking opportunities, the preceding stretch should do so.

Evaluation criteria: if the answer to pre previous requirement was "1", then put "na". Otherwise, if the requirement on point b is satisfied in a stretch traveled in the last 5 minutes, put "1", otherwise "0".

d. Bridges, tunnels, and crests visible at least 6 seconds ahead

Narrow bridges, dark tunnels (or underpasses), and crests that hide the further development of the road, can provoke an unconscious fear in drivers, who may suddenly brake if they are not prepared. For this reason, bridges and crests, should be visible at least 6 seconds ahead. An example of a crest that hides the further development of the road, is provided by Figure 10. An example of a dark tunnel entrance is instead provided in Figure 35 (black hole effect).

Evaluation criteria: if a bridge, a tunnel, or a crest is present, but its conformation is such that the driver will not feel any fear or disorientation (e.g., a well-illuminated tunnel), then put "1". Otherwise, if that bridge, tunnel, or crest is visible at least 6 seconds ahead, put "1", otherwise put "0". If no bridge, tunnel, or crest that hides the further development of the road, is present, put "na".

Figure 35 - Example for requirements 2.3.3.d., https://www.pond5.com/stock-footage/tag/tunnel-speed/19

7.5. Third Rule

The Third Rule sheet (III Rule) is divided into five main investigation topics, and eight subsections.

- **3.1 Change of road's function**

Driver should be clearly aware of changes in the road function, so that the road does not violate their expectations. To make the change clear, it must be underlined by a change of both the road cross section and the surroundings. Furthermore, a transition zone must be present to ensure that the driver changes their driving behavior. If no change in the road function is present for the stretch analyzed, then all the requirements of subsection 3.1 should be judged as "na". All the following requirements must be evaluated both when the road function changes and considering CHLs immediately after the change, to verify if the change has been perceived also after the "ideal" point of change.

- ***3.1.1 - Visual clues reinforce changed road function?***

Visual clues are the main clues that can help to identify a change in the road function. Visual clues can be implemented within the road margins and outside the road margins. A road's cross-section often changes when a change in the road function is present, but it is generally not sufficient. Some examples of a change in the road function can be where different road users will use the road for a longer section (more than a hundred meters), or can be a change in the road category, or also a high change in speed (e.g., an area with a speed limit of 50 km/h, while the road is generally travel at a speed of 90 km/h).

a. There is a change in the road surface characteristics

Changes in road surface characteristics are mainly made by the use of different colors or different textures for the road surface. The example of Figure 36 from Singapore shows the entrance to "silver zones", which are streets developing into residential areas, that want to give priority to pedestrians, mainly elderly people, and where the maximum speed limit is 40 km/h. The change in the road functions is addressed using colored yellow strips and colored black and white

curbstones. The general perception of change is also improved by the highly contrasting vertical signs that provide information about the area.

Evaluation criteria: if a change in the surface characteristic is present, put "1", otherwise "0". If a change in the road function is not present, put "na".

Figure 36 - Example for requirements 3.1.1.a. [7]

b. There is a change in the roadside characteristics

A change in the roadside characteristics means a change in the elements composing the road margins such as planting, sidewalks, footpaths, and safety barriers. A specific use of a particular element type is generally for specific road categories. Consequently, if the same element is used also for different road categories, the driver can be led to wrong expectations about the road. Furthermore, changes in the roadside characteristics underline that a change is present and required. The two examples proposed in Table 12 show two urban two carriageways urban arterial, both developing from rural motorways. In both examples, the perceived rural environment misleads the driver, who may act in a way that is not consistent with the road requirements (in both cases the speed limit is 70 km/h). However, a difference is present in the two examples, because the roadside characteristics are different. The first one (left) shows concrete road safety barriers and a wide paved shoulder on the right. This cross-section configuration is very similar to the one of the preceding motorway. The second example instead, is characterized by a change in the road's marginal element: the paved shoulders are removed and the safety barriers, while two lines of trees are included. In the second example, the perception of a different road function is improved[2]. Finally, in the example provided in Figure 37, a town is visible ahead. To improve the perception of a change in the environment, in the stretch preceding the entrance of the town a sidewalk is placed on the left and a series of light

[2] Please not that this does not mean that the second road is safer than the first. For example, a crash into a tree may have more severe consequences than a crash into the barrier. The second example is considered as better for the purpose of improving the perception of a change in the road function by changing the roadside characteristics.

poles is placed on the right. These elements improve the perception of a change during the transition zones to the town.

Evaluation criteria: if a change in the roadside characteristics is present put "1", otherwise put "0". If a change in the road function is not present, put "na".

Table 12 - Example for requirements 3.1.1.b., photo by Google Maps

Not-changed roadside characteristics	Changed roadside characteristics
	

Figure 37 - Example for requirements 3.1.1.b. and 3.1.1.d.

c. Eye-catching and/or fixation objects are used to reinforce the change

Objects that catch the attention of the drivers to the point of the change help to alert the driver, communicating the change. Those objects can be the town entrance portal, town entrance signs that are eye-catchers, plants, plant compositions (also with colored flowers), and elements that modify road cross-sections. An example of the latter case is provided in Figure 38, where a flowerbed with a tree in the middle is set in the center of the road. The two lanes, one for each direction, develop on the two sides of the flowerbed. These objects in the middle of the road, unusual for rural roads, force the driver to react and provide them with the information that the environment is changing.

Evaluation criteria: if eye-catching and/or fixation objects are present where the change of function takes place and are used to reinforce the change, then put "1", otherwise put "0". If a change in the road function is not present, put "na".

Figure 38 - Example for requirements 3.1.1.c.

d. For town entrance: the urban environment beyond the road margins is well-perceived

The transition from rural to urban areas is crucial because drivers must widely change their driving behavior. Drivers know that driving requirements in urban areas are different than those in a rural environment (e.g., speed), but they must be aware that they are driving in an urban area. The environment around the road must suggest that the driver is driving in an urban area. An example of a well-perceived urban area is provided in Figure 37, where many houses are visible. From that line of houses, the driver will have probably changed his driving behavior, because they have the time to see those houses, to understand that a town is present, and to adapt their driving style. Figure 39 shows instead a situation when the urban area begins is addressed only by a vertical sign. A couple of houses can be noticed on the left, but the road is the same as in the previous rural stretch and the environment appears as a rural one. In this case, the driver will continue holding their previous driving behavior. This is a very common situation in a suburban area, where roads are designed as urban roads, but where drivers hardly comply with the correct driving behavior, because the road function is not clear. The two images in Table 12 are two examples of urban roads where the urban environment is not perceived.

Evaluation criteria: if the change in road function is not from a rural road to an urban road, put "na". Otherwise, if the urban environment is clearly perceived put "1", otherwise "0". If a change in the road function is not present, put "na".

