STUDY OF DRIVER BEHAVIOUR ON THE ROADS OF THE PROVINCE OF UDINE (ITALY)

M. BORDIN
Civil Engineering Department, University of Udine, Italy
mario.bordin@dic.uniud.it

ABSTRACT

An extensive research was carried out during 2001 on the roads of the Province of Udine (Friuli-Venezia Giulia Region, Italy), to examine the relationship between driver behaviour and the geometrical characteristics of the road layout. Among the roads under consideration, this paper describes Provincial Road 49, the *Osovana.*

The analysis of the road was carried out by checking whether its geometrical characteristics corresponded to the design standards and by constructing speed diagrams. A hidden camera was employed to record the trajectories described by vehicles and speeds: specific attention was given to the examination of manoeuvres executed by drivers when approaching a bend.

The research showed that drivers tend to regulate speed in relation to the road characteristics on the whole, adapting with difficulty to the presence of sections that require lower speeds.

At the conclusion of the study, general criteria and recommendations were obtained, aimed at evaluating the safety both of existing roads and of new roads.

KEY WORDS

DRIVER / TRAJECTORY / SPEED / CURVE / SAFETY

1. INTRODUCTION

In 2001, on the basis of a convention stipulated between the Province of Udine and the University of Udine, a “Study of Driver Behaviour on the Roads of the Province for Analysis of the Geometrical Characteristics and Safety of Road Layout” was carried out under the scientific responsibility of the writer.

This paper will present the results of the study of Provincial Road 49, the *Osovana* (S.P. N. 49), a two-lane interurban road about 20 kilometres long connecting Udine to the Rivoli di Osoppo industrial area northwards.

The most significant traffic datum is the AADT recorded at the locality of Feletto Umberto in the 1998/99 road use survey, 6,459 vehicles per day, 9% of which heavy vehicles.

Figure 1 represents the road and shows the section to be examined below, in which there is a high accident rate (§ 4).

2. ANALYSIS OF THE LAYOUT OF THE S.P. N. 49 *OSOVANA*

The layout of the S.P. N. 49 *Osovana*, obtained from the regional technical map, was examined in comparison with the rules of composition of road axis fixed by design standards (C.N.R., 1980; Ministero delle Infrastrutture e dei Trasporti, 2001).

Design standards define the proportions to be observed by the different elements making up the road axis, among which in particular the ratio between successive circular curves and the ratio between the length of a straight stretch and the radius of the next curves.

It was found that the layout consisted of straight stretches and circular curves, without the interposition of transition curves.
Among other results, in the section examined (§ 4) the radius of the last curve was found to be too small in proportion to the length of the straight stretch that followed it northwards.

Figure 1 – S.P. N. 49 *Osovana* (**–**) and the section examined (**O**).

A diagram showing design speed, operating speed (V_{85}) and speed limits was drawn up for the entire road.
Operating speed was calculated with the formula (R. Lamm et al., 1999):

$$V_{85} = 8.549 \cdot 10^{-21} \cdot CCR_S{}^6 - 2.446 \cdot 10^{-16} \cdot CCR_S{}^5 + 2.748 \cdot 10^{-12} \cdot CCR_S{}^4 -$$

$$- 1.540 \cdot 10^{-8} \cdot CCR_S{}^3 + 4.620 \cdot 10^{-5} \cdot CCR_S{}^2 - 0.0784 \cdot CCR_S{}^2 + 101.8;$$

where CCR_S (Curvature Change Rate of the Single Curve) is defined as follows:

$$CCRs = \frac{\frac{L_{c11}}{2R} + \frac{L_{cr}}{R} + \frac{L_{c12}}{2R}}{L} \cdot \frac{200}{p} \cdot 10^3 .$$

CCR_S is expressed in gon/km, L_{c11}, L_{c12} are the lengths of the clothoids (m), L_{cr} is the length (m) and R the radius (m) of the circular curve (m), L (km) = L_{c11}+L_{c12}+ L_{cr}.
A significant difference was observed between design speed and operating speed.

3. STUDY OF DRIVER BEHAVIOUR

The elements representing driver behaviour, vehicle trajectories and speeds, were recorded by means of a hidden video-camera.
Particular attention was paid to vehicle trajectories on curves, since, as the driver passes from a straight stretch to a circular curve (or from one curve to another) in the absence of a transition curve, he turns the wheel gradually, describing a variable radius curve assimilable to a clothoid, named a *"spontaneous clothoid"* (Bordin & Stefanutti, 2000).
Analysis of the trajectories determines the length (Λ) of the clothoid and the *sideways displacement* (Ψ) of the vehicle in the passage from straight stretch to curve and vice versa. The *lateral distance* (Δ) is the distance between the trajectory and the lane axis.
Safety is evaluated in terms of speed safety coefficient (ssc), which is the ratio between speed at stability limit (V_{st}) and vehicle speed (V):

$$ssc = \frac{V_{st}}{V}.$$

Speed at stability limit is calculated with the following expression:

$$V_{st} = \sqrt{\frac{127.138\,R\,(f_R + tga)}{1 + f_R\,tga}};$$

in which:

$$f_R = 1.016 - 0.09995 \log V,$$

side friction factor on dry pavement surface (AASHTO, 1994).

