

A Study of Speed on Two-Lane Roadways

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Abstract. Speed represents the most important functional characteristic of roads. That is why the article attempts to give a view of the overall speed generation procedure on main (trunk) roadways (magistralne ceste) and its measuring methods. Also proposed is the back calculation approach in analyzing the conditions for main (trunk) road rehabilitation from the aspect of bringing speed to conform with the legally set limits, but also road protection from speed degradation due to elemental conditions taking place during road exploitation.

1 Introduction

The article discusses important issues of defining speed on two-lane roads.

Speed represents the most important functional characteristic significantly affecting travel time and costs, travel safety, capacity and level of road services.

That is why the driving dynamic parameters used in designing roads are important for speed analysis, as well as the impact of road parameters on speed in roads that are in use, and the state of speed on two-lane roads on the basis of signalization.

One may thus notice the complexity of the speed generation process, wherein one should also be mindful of spontaneous processes pertaining to environmental factors and traffic safety factors, or frequent traffic accidents.

2 Defining Speed and Method of Measurement

Speed is generally defined as the length of road covered during a unit of time, which is usually indicated in kilometers per hour (km/h). Due to the fact that in a traffic stream the speed of particular vehicles may vary across a broad spectrum, in the analysis of traffic conditions on a road network, speed is usually construed to mean average speed.

Average speed (v) represents a ratio between the length of a particular road or street, a section (segment) thereof, and the average time all vehicles within the observed traffic stream spent on the observed section of the road.

The general formula for calculating the average speed is as follows:

$$V = \frac{L}{\sum_{i=1}^n \frac{t_i}{n}} = \frac{nL}{\sum_{i=1}^n t_i}, \quad (1)$$

where are:

- V average stream speed (km/h)
- L length of road section (segment) (km)
- t_i time of i-th vehicle's travel along the section (h)
- n number of vehicles covered by the measurement of time they took to pass along the observed section

Travel time stands for the total time a vehicle spends on the road.

2.1 Traffic Stream Speed

There are different notions for the average stream speed that are applied in traffic flow analyses, such as:

- Average running speed
Average running speed is a ratio between the length of the observed road section and the time spent moving along the observed section. In the literature, the notion is often (albeit wrongly) referred to as space mean speed.
- Average journey speed
Average journey speed is a ratio between the length of the observed road section and the time the vehicle took to complete the journey along the observed road section. Journey time includes the running time and time losses due to vehicle stoppage.
- Space mean speed
Space mean speed is the mean speed of all vehicles within the traffic stream of the road section at the observed point in time.
- Time mean speed
Time mean speed is an arithmetic mean speed of all vehicles passing through the observed road section over a given period of time.

Figure 1 shows a ratio between the time mean speed and space mean speed.

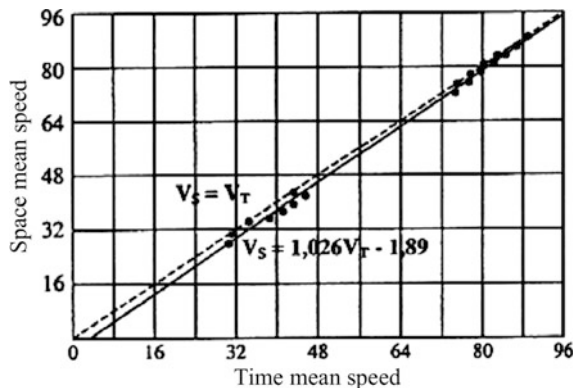


Fig. 1. Typical relations between time mean speed and space mean speed [1]

Fundamental traffic flow parameters are as follows:

1. Density

Density is the number of vehicles per unit of length on a traffic lane or road. Density is expressed by the symbol q (veh/km).

$$Vg = \frac{q}{V}, \quad (2)$$

where are:

- g flow of vehicles (veh/h)
- V average flow speed (km/h)
- q density (veh/km)

2. Distance headway

Distance headway is the distance between the heads of two successive vehicles in a traffic stream. Distance headway is expressed by symbol S_h (m/veh).

3. Interval headway

Interval headway is a time interval between the passage of two successive vehicles through the observed road section. Interval headway is expressed by symbol t_h (s/veh).

