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PRIMERJALNA ANALIZA EVROPSKIH TEHNIČNIH PREDPISOV O NAČRTOVANJU CEST

COMPARATIVE ANALYSIS OF EUROPEAN TECHNICAL REGULATION OF ROAD DESIGN

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2018

I, the undersigned __**Alexandre Donaire Espigares**_____, exchange student at the Faculty of Civil and Geodetic Engineering, the University of Ljubljana, with registration number _**70079188**__________**,** author of the written final work of studies, entitled:
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Alexandre Donaire Espigares

Ljubljana, 04. 06. 2018

BIBLIOGRAFSKO – DOKUMENTACIJSKA STRAN IN IZVLEČEK

UDK:	**625.73:005.52(4-6EU)(043.3)(094.2)**
Avtor:	**Alexandre Donaire Espigares**
Mentor:	**Doc. dr. Peter Lipar**
Somentor:	**Viš. pred. mag. Robert Rijavec**
Naslov:	**Primerjalna analiza evropskih tehničnih predpisov o načrtovanju cest.**
Tip dokumenta	**Magistrsko delo**
Obseg in oprema:	**100 str., 30 pregl., 29 sl.**
Ključne besede:	**Oblikovanje cest, primerjalna analiza, evropska ureditev**

Izvleček

Magistrsko delo temelji na obravnavi primerjav evropskih tehničnih predpisov za projektiranje cest v določenih evropskih državah. Obravnavane so Slovenija, Španija, Italija in Združeno Kraljestvo. Z analizo so predstavljene največje razlike med načrtovalnimi metodami pri posameznih državah in ugotovitve potrebnih ter priporočenih sprememb pri le teh za izboljšavo varnosti in kvalitete cest. V prvem delu magistrska naloga prikazuje teoretičnega ozadja in grafične primere za lažje razumevanje obravnavanih tem. Drugi del naloge je usmerjen v prikaz primerjave pravil projektiranja cest med omenjenimi državami. Primerjave so prikazane z uporabo grafov in podatkovnih tabel opremljenih z osebnimi razlagami. Za predstavitev primerjave je izdelan model ceste z računalniško programsko opremo, ki služi kot praktični prikaz prednosti in slabosti uporabe različnih evropskih tehničnih predpisov. V času načrtovanja ceste je potrebno upoštevati predhodno začrtane cilje, ki so povezani z zagotavljanjem funkcionalnosti ceste, varnosti prometa in prijaznosti do uporabnikov, zagotavljanjem pozitivnega odnosa do okolja, krajinske usklajenosti, estetike ter racionalnosti in ekonomičnosti.

BIBLIOGRAPHIC-DOCUMENTALISTIC INFORMATION AND ABSTRACT

UDC:	**625.73:005.52(4-6EU)(043.3)(094.2)**
Author:	**Alexandre Donaire Espigares**
Supervisor:	**Assist. prof. Peter Lipar, Ph.D.**
Co-advisor:	**Sen. lect. Robert Rijavec, M.Sc.**
Title:	**Comparative analysis of European technical regulation for road design.**
Document type:	**Master Thesis**
Scope and tools:	**100 p., 30 tab., 29 fig.**
Keywords:	**Road design, Comparative analysis, European regulation**

Abstract

This thesis addresses the comparative of European technical regulation for road design in specific countries: Slovenia, Spain, Italy and the United Kingdom. An analysis is made to see which are the biggest differences between design methods and what should be done in road design to improve safety and quality of roads in general. The first part of this thesis presents a theoretical background to understand the topics treated; also, graphical examples are introduced in order to facilitate the comprehension. The second part of this thesis is focused on showing the road design rules comparison between the mentioned countries. These comparatives are demonstrated with graphics and using data tables with personalized explanations. Finally, in order to show the comparison in a more practical way, a design with computer software is made and the advantages and disadvantages of using the different technical regulations are concluded. In this sense, we want to improve the safety and quality of the road. At the time of the road design, it is necessary to take into account the previously set goals that are related to ensuring the functionality of the road, traffic safety and user-friendliness, ensuring also a positive attitude to the environment, landscape harmonization, aesthetics and economy.

ACKNOWLEDGEMENTS

I am very grateful to my mentor Peter Lipar who helped me in the whole realization process of this thesis for his advice and support. I would like to thank Robert Rijavec who assessed and oriented me with this thesis' design. Finally, to my parents for their patience, encouragement and kindness.

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1. INTRODUCTION

1.1. Background

This thesis reviews highway alignment design policies and practices in four countries such as Slovenia, Spain, Italy and the United Kingdom. The aim is to increase our comprehension and vision of alignment design by emphasizing similarities and distinctions among design philosophies and quantitative standards. Achievement of this objective is expected to stimulate continuous improvement in the geometric design of the road.

The research presented in this thesis combines and builds on current the UK studies that involved reviews of alignment design policies and practices in a selection of countries. Also, it is used regulations, technical guidelines, specifications and standards of the four countries mentioned. In general, it was noticed that there are many similarities in the principles and philosophies of fundamental alignment design and in the quantitative guidelines on basic design parameters. These similarities can reinforce the reasonableness of the patterns of countries that fall within the norm of world practice. However, the most interesting and important thing may be the differences in emphasis and policy concern that have led to more advanced patterns of certain geometric elements and differences in local conditions and experience which also have led to deviations from apparent global norms for certain quantitative patterns. The purpose of this thesis is to get an idea by understanding the reasons of these differences rather than making judgments about deviations from the norm.

Some countries combine their policies for rural and urban streets, while others have separate policies. This review focuses on alignment design of rural roadways.

The review is divided into two main sections: first, a theoretical background and a qualitative comparison of alignment design philosophies; and second, a quantitative comparison of design guidelines. The paper concludes with general comments on the alignment design policy and practice discussed at the country level.

Regarding the practical part, it contains a basic design of a road to contemplate the differences between regulations and how these affect the road design in order to improve the safety and quality of the road thinking always to reduce the road accidents as it is shown in figure 1 (EU fatalities and targets 2001-2020).

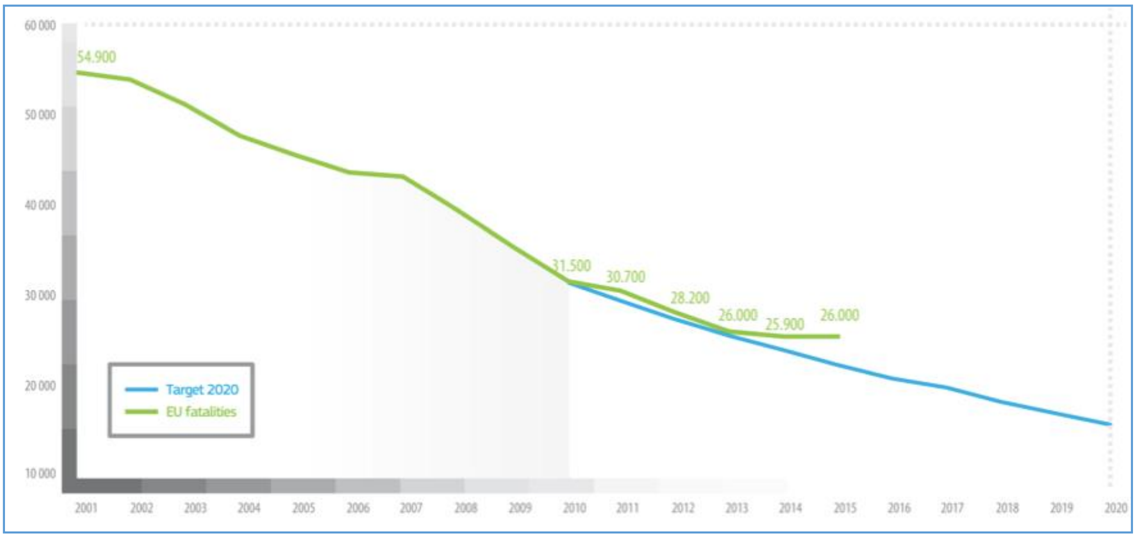

Figure 1: EU road accidents database [1]

1.2. Objectives

The main objective of this thesis is to make a comparison between technical road design regulations of four European countries (Slovenia, Spain, Italy and the United Kingdom) in order to see which parameters differ more between them and what advantages and disadvantages we get designing with each technical regulation.

In order to do that, we introduce the alignment design philosophies between countries, and then we explain the definitions of the parameters that influence in the road design introducing practical examples in 3D. After that we proceed to make qualitative and quantitative comparisons of the regulations through data tables and graphics.

Finally, a design of a road is made, to contemplate such differences between regulations and how these affect the road design and we discuss the improvements we will achieve.

1.3. Methodology

Firstly, a theoretical background of the most relevant parameters for geometric road design is carried out. Then, different technical regulations, technical guidelines, specifications and standards of road design are used. Once the parameters of each country are located, a comparison of them is made too. Finally, with the data collected, a road design is made to contemplate the differences between regulations in order to improve quality and safety on the road.

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2. THEORETICAL BACKGROUND

2.1. Definition of Geometric Road Design

The geometric design of roads is the branch of highway engineering related to the positioning of physical road elements in accordance with standards and limitations. The basic goals of geometric design are to optimize efficiency and safety while reducing costs and environmental damage. Geometric design also impacts an emerging fifth target called "livability," which is described as the design of roads to promote broader community objectives, including access to employment, schools, businesses and residences, and accommodates a variety of travel modes such as walking, cycling, traffic and automobiles, and minimizing fuel use, emissions and environmental damage. [2]

In overall for the purposes of developing initial layouts, the Design Organisation should determine the appropriate typical width for the highway cross-section and any variation in width required. The type of highway and number of lanes needed for a facility is usually determined during the concept stage of project development. Figure 2 provides a flow chart as simplified guidance on the road design process.

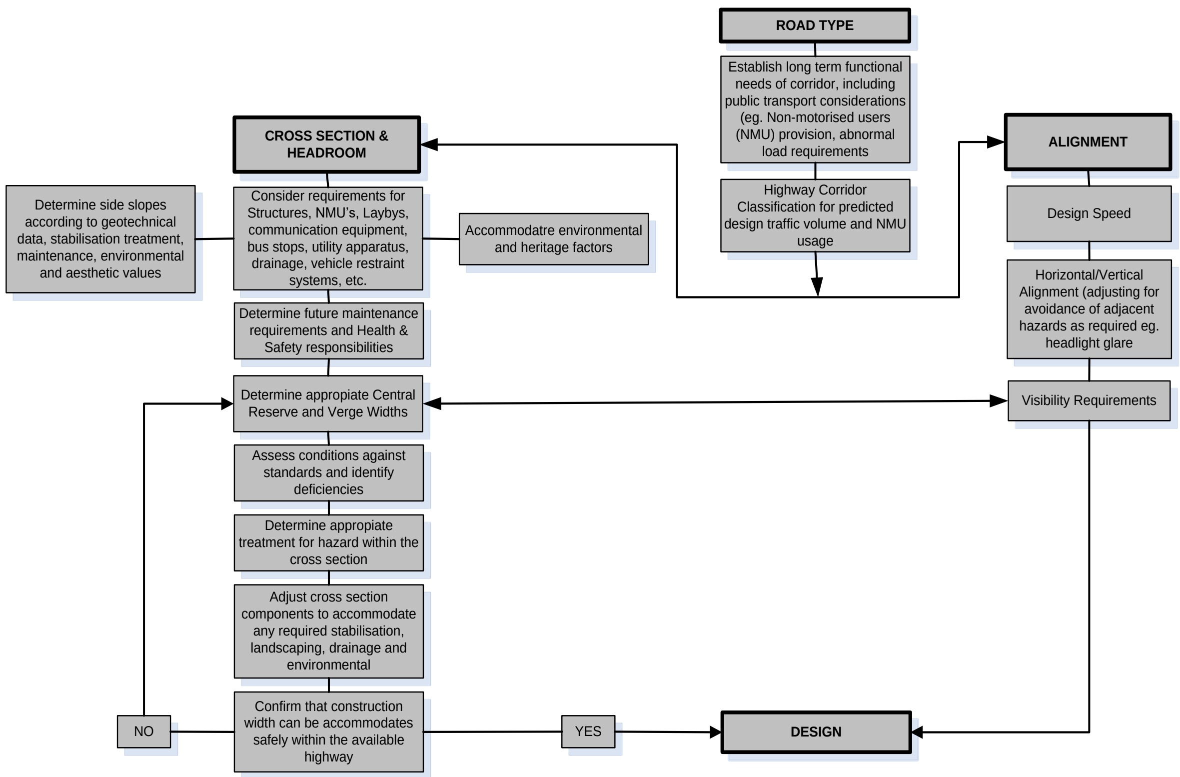

Figure 2: Flow chart of the design Cross-section

The scheme design should make adequate provision for the accommodation of roadside equipment and allow for safe installation and maintenance access.
Allowances should also be made within the cross-section for the future installation of additional equipment as more sophisticated control systems are developed for the network.

The geometric design of the road can be divided into three main parts: horizontal alignment, vertical profile or alignment, and cross-section. Together, they provide a three-dimensional design for a road.

The horizontal alignment is the road's route defined as a sequence of horizontal curves and tangents.
The vertical alignment is the vertical aspect of the road, including sag and crest curves, and the straight grade lines linking them.
The cross section shows the position and number of lanes and sidewalks for vehicles and sidewalks and bicycles in case to deal with urban areas, along with their cross slope or bench. Cross sections also show drainage characteristics, pavement structure and other elements outside the geometric design category, good example of that is the typical cross section.

2.2. Horizontal Alignment

The horizontal alignment of a road or street is the combination of straight and curves (or tangents) presented in a plan view. Curves are generally circular, although spirals and other higher order polynomials can be used in very specific circumstances, rarely found in residential environments.
Determining the horizontal alignment of an urban street is a planning function rather than a detailed design function, and is highly iterative in nature. Iteration is not only between the three dimensions of design. These constraints on the vertical dimension may force a change in horizontal alignment but also involves the ongoing review of the intentions originally formulated with respect to decision making.
The design of the horizontal alignment should also give effect to the proposed function of the road or street. For example, the horizontal alignment of a motorway is characterized by long

tangents and soft curves, while a residential road should be designed to discourage operating speeds above 40 to 50 km/h.

2.2.1. Tangents / transition curves

Since the horizontal curves are circular, the connecting lines are often called tangents. While the selection of the horizontal bend radius determines the operating speed selected by the driver, long tangents can cause speeds to increase to unacceptable levels, followed by deceleration as the next curve is found. It has been found that limiting the length of the tangents (in meters) to approximately ten times the design speed (in km/h) [4] will make the speeds remain fairly constant. A design speed of 40 km/h therefore suggests that the tangents should not be more than about 400 m in length. Figure 3 shows the different scenarios for presenting these transition curves.

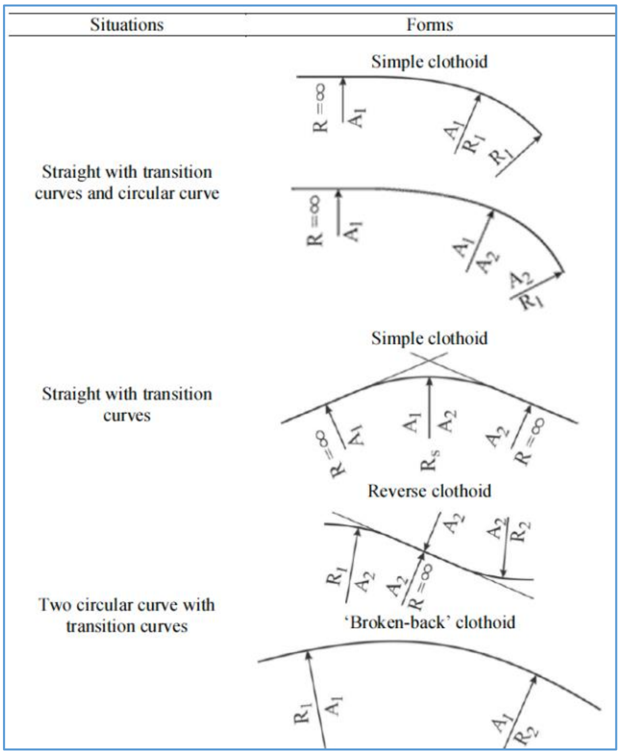

Figure 3: Transition curves scenarios [3]

2.2.2. Curvature and superelevation

The minimum radii of horizontal curves for various design speeds and maximum rates of superelevation are calculated from the relationship:

$$R = \frac{v^2}{127(e + f)} \tag{1}$$

where:

R = radius (m)

v = speed (km/h)

e = superelevation rate (m/m)

f = coefficient of side friction

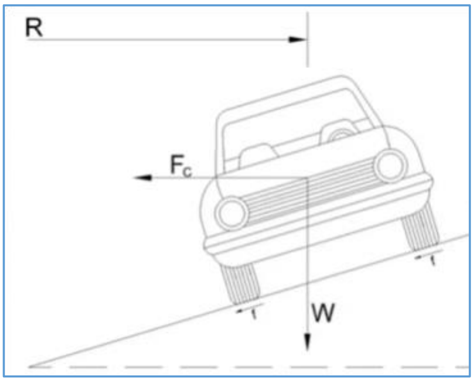

Figure 4: Superelevation in Highway Engineering [6]

In contrast to the rural situation in which an adjusted radius curve can be matched by a high superelevation value, large variations in vehicle speeds found in the urban environment make high superelevation values inappropriate. In addition, there is a clear probability that there is not enough distance available to accommodate superelevation development. Access to the property in the vicinity of the curve probably would not allow a cross-section where one side of the road is one meter or more above the other.

A cross-sectional slope of 2 to 3% suggests that rates of superelevation of -0.02 to +0.02 are usually normal transverse slope situations. There is no known application for an over-elevation of 0% and it should be avoided as, in the absence of a longitudinal gradient, it will cause drainage problems and water accumulation on the road surface, known as aquaplaning effect.

2.2.3. Superelevation transition / runoff

Roads usually have a cross-sectional slope with the high point on their centreline and a drop, typically in the order of 2 to 3% as suggested above, to either edge. Superelevation is developed or executed by turning the outer lane around the centre lane until a cross is reached along the entire width of the road, equal to the slope of the original cross-section. From this point, both lanes are rotated further around the centre line until the maximum slope of superelevation has been reached.

This additional rotation does not necessarily have to be on the centre line. Special circumstances may require a different rotation point. A restriction on the level of one or other of the roadsides may require the restricted edge to become the axis of rotation. The need to ensure an adequate but not too steep inlet on the inside of a curve may require the rotation axis to move to a point slightly away from the inner edge.

Rotation at too short distance will create the impression of an unsightly twist on the road surface and, if the distance is too long, drainage problems are likely to occur in the area where the slope of the cross-section is less than approximately 0.5% [4]. The rotational speed is measured by the relative slope between the edge of the road and the axis of rotation. Where space does not permit the use of these charges, minimum lengths for superelevation runoff for two-lane roads have to be adopted. These lengths are based on relative slopes that are generally 50% higher than those recommended for normal use.

In general, the superelevation transition has some limitations. It must to be limited for:

-Driving comfort reasons (bounded gradient range).

-Velocity of the project.

-Distance from the edge of the road to the rotation axis of the superelevation.

-Adjustment factor depends of the number of lanes that are rotating.

When a circular arc is preceded by a transition curve, the entire superelevation develops along the transition. Transition curves, however, are only used in the most compact radius curves applied to roads with design speeds more than 40 km/h. In all other cases, superelevation transition must be distributed between the tangent and curve because the complete superelevation at the end of the tangent is as undesirable as it is not perishable at the beginning of the curve. Drivers tend to follow a transition path as they enter a curve and this path usually has two thirds of its length in the tangent and the remaining third is in the curve itself. Superelevation transition is distributed similarly to match the actual route of the vehicle.