4. S. P. N. 49 *OSOVANA* – S-CURVE NEAR THE *OSTERIA "AL CACCIATORE"*

This section near the *Osteria "al Cacciatore"* (figure 2) comprises two curves with opposing curvature, wich are linked by a short straigth stretch.

From south to north, the curve to the south has a radius of 180 m and is developed over 95.10 m, preceded by a straight stretch 71.80 m long; it is followed by a short straight stretch (64.30 m long). The curve to the north has a radius of 200 m and is developed over 94.10 m; it is followed by a straight stretch of 1,015 m, along which vehicles run very fast. The speed of the vehicles coming from the north generally remains high in spite of the 70 km/h limit, and accidents are frequent. The lanes are 2.90 m wide and the hard shoulder 0.40 m wide.

Figure 2 – The s-curve near the *Osteria "al Cacciatore"*.

Trajectory and speed surveys T3 and T4 were made (figure 3).

Figure 4 shows the vehicle trajectories recorded for section T4; tables 1 and 2 show the significant values of the geometric and dynamic parameters. In the results in T4 it is seen that average speeds (V_m) and operating speeds in the two directions are perceptibly different: for passenger cars, northwards the results are V_m=70,9 km/h and V_{85}=81,6 km/h, southwards V_m=79,9 km/h and V_{85}=87,5 km/h, which highlights how speed is related to the overall geometry of the road.

One action that could be taken is to re-design the s-curve, describing two curves with a radius of 300 m (instead of the present 200 m), which would constitute a connection between the easy section to the north and the bending section to the south.

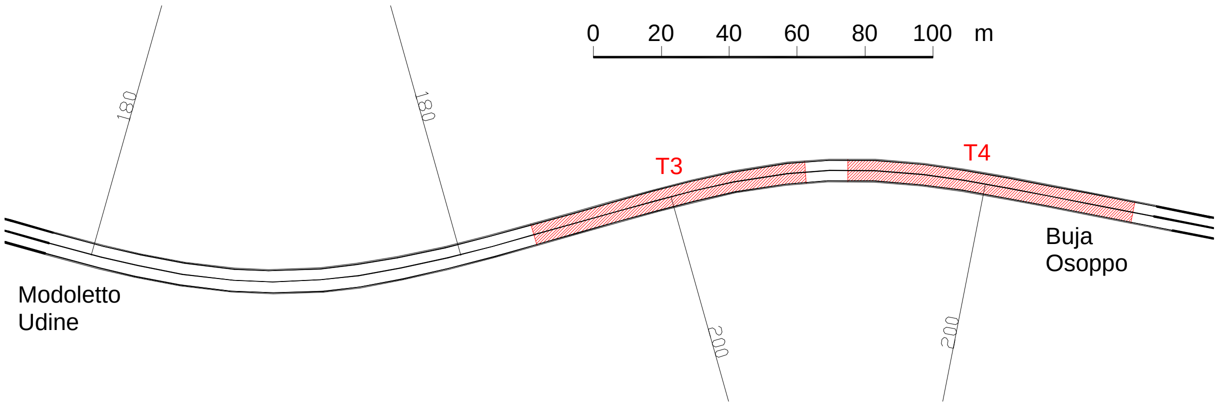

Figure 3 – Surveys made in the s-curve near the *Osteria “al Cacciatore”*.

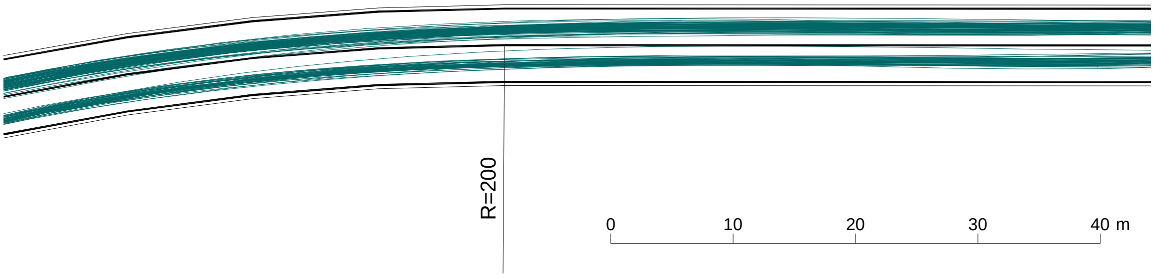

Figure 4 – Distribution of trajectories in section T4.

