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Identification of safety hazards on existing road network regarding road Geometric Design: Implementation in Greece

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The Concept

The existing National and Rural road network in Greece is more than 15.000Km. Most of these roads were designed and constructed before the first regulations were created and used. Therefore the concept of this project aims to create a large database of geometrical data of the existing National and Rural road network and specify the locations where geometry has critical deviations from existing guidelines and thus constitute potential areas for traffic accidents.

The critical points of the investigation are:

1. Coordinates (X, Y, Z) for every road should be recorded.
2. Geometrical data (horizontal plan, vertical profile, superelevations etc) must be defined.
3. The traffic velocity needs to be estimated. Geometrical data of each road need to be compared with the existing guidelines.
4. The locations where geometry has critical deviations from guidelines must be defined.
5. Areas with poor geometric design elements should be reconsidered in combination with other factors (e.g. pavement condition, sight distance adequacy, object hindrances, driver disturbance, etc).

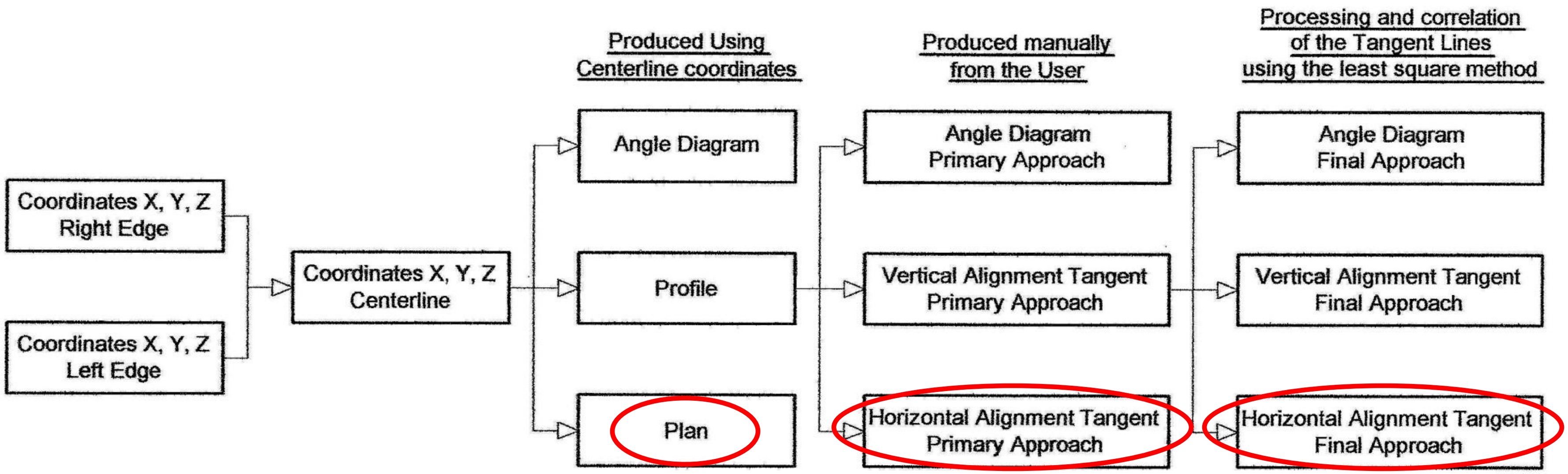
The Research

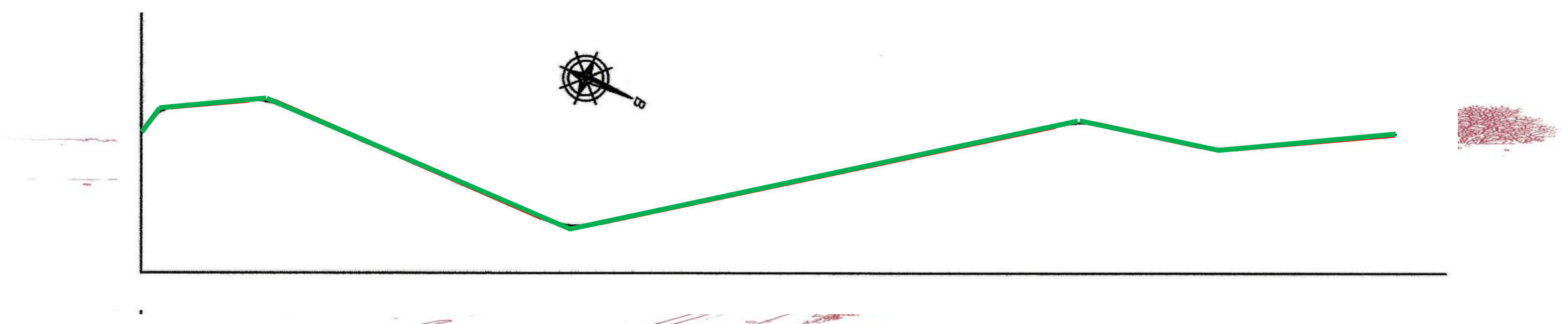
Based on this concept we proceeded to a research program including a large part of National and Rural road network (910Km). The research consists of the following tasks:

1. A GPS supported by IMU unit was placed on the roof of a moving vehicle and was synchronized to record data every 3-5 meters. The vehicle run each road both ways in order to record the right and left sides of the road. The X, Y and Z coordinates of the road centerline was generated as the middle point of the two edges.
2. The alignment (horizontal and vertical) of each road has been evaluated by using a specific software (named H12). Superelevations were not taken into consideration.
3. Posted speed limit was selected to be the design speed. A more realistic approach of the vehicle operating speed should be considered.
4. Geometrical data of each road have been exported and compared with the existing guidelines.
5. The locations where geometry had critical deviations from guidelines were defined. These locations were initially categorized and classified according to their importance and finally those with the greatest severity in relation with road safety were speculated.

Brief presentation of H12 Software (1/2)

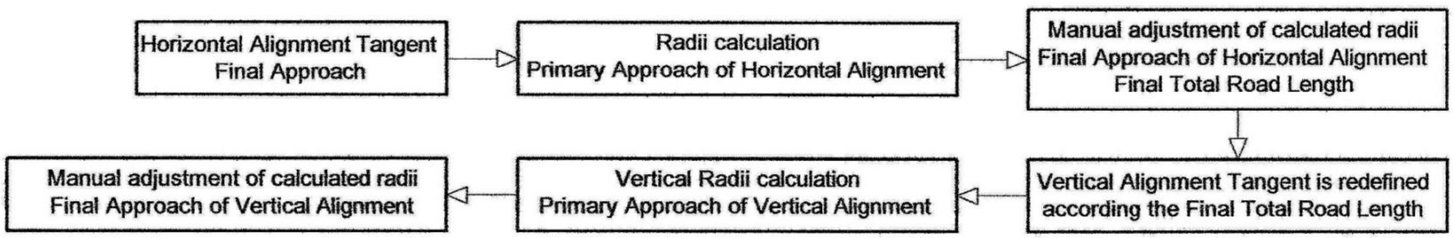
In order to accelerate the data processing, a specific software was developed by a research group within the NTUA, called H12. A flowchart of the software approach is presented in the figure below.