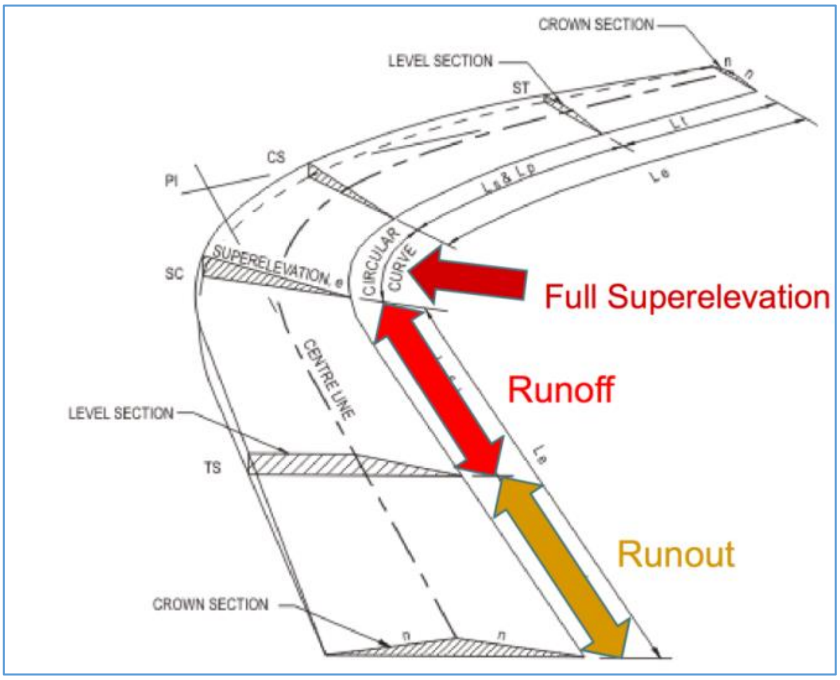

Figure 5: Superelevation, runoff and runout [5]

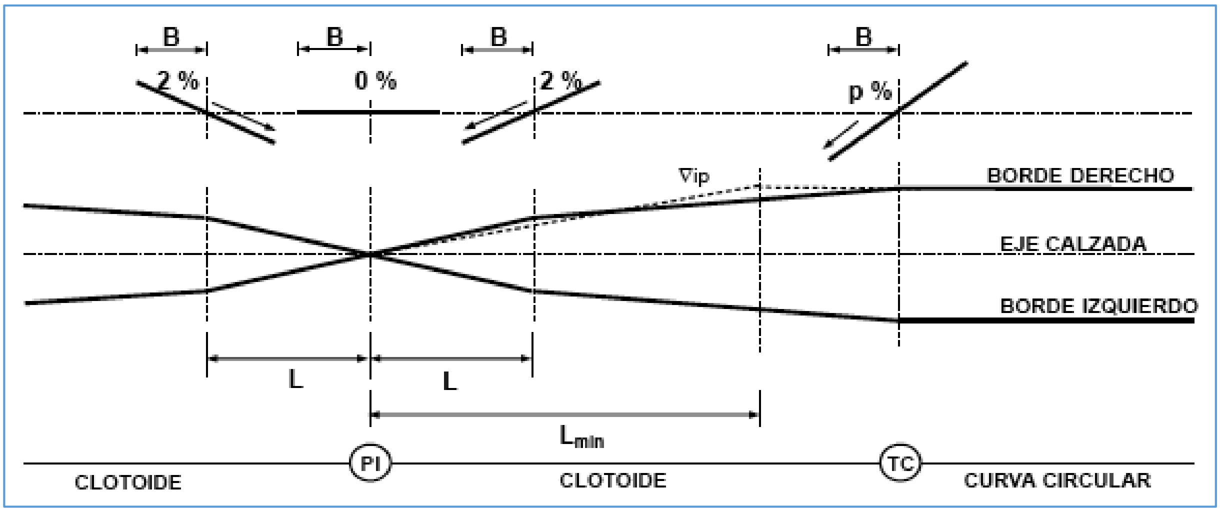

Figure 6: Superelevation transition between curves of the opposite direction. Axis rotation in the roadway edge [6]

2.3. Vertical Alignment

The vertical alignment is the combination of vertical parabolic curves and straight sections joining them together. Straight sections are called degrees, and the value of their slope is the gradient, usually expressed by the percentage, e. g. a gradient of 5% climbs to 5 meters over a horizontal distance of 100 meters.

Bearing in mind the life-time economy of the road, vertical alignment should always be designed at such high level in order to be compatible with the topography. Passenger car speeds are dictated by the standard of horizontal alignment rather than vertical alignment, while bus and other heavy-duty vehicle speeds are more limited by vertical alignment. The design velocity applied to vertical alignment should therefore coincide with the design velocity applied to horizontal alignment and it could be argued that a higher vertical design velocity is preferable. Like horizontal alignment, vertical alignment should be designed to be aesthetically pleasing. In this context, the recognition should also be given to the interrelationship between horizontal and vertical curvature. If it is possible, a vertical curve which coincides with a horizontal curve should be contained within the horizontal curve and it would be ideal if it is the same length.

When a vertical curve falls into a horizontal curve, the superelevation generated by the horizontal curvature improves the availability of visual distance beyond what is suggested by the value of the vertical curvature. This allows the edge profiles to have a sharper curvature than the minimum suggested. However, the condition is that the driver's line of sight is within the width of the road. When the line of sight goes beyond the edge of the road, the effect on the visibility distance of side obstructions, such as boundary walls or high vegetation, should be controlled.

A smooth slope line with gradual changes appropriate for the type of road and the character of the topography is preferable to an alignment with numerous short slope lengths and vertical curves. A smooth slope avoids the type of "roller coaster" or "hidden dive" profile. This profile is particularly misleading in terms of viewing distance availability and, when unavoidable, a greater viewing distance than suggested above in terms of accident experience may be necessary. For aesthetic reasons, a broken alignment is not desirable in voids where a full view of the profile is possible. On crests, the discontinuous curve adversely affects the opportunity to pass.

2.3.1. Curvature

The horizontal circular curve provides a constant rate of course change. Similarly to this, there is the vertical parabola, which provides a constant rate of gradient change. Apart from academic subtleties, there is little choice between applying the parabola or the circular curve, as the differences between them are virtually impossible to track and, in any case, within the levels of precision at which pavement is typically built.

In general form of a parabolic function:

$$y = ax^2 + bx + c \quad \text{(IT \& UK)} \qquad \text{or} \qquad y = \frac{x^2}{2 \cdot Kv} \quad \text{(SLO \& SP)} \tag{2}$$

Vertical curves are specified in terms of this parameter, K_v, and their horizontal length is shown in the relationship:

$$L = A\theta \cdot K_v \tag{3}$$

$$L = 2 \cdot T \tag{4}$$

where:

$A\theta = |g1 - g2|$ absolute algebraic difference in grades

K_v = radius of the circumference at the vertex of the parabola

L = Length of vertical curve

T = Tangent point

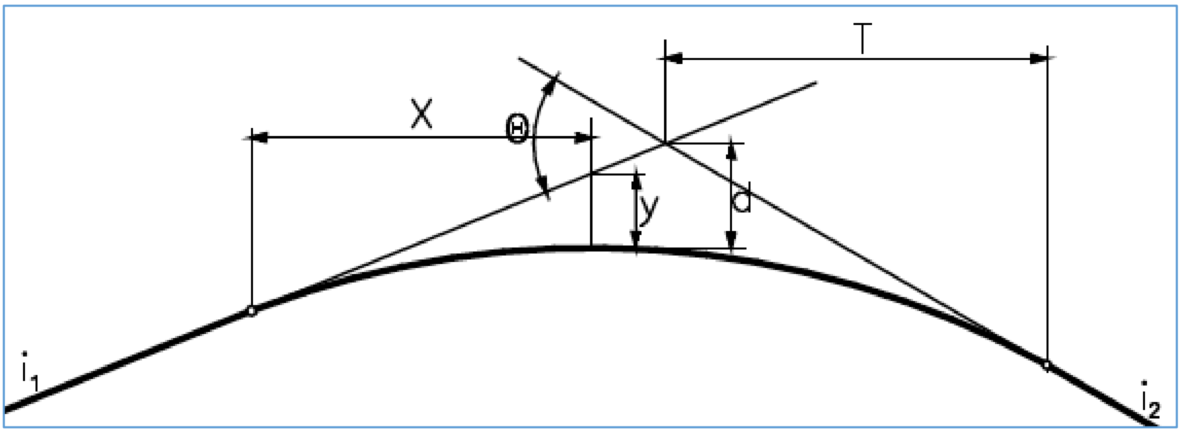

Figure 7: Vertical curvature parameters [6]

2.3.1.1. Minimum rates of curvature

The minimum curvature rate is determined by the viewing distance as well as by considerations of operating comfort and aesthetics. The most commonly used viewing distance is the stopping viewing distance which, as indicated above, is measured from an eye height of 1.05 - 1.10 m to an object height of 0.15 m, although, in the case of residential streets, an object height of 0.5 - 0.6 m could be used. (Depending on the country what we are dealing with, these heights values may differ a little. Above are written the most common heights).

In the case of sag curves, the viewing distance is replaced by a headlamp illumination distance of the same magnitude, assuming a headlamp height of 0,6 m and a deviation angle of 1 ° above the longitudinal axis of the headlamps. Where appropriate street lighting is available, the headlight criterion does not apply and comfort is the only criterion restricting the values.

Special circumstances may dictate the use of the decision viewing distance or even the step viewing distance. When a viewing distance rather than the stopping distance is to be used, the ratio given below can be used to calculate the required curve length and thereafter the K-value of the vertical curvature.

- Where the sight distance, S, is less than the curve length, L:

Sight Distance < Curve Length (S<L)

$$L = \frac{AS^2}{200(\sqrt{h_1} + \sqrt{h_2})^2} \tag{5}$$

- Where S is greater than L:

Sight Distance > Curve Length (S>L)

$$L = 2S - \frac{200(\sqrt{h_1} + \sqrt{h_2})^2}{A} \tag{6}$$

where:

L = length of vertical curve (m)

S = sight distance (m)

Aθ = g1-g2 , algebraic difference in grades (%)

h1 = height of eye above road surface (m)

h2 = height of object above road surface (m)

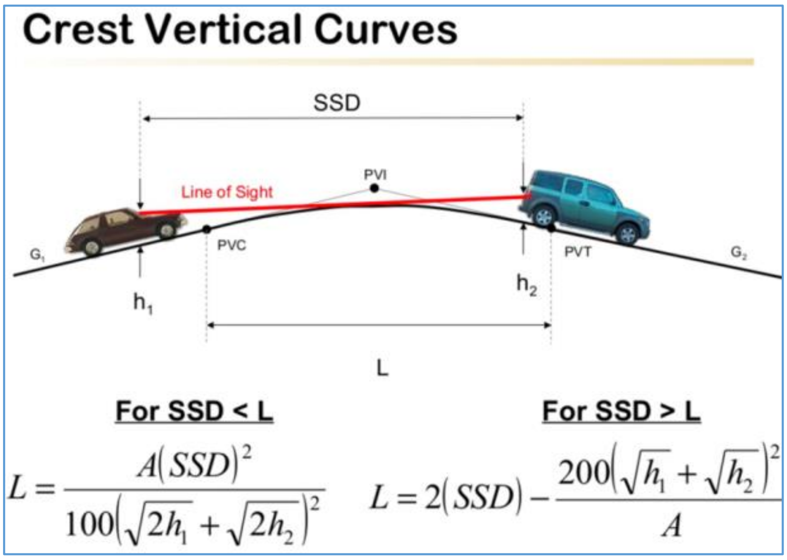

Figure 8: Graphical representation of rates of crest vertical curves [7]

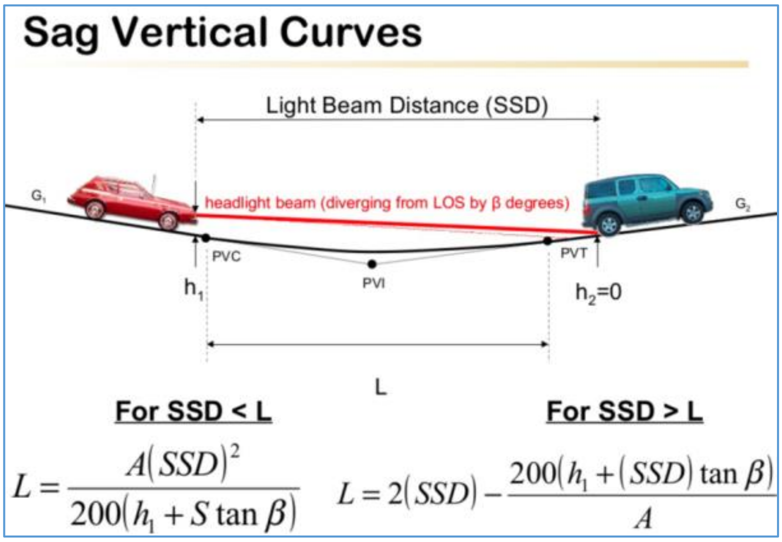

Figure 9: Graphical representation of rates of sag vertical curves [7]

β = angle of light beam intersects the surface of the roadway, degree (assumed 1º)

The K_v values are based on stopping sight distance in the case of crest curves, and on headlight illumination distance in the case of sag curves.

2.3.1.2. Minimum lengths of vertical curves

When the algebraic difference between consecutive degrees is short, the minimum intermediate vertical curve becomes very small, and especially when the surrounding tangents are large, the impression of a bend in the slope line is created. When the difference in grade is lower than

0.5%, the vertical curve is often ignored. A minimum curve length is suggested for algebraic differences in the degree higher than 0.5% for strictly aesthetic purposes.

When a crest curve and a successive sag curve have a common endpoint, the visual effect created is that the road has suddenly lost its appearance. In the reverse case, the illusion of a hump is produced. Any effect is eliminated by adding a short length of straight slope between the two curves and usually from 60 m to 100 m is suitable for this goal.

2.3.2. Gradients

2.3.2.1. Maximum gradients on higher order roads

Maximum gradient guidelines range in complexity from one country to another considering some or all of the following factors: road type (or functional classification), design speed, and terrain. For example, in the United Kingdom, desirable-absolute maximum gradient values are specified for road types: motorway (3-6 percent), dual carriageway (4-8 percent), and single carriageway (6-8 percent). In Switzerland [8], maximum gradient is a function of design speed (from 10 percent for a 60 km/h design speed to 4 percent for a 120 km/h design speed). In Germany, maximum gradient is a function of road type and design speed; for main rural roads, values range from 8 percent for 60 km/h to 4 percent for 120 km/h. In South Africa, maximum gradients are based upon design speed and topography; in flat terrain maximums range from 6 to 3 percent for 60 to 120 km/h design speeds, in rolling terrain 7 to 4 percent and in mountainous terrain 8 to 5 percent for the same design speed range. In the United States, maximum gradients are based upon road type, topography, and design speed.

Bus and truck speeds are strongly affected by the gradient. Bus routes must be designed with gradients, which will not reduce the speed of these vehicles enough to cause unacceptable conditions for subsequent drivers. Glennon (1970) [9] discovered that the frequency of crashes rises dramatically when the speeds of heavy vehicles are lowered by more than 15 km/h.

For southern African conditions, it is generally accepted that a 20 km/h reduction in speed represents intolerable conditions. If gradients where the reduction in bus or truck speed is less than 20 km/h cannot be reached economically, it may be necessary to provide auxiliary lanes for slow-moving vehicles. Wolhuter (1990) [10] stated that, in flat qualities, 50 percentiles of bus and truck speeds are approximately 17 km/h less than the car's equivalent speeds, so a 20 km/h reduction in speed actually represents a total speed differential of approximately 37 km/h.

Table 1 suggests maximum gradients for different design speeds and topography types. It is noted that these are only guidelines. Optimizing the design of a specific roadway, taking into account the economy of the entire life of the road, may suggest another maximum gradient.
The three types of terrain described are defined by the differences between passenger car speeds and the bus or truck speeds prevailing on them. On flat terrain, the differences between car and bus speeds remain relatively constant at about 17 km/h, while the mountainous terrain results in substantial speed differences. On mountainous terrain, buses and trucks reduce to towing speeds on considerable distances.

Maximum gradients on major roads (%)			
DESIGN SPEED (Km/h)	TOPOGRAPHY		
	FLAT	ROLLING	MOUNTAINOUS
40	7	8	9
60	6	7	8
80	5	6	7
100	4	5	6
120	3	4	5

Table 1: Maximum gradients on major roads [7]

2.3.2.2. Minimum gradients

If the road cross-section does not include kerbing, the gradient could be 0% because the inclination of the cross-section continues through the adjacent shoulder, allowing adequate drainage of the road surface. The rim will have to accommodate the drainage of both the road reserve and surrounding properties. The decision to accept a zero gradient would have to be informed by the stormwater drainage design. The zero gradient is not recommended as a general rule and the preferred minimum is 0.5%.
Kerbed roads must have a minimum gradient of no less than 0.5%. If the gradient of the road is smaller than this, it is necessary to level the kerbstones and channels separately and reduce the gap between the drop inlets to ensure that the height difference between the edge of the road travelled and the channel is not too pronounced.

2.4. Cross Section

The cross-section of a roadway can be understood as a representation of what it would look like if an excavator dug a hole through a roadway, showing the number of lanes, their widths and cross slopes as well as the existence or the absence of verges, curbs, sidewalks, drains, ditches and other roadway features.

The cross section of a road or any element of it, will be established according to the intensity and composition of the traffic foreseen in the project time of the horizon year, considering as such the later in twenty (20) years to that of the date of entry into service. [6]

Platforms with different directions of circulation on highways, dual carriageways and multi-lane roads will be separated with a median.

The number of basic lanes of each lane will be established based on the foreseeable intensity and composition of the traffic, at the project time of the horizon year, the level of service desired and, where appropriate, the relevant economic studies. These studies will deduct the expansion forecasts.

- Elements and Dimensions:

Lane width selection affects the cost and performance of a roadway. Typical lane widths range from 2.5 to 3.75 meters. Larger lanes and shoulders are typically used on roads with great speed and traffic volume and a substantial number of trucks and other large vehicles. Slimmer lanes can be used on roads with slow speeds or low traffic volumes.
Slim lanes cost less to build and maintain, but they also decrease a road's ability to handle traffic [11]. On rural roads, narrow lanes are likely to experience higher rates of run-off-road and head-on collisions. Wider roads increase the time needed to walk across and increase stormwater runoff.

Among the elements that constitute the cross section of a road are the platform (lanes and shoulders) and the berms. Its dimensions will be adjusted to the values indicated in the tables of each regulation.

The level of service will be obtained according to the methodology developed in the Capacity Manual of the TRB (Transportation Research Board).

The cross section of a side road will be similar, unless justified, to a collector or distributor road.

The section of a transfer branch shall be assimilated, unless justified, to a one-way link branch.

The usual width of the lanes will be three meters and fifty centimeters (3.50 m) and can be reduced, if necessary and justifiably, in peri-urban and urban sections, considering simultaneously a reduction in speed. On roads with separate roadways, the width of the lanes may be greater in those on the left than in those on the right, which are more frequently used by heavy vehicles. Exceptionally, in the interurban section of roads where traffic intensity is very low (IMD <300 vehicles / day), the lane width can also be reduced.

On roads with separate roadways with a project speed greater than or equal to one hundred kilometres per hour (100 km / h), the inner shoulder will be required to have a width of one meter and fifty centimetres (1.50 m). The medians will have the security barrier attached to the edge of the platform.
As an estimate it can be considered that a safety barrier is attached continuously if this length is greater than or equal to five hundred meters (500 m).

On roads with rugged or very hilly reliefs and with low traffic intensity (IMD <3 000), the shoulder width can be reduced by 50 centimeters (50 cm). In addition, the absence or reduction of the berm can be justified, always guaranteeing a width that allows the implementation of vertical signage.

The right shoulder of a link branch will have a width not less than the shoulder of the road from which it leaves with a value greater than or equal to one meter and fifty centimeters (1.50 m).

The width of the shoulders may be reduced, justifiably, in some areas provided that the visibility of the stop is guaranteed.

The minimum width of the berms may be increased for reasons of visibility, working width of vehicle containment systems, dimensions of traffic signs, etc., taking into account the possible simultaneity of elements.

In two-way linking branches separated by a vehicle containment system, the width of each semi-platform will correspond to that of a one-way link.

* Widenning of pavement on horizontal curves: Is interesting to know that when the horizontal curves do not have large radius, it is a common practice to widen the pavement slighty more than the normal width with the object to provide more space to the trucks to follow the path of the road without to intercept the other lane. To provide more space, due to the drivers have a tendency to follow outer edge of the pavement to have better visibility.