- Mathematical relations between two basic traffic flow parameters

Density on the basis of an average distance headway is calculated as follows:

$$g = \frac{1000}{S_h} \left(\frac{\text{veh}}{\text{km}} \right), \quad (3)$$

Mean interval headway on the basis of mean distance headway and flow speed is calculated as follows:

$$t_h = \frac{S_h}{V} \text{ (s/veh)}, \quad (4)$$

Analytical expressions of relations between the fundamental traffic flow parameters are as follows:

$$q = gV, \quad (5)$$

$$g = \frac{q}{V} \text{ and } V = \frac{q}{g}, \quad (6)$$

Diagrammatic interpretation of interdependence between the fundamental traffic flow parameters per pairs V - g , V - q and q - g is shown in Fig. 2.

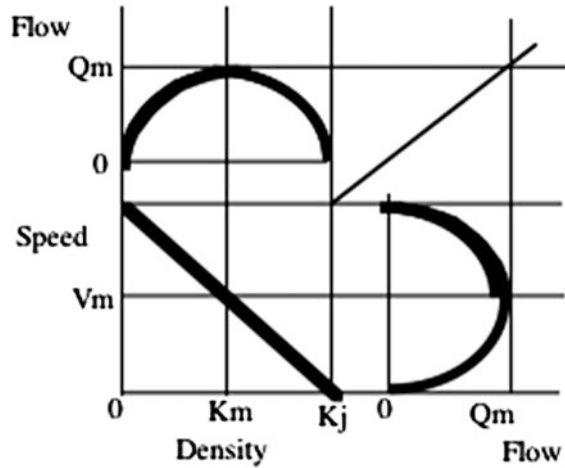


Fig. 2. Graphic interpretation dependencies of three basic parameters of traffic flow in ideal conditions [1]

2.2 Design Speed

The following types of speed are taken into account in designing roads:

- Vv driving speed is the actual speed of vehicle moving on the road,
- Vdoz permissible driving speed is the speed that is limited by legislation on a particular road section,
- Vput travel speed represents an average driving speed on a particular road,
- Vpl planned/defined travel speed represents the average driving speed, which vehicles are supposed to have at the end of the period covered by the plan, which represents a relevant speed to determine the dimensions of a normal cross profile, geometric and technical elements of the road,
- Vpred anticipated speed is a speed calculated for particular categories of road, based on which to estimate road feature dimensions (a particular road section will typically have one and the same anticipated speed),
- Vpro design speed is a speed of a moving vehicle in a free stream on a clean and wet carriageway (free stream speed V85%), used as a designed speed to analyze traffic safety. Design speed cannot be lower than the anticipated speed (Vpred), and its highest value must not exceed the highest legally permissible driving speed on the road or a road section (Vdoz), and
- Vrad radial speed of moving—laterally, while switching lanes, and
- Vr designed speed is any speed used to determine or calculate technical road features

2.2.1 Design Speed

Design speed V_{pro} is determined by analyzing road elements, situation plan and longitudinal profile. The set speed must not exceed the maximum permissible speed on the

given roadway. The analysis is performed for the roads belonging to the technical groups A and B, where the anticipated speed exceeds 70 km/h. The following formulas are in application:

For two-way roads with separate carriageways, where $V_{\text{pred}} < V_{\text{doz}}$

$$V_{\text{proj}} = V_{\text{pred}} + 10 \text{ km/h for extremely curved routes, and}$$

$$V_{\text{proj}} = V_{\text{pred}} + 20 \text{ km/h for straight-line routes,}$$

For two-way roads with a single carriageway, where $V_{\text{pred}} < V_{\text{doz}}$

$$\text{Max } V_{\text{proj}} = V_{\text{doz}} \text{ for a particular category of road, or } \text{max } V_{\text{proj}} = V_{\text{pred}}.$$

The difference between the design speed and anticipated speed must not exceed 20 km/h. If the difference is:

$$V_{\text{proj}} - V_{\text{pred}} \geq 20 \text{ km/h,}$$

It is necessary to check the adopted levels of anticipated speed and increase them, or reduce the design speed by correcting the route in order to have the difference be within the scope as follows:

$$V_{\text{proj}} - V_{\text{pred}} \leq 20 \text{ km/h}$$

2.2.2 Lateral Speed

Lateral speed is a speed while switching traffic lanes. It depends on the width of traffic lanes, speed of driving and route stream, straight lines—curves.