Figure 39 - Example for requirements 3.1.1.d., https://commons.wikimedia.org/wiki/File:Ingresso_centro_abitato_Villasor.jpg, 04-02-2021

e. Transition zone before the change of road function is adequate (4-6 seconds).

The transition zone, including the maneuver, response, and anticipation sections already analyzed in 1.1. Moderation of Transitional Areas must be considered also here. This requirement stresses the importance of the transition zone, mainly where the road function changes.

Evaluation criteria: if a change of road function is present and the Maneuver, Response, and Anticipation sections are present, put "1", otherwise "0". If a change in the road function is not present, put "na".

- **3.2 Course of the road supported by dominant eye-catching guidance**

Eye-catchers are not only single objects but also a series of objects or some wider elements (also an empty space on a background of continuous elements can be an eye-catcher). The road must be clear and eye-catching elements should clarify which is the right path of the road.

- ***3.2.1 - The Road's main direction is clearly identifiable***

The driver must not be surprised, thus the expectation created by the road must be in accordance with reality.

a. The right road direction is visible and clearly perceived

The road direction must be clearly identifiable. In some cases, is not possible to clearly see how the road develops and so our brain searches for clues in the environment. Lines of trees are some of the most influencing reference clues, because generally, they follow the road course. An example of road development that is not clear, is again provided in Figure 10. The chevrons help to understand the course of the road; however, it is still not clear. Another example is provided by Table 11, where the main road appears to be the ramp of the motorway. Also, Figure 13 shows misleading road configuration: the main direction of the road seems straight; however, it is forbidden for drivers to go straight. A last example is provided in Figure 40. Approaching a curve, the road seems to develop straight. The curve is unexpected and can surprise the driver.

Evaluation criteria: if the road development is not clear during at least the anticipation section before the CHL, put "0", otherwise put "1".

Figure 40 - Example for requirements 3.2.1.a., [21]

b. Eye-catching/fixation objects are used to focus attention on the right alignment

Eye-catching or fixation objects are placed along the right course of the road to improve its visibility and keep the attention of the driver. These elements can be traffic signs, high-contrasting objects, plants, and buildings.

Evaluation criteria: if effective eye-catchers are used to keep the driver's attention on the right course of the road, then put "1", otherwise put "0". If the judgment of 3.2.1.a. was "1", then put "na".

c. Transition zone before the alignment misleading is adequate (4-6 seconds).

The transition zone, including the maneuver, response, and anticipation sections already analyzed in 1.1. Moderation of Transitional Areas must be considered also here. This requirement stresses the importance of the transition zone. The Excel file will automatically compile the relative cell based on the previous results (if 3.2.1.a. = "1", then it automatically sets "na", otherwise it evaluates the presence of all the three sections from 1.1. Moderation of Transitional Area).

Evaluation criteria: if 3.2.1.a. is "na", put "na". If 3.2.1.a. is not "na", if Maneuver, Response, and Anticipation sections are present, put "1", otherwise "0".

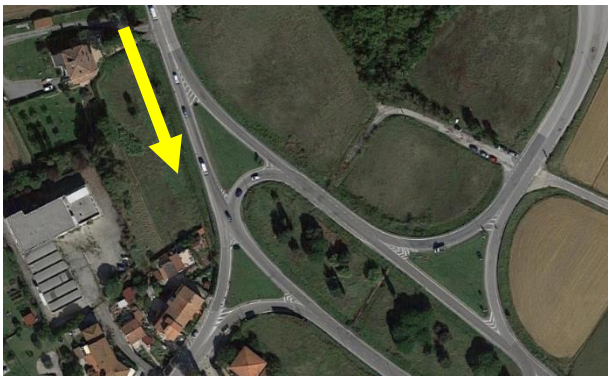
d. There are no misleading eye-catchers along the wrong road alignment (or if so, their influence is eliminated by planted embankments, placement of fixation objects, ...).

Eye-catchers' elements can greatly improve the understanding of the right direction to follow if they're located along the main right direction. Similarly, they can drastically reduce the understanding if they are located in the wrong direction. Table 13 provides two examples of the wrong use of eye-catchers' elements. Both examples are provided with an image of the road from the road itself, and an image of the road from a satellite map. In the first example, the leading wrong eye-catching element, is the light grey surface of the road. The light grey surface is the natural continuation of the lane surface, while the dark surface differs from the preceding

lane surface color. From the left side of the lane, which becomes dark grey, a new lane departed, which represents the lane to follow the main direction. It is not easy for the driver to recognize the left lane as the main direction, because the eye-catcher guides to the right lane. Example 2 provides instead a classic example of intersection modification, where the layout of the old road is still visible. In this example, the eye-catcher is the old layout itself, because it creates a natural continuation of the road, an interruption of the environment and two lines of trees on the horizon underline the possible presence of a road. Fortunately, the safety barrier helps to reduce this effect, however it is only visible very close to the curve. In this case, the requirement must be judged as "0", because even if the safety barriers improve the comprehension of the CHL (i.e., the curve), it is not enough to eliminate the effect.

Evaluation criteria: if eye-catching elements are located along the wrong road path and their effect is not eliminated, put "0", otherwise put "1". If the judgment of 3.2.1.a. was "1", then put "na".

Table 13 - Example for requirements 3.2.1.d. (Example 1 top), [7]*(Example 2), and Google Maps (Example 1 bottom)*

	Example 1	**Example 2**
On road view		
Satellite view		

- **3.3 Effect of pre-programmed habits and expectations**

Pre-programmed habits and expectations either of the specific stretch, or more often of similar stretches (e.g., road stretch of the same road category), influence driver behavior. The driver chooses their maneuvers, their speed, and their position based on what they expect from the road. For this reason, the road must never surprise the driver.

- ***3.3.1 - Is the CHL expected?***

a. Based on the road characteristics, the CHL is expected

Some Challenging Locations can be completely unexpected in some road categories, but also because of the specific characteristics of the road. An unexpected CHL requires more time to be understood. The inspector should evaluate this requirement based on how often that CHL can be found on that specific road and in that specific road type. For example, a pedestrian crossing is highly expected on an urban road but is quite unexpected on a rural road in the countryside, away from any visible town or village. Moreover, if in the last km, the road was characterized by many long straight and few curves of high radius, a curve with a very low radius is completely unexpected. The unexpectedness is also analyzed through other requirements provided in the HFET; however, this specific requirement is necessary to give more way to this crucial aspect.

A literature analysis has been conducted by Paliotto [3] about the design standards in different countries, and based on the results of the analysis, a survey has been carried out to investigate which CHL is more expected under specific conditions for rural highways. The document may provide some information to the inspector.

Evaluation criteria: if the CHL can be considered unexpected based on the road stretch characteristics, put "0", otherwise "1".