2.5. Elements of 3D alignment

A spatial view of a combination of road elements exerts an essential influence on driving behaviour and road safety. Therefore, it is necessary to take into account the principles of a smooth spatial alignment design. The alignment of the roadway must be designed as an optically smooth spatial line by combining the elements of horizontal and vertical alignment between them and also with the surrounding landscape, taking into account their impact on traffic conditions and the visual perception of the road, i. e. the alignment of the roadway must be completely clear, timely, recognisable, perceptible and unambiguous for the drivers.
Spatial smoothness of alignment is created when the chosen parameters and combinations of alignment elements ensure that a perspective view of the road alignment is incorrupt.
The road seen by drivers includes the pavement, the slopes of cuts and embankments, and the surrounding environment that does not really belong to the road (but to the natural environment or populated areas). Road geometry is specified by three separate aspects of the design: horizontal alignment, vertical alignment and cross-section.
In consideration of the fact that road design involves three different elements (3D), it is not always easy to perceive the three-dimensional result. Therefore, German RAL [3] suggests that in order to get an idea of the 3D impact of the road, specific 3D elements are defined. Each of these elements comprises a horizontal and a vertical alignment element. For these normalized

3D elements, perspective views of the road are provided in Fig. 10 (horizontal straight line) and Fig. 11 (horizontal curve).

Based on these elements, the previous perspective views allow the first approximate evaluation of the three-dimensional (or spatial) alignment impact. A thorough inspection of the three-dimensional alignment is only possible when we use perspective views that are created for each section of the path to evaluate. In this sense, the drivers' perspective is the only useful perspective when it comes to assessing the course of the road. Perspective views can be developed using appropriate planning software modules and digital terrain and road models, including slopes in adjacent areas.

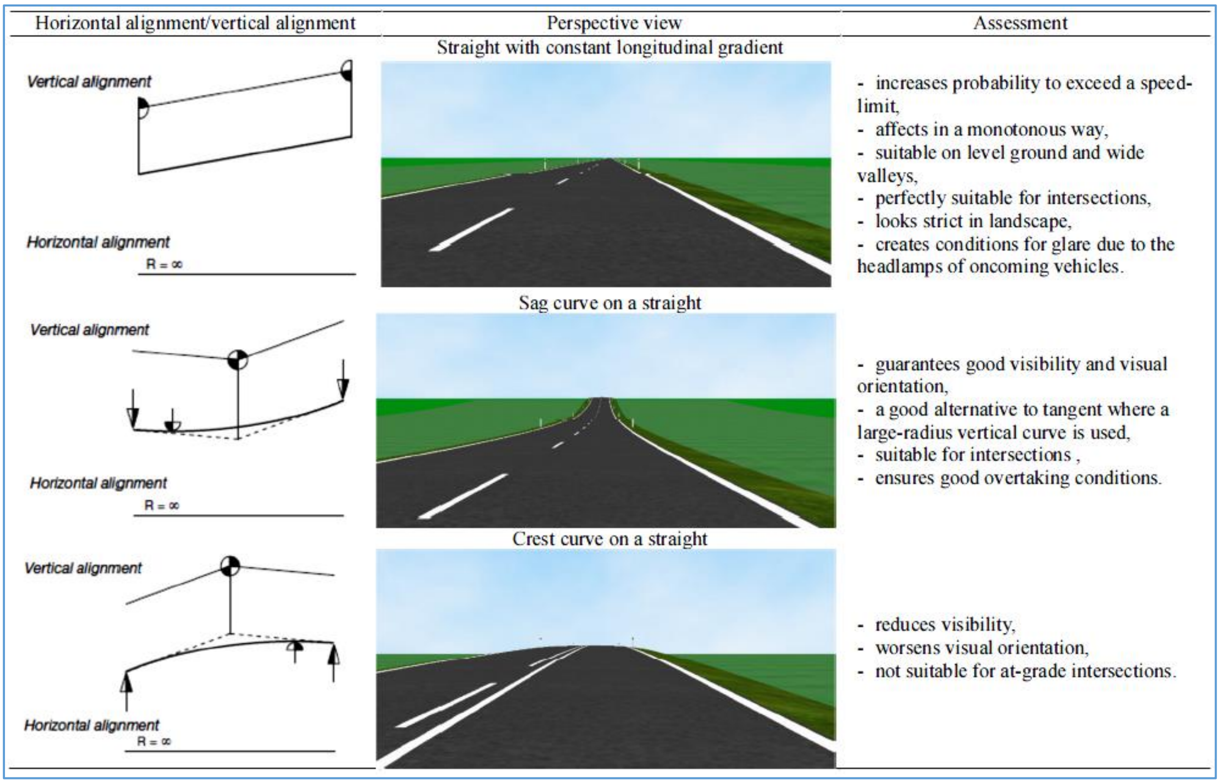

Figure 10: Spatial elements of horizontal straights (superimposition of horizontal and vertical alignment design elements and including cross-sections) [3]

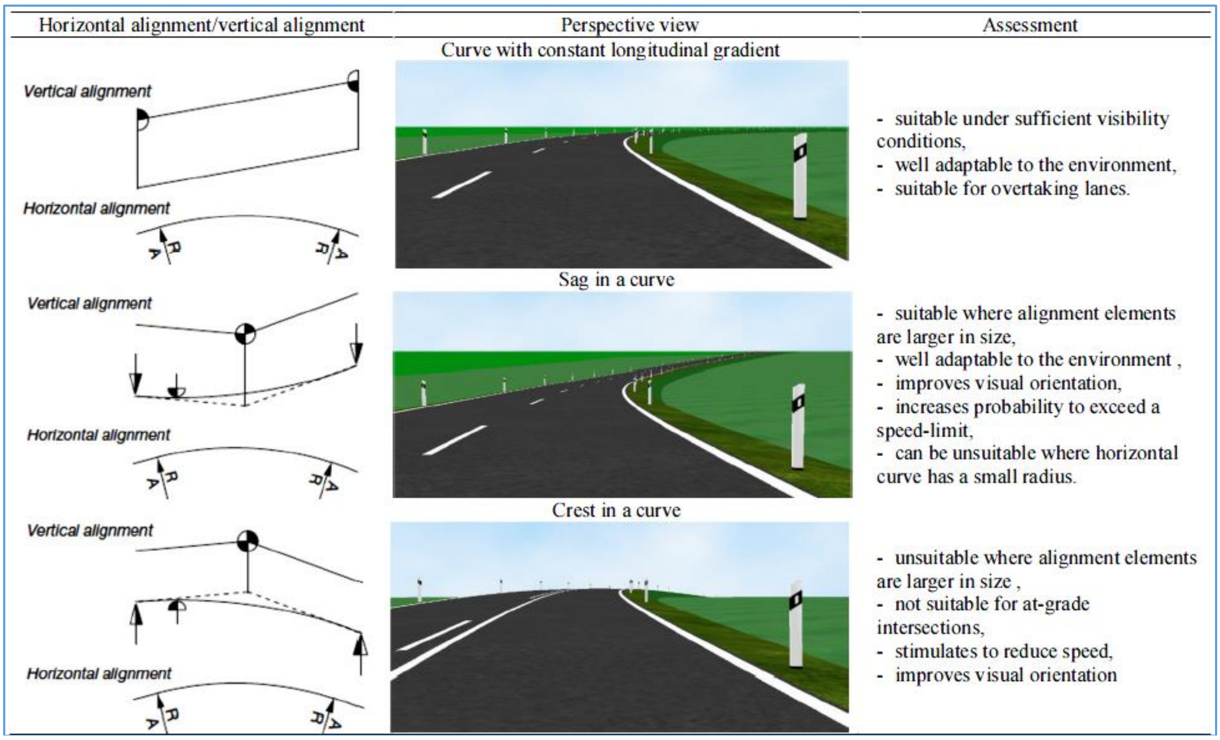

Figure 11: Spatial elements of horizontal curves (superimposition of horizontal and vertical alignment design elements and including cross-sections) [3]

2.6. Deficiencies of three-dimensional alignments in road design

Due to poorly designed spatial elements or their combinations, the road may have many deficiencies which will affect driving behaviour and road safety. Table 2 presents the main shortcomings of roads and their impact on road safety which is recommended to be taken into account in the road design regulations of European Union countries.

DEFICIENCY	IMPACT ON ROAD SAFETY
Invisible zones (ascent/descent)	High
Invisible start of a bend (unclear direction)	High
Outstretched bend in depression	Average
Curvy bend on peak	Low

Table 2: Road shortcomings and their impact on road safety [3]

In order to ensure visibility on a long road section, combinations of spatial elements which cause invisible areas (rise/fall) on the road and unclear alignment directions should be avoided.

In invisible sections it is impossible to create safe overtaking conditions. A combination of spatial elements is not allowed where short sag vertical curves are designed, as they create invisible areas (Fig. 12). In this case, a vertical curve radius shall be increased and, if this is impossible, engineering actions shall be applied to restrict overtaking.

The invisible start of a curve refers to the situation where a driver at least 75 m away cannot see the start of a curve in front of him at least to the point where the change in the direction of alignment is 3.1 ° [3]. To ensure recognition of the start of a curve, the start of the horizontal curve must begin before the start of the vertical curve.

In depression, i.e., in sag vertical curve, horizontal curve appears to be more stretched (Fig. 12), and in crest vertical curve – more curvy (Fig. 13) than in the continuous longitudinal gradient curve. The size (visibility) of these road deficiencies is shaped by a ratio of horizontal and vertical curve radius (R/H_w or R/ H_k).

Being R: Radius of the circle of curvature (m), H_w: Radius of crest vertical curve, H_k: Radius of sag vertical curve.

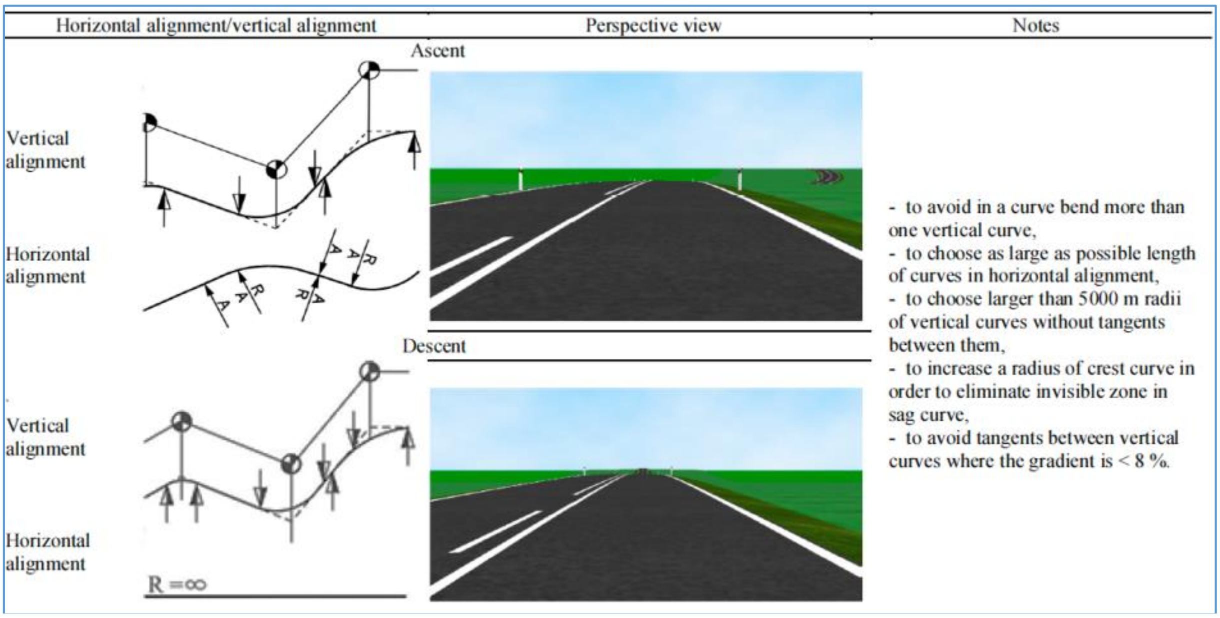

Figure 12: Deficiencies of road causing invisible zones [3]

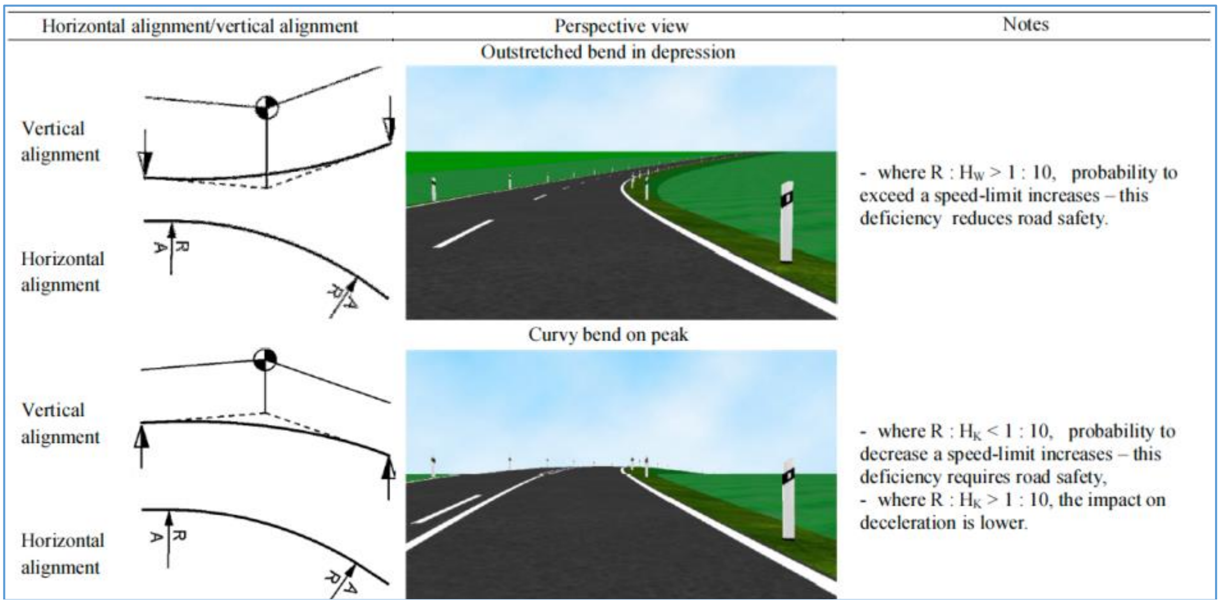

Figure 13: Deficiencies where road bend seems too overstretched or curvy [3]

Non-smoothness (optical distortions, ruptures) is due to the variability of the parameters of the alignment elements where very short vertical curves are designed in long straight sections or in curves and also where long horizontal sections are used, especially with continuous longitudinal gradient. designed (Fig. 14).

Having made a perspective vision of the alignment of the road and having analyzed its shortcomings, corrections of horizontal and vertical alignment are carried out which will improve the smoothness of the road.

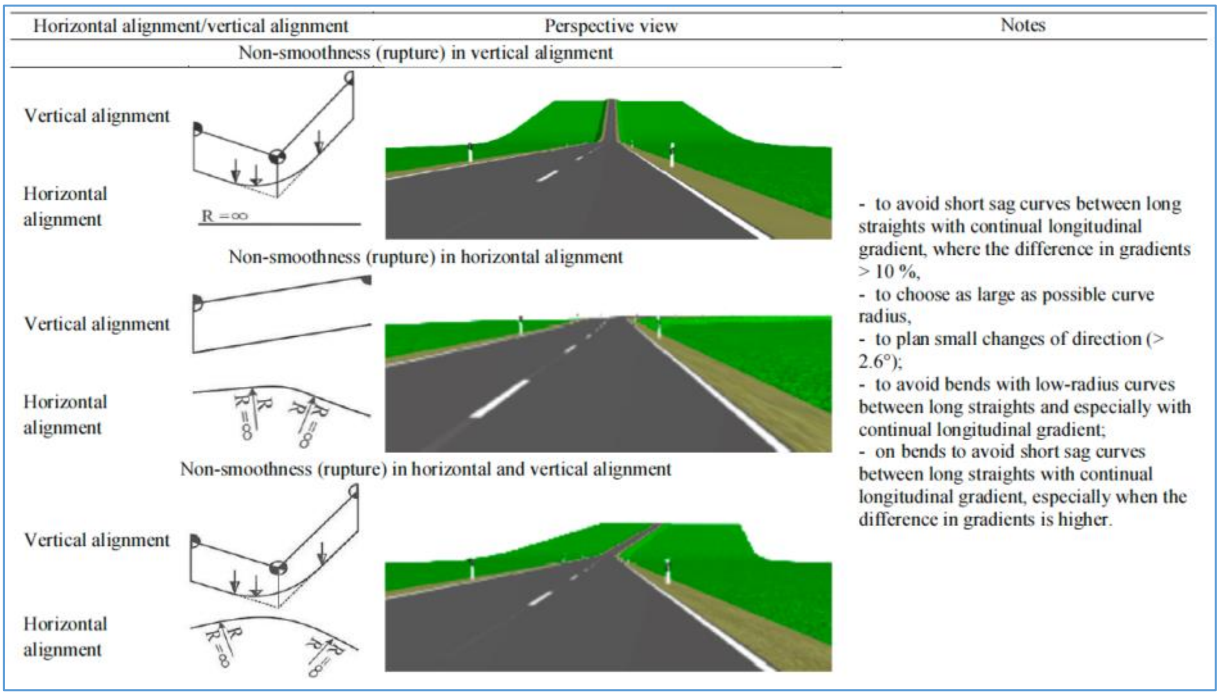

Figure 14: Deficiency where road looks unsmooth (with ruptures) [3]

2.7. Alignment design philosophies between countries

Many countries' alignment design policies were based initially upon the design-speed concept described by the American Association of State Highway and Transportation Officials in 1940 (AASHTO) [7]. This classical approach involves the selection and application of a design speed to assure uniformity of operating speed along an alignment. Design speed is selected and based upon road type, terrain, and development environment (rural versus urban). The selected design speed is used to determine minimum curve radii, actual superelevation rates, and required sight distances. It is presumed that drivers operate at the design speed and, therefore, that no checks on actual operating speeds are required.

During the past 55 years, many countries have adapted, refined, and updated their policies to reflect national conditions, safety and operating experience. Design speed continues to be a cornerstone of alignment design, but nowadays there are some interesting differences in selecting and applying design speed. Several countries have recognized a need to base design speeds more directly upon actual driver speed behaviour and to include checks on estimated operating speeds along designed alignments.

To illustrate the similarities and differences in alignment design philosophy, a sample of 4 countries' alignment design policies (SLO, SP, IT, UK) were reviewed in some detail:

2.7.1. Spain

The traditional process of geometric design of roads in Spain uses the rule: "Instrucción de Carreteras, Norma 3.1-IC" [6].

The most important part of a road project is its geometric design. This process consists of defining the definitive geometric configuration based on series of previous conditions that will satisfy the following fundamental objectives: functionality, safety, comfort, environmental integration, harmony or aesthetics, economy and elasticity.

The road is a three-dimensional reality, although it is not usually conceived directly as such. The traditional design process consists of focusing iteratively on each of its parts or projections (plant, elevation and cross section). At the same time, in each step, we have to keep in mind the three-dimensional reality of the whole, analysing the fulfilment of the regulations and the set of criteria or objectives.

In addition, not all design objectives are in correspondence. In fact, some of them are opposed. The impossibility of satisfying all of them entails the necessary prioritization of each other. Another problem is the difficulty or impossibility of measuring the degree of compliance. In fact, the road safety objective has traditionally been associated with the mere verification of the fulfilment road regulations.

Referring to influential factors, they are very numerous, so it is convenient to classify them in external (or previously existing) and internal (own of the track and its design). Thus, external factors could include orography, geology and geotechnics, traffic demand, urban conditions and climatology. Internal factors such as velocities or operational effects of the geometry (visibility, etc.) can be mentioned.

From all these factors, the most obvious one for engineers is perhaps the expected speed to provide to the drivers, and, perhaps, it is the most important in the design process. Thus, defining a starting speed to base on, the road design becomes a fundamental issue. This speed is known internationally as design speed, and as project speed in Spain. Its selection is based mainly on the class or type of road and on the orographic and urban features of the surroundings.