The following factors are in play:

Mild lateral speed 0.7 m/s for $V_v > 70 \text{ km/h}$, for heavy vehicles and curved roadways, and

Acceptable lateral speed 10 m/s for $V_v \leq 70 \text{ km/h}$, for passenger vehicles and straight-line roadways.

2.3 Speed Measurement/Recording

Speed recording may be performed by using following tools:

- Moving traffic-monitoring vehicle

It is used to determine the speed recording route. The co-driver writes down into the log/form the following data: route, direction of driving, weather conditions, day, month of recording, initial recording, initial mileage, time of departure and time of arrival, number of vehicles from the opposite direction under the PA, BUS, TV, AV structure, number of vehicles overtaken by the traffic-monitoring vehicle, number of vehicles that overtook the traffic-monitoring vehicle. It is based on these data that one determines relevant indicators; stream speed and traffic flow.

- Video camera
A camera is set vertically to the roadway at a distance of 15–20 m. Since video recording made by a camera is not expressed in speed-characteristic units (km/h or m/s), a pixel (video recording units) measuring unit conversion must be made to eventually arrive at a speed unit. In order to make unit conversion, it is necessary to know current relationship between the recording and a known length in the recording.
- Counter
Automatic counters may record speed per thresholds, as follows; lower than 60 km/h, 60–80 km/h and higher than 80 km/h.
- Radar
Radar speed recording is most commonly used during road speed controls.

3 Speed Determination Procedures

3.1 Design Phase

Design speed V_{pro} is determined by analyzing road elements, situation plan and longitudinal profile. The set speed must not exceed the maximum permissible speed on the given roadway.

The basic road features that affect design speed are as follows: curve radius, longitudinal slope, traffic lane width, tonnage and surface construction features, road warping, presence of sight distance in excess of 450 m.

3.2 Road Safety

Road safety check is performed through geometry rectification, situation plan and longitudinal road profile conformity analysis, surface water drainage, analysis of capacity, speed, uncertainty factors, and speed model analysis (driving dynamics test) and design geometry dimensioning. The largest number of traffic accidents occur exactly because of a superposition of multiple factors, including road-related factors, such as unfavorable horizontal and vertical elements and spatial road features, road surfacing features, drainage solutions, lighting, environment etc.

It is by checking all designed elements that one arrives at the extent of speed from the safety aspect.

3.3 Speed According to Traffic Signalization

The state of speed on roads in use is determined according to signalization. Apart from the foregoing factors, the state of speed is also largely affected by road environment factors, roadside development, connections, and especially the impact of local communities and police, all of which affect speed limits significantly. Figure 3 displays speed according to traffic signalization conditions on a main (trunk) road section. Under the law, the maximum speed on main (trunk) roads (*magistralne ceste*) is 80 km/h, and minimal 60 km/h.

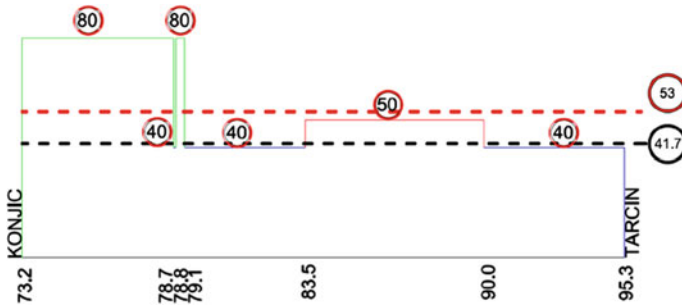


Fig. 3. Speed according to traffic signalization and conditions [2]

Speed recording on main (trunk) roads has shown that in a large number of cases there existed considerable speed limits, even down to 40 km/h or 50 km/h, without any meaningful logical explanation.

3.4 Traffic Flow Speed on Roads in Use

Studies of traffic flow speed on roads in use have been conducted by measuring speed using the method of a moving traffic-monitoring vehicle, camera or automatic-counter-determined speed.