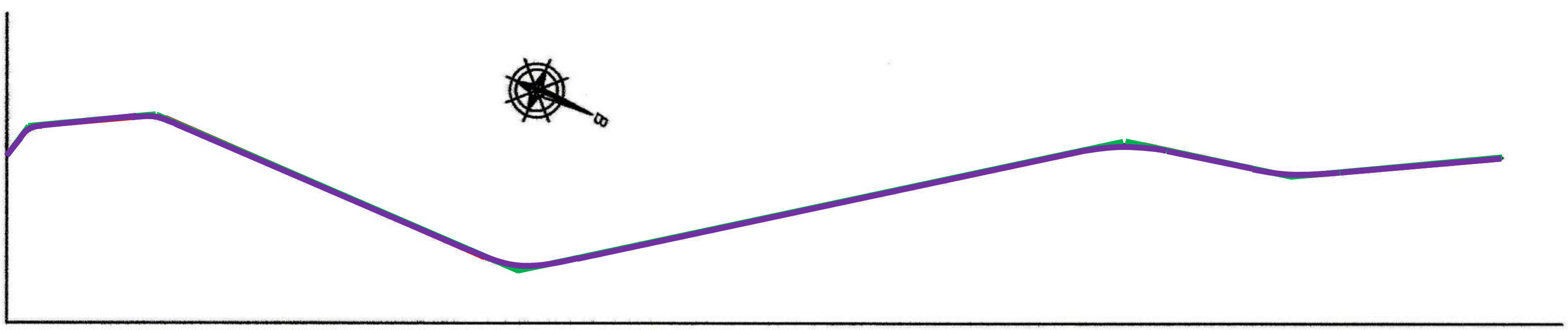




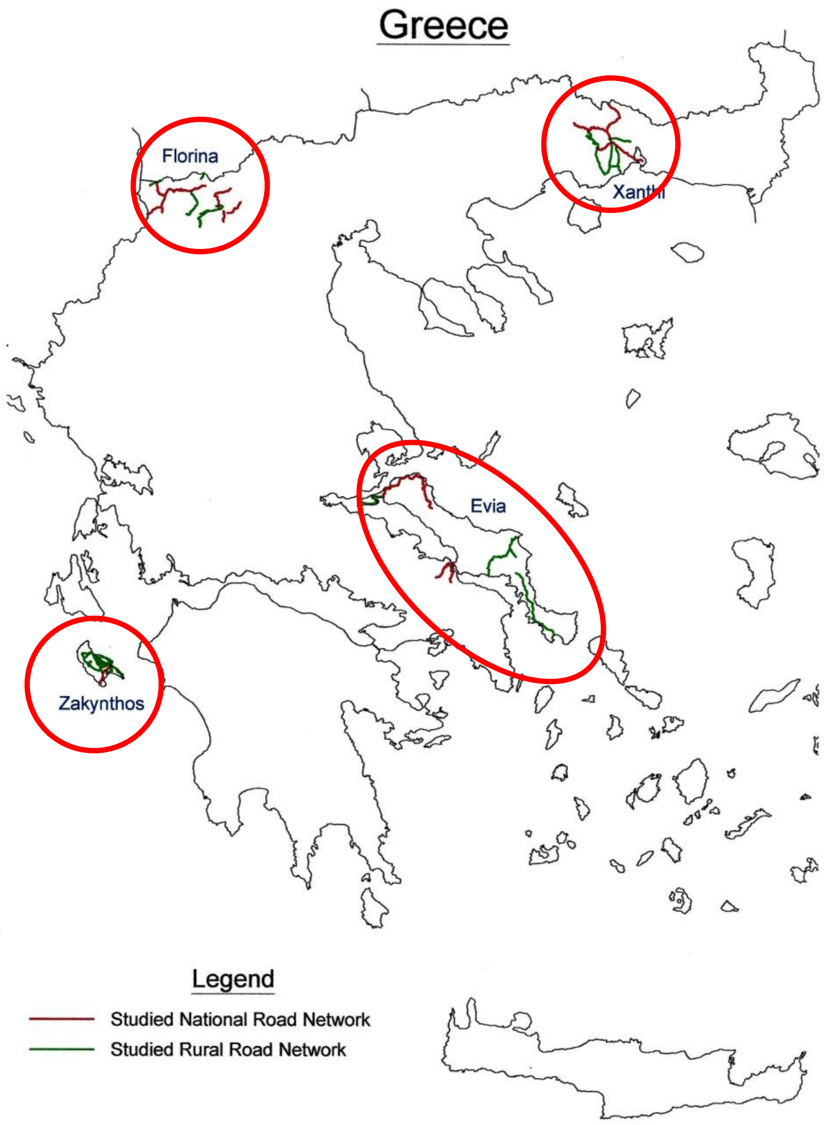
Brief presentation of H12 Software (2/2)

By using the final approaches, we proceed to derive the final horizontal and vertical alignment as follows:





Studied Network



The studied network consists of 910km of National and Rural road network.

Four (4) prefectures were investigated:

1. Evoia (Mountainous Island close to Athens)
2. Xanthi (Flat and mountainous relief)
3. Florina (Mountainous relief)
4. Zakinthos (Island)

Accuracy achieved in estimating plan and profile

The surveillance was made by means of a GPS with IMU and only the road edges were registered. The final geometry produced and the achieved accuracy between geometry and survey is presented below:

Type of road network	National	Rural
Studied length (km)	384,5	528,5
Accuracy in plan (m)	0,24	0,18
Accuracy in profile (m)	0,12	0,09

It should be noted that the centerline coordinates were produced as the geometric mean of the two edges. Therefore the superelevations were not taken into consideration, which produces an error concerning the Z values. This error may be significant in the production of the road profile and may affect the resulting geometry.

Compliance of road geometry with the applicable standards

For each road section the program H12 performs a high number of automated checks, of which the most significant are the following:

1. Horizontal curve radius (H.C.R.)
2. Maximum tangent length (Max. T.L.)
3. Minimum tangent length between curves of same direction (Min T.L.C.)
4. Length of circular arc (L.C.A.)
5. Radii of consecutive curves (R.C.C.)
6. Radii of sag and crest vertical curves (R.S.C.V.C.)
7. Maximum gradient (Max. S)
8. Minimum gradient (Min. S)
9. Minimum length of vertical curves (Min. L.V.C.)