This velocity is considered as the starting point for the definition of the geometric controls that affect the section design. Thus, the minimum values of visibility, curve radius in top view, the parameter of vertical curves or cross section are defined from this velocity.

The next step is the geometric design of the track, respecting these controls and the design rules. Over the last few years, there has been an important advance in learning the influence of the human factor and its relation to geometry and the accident rate. Regarding geometry, this knowledge allows to estimate with some reliability degree how the drivers will respond to a certain design. This is very useful, since it allows designing routes to be more adapted to the possibilities and the requirements of the users, and that does not produce surprises. On the other hand, it is also known to a greater extent how the human factor and infrastructure are related to the accident rate, which allows the designers to estimate the effects that a design will have on it.

However, this knowledge is not taken into account in the traditional design process. In this process there are several parameters introduced by the designer that they do not verify their fulfilment, potentially increasing a lack of agreement between the facilities of the road and the needs of drivers.

2.7.2. Slovenia

Slovenian rules on Road Design are set by Official Gazette of the Republic of Slovenia (Pravilnik o projektiranju cest) [12]. The current version is dated 2006.

The design speed is taken into account in the determination of the geometric elements of the road axis and the cross section of the roadway. This speed enables safe driving on the wet and clean road surface. Design speed is determined for each individual traffic function and type of road, and depends on the type and difficulty of the terrain. It is allowed to change the design speed due to changes in the type or complexity of the terrain in some places or to protect the environment in the minimum length. It is also allowed to change the speed design in urban areas. This allows the designer a certain freedom in adapting the alignment to the traverse terrain.

The stopping distance is the shortest length, in which the driver is able to brake the vehicle on the wet and clean surface of the road, considering terms of allowable slip friction coefficient. Taking this into account, the permissible longitudinal deceleration is 1.5 m / s2, the reaction time is 2.0 s.

On the road with a design speed up to 60 km / h, the braking distance is considerably shorter, taking into account that the reaction time is 1.5 seconds and a longitudinal deceleration is 3.5 m / s2.

The superelevation of the road asphalt outside the settlement is from 2.5% to 7.0%, in some places from 2.5% to 5.0%. The roadway preferably must have a single superelevation, but also crowned cross-sections are used in urban areas. The superelevation of the fixed sand or stone/rock roadway of non-bonded materials is from 4.0% to 10.0%.

The horizontal elements of the axis of the road are: the straight line, the arc or curve and the transition curve (clothoid). The minimum radius of the arc is determined by the design speed and by the rate of road superelevation. The maximum value of clothoid parameter (transition curve) is the same as the radius of the arc Amax = R, in certain cases, it can also be larger, up to 1.77 R. The road with the elements and a design speed of 40 km / h, does not require the use of the transition curve.

In order to ensure the conformity of geometrical elements of the road axis, the technical and aesthetic design conditions must be considered.

The minimum length of the transition curve for the straight-to-curve pass has a size of 0.3 R to R and the same length as the circular arc. The minimum length of the road arch is determined by the path travelled by the vehicle for five seconds at a design speed.

The minimum radius of the vertical curves is adjusted to the design speed.

The width of the lane must be equal to the entire length of the highway, except the tunnel and the development area of the construction within a town.

2.7.3. The United Kingdom

The UK geometric design standards for national roads are set out in the Design Manual for Roads and Bridges, and the lead organization is the Highways Agency, an executive agency of the English Department of Transport. The current the UK standard for alignment is TD9/93, which is based upon principles that were first established in 1981 [13].

For rural roads, the design speed is based upon the actual 85th percentile speed for light vehicles on the wet surface and is determined from the "bendiness," forward visibility (single carriageways only), carriageway and verge widths, the number of access points and junctions of a particular road taken over a minimum distance of 2 km. (Bendiness is a measure of the angle through which the road turns over a distance of 1 km.) It should be mentioned that the

UK uses values for various design parameters (horizontal radius, stopping sight distance, etc.) which give a consistent speed along the road.

For urban roads, the design speed is determined by the appropriate speed limit. The design speed is used to calculate "desirable minimum" values for the various design parameters such as horizontal radius and stopping sight distance. These are the values that produce a high standard of safety and the designer's initial objective should meet desirable minimum values.

In the UK there is a fixed relationship between the 50th percentile, 85th percentile, and the 99th percentile speeds. The design speeds are structured in this way: 85th percentile parameter values for a particular design speed would be appropriate for the 99th percentile speed for the next lower design speed and the 50th percentile speed for the next higher design speed (different like in SLO, IT and SP). For example, the horizontal radius for a 100 km/h design speed would accommodate 99 percent of the traffic if the actual design speed were 85 km/h and 50 percent of the traffic if the actual design speed were 120 km/h.

This structured system of design speeds enables the UK to adopt a flexible approach to design and afford the opportunity to use values below the desirable minimum when doing this would result in significant cost savings and/or environmental benefits and there is no significant effect on safety and operation. The design process is therefore an iterative one.

In the UK, forward visibility (sight distance) is required in two different ways. On both single and dual carriageways, adequate forward visibility is required to enable a driver to see an object on the carriageway and stop safely on the wet surface. On single carriageways, it is necessary to provide lengths of carriageway where a driver can safely overtake (overtaking sections). At the start of these sections, forward visibility will be such that the driver can see vehicles sufficiently far ahead to be able to complete the overtaking manoeuvre (full overtaking [passing] sight distance). Certain horizontal radii can produce situations where forward visibility is unclear to the driver whether it is safe to overtake. The use of such radii is not recommended. Thus on horizontal curves on single carriageways, the driver should either be able to see sufficiently far ahead that is clear and safe to overtake or, alternatively, visibility should be so restricted that he/she will not overtake.

Values of superelevation are determined by the lateral acceleration, which is comfortable to the driver. At desirable minimum values, the driver travelling at design speed experiences a lateral acceleration, which is half the maximum level of comfort. At radii below desirable minimum, the superelevation is increased to an arbitrary maximum and the maximum comfortable acceleration for a driver travelling at design speed is attained when the radius is equivalent to the desirable minimum value for a design speed two steps below the actual design speed. Superelevation at desirable minimum radius is 5 percent; at smaller radii, the superelevation is increased to a maximum of 7 percent.

Transition curves (clothoids) are required to limit the rate of increase of centripetal acceleration when approaching a horizontal curve. Superelevation is applied on or within the transition.

For crest vertical curves, desirable minimum values are determined by the need to provide adequate forward visibility (stopping sight distance) although if values below desirable minimum are to be used, comfort may be a consideration, particularly at lower design speeds.

For sag vertical curves, the values are determined by comfort criteria for design speeds of 85 km/h and above and by headlight visibility (i.e., the distance illuminated by headlamps) for speeds of 70 km/h and below.

Desirable minimum gradients are 3 percent for motorways, 4 percent for other dual carriageways, and 6 percent for single carriageways. Steeper gradients up to 8 percent may be used where consideration has been given to the savings in construction costs compared to the increase in journey times.

2.7.4. Italy

Italian standards are set by Consiglio Nazionale Delle Ricerche [14] and Norme Funzionali e Geometriche Per La Costruzione Dele Strade [15]. The current version is dated 1980. The design speed is determined from the type of road and its cross section. However, rather than set a specified design speed, a speed range, within which the design speed of the various sections (or elements) must fall, is given. The upper limit is the safe speed for a single vehicle within acceptable margins of safety. Therefore, it is possible for different sections of the same road to have different design speeds. This is done to allow the designer a certain freedom in adapting the alignment to the terrain, which is being traversed. The range is limited to ensure that the design speed does not vary much along a road, thus giving a consistent message to the driver, which should lead him/her to behave in a manner forecast by the designer.

Although two successive elements can have different design speeds, the difference must not be so great to create a safety risk. For example, it is not permissible to have an element designed to the maximum permissible design speed followed immediately by one designed to the minimum design speed.

A maximum length of straights, which is based upon design speed, is suggested to maintain the drivers' attention and to ensure that he drives at a speed within the design speed range and to enable the designer to adapt the alignment in hilly and mountainous terrain to meet environmental requirements. When the alignment is predominantly composed of circular and transition curves, it may be necessary to introduce stated minimum length straights to ensure full overtaking sight distance is achieved.

The radius must exceed certain minimum values, which are determined by the length of the adjoining straight. The minimum horizontal radius is also a function of design speed and superelevation (the same function like SP (1)) and primarily derived from safety considerations. Superelevation is applied below certain stated radii and is determined from the horizontal radius and design speed. The amount of superelevation is derived from limiting values of sideways friction, which in turn vary with design speed. The maximum superelevation is 7 percent.

Transition (clothoid) curves must be used between curves of a constant radius and between straights and constant radius curves.

Requirements for sight distance: stopping, overtaking (passing) and decision sight distance are stated. The stopping sight distance is a function of design speed, longitudinal gradient and skidding resistance (which is in itself a function of speed). It includes a perception and reaction time of 1 sec. Two different object heights are used, one for moving objects and a lower one for fixed objects. The overtaking sight distance is notionally derived from design speed, the difference between design speed and the speed of overtaken vehicle and the average length of the two vehicles, but a relationship is given as a function of design speed. A "reduced" distance, which is the half of full overtaking distance, may also be used. The decision sight distance is calculated like a function of design speed as well. the necessary space is evaluated; which lets some time to include the time necessary to perceive and recognize the situation and for the decision and execution of the changeover maneuver of a single lane. On dual carriageways, the requirement for forward visibility is either the stopping sight distance or the reduced overtaking sight distance, whichever is the greatest. On single carriageways (two-lane roadways) forward visibility is twice the stopping sight distance where overtaking is not allowed and the full overtaking sight distance is. Signing is required where overtaking is not allowed.

Crest curve radii are designed to ensure that the relevant requirement for forward visibility is met along the vertical curve. For sag vertical curves, the designer is advised to use radii close to those required for crest curves in exceptional cases, the use of a lower minimum radius will guarantee night time visibility using headlamps is permissible.

Maximum longitudinal gradients depend upon the type of road and range from 5 to 12 percent.

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3. COMPARISON OF DESIGN PARAMETERS AMONG THE ANALYSED COUNTRIES

This section provides a quantitative comparison of selected horizontal and vertical alignment design parameters. Horizontal alignment parameters include maximum superelevation rate, maximum coefficient of side friction, maximum coefficient of longitudinal friction, and the resulting minimum radius of horizontal curves. Vertical alignment parameters include maximum grade and minimum radius of crest (convex) and sag (concave) vertical curves. The data comes either directly from countries' design guidelines or indirectly from reviews of design guidelines [16], [17] .

3.1. Kinds and hierarchy of roads

The road hierarchy categorizes roads according to their functions and capabilities. Although the sources differ in the exact nomenclature, the basic hierarchy includes highways, arterials, collectors and local roads that make it possible to find countries with primary, principal, secondary and local roads.

The related concept of access management aims to provide access to land development while ensuring the flow of traffic freely and safely on surrounding roads.

Most of the Europe as a legal framework based on European and global agreements which define at European / worldwide level three kinds of roads: motorways, fast roads and other roadways. This approach comes from the 20th century and is restricted to traffic code and legal affairs. Actually, each country has its own road hierarchy, although there is also a European road numbering system for European roads.

Most of european countries have taken Motorways (Autoroutes / Avtocesta / Autopistas / Autostrade) generally similar to those in France and the United Kingdom. The idea was first developed in Germany, where all motorways are free of charge and has spread widely. All major routes in the EU and neighbouring countries have a European E-Road number in addition to, or in the case of motorways in some countries, rather than a national number. In the UK, these numbers are not shown.

On the other hand, most other European countries have some ways of distinguishing between national, regional and interregional routes and other local routes. [18]

3.1.1. Slovenian traffic technical roads classification

SLOVENIA						
Road function	**Designation**	**Road type**	**Designation**	**Flat and rolling terrain (km / h)**	**Hilly terrain (km/h)**	**Mountainous terrain (km/h)**
Daljinska cesta	DC	Avtocesta cesta	AC	130	100	80
		Hitra cesta	HC	120	100	70
		Glavna cesta	GC	100	80	60
Povezovalna cesta	PC	Glavna cesta	GC	90	70	60
		Regionalna cesta	RC	80	60	50
Zbirna cesta	ZC	Regionalna cesta	RC	70	50	40
		Lokalna cesta	LC	60	50	40
Dostopna cesta	DP	Lokalna cesta	LC	50	50	Transport.
		Javna pot	LP	40	Transport.	Transport.

Table 3: Kind of Slovenian roads [12]

DC: Daljinska cesta (Long distance road) **PC: Povezovalna cesta** (Connecting road) **ZC: Zbirna cesta** (Collective road) **DP: Dostopna cesta** (Access road)	**AC: Avtocesta cesta** (Motorway road) **HC: Hitra cesta** (Expressway) **GC: Glavna cesta** (Main road) **RC: Regionalna cesta** (Regional road) **LC: Lokalna cesta** (Local road) **LP: Javna pot** (Public paths)

Table 4: Slovenian-English translations of functions and types of roads

3.1.2. Spanish traffic technical roads classification

SPAIN		
Group	**Kind of road**	**Nomenclature (divided by velocities – Km/h)**
Group 1	Autopista / Autovía	A-140, A-130
Group 2	Autopista / Autovía	A-120, A-110, A-100, A-90, A-80 and C-100
Group 3	Convencional	C-90, C-80, C-70, C-50 and C-40

Table 5: Kind of Spanish roads [6]

Autopista: Motorway road
Autovía: Expressway
Convencional: Conventional road

Table 6: Spanish-English translations of kind of roads

3.1.3. Italian traffic technical roads classification

ITALY			
Kind of road	**Group**	**Territorial scope**	**Speed limit**
Autostrada	A	Suburban	130
		Urban	130
Extraurbana Principale	B	Suburban	110
Extraurbana Secondaria	C	Suburban	90
Urbana di Scorrimento	D	Urban	70
Urbana di Quartere	E	Urban	50
Locale	F	Suburban	90
		Urban	50

Table 7: Kind of Italian roads [14]

Autostrada: Motorway / Highway
Extraurbana Principale: Dual carriageway
Extraurbana Secondaria: Secondary extra-urban road
Urbana di Scorrimento: Fast urban road
Urbana di Quartere: Neighborhood urban road
Locale: Local road

Table 8: Italian-English translations of kind of roads

3.1.4. The United Kingdom traffic technical roads classification

THE UNITED KINGDOM			
Classification	**Kind of road**	**Speed limit (Km/h)**	**Territorial scope**
M/A	Motorway	113	Suburban
A	Dual carriageway	113	Suburban
B	Single carriageway	97	Suburban
C/D	Single-track road	97	Suburban / Urban
U	Restricted road	48	Urban

Table 9: Kind of English roads [13]

3.2. Cross Section

Looking at the regulations in the analysed countries, we observe that in terms of dimensions of cross sections there are not too many differences. All cross sections of motorways maintain approximately the same widths of lanes around 3.75m, shoulders around 2.5m in the right side and 0.7m in the left side and central reservation around 3m. The other kinds of roads follow the same philosophy.

DIMENSIONS OF CROSS-SECTIONS (m)					
COMPONENTS / COUNTRIES	**Right/hard shoulder (out)**	**Lane 1**	**Lane 2**	**Left/hard strip (in)**	**Central reservation**
Slovenia	2.5	3.75	3.75	0.5	4
Spain	2.5	3.5	3.5	1/1.5	2/10
Italy	3	3.75	3.75	0.7	2.6
The United Kingdom	3.3	3.65	3.65	0.7	3.1

Table 10: Dimensions of Cross-Sections per country analysed [6], [12], [13], [14]

*Lane 1 is considered the main lane were the users are driving with the lower velocities.

Below it is shown some sketches and some origin tables and figures of every country to see how this topic is represented in each area:

3.2.1. Slovenian dimensions representation:

Vrsta ceste	Projektna hitrost	Vozni pasovi	Robni pasovi	Sirina vozišča	Sirina sr. pasu	Sirina bankine	TPP
Daljinske ceste		PLDP > 15 000voz/dan					
AC	130 km/h	4 x 3,75 m	2 x 0,50 m 2 x 2,50 m	2 x10,50 m	4,00m	2 x 1,00 m	27,00

Table 11: Dimensions of Slovenian Cross Sections of Highway (Avtocesta) [12]

3.2.2. Spanish dimensions representation:

CLASE DE CARRETERA	VELOCIDAD DE PROYECTO (V_p) (km/h)	ANCHO (m)				NIVEL DE SERVICIO MÍNIMO EN LA HORA DE PROYECTO DEL AÑO HORIZONTE
		CARRILES	ARCENES		BERMAS (MÍNIMO)	
			INTERIOR / IZQUIERDO	EXTERIOR / DERECHO		
Autopista y autovía	140, 130 y 120	3,50	1,00 / 1,50	2,50	1,00	C
	110 y 100	3,50	1,00 / 1,50	2,50	1,00	D
	90 y 80	3,50	1,00	2,50	1,00	D

Table 12: Dimensions of Spanish Cross Sections of Highway (Autopista) [6]

3.2.3. Italian dimensions representation:

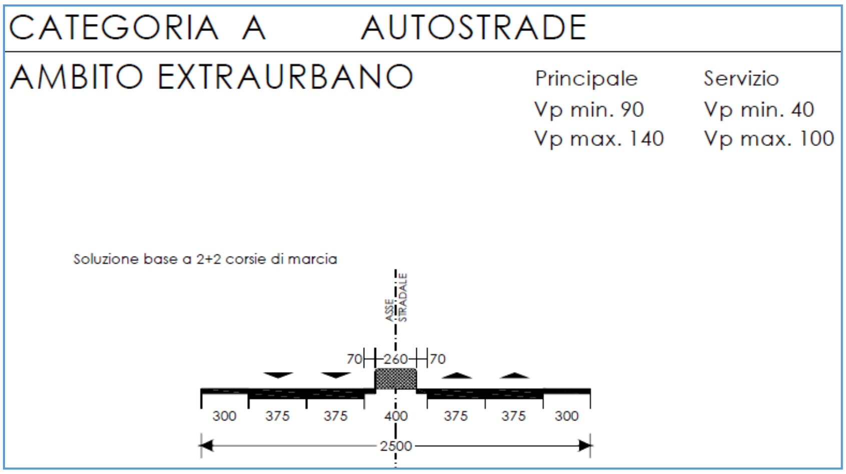

Figure 15: Dimensions of Italian Cross Sections of Highway (Autostrade) [14]

3.2.4. The United Kingdom's dimensions representation:

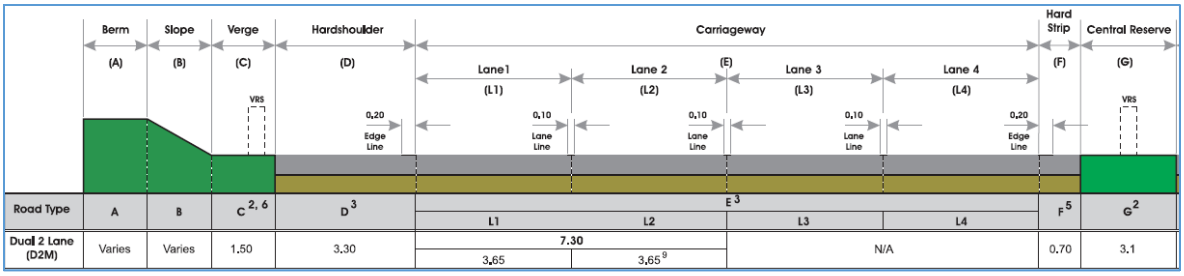

Figure 16: Dimensions of Cross Sections of Highway in the United Kingdom [13]

3.2.5. Maximum Superelevation Rates (Crossfall)

Table 13 summarizes and Figure 17 illustrates the maximum superelevation rate(s) for rural roadways in these 4 countries. Most countries have a single nationwide maximum rate, which is supplemented by a higher rate for exceptional cases. Maximum rates are limited by the risk of stationary vehicles sliding on icy or frozen pavement surfaces. Curious to know that in large countries (e.g., Australia, Canada, and the United States), which have wide ranges of climate, individual States or Provinces may select their own maximum rates, and therefore a range of rates is indicated.