The method used for determining speed was multivariate regression analysis. Following are some of the studies conducted in our region:

D. Dmjanović tried to determine the impact of road elements on a traffic flow speed, and came up with a joint effect equation [3]:

$$V = 34,37 \log R + 15,42 s. - 0,029 Kn - 0,038 K - 47,80 \tag{7}$$

where are:

- R horizontal curve radius
- S traffic lane width
- Kn specific curve turns
- K road section curvature

with the author’s note that satisfactory sight distance is required along the entire road section.

B. Mazić et al. have come up with a correlation equation, which reads as follows [3]:

$$V_t = 67,71 - 6,63 R - 2,39 KT + 4,39 \check{S} - 1,37 N - 0,04 K \tag{8}$$

where are:

- R technical road class
- KT terrain category
- Š carriageway width

- N average slope (%) and
- KV share of commercial vehicles BUS + TV + AV (veh/h)
- R 0.82

Vehicle speed dependent on road elements is as follows [3]:

$$U_p = 65,89 - 6,632 R - 2,39 KT + 4,39 \check{S} - 1,37 N, \tag{9}$$

For cargo vehicles, the relevant correlation equation reads as follows [3]:

$$V_t = 52,14 + 2,92 \check{S}k - 0,059 Su - 2,94 Un, \tag{10}$$

$$R = 0,82$$

where are:

- Vt average speed of heavy cargo vehicles + bus (km/h)
- Šk carriageway width (m)
- Su deviation angle (0) and
- Un longitudinal slope (%)

For the needs of Ljubljana region development, there is a correlation equation that reads as follows:

$$V = 6,82 + 8,9 \check{S} - 62,85 D, \tag{11}$$

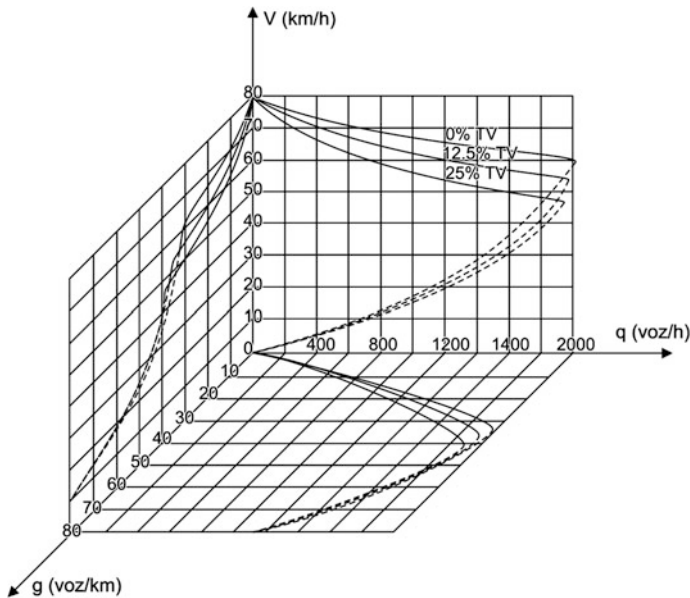


Fig. 4. Basic traffic flow diagram for various heavy vehicle shares [5]

$$R = 0,765$$

where are:

V speed (km/h)

Š road width (m)

D roadside development percentage

The equation has been used for the anticipated speed and travel time from one zone to another while testing various road network variants.

Ivan Lovrić has studied traffic flow speed models on out-of-town two-lane roadways, and came up with a traffic flow diagram for various heavy vehicle shares, as shown in Fig. 4 [4].

4 Conclusions

The analysis of determining speed has pointed to the complexity of speed generation on two-lane roadways.

In relation to the designed speed, significant changes take place especially due to traffic accidents and spontaneous interventions in the road-gravitating area.

Road rehabilitation should start from an analysis of conditions for the existing state of speed and the possibility of bring the speed down to the legally set level by affecting a change of road parameters and hindering factors that emerged in the road-gravitating area.

This is why back-calculation analyses are important before initiating road rehabilitation projects, and speed is one of the most significant effects achieved by road rehabilitation. Given a rather large pressure exerted by external factors in our conditions (roadside construction, connection/access roads, presence of various facilities, lobbying by local communities, influence of the police...), it is necessary to draft a spatial plan for the special area of main (trunk) roads as a legal framework for regulating interventions into the given road strip.

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