Limits according to the applicable standards

The design parameter limits in respect to the design/posted speed limit are outlined in the following table:

Check ID *			30	40	50	60	70	80	90
			Design Speed / Posted Speed Limit**						
1) H.C.R.		m.	25	40	95	140	200	280	370
2) Max. T.L.		m.	Equal to 20 times the design/posted speed limit (in km/h)						
			600	800	1.000	1.200	1.400	1.600	1.800
3) Min T.L.C.		m.	Equal to 6 times the design/posted speed limit (in km/h)						
			180	240	300	360	420	480	540
4) L.C.A.		m.	Minimum length is equal to the traveled length in 2 sec						
			16,67	22,22	27,78	33,33	38,89	44,44	50,00
5) R.C.C.			According OMOE-X, 2001 edition, Figure 7-4						
6) R.S.C.V.C.	Sag	m.	150	250	1.350	1.900	2.500	3.300	4.200
	Crest	m.	400	450	800	2.000	3.000	4.500	6.200
7) Max. S.		%	13	12	10	9	8	7	7
8) Min. S		%	0,5						
9) Min. L.V.C.			Equal to the double of the design speed / posted speed limit						
		m.	60	80	100	120	140	160	180

* Check ID refers to the above numbering

** Speed 50-90 km/h : According to OMOE-X,
Speed 40 km/h : According to RAS-L (1984),
Speed 30 km/h : According to Greek Guidelines for roads with low design speed

Results after the analysis (National Road Network)

385 Km of National Road Network has been investigated. The results are presented in the table below:

National Road Network		
Check ID *	Number of locations	Incidents/km
1) H.C.R.	312 out of 2.158 **(14,5%)**	0,8
2) Max. T.L.	6 out of 2.178 **(0,3%)**	0,0
3) Min T.L.C.	663 out of 707 **(93,8)**	1,7
4) L.C.A.	87 out of 2.158 **(4,0%)**	0,2
5) R.C.C.	547 out of 2.118 **(25,8%)**	1,4
6) R.S.C.V.C.	350 out of 1.914 **(18,3%)**	0,9
7) Max. S.	22 out of 1.934 **(1,1%)**	0,1
8) Min. S	316 out of 1.934 **(16,3%)**	0,8
9) Min. L.V.C.	1.267 out of 1.914 **(66,2%)**	3,3
TOTAL	**3.385**	**8,8**

In the National Road Network

8,8 locations/km

seem to have deviation from the applicable standards.

Results after the analysis (Rural Road Network)

528 Km of Rural Road Network has been investigated. The results are presented in the table below:

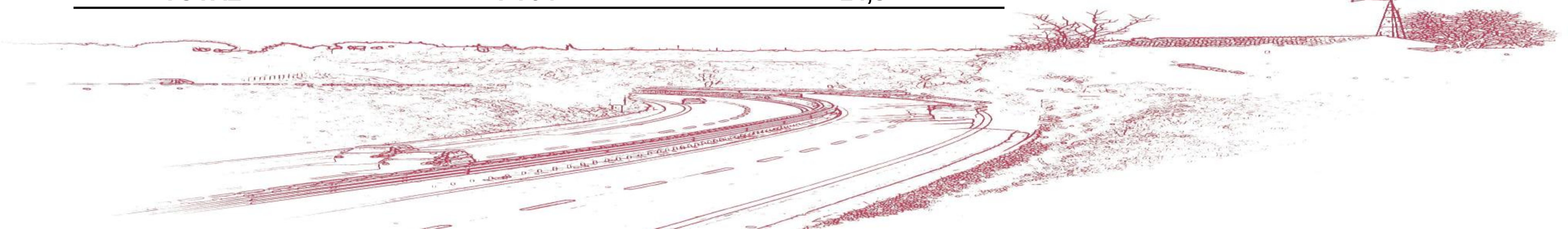
	Rural Road Network	
Check ID *	Number of locations	Incidents/km
1) H.C.R.	814 out of 4.585 **(17,8%)**	1,5
2) Max. T.L.	19 out of 4.620 **(0,4%)**	0,0
3) Min T.L.C.	1.185 out of 1.239 **(95,6%)**	2,2
4) L.C.A.	522 out of 4.585 **(11,4%)**	1,0
5) R.C.C.	1.010 out of 4.515 **(22,4%)**	2,0
6) R.S.C.V.C.	774 out of 3.837 **(20,2%)**	1,5
7) Max. S.	107 out of 3.872 **(2,8%)**	0,2
8) Min. S	566 out of 3.872 **(14,6%)**	1,1
9) Min. L.V.C.	3.101 out of 3.837 **(80,8%)**	5,9
TOTAL	**7.794**	**14,8**

In the Rural Road Network

14,8 locations/km

seem to have deviation from the applicable standards.