Most countries' normal maximum rate falls within the range from 6 to 8 percent.

Country	Maximum Superelevation Rates (Percent)	Comments
Slovenia	5, 7 %	10% is used only in exceptional cases
Spain	7, 8 %	10% is used only in exceptional cases
Italy	7 %	
The United Kingdom	5, 7 %	5 % is the desirable maximum 7 % is the absolute maximum

Table 13: Maximum Superelevation Rates per country [6], [12], [13], [14]

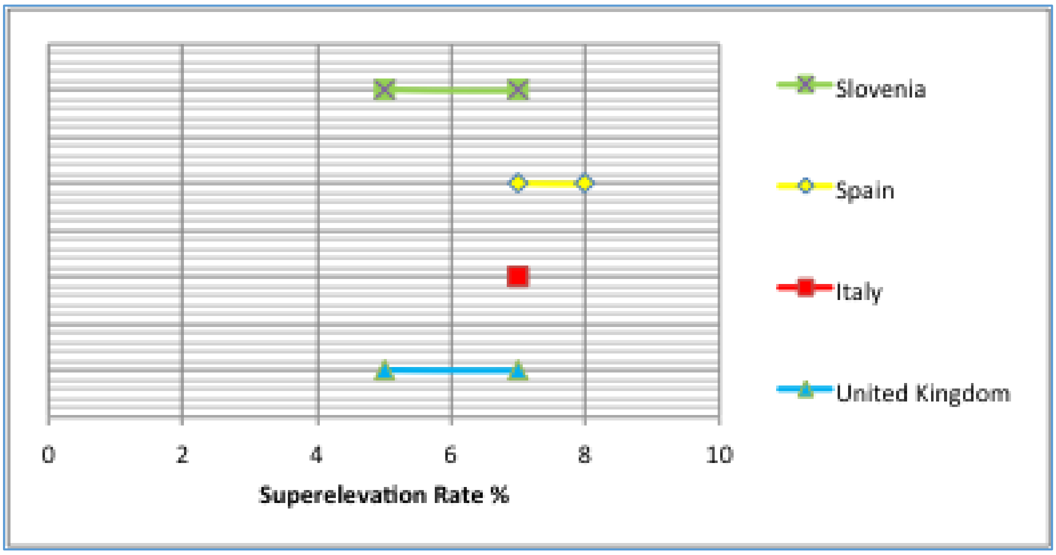

Figure 17: Illustration of superelevation rates (%) [6], [12], [13], [14]

3.3. Horizontal Alignment

3.3.1. Maximum Coefficients of Side Friction

Maximum coefficients of side friction (sideways friction) or lateral acceleration rates are specified for driver safety and/or comfort. Table 14 summarizes and Figure 18 illustrates the maximum coefficients of side friction in the 4 analysed countries. Many countries do not report the used values. Where it was possible, values were calculated from their minimum radius of a given design speed and their maximum superelevation rate. Two groups of values can be observed. Many countries' values range from 0.10-0.21 for a 50 km/h design speed to 0.08-0.10 for a 120 km/h design speed. Some countries use higher values for low design speeds. For example, Slovenia uses values between 0.37 and 0.26 for 50 to 80 km/h roadways; these are the values, based upon their 85th percentile speeds on curves. It is also appreciated, that the values of Slovenia are practically half of the values of the other countries. This is because Slovenia when is applying the formula of the coefficient of side friction allocates 50% for the vehicle-dynamics in curve with maximum rate of superelevation (7%) and the tangential or longitudinal friction 100% is used for stopping. Resulting in the end, the similar coefficients of side friction.

Design Speed (km/h)	Maximum Coefficients of Side Friction (F_t)			
	Slovenia	Spain	Italy	The United Kingdom
50	0.37	0.18	0.21	0.10
60	0.33	0.15	0.17	0.10
70	0.30	0.14		0.10
80	0.26	0.12	0.13	
85				0.10
90	0.23	0.11		
100	0.21	0.10	0.11	0.10
110	0.19	0.09		
120	0.17	0.08	0.10	0.10

Table 14: Coefficients of Side Friction vs. Design Speed [6], [12], [13], [14]

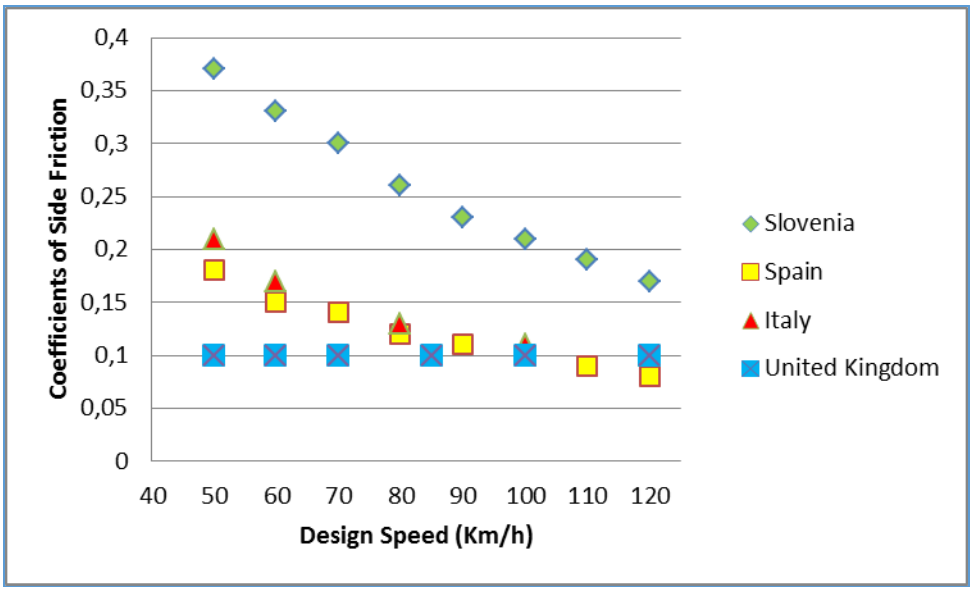

Figure 18: Maximum Coefficients of Side Friction in the analysed countries [6], [12], [13], [14]

The radius deduced from the above expression is the minimum permissible in the design of the circular curve. The systematic use of circular curves with minimum radii will be sufficiently justified.

3.3.2. Minimum Radius of Horizontal Curvature as a Function of Design Speed

Design Speed (km/h)	Minimum Radius (m)			
	Slovenia	Spain	Italy	The United Kingdom
50	75	85	77	127
60	125	130	118	180
70	175	190	178	255
80	250	250	252	
85				360
90	350	350	339	
100	450	450	400	510
110	600	550		
120	750	700	650	720

Table 15: Minimum Radius of Horizontal Curvature vs. Design Speed [6], [12], [13], [14]

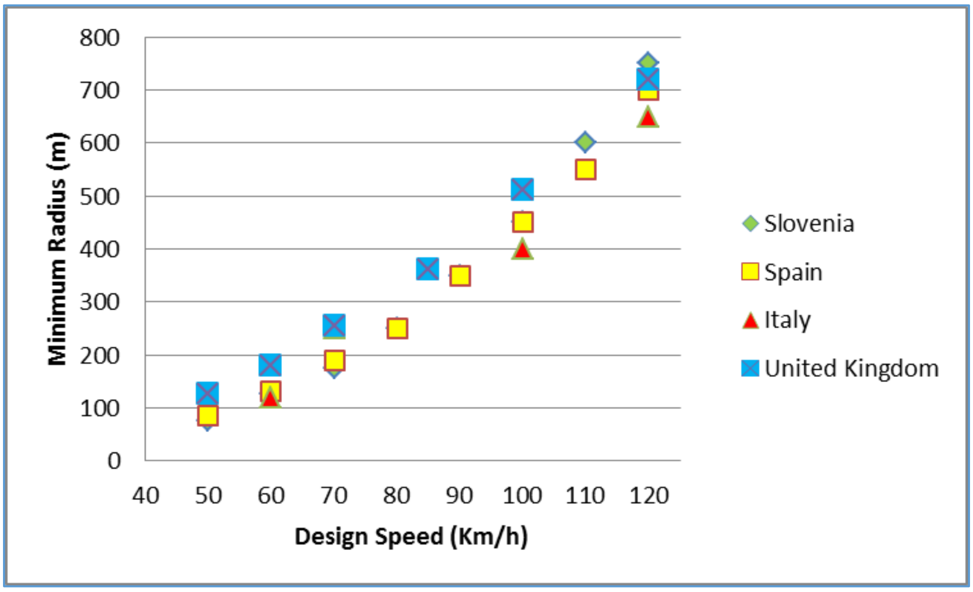

Figure 19: Minimum Radius of Horizontal Curvature vs. Design Speed [6], [12], [13], [14]

Table 15 and Figure 19 summarize minimum radius of horizontal curvature as a function of design speed in these countries. These values are a product of maximum superelevation rates and maximum coefficients of side friction. For a 60 km/h design speed, for example, most countries' minimum radius is between 118 and 130 m. Exceptions include the United Kingdom, whose value is 180 m, based upon lower observed side friction values, observed above. Curious to figure it out that the radius in UK is double oversized to absorb the excess of speed. For a 100 km/h design speed, minimum radius ranges between 400 and 510 m.

3.4. Vertical Alignment

3.4.1. Maximum Gradient

Maximum gradient guidelines range in complexity in various countries considering some or all of the following factors: road type (or functional classification), design speed and terrain. For example, in the United Kingdom, desirable-absolute maximum gradient values are specified for road types: motorway (3-6 percent), dual carriageway (4-8 percent) and single carriageway (6-8 percent).

In Spain, maximum gradient is a function of design speed (from 10 percent for a 50 km/h design speed to 4 percent for a 120 km/h design speed).

In Slovenia, the maximum gradients are not a function of design speed but these gradients depend of road types and the terrain types.

Design Speed (km/h)	Maximum Gradient (%)			
	Slovenia	Spain	Italy	The United Kingdom
50	7	10	10	8
60	7	8	8	8
70	6	8	7	6-8
80	5-6	5-7	7	6
85	5	5-7	6	6
90	4	5-7	6	6
100	3-4	4-5	6	3
110	3	4	5	3
120	3	4	5	3

Table 16: Maximum Gradient vs. Design Speed in the analysed countries [6], [12], [13], [14]

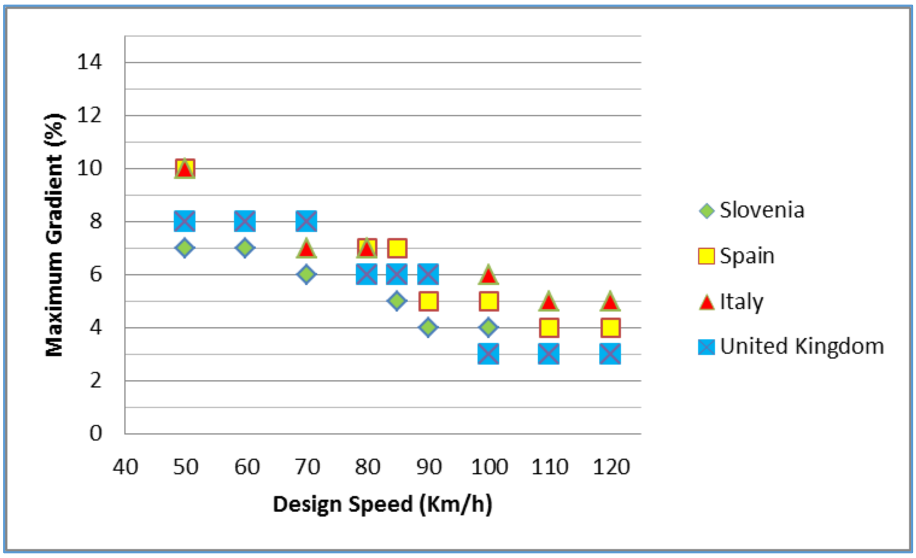

Figure 20: Maximum Gradient vs. Design Speed in the analysed countries [6], [12], [13], [14]

Table 16 and Figure 20 summarize the maximum gradient as a function of design speed in the analysed countries. We can appreciate that in the United Kingdom the values are always inferior to the rest of countries due to its flat orography. On the other hand, Italy, due to its orography, has more adjusted values than the rest of countries as it is a very mountainous country.

3.4.2. Minimum Radius of Crest (Convex) Vertical Curves

Most countries specify the use of parabolic vertical curves. They report a minimum radius for crest vertical curves to satisfy stopping sight distance requirements. This radius corresponds to the K-value multiplied by one hundred times or rate of vertical curvature, which is used in several countries. Table 17 and Figure 21 summarize the minimum radii for various design speeds. For a 60 km/h design speed, the values range from 1000 to 1900 m; for a 100 km/h design speed, the range is from 5200 to 10500 m; and for a 120 km/h design speed, the range is from 11000 to 18500 m.

Design Speed (km/h)	**Minimum Radius (K-Value) of Crest (Convex) Vertical Curvature (m)**			
	Slovenia	**Spain**	**Italy**	**The United Kingdom**
40	800	250	500	
50	1000	450		1100
60	1500	800	1000	1900

70	2000	1400		3300
80	4000	2300	3000	
85				5900
90	6000	3500		
100	9000	5200	7000	10500
110	12000	7600		
120	15000	11000	14000	18500

Table 17: Minimum Radius of Crest Vertical Curvature (Convex K-Value) [6], [12], [13], [14]

*The Kv values of this Table have been obtained for an obstacle height h2 = 0.50 m. (Remember the relation R=100·Kv)

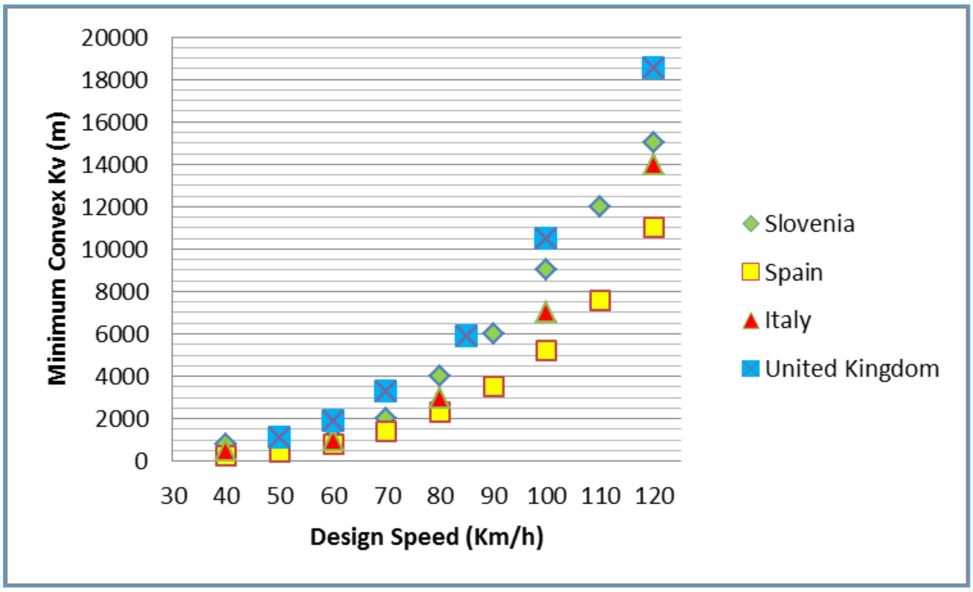

Figure 21: Minimum Radius of Crest Vertical Curvature (Convex K-Value) [6], [12], [13], [14]

3.4.3. Minimum Radius of Sag (Concave) Vertical Curves

Table 18 and Figure 22 summarize the minimum radii of sag (concave) vertical curves for various design speeds. Sag vertical curves are generally considered less critical from a safety standpoint than crest vertical curves. Several different principles are applied as a basis for the design standards. Several countries base their values on headlight illumination distances to satisfy stopping sight distance requirements on unlit roadways at night. Other countries base their design values on driver comfort.

Design Speed (km/h)	Minimum Radius (K-Value) of Sag (Concave) Vertical Curvature (m)			
	Slovenia	Spain	Italy	The United Kingdom
40	600	760	550	
50	750	1160		900
60	1200	1650	1200	1300
70	1500	2300		2000
80	3000	3000	2200	
85				2000
90	4000	3800		
100	6000	4800	3900	2600
110	8000	5900		
120	10000	7100	5800	3700

Table 18: Minimum Radius of Sag Vertical Curvature (Concave K-Value) [6], [12], [13], [14]

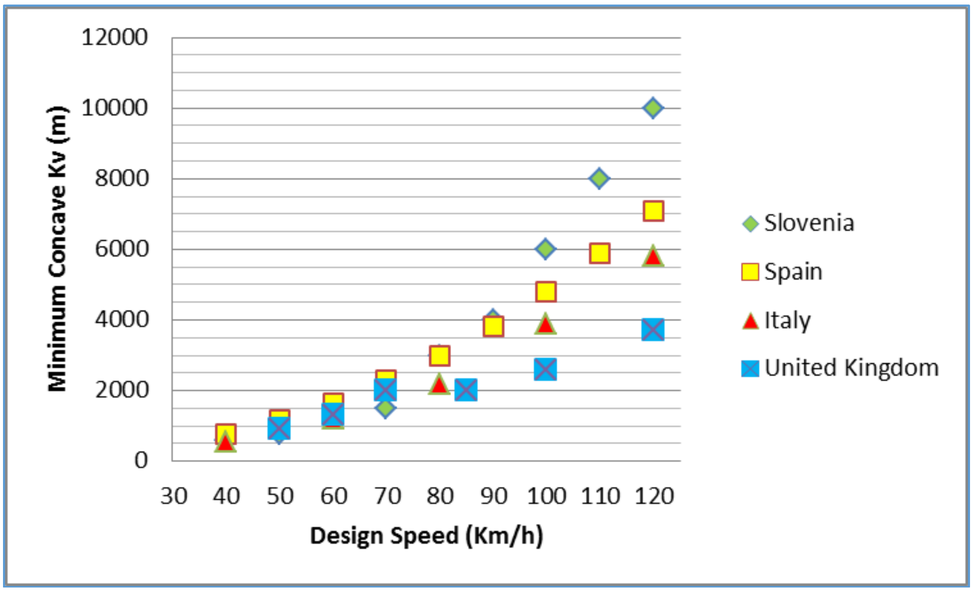

Figure 22: Minimum Radius of Sag Vertical Curvature (Concave K-Value) [6], [12], [13], [14]

3.5. Stopping Sight Distance

The minimum stopping distance is determined as a function of the design speed and the gradient of the road as it is shown in the following tables and figures.

In general, all the analysed countries use the formulation and the following parameters to calculate this distance:

$$Dp = \frac{V \cdot tp}{3{,}6} + \frac{V^2}{254 \cdot (fl + i)} \tag{7}$$

Dp = Stopping distance (m).

V = Speed at the beginning of the braking maneuver (km / h).

fl = Coefficient of longitudinal friction wheel-pavement.

i = Gradient of the slope (by one).

tp = Time of perception and reaction (s). (different from country to country)

For design purposes, the distance obtained from the value of the design speed (Vp) of the section in question shall be considered as a stopping distance.

Even though, to make such comparison, we have taken data of slope 0% in all countries analysed.