- ***3.3.2 - The road has been modified during the last 3 years***

Sometimes the road or the way it is traveled, can be modified (new intersection, new crossing, change in the right of way, etc.) and drivers require time to adapt to the changed environment (many driving along the road). For this reason, the countermeasures improved to reduce the unexpected change of a CHL must be evaluated. Work zones should be judged as road modifications that require a new driving program. If the road modification is older than 3 years, it can be assumed that the drivers' habits have adapted to the new layout, thus all the following requirements must be judged as "na".

a. Requirement for a new driving program is easily recognized.

To be satisfied, it is required that the new road layout is clear, and it appears that drivers adapt to the new layout without problems. No clues of hazardous maneuvers are present, such as tire tracks.

Evaluation criteria: if the requirement for a new driving program is easily recognized, then put "1", otherwise "0".

b. New driving program because of road modification underlined by change of alignment.

Changes in road alignment are represented by changes that force the driver to activate himself, reducing speed and accounting for any possible maneuvers. Such changes of alignment are for

example roundabouts, curved approaches, median entry treatments, and eye-catching median elements.

Evaluation criteria: if a modification of the road alignment has been made, put "1", otherwise "0".

c. New driving program because of road modification underlined by adequate transition zone with anticipation and response section at minimum.

The road modification must be clear. The transition zone must be evaluated again to account for its higher influence under these specific conditions. The transition zone, including the maneuver, response, and anticipation sections already analyzed in 1.1. Moderation of Transitional Areas must be considered also here. The Excel file will automatically compile the relative cell based on the previous results (if 3.3.2.a. is "na", then it automatically sets "na", otherwise it evaluates the presence of all the three sections from 1.1. Moderation of Transitional Area).

Evaluation criteria: if 3.3.2.a. is "na", put "na". If 3.3.2.a. is not "na", if Maneuver, Response, and Anticipation sections are present, put "1", otherwise "0".

d. New driving program because of road modification underlined by ensuring that the modified road arrangement and alignment beyond are clearly visible.

This means that the road layout should be clear, not only visible. It must be considered that the new road layout must be clear and understandable at least at the start of the response section, thus during the whole response and maneuver section. The Excel file will automatically compile the relative cell based on the previous results (if 3.3.2.a. is "na", then it automatically sets "na", otherwise it sets the value from 1.2.1.a).

Evaluation criteria: if 3.3.2.a. is "na", put "na", otherwise put the value from 1.2.1.a.

e. New driving program because of road modification underlined by ensuring visibility of the modified traffic control devices.

Traffic control devices are useful clues to understanding the function and the composition of a CHL. For this reason, if a road modification has occurred, they must ensure that the CHL is well perceived and its function clear. The Excel file will automatically compile the relative cell based on the previous results (if 3.3.2.a. is "na", then it automatically sets "na", otherwise it sets the value from 1.2.1.c).

Evaluation criteria: if 3.3.2.a. is "na", put "na", otherwise put the value from 1.2.1.c.

- ***3.3.3 - Road geometrical alignment conforms with drivers' expectation***

The sequence of geometrical elements along the road alignment is crucial to correctly drive along the road.

a. The curve where the CHL is located, is consistent with the previous element (curve/curve, or curve/straight).

To be consistent the road alignment must assure consistency between its geometrical elements which are straights and curves. The consistency of a curve to its preceding element is crucial. This requirement asks to analyze the relationship between the curve where the CHL is located and the previous element. A long straight before a curve, may increase the possibility of accidents. The same can be due to inconsistent consecutive curve radii (the two consecutive curves must be considered as if the straight in-between were not present). It must be assured that this won't happen. As an indicative value, the following diagram can be considered to judge if the radius of two different curves is consistent.

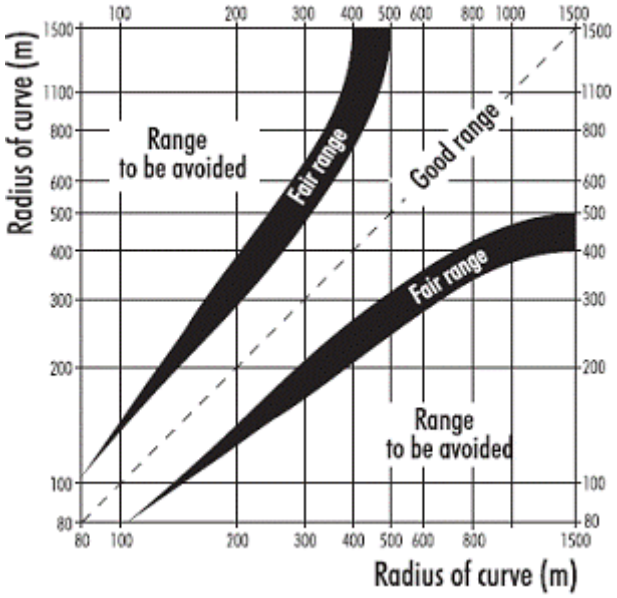


Figure 41 - Tuning radii in curve sequences, [22]

Moreover, to evaluate the consistency of a curve and a straight, the following principles can be considered: $R > L_R$ if $L_R < 300$ m, and $R \geq 400$ m if $L_R \geq 300$ m [20], where R is the radius of the curve and L_R is the length of the straight. The provided criteria can be substituted with others of proven validity (e.g., Lamm safety criteria on consecutive elements' speed can be also used [23] [24]).

Evaluation criteria: if the curve where the CHL is located (or immediately before it) is consistent with the previous element, then put "1", otherwise "0". If no curves are present in the analyzed section, put "na".

b. The element where the CHL is located, is consistent with the whole stretch alignment (curve/curves, or straight/straights).

For this requirement, it must be considered a road stretch longer than the analyzed segment. The inspector must judge if the radius of the curve is similar to the radius of the preceding curves or if the straight length is similar to the preceding ones. No specific thresholds can be provided for

this requirement. Finally, Lamm safety criteria on operating speed and design speed, can be also used [23] [24], if the design speed is considered the same for the entire stretch.

Evaluation criteria: considering the element to which the CHL belongs**,** if the radius of the curve is greatly smaller than the average curve radius of the preceding curves, or the straight length is greatly higher than the average preceding straight length, then put "0", otherwise put "1". If the result of 3.3.3.a. is "1", then put "na".

c. Compound curves with multiple radii are avoided.

Compound curves with a changing radius can be an issue for drivers, even if well-designed because a change in the driving program is required inside the curve itself (steering and speed reduction).

Evaluation criteria: if the CHL is not a curve put "na". If the CHL is a curve and it is a compound curve, put "0", otherwise if the CHL is not a compound curve put "1".

- ***3.3.4 – Challenging Transitions and Challenging Locations are visible, understandable, and progressively introduced.***

This subsection analyses some specific aspects of the CHL and their transition zones (CHTs).

a. Visible (at least 4-6 seconds ahead).