Table 1 – Vehicle speeds and safety coefficients.

Direction	Speed - passenger cars		Speed - all vehicles		Safety coefficient	
North	Vm (km/h)	**70.9**	Vm (km/h)	**65.6**	ssc, average	**1.97**
	St. Dev. (km/h)	10.4	St. Dev. (km/h)	14.2	St. Dev.	0.57
	V85 (km/h)	81.6	V85 (km/h)	80.3	α	11.97
					β	0.16
					ssc15	1.39
South	Vm (km/h)	**79.9**	Vm (km/h)	**78.2**	ssc, average	**1.55**
	St. Dev. (km/h)	7.4	St. Dev. (km/h)	8.4	St. Dev.	0.17
	V85 (km/h)	87.5	V85 (km/h)	86.9	α	82.51
					β	0.02
					ssc15	1.37

Table 2 – Vehicle trajectories parameters.

Direction	Transition length		Sideways displacement		Lateral distance	
North	Λ, average (m)	**53.0**	Ψ, average (m)	**0.63**	Δmax, average (m)	**0.62**
	St. Dev. (m)	14.4	St. Dev. (m)	0.34	St. Dev. (m)	0.34
	Λ85 (m)	67.9	α	3.38	Δmax85 (m)	0.97
			β	0.19		
			Ψ85 (m)	0.97		
South	Λ, average (m)	**64.1**	Ψ, average (m)	**0.87**	Δmin, average (m)	**-0.69**
	St. Dev. (m)	8.9	St. Dev. (m)	0.24	St. Dev. (m)	0.30
	Λ85 (m)	73.4	α	13.68	Δmin15 (m)	-0.99
			β	0.06		
			Ψ85 (m)	1.12		

It was also seen that there are important variations in the width of the carriageway along the route: it is advisable, also in view of the volume of traffic, to make the whole road conform to the C1 type (secondary interurban road) consisting of two lanes 3.75 m wide and hard shoulders 1.50 m wide, with design speed interval 60-100 km/h.

5. CONCLUSIONS

The results of this research enable it to be said that there are very often two immediately recognisable tendences in driver behaviour.
The first, which could be defined as *”driver inertia”*, consists in the fact that the great majority of drivers prefer to go at as uniform a speed as possible and do not like slowdowns imposed by the road layout or by traffic. The consequence is that if, among sections of road that can be covered at a certain speed, there is a feature requiring a notable reduction in speed (the classical example is a tight curve after a long straight stretch), drivers will tend to maintain a high speed.
The second might be called *”driver expectation”:* a driver going along an easy section of road expects the road, in the section that follows and that he cannot see, to maintain similar characteristics to the previous section.
These tendencies clearly emerged from the research carried out on the roads of the Province of Udine. Analysis of speeds showed:
- the gap between operating speed and design speed;
- frequent non-observance of speed limits;
- substantial independence of speed from the carriageway;
- limited effect on driver behaviour of the curvature of the single curve.

Speed, on the contrary, was shown to be essentially correlated to the characteristics of the road layout and especially to those of the section of road already covered, so that it becomes important to make the road as uniform as possible.
Another theme investigated during research was that of the manoeuvre performed by the driver in order to approach a bend: studies showed that when there is no transition curve, gradual turning of the steering wheel does not enable the driver to follow exactly the geometry of the road.
In conclusion, general considerations for applications of this study, valid both for checking existing roads and for optimisation of the design geometry of new roads in the framework of road safety audit programmes, might be summarised as follows:

- To ensure that the category of the road corresponds to the traffic class and that the carriageway and geometry of the road are homogeneous.
- To insert a transition curve between a circular curve and a straight stretch and between one curve and another.
- To avoid curves with a low radius (R < 200 m) within easy sections.
- To limit the length of straight stretches (L < 2,000 m).

REFERENCES

AASHTO (1994) A Policy on Geometric Design of Highways and Streets. Washington.
Bordin M., Stefanutti M. (2000) Studio delle traiettorie veicolari in curva: la “curva di transizione spontanea”. Atti del X Convegno Nazionale SIIV, Catania, 26-28/10/2000.
C.N.R., Consiglio Nazionale delle Ricerche (1980) Norme sulle caratteristiche geometriche delle strade extraurbane. Bollettino Ufficiale, N. 78, Roma.
Lamm R., Psarianos B., Mailaender T. (1999) Highway Design and Traffic Safety Engineering Handbook. Mc Graw Hill, New York.
Ministero delle Infrastrutture e dei Trasporti (2001) Norme funzionali e geometriche per la costruzione delle strade. Decreto 5/11/2001.