Design Speed (km/h)	**Stopping Sight Distance (m) in 0% of slope**			
	Slovenia	**Spain**	**Italy**	**The United Kingdom**
40	30	40	40	
50	45	50	55	50
60	60	70	65	70
70	80	90	90	90
80	105	115	95	
85		130		120
90	130	150	140	
100	165	180	165	160
110	205	220	200	
120	250	260	230	215
130	315	320		
140		375		

Table 19: Stopping Sight Distance (m) per personal vehicle in 0% of slope in the analysed countries [6], [12], [13], [14]

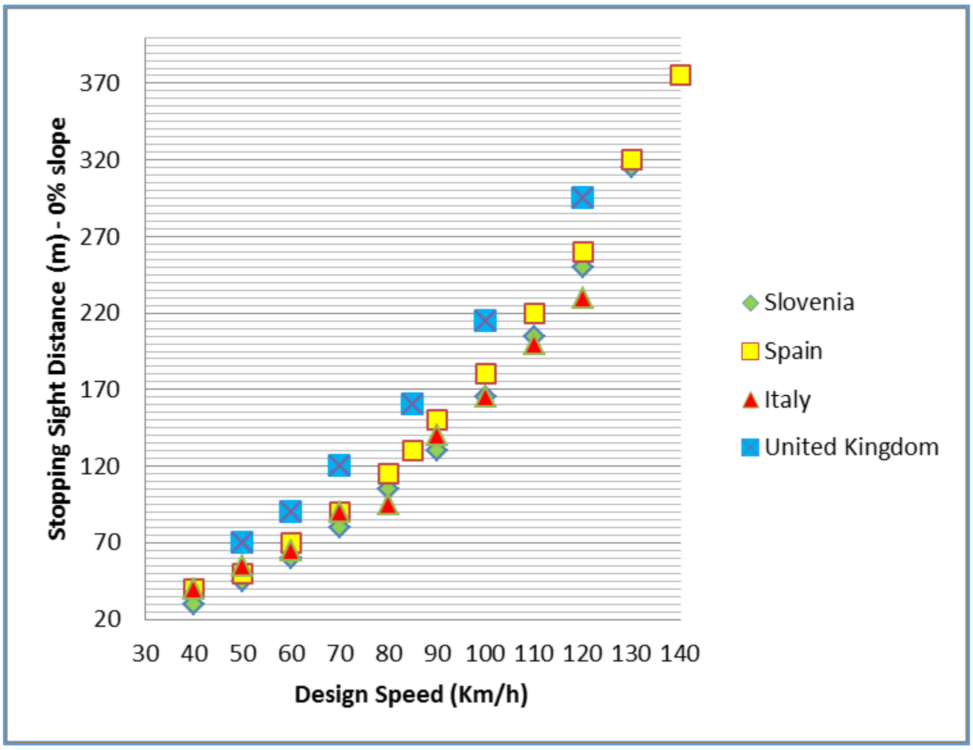

Figure 23: Stopping Sight Distance (m) per personal vehicle in 0% of slope in the analysed countries [6], [12], [13], [14]

Table 19 and Figure 23 summarize the stopping sight distance for various design speeds. We can observe that considering different coefficients of longitudinal friction of each country, we obtain very similar results.

For example, in the next section we found that Slovenia has lower coefficients, so the stopping distance should be higher than the other countries since this distance is inversely proportional to the coefficients (it is shown in the formula (7)). Otherwise, in the Figure 23 we can appreciate that the values are so close in each country; this event is justified since each country use different parameters in the main formula such as "time of perception and reaction".

3.5.1. Maximum Coefficient of Longitudinal Friction

These values of the coefficients of longitudinal friction provide decelerations of the vehicle, comfortable for the user, which must stop, in a controlled manner, the vehicle before an obstacle that is in its path. Table 20 summarizes and Figure 24 illustrates the maximum coefficients of longitudinal friction in the 4 countries analysed. As it is shown we can appreciate that Slovenia keeps the lowest values and Spain has the highest values regarding this parameter, while the United Kingdom shows little variability and Italy remains at the average values.

Design Speed (km/h)	Coefficients of Longitudinal Friction (Fl)			
	Slovenia	Spain	Italy	The United Kingdom
50	0,35	0,41	0,43	0,34
60	0,31	0,39	0,35	0,32
70	0,28	0,37	0,33	0,31
80	0,25	0,35	0,3	0,3
85				
90	0,23	0,33	0,28	0,3
100	0,2	0,32	0,25	0,29
110	0,19	0,31	0,23	0,28
120	0,17	0,29	0,21	0,28

Table 20: Coefficient of Longitudinal Friction in the countries analyzed [6], [12], [13], [14]

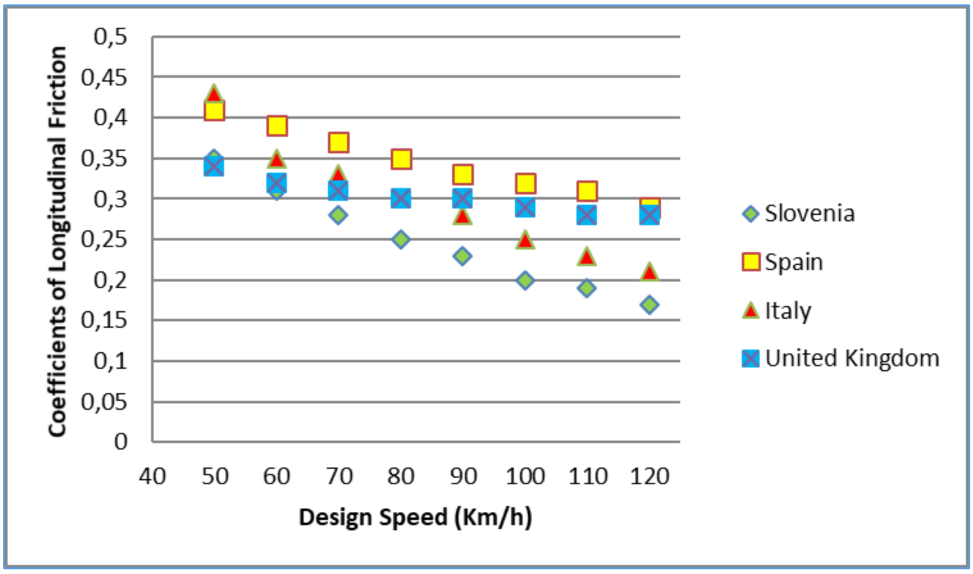

Figure 24: Coefficient of Longitudinal Friction in the countries analyzed [6], [12], [13], [14]

Two groups of values can be observed. Many countries values range from 0.34-0.43 for a 50 km/h design speed to 0.17-0.29 for a 120 km/h design speed. It is appreciated that this parameter use higher values for low design speeds.

Regarding the coefficient of longitudinal friction, we can deduce its variability due to the geographical area where the road is located since according to the country we find parameters that could be different such as:

-Acquisition of aggregates with different natures and granulometries that can affect differently in the asphalt pavement since the microtextures and macrotextures are not equal and these directly affect the coefficient.

-Other interesting factor to take into account would be the weather, because areas with wet climates and water presence, the contact with the tire and the pavement can vary, thus affecting the coefficient of friction and decreasing the grip of the system. Even so, it must be considered that the precipitations also clean the surface of the road so in this sense it would be a beneficial fact.

3.6. General observations about alignment design policy and practice in the analysed countries

This review and comparison of alignment design policies throughout these four countries show some valuable insights. There are much more similarities than differences among the alignment design policies in these countries. As it is expected, several interesting differences and unique approaches are likely to generate additional thoughts and discussions in many countries.

All countries use design speed as a basis to establish limits for basic parameters (e.g., minimum radius of horizontal curvature and maximum vertical grade). A fundamental difference among countries is the speed used to establish other alignment parameters, including superelevation rates, sight distance, and rate (or radius) of vertical curvature. The approach used in these countries presumes that drivers can exceed the design speed and, therefore, formal checks of actual speed behaviour are required. In these countries it is given more formal and explicit consideration of operating speeds and speed consistency among successive alignment features. Although the details vary, these countries estimate operating speeds (typically 85th percentile speeds) or a surrogate for operating speed along the alignment, check for excessive differences between successive features, and iterate to reduce these differences to acceptable levels. They also typically use this operating speed measure (when it is greater than the design speed) for

establishing superelevation rates and sight distance requirements (and corresponding vertical curvature parameters).
The United Kingdom has a structured system of design speeds that are explicitly related to 99th, 85th, and 50th percentile speeds and uses an interactive approach to ensure operating speeds and design speeds are in harmony.

Minimum radius of horizontal curvature for a given design speed varies among countries. This range results from differences in maximum superelevation rates and maximum side friction coefficients (lateral acceleration). Most countries' maximum superelevation rates for rural roadways fall between 7 and 8 percent, but some are as high as 10 percent (or 12 percent for exceptional cases). Countries apply margins of safety to different aspects of their design guidelines. Values for individual parameters must be evaluated within the context of a country's overall design policy, which demands considerable care in making comparisons.

Most, but not all, countries specify superelevation rates for curves with above-minimum radii. Several countries use a linear relationship between superelevation and radius.

A common concern is the relative dimensions of successive horizontal alignment elements. Several countries provide quantitative guidelines on the relationship between the radii of successive horizontal alignment elements. Most countries have guidelines on the radii of compound curves; a ratio of 1.5 to 1 is common.
Other guidelines for the radii of compound curves are related to speed. Italy for example has guidelines on the minimum radii following long tangents.
Most countries require the use of transition curves (clothoids) from tangents to most curves and between successive curves, generally for velocity design greater or equal to 40 km/h. Some countries encourage but do not require the use of transition curves. In most countries, transition curve lengths decrease with increasing radius of the subsequent circular curve.

With respect to vertical alignment, maximum gradient guidelines vary in structure but result in similar maximum values. For higher type roadways (motorways or freeways) with higher design speeds (100-120 km/h), maximum gradients of 3 to 4 percent are typical. For lower type roadways (two-lane or single carriageway) with lower design speeds (60 to 80 km/h), maximum rates of 6 to 8 percent are typical. In several countries, gradients in more rolling and mountainous terrain may be 1 to 2 percent steeper. Vertical curves are typically parabolic in shape. Crest (convex) vertical curve radii (K-values in some countries) is based upon stopping sight distance requirements. Two different criteria for minimum sag (concave) vertical curve radii are prevalent; some countries use stopping sight distance, whereas other countries use less stringent comfort criteria.

For freeways (motorways) and other multilane divided highways (dual carriageways), curvilinear alignments are preferred to conform to the terrain for cost and environmental reasons.

For rural two-lane roadways (single carriageways), some countries call for curvilinear alignments to assure operating speed consistency; whereas other countries place greater emphasis on passing (overtaking), which generally leads to segments with longer tangents (straights).

Several countries (including the United Kingdom) have observed safety problems associated with marginally adequate passing (overtaking) sight distance and have adapted their alignment guidelines to avoid this condition. The United Kingdom avoids certain ranges of horizontal and vertical curve radii, so that passing sight distance is either adequate or clearly inadequate.

Various provisions are made for dealing with exceptional cases. For example, several countries permit higher maximum superelevation rates. Several countries integrate consideration of climbing lanes as an alternative in vertical alignment design to permit go-with-the-ground designs that avoid costly earthwork but maintain desirable traffic operations. The United Kingdom has perhaps the most systematic approach for dealing with departures from standards (design exceptions), wherein a given design speed corresponds to the 85th percentile speed on a roadway with that design speed, the 99th percentile speed on a roadway with the next lower design speed, and the 50th percentile speed on a roadway with the next higher design speed.

As considerations involving impacts on natural and manmade environments become more important, that is why policies deal with exceptions.

Unique combinations of topography, climate, driving behaviour and culture, motor vehicle rules and regulations, vehicle characteristics, and traffic volumes preclude a single set of parameter values or policies working equally well in all countries. In dealing with these issues, however, individual countries can benefit from an understanding and appreciation of the practices and experiences in other countries. An ongoing interchange of ideas, policy evaluations, and research results among countries is recommended.

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4. CASE STUDY OF THE ROAD DESIGN

This chapter provides a road design. This design was carried out by means of Slovenian regulations. Subsequent to the road design example used in comparative analysis, the corresponding regulations of the countries studied were commented on, making comparisons and showing possible parameters that would influence and that would change the design.
Also, all the design was made considering the best studied practices in the previous chapters 2.5 and 2.6, to carry out a road design.

4.1. Area concerned of the Road Design

The proposed design was made for the area that is located around Lake Bled, in Slovenia. It is a by-pass road.
It has been decided to focus on this area because it is a mountainous and flat terrain. In this way, the different parameters involved in the topic of road design are better shown.

This measure also improves the conditions in the residential environment. Bypasses are built specifically to avoid going through an urban area. The measure of constructing bypasses is intended to relieve settlements of traffic transit, especially when problems there cannot be solved by any other measure.

4.1.1. Road Category

The category of road to be built according to future needs and traffic forecast will be next:

- **Road number:** nº209
- **Owner:** The state of Slovenia
- **Functional classification:** Connecting road RC80
- **Terrain:** Rolling
- **Position of road:** Regional rural road

4.1.2. Start/End point (from point A to point B)

The connection starts on the Svobode road at approximately number 51 (point B) and provides its continuity towards the Ljubljanska road number 33 (point A). (Fig.25)

Figure 25: Start and End points of the Variant

4.1.3. Road functionality, typical cross section of roadway

-This road is going to work as a connecting road.

-The design parameters comply the project speed of 80 km/h, the design has as minimum radius 300 m, this means that it would be possible to go faster in these curves. The cross-section consists of one lane for each direction of 3.25m for each lane, shoulders of 0.5 m wide and platform 7/12. (Fig.26)

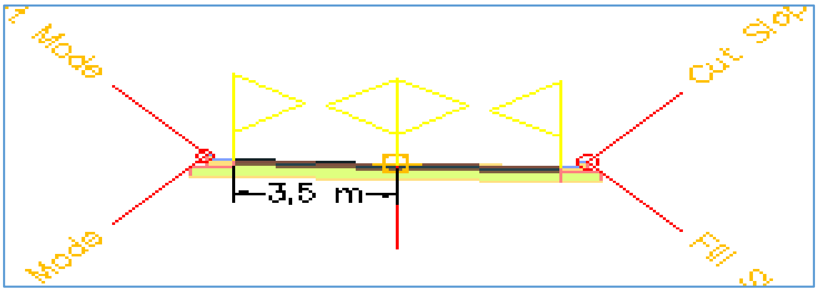

Figure 26: Typical cross-section of the designed road

4.1.4. Road Definition

This Variant is 3.561,14 meters long and it has been made in order to reduce the traffic of the Ljubljanska road as it passes through the interior of the municipality of Bled and also to avoid the rugged terrain in the area, around the city of Bled. Overcoming the massif of the natural park which is more than 550 meters high with the introduction of a tunnel in the KP: from 1 + 210 to 1 + 610 (tunnel 400 meters long). Likewise, we will have to overcome a depression produced by a valley which is more than 30 meters deep located from KP: 0 + 470 to 0 + 590 (bridge 120 m long).

In this way, high slopes are avoided and the required landslides are reduced, thus reducing the cost of construction. Even so, in this work, we will not define the typology of tunnels and bridges.

Figure 27: Top view of the road design with the junctions affected (red points)

4.2. Geometric and Technical Road Elements

4.2.1. Speed

Average travel speed: Vs = 75km/h

Design speed, Vd= 80km/h

The design speed will be taken into account when the geometrical elements of the road axis and the cross section of the roadway have been determined. This speed guarantees safe driving on a wet and clean road. The design speed will be determined according to the traffic and the type of road, and also, according to the type and complexity of the terrain.

4.2.2. Normal and characteristic's cross-section elements

- Traffic lanes, number and widths:

Single carriageway with:

-2x traffic lanes: 3.25m, 2x strip lanes: 0.25m, 2x shoulder (verge): 1.25m, safety width: 1.5m

- Carriageway Edge Elements: Extrawidths, Kerbs, Borders, Safety Barriers, Shoulders, etc.

-Extra widths, borders and Kerbs are not included in this design

-Safety Barriers in external part of the curves.

-Shoulders of 1.25 m wide.

- Embankments

-A slope V/ H = 2:3 has been adopted on embankments

- Bridges/Tunnels

-At the beginning of the variant there will be a bridge to overcome a valley and in the middle of the track there will be a tunnel to cross the mountain of the natural park. (Fig.28).

Bridge: KP = 0+470 – 0+590

Tunnel: KP = 1+210 – 1+610

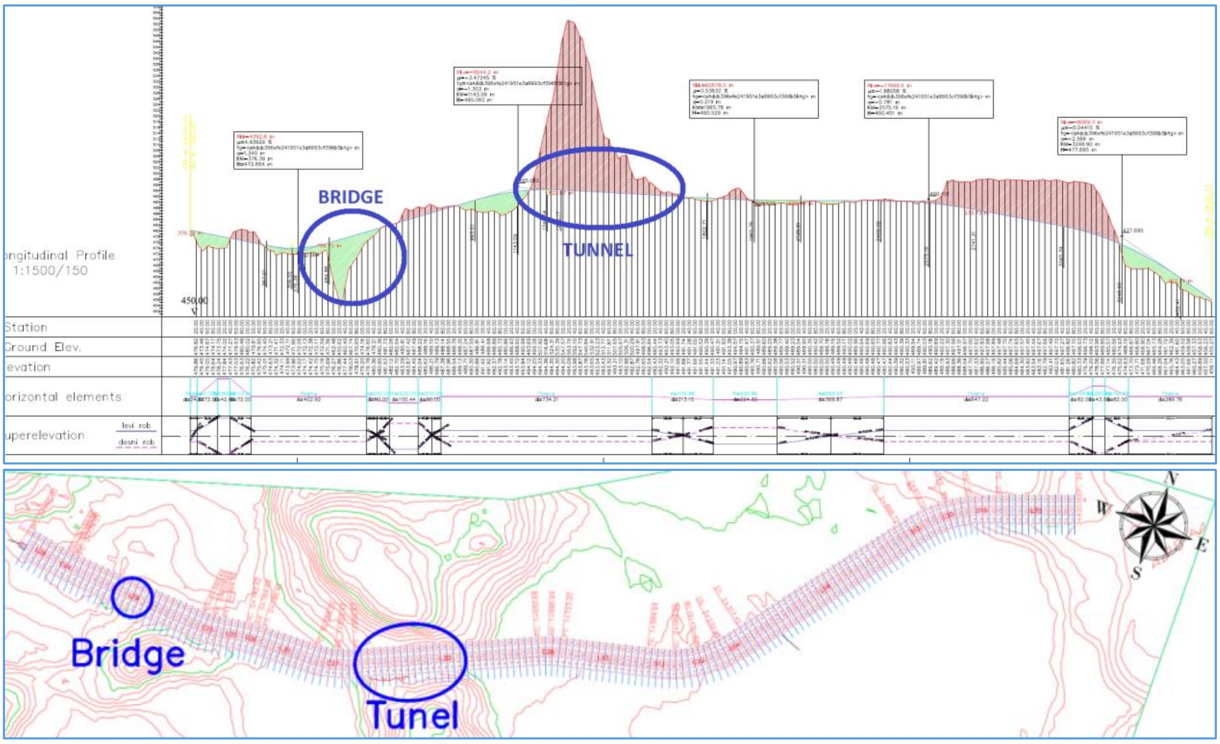

Figure 28: Topography of the area involved, geometry and elements used

- Intersections and access point; secondary roads

-Throughout the bypass, some intersections are introduced at the road level; therefore, other residential streets and secondary roads can run normally. It is contemplated that diverting secondary roads is more expensive than entering ways below the main road or making intersections.

4.2.3. Terrain characteristics

- Type of terrain (flat, hilly, mountainous)

The lake is situated in a picturesque environment, surrounded by mountains and forests. Even so, the variant to be projected crosses agricultural areas with mixed farmland and important areas of vegetation, woodland and semi-natural areas and at its start and end points also passes through urban areas. Therefore, it is flatter than mountainous (rolling terrain).

- Elevations (start, end, an intermediate climbs / downhills)

The elevations are the following ones (Fig.29):

Start: 480,26m

End: 456,03m

Climbs from left to right: 4,93%, 0,54%,

Downhills from left to right: -3,47%, -1,88%, -5,04%

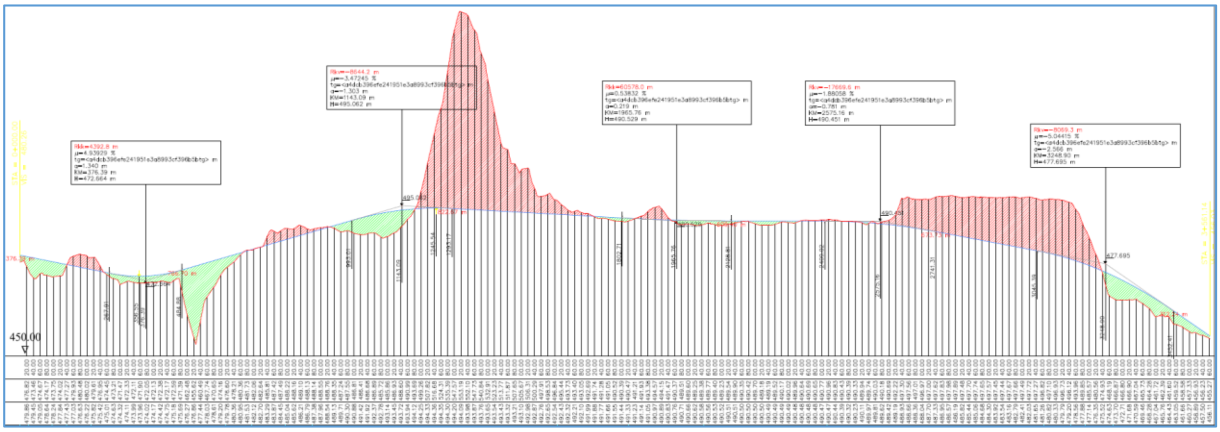

Figure 29: Longitudinal profile of the Variant

To visualize in more detail, the draw of the corresponding longitudinal profile is attached in the annex.