The visibility is mandatory to give enough time to the driver to adjust their expectations. The transition zone must be evaluated again to account for its higher influence on expectations. The Excel file will automatically compile the relative cell based on the previous results (it evaluates the presence of all three sections from 1.1. Moderation of Transitional Area).

Evaluation criteria: if the Maneuver, Response, and anticipation sections are present, put "1", otherwise "0".

b. If visible, the driver has a good overview

Even if visible the CHL may be not clear. To be clearly overviewed, the CHL must be clear in the contents where is located: its structure, development, and composition must be clear. Table 5 provides two examples where the overview of the CHL is poor, even if the CHL is visible (image on the left) or their traffic devices are visible (image on the right).

Evaluation criteria: if 3.3.4.a. is "0", then put "na". Otherwise put "1" if a clear overview of the CHL is present or "0" if it is not present.

c. Clues and instructions are provided and are understandable

Clues and instructions are useful to inform the driver about unexpected CHL. These instructions are generally provided by road signs, markings, and other traffic control devices. Sometimes instructions are not necessary. For example, a curve with a radius very similar to the previous

curve, which is consistent with the preceding straight, doesn't require any specific advice for the driver. Instead, a sharp unexpected curve before a long straight must be signalized.

Evaluation criteria: if instructions are not necessary to drive safely within the CHL, put "na". If instructions are necessary but not provided or not understandable, put "0". If instructions are provided and understandable, put "1".

d. Clues and instructions are easily associable to the CHL

Clues and instructions should be associated with the CHL. The optimal condition is that both the information and the CHL are visible in front of the driver at the same time (even at different distances). However, sometimes it is necessary to place some information before the point when the CHL is visible. In this case, it is mandatory to be sure that no other similar information about other CHLs overlaps. A repetition of the information can be also useful when the CHL is not directly visible contemporary to the information. Table 14 provides an example of multiple pieces of information that are both not clear and hard to associate with the specific CHL. The three images in the table are taken from three different distances from the turning point. A two-lane arterial roadway crosses over a parkway (Route 6) that prohibits trucks. The arterial approaches the parkway from a straight, but it then crosses over the parkway by curving sharply to the left. The connection to the parkway is a ramp that appears as a continuation of the arterial straight. Because trucks are prevented from using the parkway, a sign directs them to an alternative roadway to reach the portion of Route 6 with unrestricted access [14]. Unfortunately, the first sign highlights a right turning for Route 6, while the second provides a left turning arrow on the same line as the words "to Route 6". In both cases, the sign can be ridden with reduced attention because the road split is not clearly visible from the main lane (the photo is taken from the shoulder). Once in front of the road split, there are no information signs, and it is not easy to clearly remember what the previous signs were saying. As seen by the skid marks near the gore in the third image, road users have difficulty in deciding whether to follow the road to the left or continue straight onto the ramp to the parkway (furthermore the ramp appears as the main road).

Evaluation criteria: if 3.3.4.c is "0" or "na", put "na". If the instructions are easily associable to the CHL, put "1", otherwise put "0".

Table 14 - Examples for requirements 3.3.4.d., [14]

First view	
Second view	
Third view	

- **3.4 Sudden increase of decision needs and overload of information processing capabilities**

One of the most limiting aspects of human beings is that they are capable of processing only a few of the information coming from the environment, even more while driving. For this reason, if many CHLs are present at the same time, more time is required to clearly identify those CHLs and the information about them.

- ***3.4.1 - Are there many sources of information present at the same time?***

a. Multiple Locations are avoided (considering not only Challenging Locations)

It must be evaluated if at least two PCLs of the analyzed segment overlap. To overlap with each other, at least one PCL must be located within 2-3 seconds from the analyzed CHL. In this case, while judging the CHL, also the PCLs around it must be considered, not only CHLs around it. PCLs are not as risky as CHLs, nevertheless, they require an amount of driver processing capacities (even if little), which will not be available to process the information about the CHL.

Evaluation criteria: if multiple PCLs (which include CHLs) are present within 2-3 seconds from the CHL, then put "0", otherwise "1".

b. All PCLs are clearly visible and easily distinguishable.

This requirement must be fulfilled considering both the CHL (already judged by 1.2.1.a.), and the PCL(s).

Evaluation criteria: if all the PCLs within 2-3 seconds from the CHL and the CHL itself are clearly visible, then put "1", otherwise "0".

c. Overload of information processing avoided.

The presence of multiple information because of multiple PCLs should be avoided. Sometimes they are mandatory, but they still provide difficulties for the driver to read and understand them. In such a case the issue in road signs and markings is a direct consequence of a road deficiency. Furthermore, when too many sources of information are present, the driver must decide which to look at priorly (many times this happens unconsciously, looking for the most eye-catching information). The other information may be ignored or not seen on time. Example Table 15 shows three consecutive photos of a road stretch where multiple PCLs are present (only the approaching section is clearly visible from the photos, the PCLs are not visible from the photo). No more than 2 signs are considered for each vertical support, and the distance between each sign is several meters (5-10 meters), however, there is still too much information: 3 out of 6 vertical signs are about the PCLs. The driver must keep out the attention from the road to read all those signs. If they read only a part of them, it is not certain that they will obtain the required information. This example is also suitable for requirement 3.3.4.d. (mainly the first information about the intersection, which is then superseded in the memory of the driver, by the pedestrian crossing and the double curves dangerous warning signs.

Evaluation criteria: if an overload of information is present, then put "0", otherwise "1".

Table 15 - Examples for requirements 3.4.1.c.

First view	
Second view	
Third view	

d. Not more than 3 decisions are possible.

It must be evaluated if no more than 3 decisions or maneuvers are possible in a range of 1-2 seconds before the CHL, including the decision of the CHL itself. The term "decision" indicates any possible maneuvers that the driver may decide to take, or that they are forced to take (e.g., forced to change the lane because of roadworks). In the example provided in Figure 42, drivers are required to change lanes because of the road work, adjust the speed and the trajectory to enter the curve, and decide if they must exit.

Evaluation criteria: if no more than 3 decisions are possible at the same time (1-2 seconds), then put "1", otherwise "0".

Figure 42 - Example for requirements 3.5.1.a.

e. Driver is progressively informed of each PCL.

Driver must be informed about all PCLs that require specific advice. This information must be progressively implemented.

Evaluation criteria: if all the PCLs, excluding curves, within 1-2 seconds from the CHL are progressively introduced, then put "1", otherwise "0". If no other PCLs than the CHL are present, put "na".

f. If the CHL is after a tunnel entrance or exit, the transition zone is adequate (Response and Anticipation section).