Are all of them crucial?
Do all of them have the same severity and importance?



Percentage of deviation (National Road Network)

National Road Network								
Incidents categorized based on the percentage of deviation from the Standards								
Check ID *	< 10%		Between 10% and 40%		Between 40% and70%		>70%	
1) H.C.R.	56	**(17,9%)**	177	**(56,8%)**	74	**(23,7%)**	5	**(1,6%)**
2) Max. T.L.	1	**(16,7%)**	4	**(66,6%)**	1	**(16,7%)**	0	**(0,0%)**
3) Min T.L.C.	7	**(1,1%)**	56	**(8,4%)**	159	**(24,0%)**	441	**(66,5%)**
4) L.C.A.	22	**(25,3%)**	41	**(47,2%)**	19	**(21,8%)**	5	**(5,7%)**
6) R.S.C.V.C.	57	**(16,3%)**	141	**(40,2%)**	114	**(32,6%)**	38	**(10,9%)**
7) Max. S	10	**(45,5%)**	10	**(45,5%)**	1	**(4,5%)**	1	**(4,5%)**
8) Min. S	28	**(8,9%)**	103	**(32,6%)**	92	**(29,1%)**	93	**(29,4%)**
9) Min. L.V.C.	81	**(6,4%)**	358	**(28,3%)**	520	**(41,0%)**	308	**(24,3%)**
TOTAL	262	**(9,2%)**	890	**(31,4%)**	980	**(34,5%)**	706	**(24,9%)**

In the National Road Network

9,2% of locations

seem to be very close to the regulation limits and therefore insignificant.

In 65,9% of locations

the deviation is quite high.

In 24,9% of locations

the deviation is very high.

Percentage of deviation (Rural Road Network)

Rural Road Network

Incidents categorized based on the percentage of deviation from the Standards

Check ID *	< 10%		Between 10% and 40%		Between 40% and 70%		>70%	
1) H.C.R.	145	**(17,8%)**	398	**(48,9%)**	231	**(28,4%)**	40	**(4,9%)**
2) Max. T.L.	3	**(15,8%)**	13	**(68,4%)**	2	**(10,5%)**	1	**(5,3%)**
3) Min T.L.C.	7	**(0.6%)**	57	**(4,8%)**	205	**(17,3%)**	916	**(77,3%)**
4) L.C.A.	140	**(26,8%)**	242	**(46,4%)**	101	**(19,3%)**	39	**(7,5%)**
6) R.S.C.V.C.	97	**(12,5%)**	307	**(39,7%)**	268	**(34,6%)**	102	**(13,2%)**
7) Max. S	48	**(44,9%)**	50	**(46,7%)**	6	**(5,6%)**	3	**(2,8%)**
8) Min. S	43	**(7,6%)**	147	**(26,0%)**	154	**(27,2%)**	222	**(39,2%)**
9) Min. L.V.C.	144	**(4,6%)**	690	**(22,3%)**	1.378	**(44,4%)**	889	**(28,7%)**
TOTAL	627	**(9,2%)**	1.904	**(28,1%)**	2.345	**(34,6%)**	1.908	**(28,1%)**

In the Rural Road Network

9,2% of locations

seem to be very close to the regulation limits and therefore insignificant.

In 62,7% of locations

the deviation is quite high.

In 28,1% of locations

the deviation is very high.