4.3. Elements used in the whole of the road design

Throughout the road, a series of horizontal geometric elements have been used, their characteristics are shown below:

Alignment: Alignment (21)			
Description:			
Tangent Data			
Length:	24.772	Course:	N 61° 01' 45.6942" E
Spiral Curve Data: clothoid			
Length:	72.000	L Tan:	48.101
Radius:	180.000	S Tan:	24.092
Theta:	11° 27' 32.!	P:	1.198
X:	71.713	K:	35.952
Y:	4.786	A:	113.842
Chord:	71.872	Course:	N 64° 50' 52.0213" E
Circular Curve Data			
Delta:	13° 39' 08.!	Type:	RIGHT
Radius:	180.000		
Length:	42.890	Tangent:	21.547
Mid-Ord:	1.276	External:	1.285
Chord:	42.789	Course:	N 79° 18' 53.0809" E
Spiral Curve Data: clothoid			
Length:	72.000	L Tan:	48.101
Radius:	180.000	S Tan:	24.092
Theta:	11° 27' 32.!	P:	1.198
X:	71.713	K:	35.952
Y:	4.786	A:	113.842
Chord:	71.872	Course:	S 86° 13' 05.8595" E
Tangent Data			
Length:	402.922	Course:	S 82° 23' 59.5323" E
Spiral Curve Data: clothoid			
Length:	80.000	L Tan:	53.351
Radius:	500.000	S Tan:	26.683
Theta:	04° 35' 01.:	P:	0.533
X:	79.949	K:	39.991
Y:	2.132	A:	200.000
Chord:	79.977	Course:	S 83° 55' 39.6291" E
Circular Curve Data			
Delta:	11° 30' 35.4	Type:	LEFT
Radius:	500.000		
Length:	100.442	Tangent:	50.391
Mid-Ord:	2.520	External:	2.533
Chord:	100.273	Course:	N 87° 15' 41.5797" E
Spiral Curve Data: clothoid			
Length:	80.000	L Tan:	53.351

Radius:	500.000	S Tan:	26.683
Theta:	04° 35' 01.:	P:	0.533
X:	79.949	K:	39.991
Y:	2.132	A:	200.000
Chord:	79.977	Course:	N 78° 27' 02.7885" E
Tangent Data			
Length:	734.210	Course:	N 76° 55' 22.6917" E
Spiral Curve Data: clothoid			
Length:	213.145	L Tan:	142.193
Radius:	936.857	S Tan:	71.136
Theta:	06° 31' 03.:	P:	2.020
X:	212.870	K:	106.527
Y:	8.075	A:	446.863
Chord:	213.023	Course:	N 74° 45' 02.2875" E
Circular Curve Data			
Delta:	13° 43' 07.!	Type:	LEFT
Radius:	936.857		
Length:	224.319	Tangent:	112.698
Mid-Ord:	6.706	External:	6.754
Chord:	223.783	Course:	N 63° 32' 45.1445" E
Spiral Curve Data: clothoid			
Length:	369.867	L Tan:	247.083
Radius:	936.857	S Tan:	123.748
Theta:	11° 18' 36.:	P:	6.076
X:	368.428	K:	184.693
Y:	24.269	A:	588.653
Chord:	369.227	Course:	N 49° 08' 42.7699" E
Tangent Data			
Length:	647.221	Course:	N 45° 22' 35.1862" E
Spiral Curve Data: clothoid			
Length:	82.000	L Tan:	54.720
Radius:	300.000	S Tan:	27.382
Theta:	07° 49' 49.!	P:	0.933
X:	81.847	K:	40.975
Y:	3.731	A:	156.844
Chord:	81.932	Course:	N 47° 59' 10.2230" E
Circular Curve Data			
Delta:	08° 19' 31.:	Type:	RIGHT
Radius:	300.000		
Length:	43.591	Tangent:	21.834
Mid-Ord:	0.791	External:	0.793
Chord:	43.553	Course:	N 57° 22' 10.3594" E

Spiral Curve Data: clothoid			
Length:	82.000	L Tan:	54.720
Radius:	300.000	S Tan:	27.382
Theta:	07° 49' 49.!	P:	0.933
X:	81.847	K:	40.975
Y:	3.731	A:	156.844
Chord:	81.932	Course:	N 66° 45' 10.4958" E
Tangent Data			
Length:	289.757	Course:	N 69° 21' 45.5326" E

Table 21: Data of the elements in the horizontal alignment designed

4.3.1. Boundary geometric and technical elements

Below it is represented the summary of the basic parameters used throughout the road design:

- horiz. R_{min}(horizontal curve radius)→**R_{min}= 300m**
- horiz. A_{min}, L_{min}(parameter of clothoid and the length of clothoid)
  A_{min} = 113,84 , L_{min} = 72m
- vert. $r_{min\ conv.}$ – for V_d (vertical crest curve radius)→**$r_{min\ conv}$ = 8069,3m**
- vert. $r_{min\ conv.}$ – for $V_{85\%}$→**$r_{min\ conv}$ = 8069,3m**
- vert. $r_{min\ conc.}$(vertical sag curve radius)→**$r_{min\ conc}$ = 4392,8m**
- s_{min}(minimal vertical grade)→**s_{min} = 0,54%**
- s_{max}(maximal vertical grade/inclination)→**s_{max} = 5,04%**
- q_{min}(minimum crossfall or cross-section slope/grade; super elevation)→**2.5%**
- q_{max}(maximum crossfall cross-section slope/grade; super elevation)→**7%**
- P_{stop}(stop sight distance)→**P_{stop} = 105m**

Table 22: Parameters used in our road design, with Slovenian regulations

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5. COMPARISON OF THE ROAD DESIGN WITH STUDIED REGULATIONS

As it was discussed in the previous chapter, subsequent to the design, it is proceed to make the comparison of the regulations of each analysed country showing the possible parameters that would influence and that would change in the corresponding design. We need to take into account that it is not a motorway, the road design is focus on a rural road (single carriageway).

5.1. Differences between nomenclature by kind of designed road

Next table represents the different nomenclature of roads that could be used instead of use the Slovenian standards. It is appreciated that the maximum speeds would vary slightly.

NOMENCLATURE BY KIND OF DESIGNED ROAD	
Slovenian designed road	PC RC 80
Spain	C-80
Italy	C-90
The United Kingdom	B-97

Table 23: Comparative of possible nomenclature of roads used in the design done by different analysed countries.

As we can observe only Italy and the United Kingdom have higher speed limits.

5.2. Differences between dimensions of the cross-section in terms of the considered design

Considering that the proposed design is not a motorway, the differences in the dimensions of the cross-sections are shown below (oversized for a possible future speed increase to 90km/h):

DIMENSIONS OF CROSS-SECTIONS (m) BY DESIGNED ROAD			
COMPONENTS / COUNTRIES	**Lanes**	**Shoulders**	**Min. Shoulders**
Slovenian designed road	3.25	1.25	0.5
Spain	3.5	1.5	1
Italy	3.5	1.25	1.25
The United Kingdom	3.65	1	1

Table 24: Comparative of the dimensions of cross-sections by designed road

Taking into account the dimensions of the other studied countries, we appreciate that all of them are using approximately the same roadway extensions. In the Annex A are analysed the Total Volumes per Cross-Section used in the corridor, to show how the dimensions are influencing.

5.3. Differences between maximum Superelevation rates in terms of the considered design

As we are dealing with a rural road, the maximum values of superelevation may become greater. The following table shows these values:

MAXIMUM SUPERELEVATION RATES BY DESIGNED ROAD	
Slovenian designed road	7% - 10% (exceptional cases) (7% used in the design)
Spain	7% - 10% (exceptional cases)
Italy	7%
The United Kingdom	7%

Table 25: Comparative of the maximum superelevation rates by designed road

In the design realized, Slovenia and Spain have higher values of superelevation in this typology of roads. This is because these countries are using also higher values of coefficients of side friction, which allow getting higher superelevation values. This fact is also noticeable in the radii of curvature, as we shall see below.

5.4. Differences between minimum Radius of horizontal curvature in terms of the considered design

Due to the orography, the distribution of villages, the protected natural parks, the private houses, the natural resources, the infrastructures, etc. the use of small radius is required to adapt the road in the spatial planning, even though this radius is used just to join the new road with the old one. The minimum radius given by regulation is wide enough for this design, even though the bigger radius was used (300 m). Therefore, this means that there is the possibility to go faster in these curves without having safety problems.

Design Speed (km/h)	MINIMUM RADIUS (m) BY DESIGNED ROAD			
	Slovenian designed road	Spain	Italy	The United Kingdom
80	250 (300m used in the design)	250	250	360

Table 26: Comparative of the minimum radius by designed road

As it is mentioned before, due to the lower values of side friction coefficients, the United Kingdom, for example, is using higher values of minimum radius in this kind of roads. This fact is more appreciable on the higher velocity roads

This could be an important point regarding the economic valuation of the project and the lands affected (expropriations) using the United Kingdom rules.

5.5. Differences between maximum gradients in terms of the considered design

The norm reflects gradients between 5-6% using the Slovenian guidelines. In our design we used 5% as higher gradient value. This means that we are in the correct range therefore the road will not have huge slopes even if it is a rural regional road. We are aware that being respecting the gradient values set by regulations it will benefit the levels of pollution maintaining levels of pollutant gases, moreover, it will exist adequate fuel consumption

Design Speed (km/h)	MAXIMUM GRADIENT (%) BY DESIGNED ROAD			
	Slovenian designed road	Spain	Italy	The United Kingdom
80	5-6 (5% used in the design)	5-7	7	6

Table 27: Comparative of the maximum gradient by designed road

As it is shown in the table 27 above, we can observe that Italy has the largest longitudinal gradients due to its more extreme orography contrary to the United Kingdom, where the lowest gradients for the same reasons (flat orography)is not maintained. In the United Kingdom it would be logical to have the lowest values (appreciable in faster roads), even so in this kind of roads it remains in the middle although the trend in the regulations follows the minimum values.

This is due to the probability of having these gradients in some specific cases since they are more isolated roads.

5.6. Differences between minimum radius of crest and sag vertical curves

Regarding the values of minimum radius of crest and sag vertical curvatures, the design has been made with the adequate values that are higher than the minimum designated in the regulations.

Design Speed (km/h)	Minimum Radius (K-Value) of Crest (Convex) Vertical Curvature (m)			
	Slovenian designed road	**Spain**	**Italy**	**The United Kingdom**
80	4000 (8069 used in the design)	2300	3000	5900
Design Speed (km/h)	**Minimum Radius (K-Value) of Sag (Concave) Vertical Curvature (m)**			
	Slovenian designed road	**Spain**	**Italy**	**The United Kingdom**
80	3000 (4393 used in the design)	3000	2200	2000

Table 28: Comparative of the minimum radius of crest and sag vertical curves by designed road

Table 28 shows that the different analysed countries apply different K-Values. These differences are due to the different factors on which the K-Value depends, such as length of the vertical curve, sight distance, the algebraic difference in grades, height of eye/object above the road surface, etc. Indirectly, these factors are affected by the orographies of each country. In summary, it is appreciated that flat countries offer elevated K-Values while countries with more complicated orographies offer smaller K-Values (with exceptions) in order to safe as much as possible land filling and excavation costs.

5.7. Results expected / Advantages-Disadvantages of the different used guidelines

The comparative results are added in a table showing advantages and disadvantages of using one rule or another concerning the geometric design parameters. Focusing the arguments on geometric, environmental, economic, safety and quality aspects to decide which guidelines are more focused on each aspect.
To perform this qualitative analysis, weights were given to each aspect, aforementioned, of every parameter and finally it was made the sum of these.

GUIDELINES USED	ADVANTAGES	DISADVANTAGES	EC	EN	SA	QU
Slovenia	**-Concave K-Value,** highest values: makes the road safer and offer comfortable driving. Also offer more stopping sight distance in the sags.	**-Max. Superelevation,** highest values: driving not much soft. **-Concave K-Value,** highest values: highest costs of land filling and excavation in the sags.	**-1** **-1**	**-1** **-1**	**+1** **+1** **+2**	**-1** **+1** **0**
Spain	**-Convex K-Value,** the lowest values: less costs of land filling and excavation in the crests.	**-Max. Superelevation,** highest values: driving not much soft. **-Convex K-Value,** lowest values: less stopping sight distance and rough and unsafe driving in the crests.	**+1** **+1**	**+1** **+1**	**-1** **-1** **-2**	**-1** **-1** **-2**
Italy	**-Min. Radius of horizontal curvature,** lowest values: makes the road cheaper in terms of lands affected (expropriations) and possibilities to avoid better protected areas. **-Max. Gradients,** highest values: save costs of land filling and excavation.	**-Min. Radius of horizontal curvature,** lowest values: closer curves and driving not much soft nor safety due to the less superelevation. **-Max. Gradients,** highest values: increase in pollutant gases and higher fuel consumption.	**+1** **+1** **+2**	**+1** **+1** **-1** **+1**	**-1** **-1**	**-1** **-1**
The United Kingdom	**-Max. Superelevation,** lowest values: more comfortable and soft driving in the curves. **-Min. Radius of horizontal curvature,** highest values: makes the road safer and offer comfortable driving.	**-Min. Radius of horizontal curvature,** highest values: makes the road more expensive in terms of lands affected (expropriations) and possibilities not to avoid protected areas.	**+1** **-1** **-1** **-1**	**+1** **+1** **-1** **-1** **-1**	**+1** **+1** **+1** **-1** **-1**	**+1** **+1** **+1** **-1**

	-Max. Gradients, lowest values: good levels of pollutant gases and fuel consumption. **-Convex K-Value,** highest values: makes the road safer and offer comfortable driving. Also offer more stopping sight distance in the crests. **-Concave K-Value,** lowest values: less costs of land filling and excavation in the sags.	**-Max. Gradients,** lowest values: highest costs of land filling and excavation. **-Convex K-Value,** highest values: highest costs of land filling and excavation in the crests. **-Concave K-Value,** lowest values: less stopping sight distance and rough and unsafe driving in the sags.	**-2**	**-1**	**+1**	**+2**

Table 29: Advantages and disadvantages per parameter to design roads with the different guidelines

EC: Economic aspect
EN: Environmental aspect
SA: Safety aspect
QU: Quality aspect
-1: Negative punctuation
+1: Positive punctuation

Table 30: Specifications of table 29

Making a valuation and regarding the table of advantages and disadvantages above, it has been possible to verify how the different design parameters influence the different regulations.
These parameters are: Maximum Superelevation, Minimum Radius of horizontal curvature, Maximum Gradients and Minimum Radius of crest and sag vertical curves (taking into account, implicitly, the coefficients of side and longitudinal friction). In each parameter economic criteria, environmental criteria, safety criteria and criteria of quality and comfort were analysed.

Accordingly, the following conclusion has been reached:

- The design standards that puts more emphasis on economic criteria is the Italian regulation.
- The design standards that place more emphasis on environmental criteria are Italian and Spanish regulations.
- The design standards that puts more emphasis on safety criteria is the Slovenian regulation.
- The design standards that puts more emphasis on quality criteria and comfort is English regulation.

If we consider countries with similar orography and similar conditions, these previous assessments may be somewhat distorted, because the United Kingdom, with its flat orography emphasizes geometric designs of softer roads since in this area drivers do not have to overcome this type of obstacles. Therefore, leaving aside the United Kingdom, and focusing on the assessments in Slovenia, Spain and Italy, the results differ in the following:

- The design standards that puts more emphasis on economic criteria is the Italian regulation.
- The design standards that place more emphasis on environmental criteria are Italian and Spanish regulations.
- The design standards that puts more emphasis on safety criteria is the Slovenian regulation.
- The design standards that puts more emphasis on quality criteria and comfort is the Slovenian regulation.

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6. CONCLUSIONS

In general, it was noted that there are many similarities in the principles and philosophies of fundamental alignment design and in the quantitative guidelines on basic road design parameters. These similarities can reinforce the reasonableness of the patterns of countries that fall within the norm of world practice. However, what may be more interesting and important are the differences in emphasis and policy concern that have led to more advanced patterns of certain geometric elements, differences in local conditions and experience that have led to deviations from apparent global norms of certain quantitative patterns. One of the intentions of this thesis is to obtain a vision by understanding the reasons of these differences rather than making judgments about deviations from the norm.

6.1. Specific Conclusions about the real comparison case

Making this design with Slovenian road regulations, it has been proven that the final result differs a bit if this had been done with regulations of the analysed countries.
Then, the possible reasons for variability of the main design parameters used and how these parameters influence the different regulations are concluded.

➢ **Why do design parameters vary between standards?**

- **Maximum superelevation rates:** Slovenia and Spain have higher values of superelevation in this typology of roads **(7%-8% respectively, 10% exceptionally).** This is because these countries are using also higher values of coefficients of side friction, which allow getting higher superelevation values. This fact is also noticeable in the radii of curvature, as we shall see below.
- **Minimum radius of horizontal curvature:** Slovenia, Spain and Italy are in the same position (250m) in this kind of road. The United Kingdom is using higher values due to the lower values of side friction coefficients. This fact is more appreciable in the higher velocity roads.
- **Maximum gradients:** Italy has the largest longitudinal gradients due to its more extreme orography. On the other hand, the United Kingdom would be logical to have the lowest values (appreciable in faster roads) because of its flat orography, nevertheless in this kind of roads it remains in the middle. This is due to the probability of having these gradients in some specific cases since they are more isolated roads.

- **Minimum radius of crest and sag vertical curves:** In this case Slovenia is in the middle referring to the minimum radius of crest vertical curves (the most restrictive criterion) and has the highest values of minimum radius of sag vertical curve. These differences are due to the different factors on which the K-Value depends, such as length of the vertical curve, sight distance, the algebraic difference in grades, height of eye/object above the road surface, etc. Indirectly, these factors are also affected by the orographies of each country. To sum up, we can observe that flat countries offer elevated K-Values while countries with more complicated orographies offer smaller K-Values (with some exceptions).

- **How do design parameters influence different standards?**

Having made an assessment, it is possible to verify how the different design parameters influence the different regulations. These parameters are: Maximum Superelevation, Minimum Radius of horizontal curvature, Maximum Gradients and Minimum Radius of crest and sag vertical curves (taking into account, implicitly, the coefficients of side friction). In each parameter economic criteria, environmental criteria, safety criteria and criteria of quality and comfort were analysed. Taking into account that countries must have similar orography and similar conditions, therefore, leaving aside the United Kingdom, and focusing the assessments in Slovenia, Spain and Italy, the results differ in the following:

- The standard of design that puts more emphasis on economic criteria is the Italian regulation.
- The design standards that place more emphasis on environmental criteria are Italian and Spanish regulations.
- The standard of design that puts more emphasis on safety criteria is the Slovenian regulation.
- The standard of design that puts more emphasis on criteria of quality and comfort is the Slovenian regulation.

- **What will be changed in the road design if we will use different standards?**

The horizontal geometry of the road will be very similar. Where we will see differences will be in the volumes of cut and filling lands. In the Annex A are introduced the Total Volumes that we got using the different cross-section in the same corridor. Also the gradients and superelevations between the different regulations will mark significant differences in these aspects, which will indirectly affect the operating costs of the project.