Exiting from a tunnel most of the time requires some seconds for the drivers' eyes to adapt to the new light conditions. The adapting time is very variable and depends mainly on the difference in the light intensity between inside the tunnel and outside, and on how long the driver was in the tunnel (if exiting). The transient adaptation time can be considered 1-2 seconds [12]. For this reason, it must be assured that both the Anticipation and Response sections are present between the tunnel entrance/exit and the CHL.

Evaluation criteria: if both the Anticipation and Response sections are present between the tunnel entrance/exit and the CHL, put "1", otherwise "0".

- **3.5 Deficiencies in traffic control devices**

Traffic control devices range from signs and markings to traffic signals, to other road furniture (such as retroreflective elements used to improve the visibility of road alignment at night). Traffic control devices must be consistent with the road, clear, and readable. If traffic control devices are evaluated using other specific procedures that will be used together with this tool and they consider the same aspects, then it is possible to not judge these requirements using the tool. If that is the case, put "na" to all the following requirements.

- ***3.5.1 – Evaluation of traffic control devices***

All the following requirements must be always evaluated, and they should be evaluated considering the whole HFES (the results are the same for each CHL, the Excel file will automatically compile the results for all CHLs once the first has been judged).

a. Traffic control devices present, visible against the background, and in a good position

The size, contrast against background, brightness, and position of the traffic control devices must be evaluated (i.e., conspicuity and visibility, [25]). The evaluation, for the cell fulfillment, can be based on the judgment of the inspector. Furthermore, in the case of multiple devices that are generally used together (e.g., chevrons), the whole effect must be considered. A specific example is provided in Figure 43, where three chevron signs underline the outer frame of a curve. All the chevrons are quite dirty, but the first is still visible, the second only at a closer distance, and the third is completely invisible, both because of the dirt and because of the shadow of the bridge. In this case, the requirement will be judged as "0". However, even if the third chevron would be visible as the second one, the whole result will be "0" because they're still hard to see from a distance.

Evaluation criteria: if all traffic control devices along the HFES are sufficiently visible, put "1", otherwise put "0".

Figure 43 - Example for requirements 3.5.1.a.

b. Traffic control devices are consistent with the road category? (e.g., the size of the signs is too small for the road type or inappropriate shape)

In this case, the consistency of the traffic control devices with the road category must be evaluated (i.e., intelligibility, [25]). The size, shape, and color of the traffic control devices are some of the elements that must be considered. An example from Italy is provided in Figure 44. The vertical sign's surface background is green. This specific color is used in Italy for motorway signs. The road in the photo is an old road built before the current design standards, which has been recently upgraded to be a "motorway junction", which means that it must need this type

of sign. However, the alignment of the road does not provide the standards of Italian motorways (which allow it to reach a speed of 130 km/h). The speed limits on this road are always between 70 km/h and 90 km/h. The motorway-like cross section and the green signs may lead the driver to spontaneously increase their speed, according to the speed that is generally used in motorways.

Evaluation criteria: if the traffic control devices are consistent with the road category, then put "1", otherwise "0". If no traffic control devices are present other than the road longitudinal markings, put "na".

Figure 44 - Example for requirements 3.5.2.b.

c. Traffic control devices are by road characteristics/development (e.g., directions, speed limits).

Only devices that provide explicit information must be judged, most of the time they will be vertical signs. It must be evaluated if the contents of the signs provide the correct information about the road and are information provided by the road. This means that the expectations provided by the road and by the contents of the signs must coincide. The images in Table 11 show an information sign that indicates that the two possible directions are straight or left. Even if the symbols on the signs must be simplified to let them be more easily readable, in this case, the impression that the ramp in front of the driver is the main road and it is the "straight" direction, is reinforced. Instead, the main direction, represented by the straight direction in the sign, is a curve on the right. In this case, the sign contributes to creating wrong expectations. Furthermore, also speed limits that are completely unexpected and appear to be not consistent with the road, are a problem, because drivers generally ignore them. An example is provided by the photo in Figure 45, where a speed limit of 50 km/h is set on a rural highway. The limit is set on a long straight and no issues are present along the road except the curve at the end of the straight, which is far away. An operating speed of 80-90 km/h characterized that section. To reduce the speed, a speed limit is not sufficient, and a wrong use of speed limits may reduce their credibility [19]. Finally, the town entrance sign must be consistent with the road

environment. If an urban environment is not visible behind the sign, the driver may ignore the sign (see Figure 39).

Evaluation criteria: if the traffic control devices are consistent with the road development, then put "1", otherwise "0". If no traffic control devices are present which provide information about the road development and how to behave on the road (e.g., speed limits), put "na".

Figure 45 - Example for requirements 3.5.2.c.

d. Pictograms and letters are readable, unambiguous, and understandable.

Only devices that provide explicit information must be judged, most of the time they will be vertical signs. The contents of the signs must be clearly readable (letter font, spacing, size) and the symbols must be easy to read and generally used (unusual or ambiguous symbols should be avoided) (i.e., readability and intelligibility, [25]). Furthermore sufficient, but not too much information should be provided. High workload must be avoided. For this reason, the evaluation must be made considering more than one traffic control device, if they're present at the same time (less than 1 second between each other). The two photos in Figure 46 are two examples of not understandable signs: the first one (left) provides unreadable letters because of the spacing between the lines, while the second (right) provides ambiguous information because "normal" speed is not a defined speed. Figure 47 shows a set of vertical signs that are ambiguous because they are located in the same place. It is not clear to understand if it is possible to turn right or not.

Evaluation criteria: if all the pictograms, symbols, and letters are easily understandable, put "1", otherwise put "0". If no traffic control devices are present which provide information that must be ridden, put "na".

Figure 46 - Example for requirements 3.5.2.e., https://slideplayer.com/slide/3847847/, 21.04.2021

Figure 47 - Example for requirements 3.5.2.e., https://www.trekearth.com/gallery/photo1035537.htm, 21.04.2021

e. The configuration of the traffic control devices is consistent with the road alignment and provides the right expectations, especially at night.

The configuration, mainly the position, of the traffic control devices must be by the road alignment. This requirement should be evaluated mostly at night, when traffic control devices can be visible for a higher distance than the road itself. The example in Figure 48 shows three chevrons along a curve, but it is not easy to understand which is the curve direction, because the arrows on the chevrons are not clearly visible.

Evaluation criteria: if the configuration of the traffic control devices is consistent with the road alignment and provides the right expectations, put "1", otherwise put "0".

Figure 48 - Example for requirements 3.5.2.e., https://www.trekearth.com/gallery/photo1035537.htm, 21.04.2021

7.6. Results

The Results sheet provides a summary of the evaluation made for each rule, investigation topic, and subsection. The Human Factors Score is calculated for each subsection, investigation topic, and rule. Furthermore, the total Human Factors Score is calculated considering the whole rule together. The disaggregated results of the score, help to identify which factors are more influencing the HFES safety. Figure 49 provides an extract from the Results sheet, particularly an example of the results for the First Rule. Under the column "Human Factors Requirements" the requirements are listed, grouped by each subsection and investigation topic. Under the "Human Factors Score" column, the evaluation for each requirement and the results for each subsection, investigation topic, and rule, are provided.