Remarks made for the horizontal alignment

1. The existing road curve radii are not sufficient. (17%)
2. In very few cases the existing tangent lengths are higher than the maximum. (0,5%)
3. The existing tangent lengths between curves of same direction are insufficient. (95%)
4. In few cases the circular curve lengths are smaller than the ones required. (9%)
5. The radii of consecutive curves do not comply with standards. (23%)

Remarks made for the vertical alignment

1. The vertical curve radii are insufficient. (20%) The adequacy of the existing sight distance should be investigated.
2. The maximum gradient is generally below maximum. (2%)
3. There are many areas where the minimum slope is smaller than the minimum required according to the drainage purpose standards. (15%)
4. The length of the vertical curves do not comply with standards. (76%)

Subjects for further research

1. Surveillance of an existing road with such accuracy so as to allow the extraction of superelevation diagram and existing road widenings. Combined checks of horizontal alignment, vertical alignment and superelevation diagram concerning the road safety must be carried out.
2. Surveillance of side hindrances (safety barriers, cut side slopes, etc) to allow checking of the existing stopping sight distance on a wet pavement and the passing sight distance.
3. Collection and processing of more kilometers of road network to extend the database.
4. Interrelating of the outcomes obtained by this project with other factors that affect road safety, such as pavement condition, drainage control, safety barriers, signage, etc., as well as with actual traffic accident data.

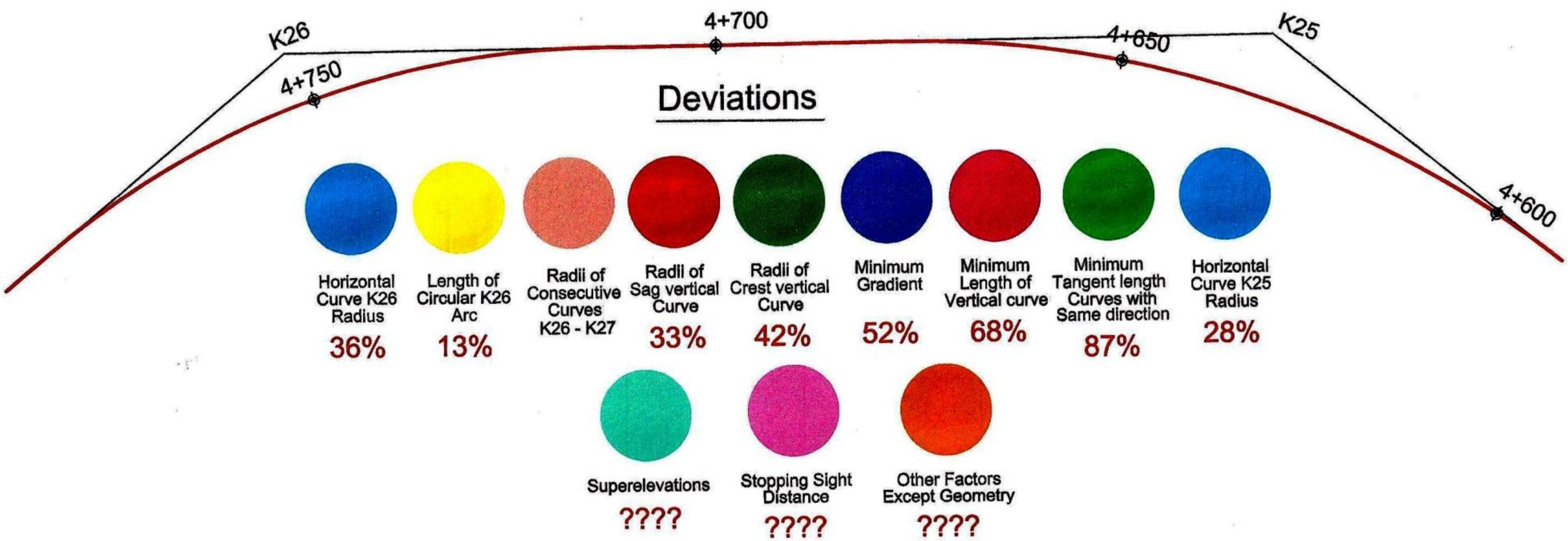
Discussion

1. The X, Y, Z coordinates of the road centerline in this project were generated by the geometric mean of the road edges. Therefore the superelevations were not taken into consideration, which produces an error concerning the Z values. This is particularly important especially to the production of the road profile which may include a considerable error. For this reason it is desirable to obtain the road centerline data directly.
2. The design speed used for the checking of road geometry was the posted speed limit. A more realistic approach could be the vehicles' operating speed. The 85 percentile (V_{85}) provides a good approach of this speed, however this should be estimated.
3. It is essential to conduct further research to determine the degree of importance of each parameter, allowing better and more accurate evaluation of road safety.

Closing…

There are a lot of locations where geometrical elements are strongly deviating from the applicable standards. These, may constitute potential areas for traffic accident… Maybe not…But…

How would you feel when you drive in the following area???



Thank You!!!