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7. POVZETEK

Splošno je znano, da je veliko podobnosti med pristopom in osnovnimi principi načrtovanja in projektiranja cest v državah Evropske unije in tudi v svetu. Podobnosti določajo razumevanje smernic določenih držav ne glede na jezik. Podobnosti določajo t.i. splošno oziroma svetovno prakso. Najpomembnejše in najzanimivejše so razlike povezane z izkušnjami, ki so povzročile odstopanja mejnih vrednosti od splošne prakse projektiranja cest. Tako so se po državah nadgradila posamezna poglavja regulative, ki obravnavajo lokalne pogoje družbe in okolja.

Namen magistrske naloge je med drugim pridobiti vpogled in razumevanje razlogov za razlike namesto presojanja odstopanj od omenjenih praks. Ob upoštevanju dokazanih izkušenj Evropske unije so projektne rešitve za rekonstruirane ali novo zgrajene ceste zaradi nepopolnih metod načrtovanja morda neprimerne z vidika obravnavanja prometne varnosti in zagotavljanja ustreznega nivoja usluge. V evropskih državah se pravilom projektiranja cest, še posebej trasiranju, posveča velika pozornost za oblikovanje varne, udobne in funkcionalne ceste. Od projektanta se zahteva uporaba načel prostorskega oblikovanja cestne osi, saj prostorski pogled na kombinacijo cestnih elementov bistveno vpliva na vedenje v vožnji in varnost v cestnem prometu. Iz tega vidika morajo biti cesta oziroma njeni elementi jasni, pravočasno prepoznavni, razumljivi in nedvoumni za uporabnike.

V okviru naloge je pripravljen cestni model, ki je oblikovan na podlagi zahtev slovenske regulative. Rezultat je le nekoliko drugačen kot bi bil, če bi bilo to storjeno s predpisi drugih analiziranih evropskih držav: Španije, Italije in Združenega kraljestva. Iz čistega tehnološkega vidika bi lahko rekli, da bistvenih razlik ni, še posebej če projektant ne izbere minimalnih oziroma mejnih elementov.

Na splošno se predpisi razlikujejo v t.i. dopustnih ali tudi mejnih elementih cestne geometrije, ki so povezani tudi s klasifikacijo ali tipizacijo ceste mreže, ki v večini primerov pogojuje izbor osnovnih parametrov projektiranja cest med katere uvrščamo računsko ali projektno hitrost. Državi, kot sta Slovenija in Španija, uporabljata višje vrednosti koeficienta drsnega trenja, tako v vzdolžni, kakor tudi v prečni smeri. Ta se uporablja za različne namene dimenzioniranja elementov, kjer je prav gotovo zelo pomembna preglednost. Na ta način so opazne razlike med mejnimi vrednostmi horizontalnih, kakor tudi vertikalnih geometrijskih elementov cestne osi. Za minimalni polmer krožne krivine velja, da sta Slovenija in Španija v tem parametru postavljeni med Združenim kraljestvom in Italijo. Kot že omenjeno, Združeno kraljestvo zaradi zahtev po nižji vrednosti koeficienta drsnega trenja v prečni smeri uporablja višje vrednosti minimalnega polmera horizontalne krivine na tovrstnih cestah. Največji dopustni nagib nivelete imata Italija in Slovenija, predvsem na račun raznolike orografije. Še več, Slovenija je edina, kjer je ta raznolikost zapisana kot parameter. V drugih državah je maksimalni nagib nivelete pogojen z izborom projektne hitrosti. Združeno kraljestvo zaradi ravninsko-gričevnate orografije ohranja najnižji dopustni nagib nivelete. Ko govorimo o minimalnem polmeru konveksne vertikalne zaokrožitve Slovenija pri upoštevanju največjega omejevalnega merila spada v sredino. Ima pa najvišje vrednosti minimalnega polmera konkavne vertikalne zaokrožitve rv_min. Ostale države polmer vertikalne krivine prikazujejo kot parameter parabole K, ki računsko nadomešča vertikalno krožno krivino. Ne glede na to kako definiramo vertikalno zaokrožitev je mejna K-vrednost ali rv_min definirana z dolžino vertikalne krivulje oziroma vertikalno preglednostjo, ta pa odvisi od izbora višine očesa voznika in višine ovire (predmeta), algebrske razlike zaporednih vzdolžnih naklonov in projektne hitrosti. Orografija vsake države posredno vpliva tudi na te dejavnike. Če poenostavljeno povzamemo lahko vidimo, da ravninske države ponujajo povišane K-vrednosti, medtem ko države z bolj zapletenimi orografijami ponujajo manjše K-vrednosti. Slovenija je tu izjema.

Na primeru projektiranja oziroma računalniškega modeliranja nove južne obvoznica Bled smo preverili kako različni pogoji vplivajo na izbor cestnih elementov. Ob upoštevanju maksimalnega koeficienta drsnega trenja in projektne hitrosti ter ocene vrste terena so bili po državah definirani naslednji mejni elementi: prečni nagib, minimalni polmer krožne krivine, največji dopustni nagib nivelete ter minimalni polmer konveksne in konkavne vertikalne zaokrožitve. Za vsako državo so izbrani cestni elementi analizirani iz ekonomskega, okoljskega vidika in vidika prometne varnosti ter udobja. Ugotovili smo, da za standard oblikovanja, ki daje večji poudarek ekonomičnosti veljajo italijanski predpisi. Za regulativo, ki bolj poudarijo okoljska merila veljajo italijanski in španski predpisi. Slovenski predpisi veljajo kot referenca, ki daje poudarek varnostnim merilom. Angleški predpisi pa veljajo kot referenca, ki daje večji poudarek merilom kakovosti in udobja. Če upoštevamo dejstvo primerjave, da morajo imeti države podobno orografijo ter podobne pogoje okolja, potem je Združeno kraljestvo izvzeto.

Zato smo se osredotočili na ocene Slovenije, Španije in Italije, kjer se rezultati med seboj razlikujejo v naslednjih pogledih: italijanski predpisi veljajo za standard oblikovanja, kateri daje večji poudarek ekonomiki, lahko bi tudi rekli varčnosti. Za tehnično regulativo, ki bolj poudarja okoljska merila veljajo italijanski in španski predpisi. Slovenski predpisi veljajo za standard oblikovanja, ki daje več poudarka varnostnim merilom in tudi merilom kakovosti in udobja.

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ANNEX A

In this annex, all the sketches of the road design are shown. As it was explained in this thesis before, this part was made by using the software AutoCAD Civil 3D. Below the different sheets are summarized:

- Page 1: Road geometry design and Ortophoto top view from PK: 0+000,00 - 0+880,00
- Page 2: Road geometry design and Ortophoto top view from PK: 0+700,00 - 3+561,00
- Page 3: Road Longitudinal Profile
- Page 4: Typology of the cross-sections
- Page 5: Total Volumes per Cross-Section used

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Fakulteta za gradbeništvo in geodezijo

Jamova 2, 1000 Ljubljana, Slovenija

ŠTUDIJ
PREDMET
MODUL

Seminarska naloga: **Comparative analysis of European technical regulation for road design**

Objekt: **Horizontal Geometry**

	ime in priimek, naziv:	id. štev.:	podpis:	Št. sem. naloge:	XXXXXX
Mentor:	doc. dr. Peter Lipar, univ. dipl. inž. grad.			Datum:	10. 11. 2017
Somentor:	viš. pred. mag. Robert Rijavec, univ. dipl. inž. grad.			Vrsta načrta:	
Kandidat:	Alexandre Donaire Espigares	2620xxxxxx		Vrsta proj. dok.:	
				Merilo:	1:2500

Opis risbe: **Road Geometry Ortophoto Top View**

Del risbe: from km 0+000 to km 1+880

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ŠTUDIJ
PREDMET
MODUL

Seminarska naloga: **Comparative analysis of European technical regulation for road design**

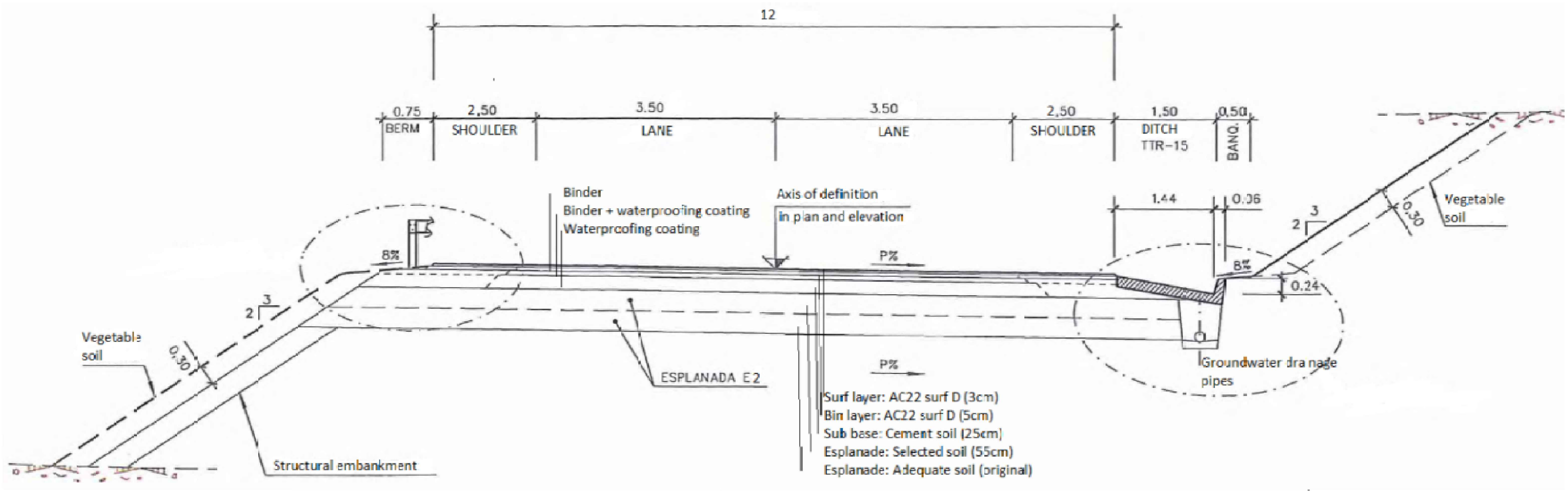
Objekt: **Horizontal Geometry**

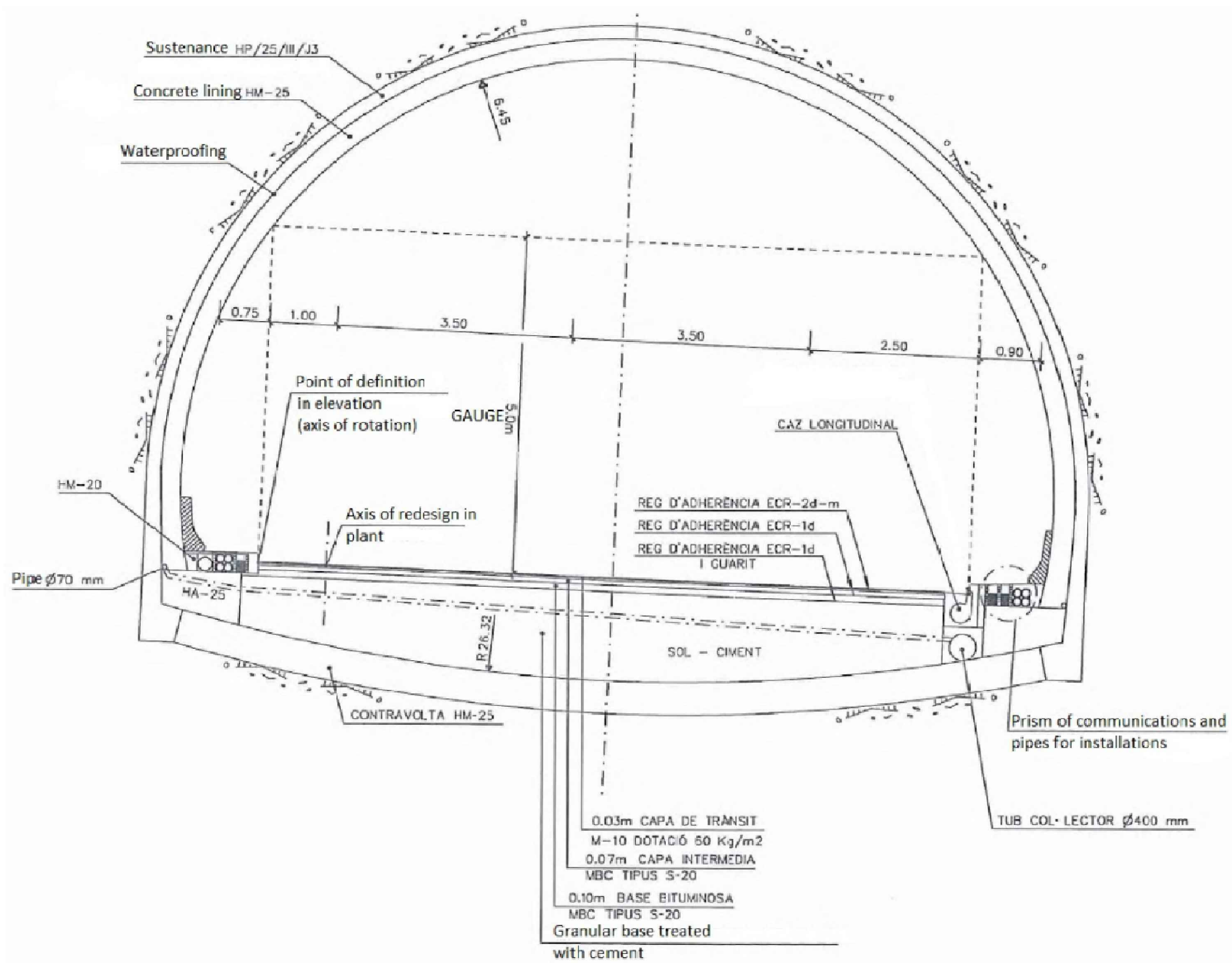
	ime in priimek, naziv:	id. štev.:	podpis:	Št. sem. naloge:	XXXXXX
Mentor:	doc. dr. Peter Lipar, univ. dipl. inž. grad.			Datum:	10.11. 2017
Somentor:	viš. pred. mag. Robert Rijavec, univ. dipl. inž. grad.			Vrsta načrta:	
Kandidat:	Alexandre Donaire Espigares	2620xxxxxx		Vrsta proj. dok.:	
				Merilo:	1:2500

Opis risbe: **Road Geometry Ortophoto Top View**

Del risbe: from km 0+700 to km 3+561

Univerza v Ljubljani Fakulteta za gradbeništvo in geodezijo	Jamova 2, 1000 Ljubljana, Slovenija ŠTUDIJ PREDMET MODUL	Seminarska naloga:	**Comparative analysis of European technical regulation for road design**		
		Objekt:	**Vertical Geometry**		
	ime in priimek, naziv:	id. štev.:	podpis:	Št. sem. naloge:	XXXXXX
Mentor:	doc. dr. Peter Lipar, univ. dipl. inž. grad.			Datum:	10.11.2017
Somentor:	viš. pred. mag. Robert Rijavec, univ. dipl. inž. grad.			Vrsta načrta:	3 - Grad. načrt prometne infrastrukture
Kandidat:	Alexandre Donaire Espigares	2620xxxxxx		Vrsta proj. dok.:	IZ - Idejna zasnova
				Merilo:	
Opis risbe:	**Road Longitudinal Profile**	Del risbe:	from km 0+000 to km 3+561		

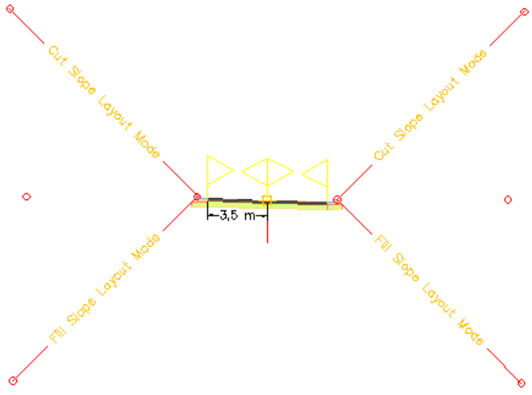




Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo — Jamova 2, 1000 Ljubljana, Slovenia — ŠTUDIJ, PREDMET, MODUL		Seminarska naloga: **Comparative analysis of European technical regulation for road design**			
		Objekt: **Cross-Section Geometry**			
	ime in priimek, naziv:	id. štev.:	podpis:	Št. sem. naloge:	XXXXXX
Mentor:	doc. dr. Peter Lipar, univ. dipl. inž. grad.			Datum:	10. 11. 2017
Somentor:	viš. pred. mag. Robert Rijavec, univ. dipl. inž. grad.			Vrsta načrta:	
Kandidat:	Alexandre Donaire Espigares	2620xxxxxx		Vrsta proj. dok.:	
				Merilo:	
Opis risbe:	**Typology of the cross-sections**	Del risbe:			

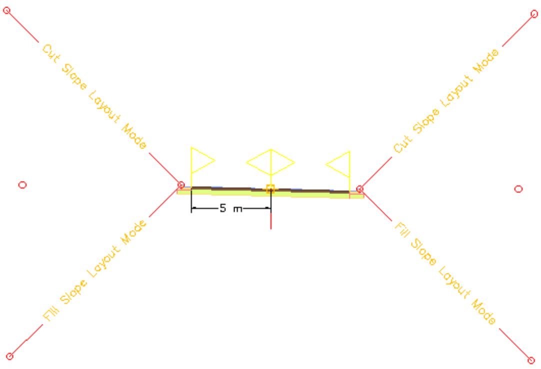
TOTAL VOLUMES PER CROSS SECTION USED IN THE CORRIDOR

SLOVENIA:



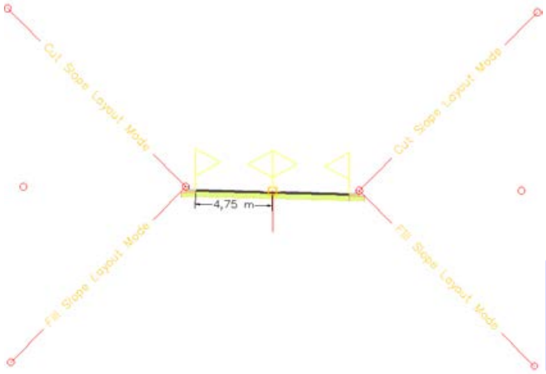
Total Volume Table SLO						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
3+540.00	12.31	0.00	319.21	0.00	71029.51	380567.24
3+560.00	4.55	0.00	162.30	0.00	71191.81	380567.24

SPAIN:



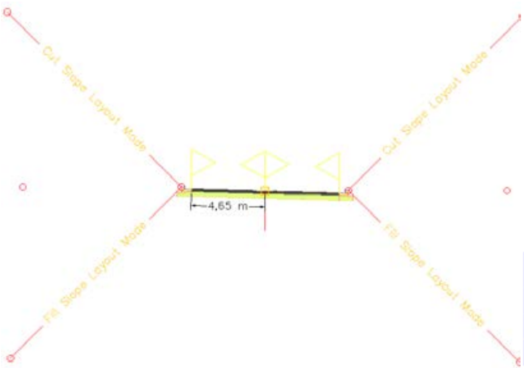
Total Volume Table SP						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
3+540.00	16.34	0.00	410.49	0.00	81640.65	413955.17
3+560.00	5.86	0.00	213.23	0.00	81853.88	413955.17

ITALY:



Total Volume Table IT						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
3+540.00	15.65	0.00	394.89	0.00	79872.96	406409.83
3+560.00	5.64	0.00	204.50	0.00	80077.46	406409.83

THE UNITED KINGDOM:



Total Volume Table UK						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
3+540.00	14.83	0.00	375.54	0.00	77455.72	404064.18
3+560.00	5.59	0.00	196.81	0.00	77652.52	404064.18

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in geodezijo

ALEXANDRE DONAIRE ESPIGARES

PRIMERJALNA ANALIZA EVROPSKIH TEHNIČNIH PREDPISOV O NAČRTOVANJU CEST

MAGISTRSKO DELO

MAGISTRSKI ŠTUDIJSKI PROGRAM DRUGE STOPNJE GRADBENIŠTVO

Ljubljana, 2018