Figure 49 – Extract from the Results sheet of the HFET – Results for the First Rule

Human Factors Requirement				Human Factors Score			
Rule	**Inv. Topic**	**Subsection**	**Demand**	**Evaluation**	**Subsection %**	**Inv. Topic %**	**Rule**
I RULE	1.1	1.1.1	a	**1**	50%	50%	57%
			b	**1**			
			c	**0**			
			d	**0**			
	1.2	1.2.1	a	**0**	60%	60%	
			b	**1**			
			c	**0**			
			d	**1**			
			e	**1**			
		1.2.2	a	**na**	-		
			b	**na**			
			c	**na**			
			d	**na**			
		1.2.3	a	**na**	50%		
			b	**1**			
			c	**na**			
			d	**0**			
		1.2.4	a	**1**	67%		
			c	**1**			
			d	**0**			

8. EVALUATION CRITERIA SUMMARY

The following tables (Table 16, Table 17, and Table 18) provide a synthesis of the Evaluation Criteria for all the requirements. The tables' columns represent respectively the rule (RL), the investigation topic (IT), the subsection (SS), the requirement (RE), and the Evaluation Criteria.

Table 16 – Evaluation Criteria for the First Rule

RL	IT	SS	RE	Evaluation Criteria
I RULE	1.1	1.1.1	a	if the available distance is greater than the calculated length for the Maneuver section, put "1", otherwise "0".
			b	if the available distance is greater than the calculated length for the Maneuver + Response sections, put "1", otherwise "0".
			c	if the available distance is greater than the calculated length for the Maneuver + Response + Anticipation sections, put "1", otherwise "0".
			d	if the available distance is greater than the calculated length for the Maneuver + Response + Anticipation + Advance Warning sections, put "1", otherwise "0".
	1.2	1.2.1	a	if the CHL configuration is clear "1" should be put in, otherwise "0".
			b	if the visibility is not restricted "1" should be put in, otherwise "0".
			c	if roadside furniture is present and improves the identification of the CHL, the evaluation is "1", otherwise is "0" (not present or present but not helpful). If the CHL is obvious even without any furniture (rare case), "na" should be used.
			d	it would be probably not possible to evaluate the CHL under different daylights, so the inspector must judge if the conditions are good, in which case they will put "1", or bad, in which case they will put "0".
			e	if a CHL is illuminated (except curve) and all the road features (surfaces, signs, markings) are clearly visible using luminance and retroreflection, put "1", otherwise "0". If the night evaluation can't be performed, put "na".
		1.2.2	a	if a curve is on or behind a crest, "0" should be put in the evaluation, otherwise "1".
			b	if a curve is on or behind a crest, "0" should be put in the evaluation, otherwise "1".
			c	if the shoulder and markings of the outer curve are not visible, then put "0", otherwise put "1".
			d	if the visibility is restricted or partially restricted, "0" should be put in, otherwise "1".
		1.2.3	a	if the visibility is not present or reduced, put "0", otherwise put "1". If the intersection is a roundabout or a signalized intersection, put "na".
			b	if the CHL is not on or behind a crest, "1" should be put in, otherwise "0". If the minor road or driveway has a positive grade (it can be assumed as reference >3%), then put "0".
			c	if the CHL configuration is clear "1" should be put in, otherwise "0"
			d	if the CHL is not on or behind a curve, put "1", otherwise "0"
		1.2.4	a	if the road hierarchy is clear, put "1", otherwise "0"
			b	if the layout and the surface of the two roads are not similar, put "1", otherwise put "0".
			c	if a turn maneuver is required to enter the main road from the minor road (or to enter a roundabout from the analyzed road), put "1", otherwise put "0".

Table 17 – Evaluation Criteria for the Second Rule

RL	IT	SS	RE	Evaluation Criteria
II RULE	2.1	2.1.1	a	if the requirement is satisfied, then put in "1", otherwise "0".
			b	if the requirement is satisfied, then put in "1", otherwise "0".
			c	if no fixation objects are present, or the fixation objects are distracting objects, a "0" should be put in, otherwise "1".
		2.1.2	a	if no fixation objects are present, or the fixation objects are distracting objects, put "0", otherwise "1".
			b	if no "wider or longer" space is perceived, put "1", otherwise "0".
			c	if no "wider or longer" space is perceived, put "1", otherwise "0".
	2.2	2.2.1	a	if the backseats are not of equal height, put "0", otherwise "1".
			b	if an asymmetry is present, put "0", otherwise "1".
			c	if the bridge is not perpendicular to the road, put "0", otherwise "1".
		2.2.2	a	if an eye-catching object is present and disrupts the continuity of the lateral guidance, put "0", if it is present, but doesn't disrupt such a continuity, put "1". If no eye-catching objects are present, put "na".
			b	if more eye-catching objects are present and they are symmetrical with the road centerline, put "1", otherwise "0". If no eye-catching objects are present, put "na".
			c	if an eye-catching object is present and the axis to eye-catching objects is aligned with the road axis, put "1", otherwise "0". If no eye-catching objects are present, put "na".
		2.2.3	a	if lateral guidance is present and parallel, put "1", if they are present but not parallel to the road axis put "0". If no reference clues are present, put "0".
			b	if the lateral guidance clues are consistently spaced and equally organized considering together both sides of the road (searching for symmetry), put "1", otherwise put "0". If no, or very low-influencing reference clues are present, put "0".
			c	if the lateral guidance clues are unambiguous put "1", otherwise put "0". If no, or very low-influencing reference clues are present, put "0".
		2.2.4	a	if a carriageway width change is present and well delineated, put "1", if present and not well delineated, put"0". If no carriageway change of width is present, put "na".
		2.2.5	a	if all the objects along the road margins appear to be vertical, put "1", otherwise put"0". If no object is present, put 0.
		2.2.6	a	if the CHL is not a curve, put "na". If lateral guidance is present and parallel, put "1", if it is present but not parallel to the road axis put "0". If any optical guidance is not present, put "0".
			b	if the CHL is not a curve, put "na". If the lateral guidance does not have any gap, put "1", otherwise put "0". If no lateral guidance frame in the outer curve is present, put "na".
			c	if the CHL is not a curve, put "na". If the visibility in the inner curve is sufficient put "1", otherwise put "0".
			d	if the CHL is not a curve, put "na". If the markings are present and clearly visible, put "1", otherwise put "0".
	2.3	2.3.1	a	if an eye-catching object is present and the axis to eye-catching objects is aligned with the road axis, put "1", otherwise "0". If no eye-catching object is present, put "na".
			b	if an eye-catching object is present and guides the view to the Challenging Location without distracting from other locations, then put "1", otherwise "0". If no eye-catching object is present, put "na".
		2.3.2	a	if a parallel reference clue is present and a distance illusion is avoided, put "1". If a parallel reference clue is present and a distance illusion is not avoided, or a parallel reference clue is not present, put "0".

			b	if a double curve is present and if a perspective illusion is present, put “0”, otherwise if a double curve is present but there isn’t a perspective illusion, put “1”. If no double curve is present, put “na”.
			c	if a curve illusion is present, put “0”, otherwise put “1”. If the CHL is not a curve, put “na”.
			d	if retroreflecting elements are present and help the driver to understand the real course of the road, put “1”, if they are present and give the wrong expectation to the driver put “0”, otherwise put “na”.
			e	if speeding is a problem for that specific CHL and such cues are not present, put “0”. If they are present put “1”, otherwise put “na”.
			f	if reference cues on the road margins suggest to the driver that they are driving a negative slope stretch, put “1”, otherwise if a negative slope is present and not perceivable put “0”. If a negative slope is not present and no reference cues are present, put “na”.
		2.3.3	a	if the optical guidance/road image provides the right expectation about road development and the presence of the CHL, put “1”, otherwise “0”.
			b	if overtaking maneuvers are allowed and are possible under safe conditions, put “1”, otherwise put “0”, even if in that stretch the overtaking maneuver is clearly unachievable.
			c	if the answer to pre previous requirement was “1”, then put “na”. Otherwise, if the requirement on point b is satisfied in a stretch traveled in the last 5 minutes, put “1”, otherwise “0”.
			d	if a bridge, a tunnel, or a crest is present, but its conformation is such that the driver will not feel any fear or disorientation (e.g., a well-illuminated tunnel), then put “1”. Otherwise, if that bridge, tunnel, or crest is visible at least 6 seconds ahead, put “1”, otherwise put “0”. If no bridge, tunnel, or crest that hides the further development of the road, is present, put “na”.

Table 18 – Evaluation Criteria for the Third Rule

RL	IT	SS	RE	Evaluation Criteria
III RULE	3.1	3.1.1	a	if a change in the surface characteristic is present, put "1", otherwise "0". If a change in the road function is not present, put "na".
			b	if a change in the roadside characteristics is present put "1", otherwise put "0". If a change in the road function is not present, put "na".
			c	if eye-catching and/or fixation objects are present where the change of function takes place and are used to reinforce the change, then put "1", otherwise put "0". If a change in the road function is not present, put "na".
			d	if the change in road function is not from a rural road to an urban road, put "na". Otherwise, if the urban environment is clearly perceived put "1", otherwise "0". If a change in the road function is not present, put "na".
			e	if a change of road function is present and the Maneuver, Response, and Anticipation sections are present, put "1", otherwise "0". If a change in the road function is not present, put "na".
	3.2	3.2.1	a	if the road development is not clear during at least the anticipation section before the CHL, put "0", otherwise put "1".
			b	if effective eye-catchers are used to keep the driver's attention on the right course of the road, then put "1", otherwise put "0". If the judgment of 3.2.1.a. was "1", then put "na".
			c	if 3.2.1.a. is "na", put "na". If 3.2.1.a. is not "na", if Maneuver, Response, and Anticipation sections are present, put "1", otherwise "0".
			d	if eye-catching elements are located along the wrong road path and their effect is not eliminated, put "0", otherwise put "1". If the judgment of 3.2.1.a. was "1", then put "na".
	3.3	3.3.1	a	if the CHL can be considered unexpected based on the road stretch characteristics, put "0", otherwise "1".
		3.3.2	a	if the requirement for a new driving program is easily recognized, then put "1", otherwise "0".
			b	if a modification of the road alignment has been made, put "1", otherwise "0".
			c	if 3.3.2.a. is "na", put "na". If 3.3.2.a. is not "na", if Maneuver, Response, and Anticipation sections are present, put "1", otherwise "0".
			d	if 3.3.2.a. is "na", put "na", otherwise put the value from 1.2.1.a.
			e	if 3.3.2.a. is "na", put "na", otherwise put the value from 1.2.1.c.
		3.3.3	a	if the curve where the CHL is located (or immediately before it) is consistent with the previous element, then put "1", otherwise "0". If no curves are present in the analyzed section, put "na".
			b	considering the element to which the CHL belongs, if the radius of the curve is greatly smaller than the average curve radius of the preceding curves, or the straight length is greatly higher than the average preceding straight length, then put "0", otherwise put "1". If the result of 3.3.3.a. is "1", then put "na".
			c	if the CHL is not a curve put "na". If the CHL is a curve and it is a compound curve, put "0", otherwise if the CHL is not a compound curve put "1".
		3.3.4	a	if the Maneuver, Response, and anticipation sections are present, put "1", otherwise "0".
			b	if 3.3.4.a. is "0", then put "na". Otherwise put "1" if a clear overview of the CHL is present or "0" if it is not present.
			c	if instructions are not necessary to drive safely within the CHL, put "na". If instructions are necessary but not provided or not understandable, put "0". If instructions are provided and understandable, put "1".

			d	if 3.3.4.c is “0” or “na”, put “na”. If the instructions are easily associable to the CHL, put “1”, otherwise put “0”.
	3.4	3.4.1	a	if multiple PCLs (which include CHLs) are present within 2-3 seconds from the CHL, then put “0”, otherwise “1”.
			b	if all the PCLs within 2-3 seconds from the CHL and the CHL itself are clearly visible, then put “1”, otherwise “0”.
			c	if an overload of information is present, then put “0”, otherwise “1”.
			d	if no more than 3 decisions are possible at the same time (1-2 seconds), then put “1”, otherwise “0”.
			e	if all the PCLs, excluding curves, within 1-2 seconds from the CHL are progressively introduced, then put “1”, otherwise “0”. If no other PCLs than the CHL are present, put “na”.
			f	if both the Anticipation and Response sections are present between the tunnel entrance/exit and the CHL, put “1”, otherwise “0”.
	3.5	3.5.1	a	if all traffic control devices along the HFES are sufficiently visible, put “1”, otherwise put “0”.
			b	if the traffic control devices are consistent with the road category, then put “1”, otherwise “0”. If no traffic control devices are present other than the road longitudinal markings, put “na”.
			c	if the traffic control devices are consistent with the road development, then put “1”, otherwise “0”. If no traffic control devices are present which provide information about the road development and how to behave on the road (e.g., speed limits), put “na”.
			d	if all the pictograms, symbols, and letters are easily understandable, put “1”, otherwise put “0”. If no traffic control devices are present which provide information that must be ridden, put “na”.
			e	if the configuration of the traffic control devices is consistent with the road alignment and provides the right expectations, put “1”, otherwise put “0”.

9. GLOSSARY OF TERMS AND DEFINITIONS

The terms are presented in alphabetical order.

Term	*Meaning*
Challenging location (CHL):	CHLs are PCLs that are not clearly perceived by the driver, because of some problems. The consequence is that the driver doesn't change their driving program, or tries to change it too late, causing hazardous maneuvers. More precisely CHLs are PCLs that occur surprisingly for the driver without sufficient TZ because they break the Human Factors demands of the driver (6-Second Rule, Field of View-Rule, Logic Rule).
Challenging transition (CHT):	is the area preceding and including the CHL. The preceding area is the TZ ahead of a challenging location.
Critical location (CRL):	any area where drivers must adapt their driving program by changing speed, braking, steering, or changing lanes. Normally they are junctions, intersections, stops of public transport, exits, driveways, curves, carriageway width reductions, or pedestrian/cyclist crossings.
Distracting object:	distracting objects are → *Fixation objects* with poor characteristics, such as too much long information, difficult-to-read words, or uncommon objects that are unexpected and hard to recognize. Distracting objects are fixation objects that keep the attention of the driver on themselves for too much time.
Eye-catching objects/elements:	similarly, but more influencing than fixation objects. Eye-catching objects attract unconsciously driver's gaze because of their characteristics that make them easily distinguishable (e.g., high luminance contrast with the background, and lines' intersection points).
Field of View:	the visual area over which information can be extracted at a glance without deliberate eye or head movements. It decreases with age, most likely due to a decrease in visual processing speed, reduced attentional resources, and less ability to ignore distracting information. The Field of View performance is correlated with several real-world functions including the risk of an automobile crash.
Fixation objects/elements:	humans and many animals do not look at a scene in fixed steadiness. The eyes move around, locating and attracting parts of the scenery. These parts are scanned frequently. This is the base for building up a mental, three-dimensional "map" of the scenery.
Gestalt:	perceptual impression ("figure") that is distinguishable from the background of the whole scenery. The details of which are so integrated as to constitute a functional unit with properties not derivable by summation of its parts. Gestalt perception is a dynamic process. The result perceived depends on the experiences, expectations, and individual preferences of an individual. So, the result of what individuals "see" under the same conditions might be very different.
Human Factor Evaluation Segment (HFES):	a sequence of consecutive and/or overlapping challenging transitions that are merged. This segment must be assessed in one application of the →Human Factors Evaluation Tool. It must be marked blue before the Evaluation. After the Evaluation is done it will be marked with the color of the achieved results. The name is HFES-SR2-N1.
Human/driver Behavior	The natural response of the driver to the road system under standard conditions. The driver behavior considered includes and it is influenced by the unconscious

	and automatic response to the road stimuli (e.g., road perception). Driver behavior is not the consequence of road perception alone.
Human Factors Score (HFS):	The result in a percentage of the application of the Human Factors Evaluation Tool. It is called HFS both the results of the First, Second, and Third Rules and the Total of all the Rules.
Human Factors Evaluation Tool (HFET):	A series of checklists presented by PIARC and improved in this work, allow us to evaluate the compliance of the road characteristics with the Human Factor demand.
Human Factors:	it is the generic term for those psychological and physiological patterns that are verified as contributing to operational errors in machine and vehicle handling. In the case of road safety, the Human Factors concept considers road features that influence a driver's right or wrong driving activities. It considers the causes of driver operational error as the first step in a chain of actions that may proceed to an accident. Many of the often-observed operational errors result from the direct interaction between road characteristics and the driver's psychological and physiological limitations of information processing, learning, and activity regulation. Worldwide literature refers to human factors as all the human limitations that influence a driver's driving performance. In the context of this thesis, Human Factors will refer specifically to those standard and non-altered conditions common to all drivers that play a fundamental role in the driver-road interaction and will be written with first letters as capital letters. This means that altered conditions such as the use of alcohol and drugs, handicaps, state of anxiety, etc. are not considered Human Factors.
I Rule (6-Seconds Rule):	average drivers need 4–6 seconds to completely change their driving program. At a speed of 100 km/h this results in up to 300 m being travelled while the change is being made. A user-friendly road will allow an appropriate adjustment of driving actions to a new situation. It is necessary to arrange transition zones, remove visibility restrictions, ensure visibility, or use markings/advanced information and signage to indicate at least 6 seconds ahead of critical locations such as junctions, curves, railway crossings, bus stops, or bicycle paths.
II Rule (Field of View Rule):	motorized driving changes the field of view much more than any other movement. Monotonous or high-contrast periphery, optical misguidance, and illusions affect the quality of driving. The field of view can either stabilize or destabilize drivers and can tire or stimulate them. Speed, lane keeping, and reliability of directions are functions of the quality of the → field of view.
III Rule (Logic Rule):	drivers follow the road with an expectation and orientation logic formed by their experience and recent perceptions from the last 5 minutes – 10 minutes. Unexpected abnormalities disturb a mostly automated chain of actions and may cause drivers to "stumble". Several critical seconds pass before the disturbance can be processed.
Network-wide Road Safety Assessment (NWRSA):	is reviewing a transportation network to identify sites based on the potential for reducing average crash frequency. This term has been introduced in the updated 2008/96/CE Directive [2]. See also Network Safety Screening.
Optical density of the field of view:	Amount of color and brightness contrast that results in a sufficient or a poor optical flow. It influences the quality of driving. Driver's speed is a function of the number of objects/information that contrast with the background and the visible amount of the road's surface.

Optical illusion:	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 differently than it exists. So, what we see does not correspond to physical reality.
Reaction time:	the delay between the presentation of a stimulus and the initiation of a response.
Road image:	how the road appears to the driver, and not how the road is. This concept is linked to the concept of Gestalt but means the objective visual image of the whole scenery.
Road Safety Inspection (RSI):	a systematic, on-site review, conducted by road safety expert(s), on an existing road or section of road to identify hazardous conditions, faults, and deficiencies that may lead to serious accidents [21].
Section:	A part of a road of different lengths (generally more than 1 km), which is part of a stretch.
Segment:	A part of a road of short length (generally within 1 km), which is part of a section.
Stretch:	A part of a road of several km.
Transition zone:	*passage from a higher-speed road section to a lower-speed road section like the change from a rural road to a town or village streetscape.* It allows the driver an appropriate adjust of driving program to a new situation. It should give enough time for anticipation, driver’s decision, and braking maneuvers. The length depends on the kind of change, the weather conditions, and the driving speed. The more complex the scenery and demands the longer it must be. Start the transition in about 10 sec. ahead of the challenging location.

10. REFERENCES

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