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**Identification of road parameters affecting the sectional speed of motor vehicles on rural roads**

**Abstract:** The basic factors determining the driving speed of drivers on rural roads are geometric properties of the designed road and traffic conditions. Spot speed investigations and analysis are a frequent object of both Polish and foreign research, while little attention has been given to sectional speed studies. The article presents the results of sectional speed tests carried out on rural sections of national, regional and county roads. The research sections were located in the Podlasie Voivodship. A set of cameras with the function of automatic recognition of number plates was used for speed measurements. As part of the conducted research and analyses, applying the tools of statistical analysis, the significance of the influence of the width of the lane, roadside width, road accessibility and its curvature on average sectional speeds in the group of national, provincial and county roads was determined.

**Keywords:** Sectional speed; Road geometry parameters

**Introduction**

The basic factors determining the speed of movement of drivers on non-urban roads are geometric properties of the designed road and traffic conditions. With low traffic, the freedom of maneuvering increases and the driving speed increases. In such conditions, the speed at which the driver moves will depend primarily on the geometry of the road - its course in the plan and profile [2],[4].

Knowledge of the behavior of drivers, and especially the speed at which they move is very important because it is the basis for undertaking effective actions aimed at increasing the level of road safety. Speed tests are carried out primarily on non-domestic sections of national roads [1],[5],[10] and the paths of lower classes are included in the study sporadically. The conducted research focuses mainly on instantaneous speeds [3],[6],[7],[8],[9],[11]. In urban areas, also, speed research focuses on instantaneous speed. The momentary velocity can be determined by many factors that can occur pointwise, and therefore inference about the behavior of drivers can lead to erroneous conclusions. The segment speed tests allow to eliminate such temporary differentiation of road characteristics, and thus the segment speed will better reflect the behavior of drivers under specific conditions. For this reason, research on this parameter and its determining factors is a valuable source of information. The purpose of this article is to examine the impact of selected road parameters on the section speed on non-urban roads.

**Research area**

The research area covered a total of 28 sections of non-urban roads. Measurements were carried out on 10 sections of national roads (DK), 9 sections of provincial roads (DW) and 9 sections of powiat roads (DP). All sections were located in the Podlasie Voivodship and they were single-road, two-lane roads with ground roadsides. The basic geometrical parameters of

the test sections are shown in Tables 1-3. The sections selected for testing were characterized by variable widths of traffic lanes and ground roadsides as well as variable curvature and accessibility. On all sections analyzed there was an administrative speed limit of 90 km/h. The technical condition of the surface was visually determined to be good. The lengths of the measurement sections ranged from 5300 m to 8000 m in the case of national roads, from 2640 m to 9590 m in the case of provincial roads and from 2800 m to 8380 m in the case of poviats roads.

**Tab. 1.** Geometric characteristics of research sections of national roads

Research section/Road number	Technical class	The length of the section [m]	The width of the lane [m]	Width of the roadside [m]	Curvature [°]	Availability [1/km]
DK_1	GP	6600	3,5	1,5	16,3	4,7
DK_2	GP	8000	3,5	1,5	5,5	4,7
DK_3	GP	5000	3,5	1,5	1,8	4
DK_4	GP	6000	3,5	1,5	33,6	8
DK_5	GP	6300	3,5	1,5	20,7	6
DK_6	GP	5700	3,5	1,5	9,9	5,1
DK_7	G	6100	3,0	1,5	11,3	4,7
DK_8	G	5300	3,0	1,5	13,4	6,6
DK_9	G	7600	3,25	1,5	5,5	7,8
DK_10	G	7300	3,25	1,5	4,3	6,4

**Tab. 2.** Geometric characteristics of research sections of provincial roads

Research section/Road number	Technical class	The length of the section [m]	The width of the lane [m]	Width of the roadside [m]	Curvature [°]	Availability [1/km]
DW_1	G	3600	3.25	1.25	36.6	3,6
DW_2	Z	3620	3.00	1.00	10.59	1,4
DW_3	G	2640	3.0	1.00	16.91	4,5
DW_4	G	3010	3.25	1.25	23.40	3,7
DW_5	G	3320	3.00	1.25	33.05	1,8
DW_6	Z	9590	3.25	1.00	2.6	2,3
DW_7	Z	3840	2.75	1.00	45.39	5,2
DW_8	G	3220	3.00	1.00	56.47	2,2
DW_9	G	7760	3.25	1.25	61.70	2,6

**Tab. 3.** Geometric characteristics of research sections of poviats roads

Research section/Road number	Technical class	The length of the section [m]	The width of the lane [m]	Width of the roadside [m]	Curvature [°]	Availability [1/km]
DP_1	Z	2970	2.50	0.50	6.69	4
DP_2	Z	8380	2.75	0.75	8.03	3

DP_3	Z	3670	2.75	0.50	17.51	5
DP_4	Z	4300	3.00	0.75	33.54	5
DP_5	Z	2800	2.50	0.50	34.12	3
DP_6	Z	4710	2.75	0.50	41.82	6
DP_7	Z	4370	3.00	0.75	45.58	5
DP_8	Z	3320	2.50	0.50	58.00	4
DP_9	Z	3660	2.75	0.50	71.54	3

### Measurements of section speed

The section speed tests were performed using a set of 2 ANPR Rapier 50IQ (Automatic Number Plate Recognition) cameras that automatically register and read license plates of passing cars. Cameras were set in two control points at the beginning and end of the test section, where each passing vehicle was registered along with the registration time. Based on the known travel time and the length of the test section, the section speed was calculated. The measuring points were each located at least 250 m from the D-43 mark. Speed tests were carried out on the daytime. During the measurements, there were no hindrances affecting the traffic conditions.

### Results and tests and their analysis

Earlier studies by the author in the field of staple velocity allowed for the occurrence of significant differences in section speeds in relation to the genus structure of vehicles. It was found that average truck speeds are significantly lower than the average speed of passenger cars and delivery vans in the absence of such significant differences between the last two groups of vehicles. For this reason, only two categories of vehicles have been included in further analyzes: passenger cars and vans.

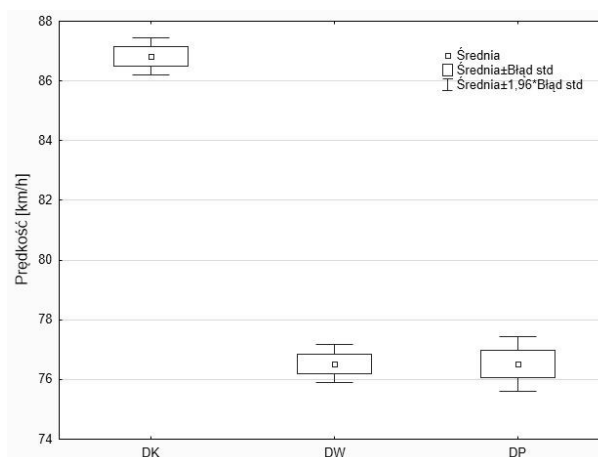
Table 4 presents the mean values of the section speed on the test sections together with the calculated standard deviation (SD). The number next to the road symbol (DK, DW, DP) is the ordinal number of the test section and is not related to the existing numbering of public roads.

**Tab. 4.** Average speeds and standard deviations of the test sections

Parameter	National roads									
	DK_1	DK_2	DK_3	DK_4	DK_5	DK_6	DK_7	DK_8	DK_9	DK_10
$V_{sr}$ [km/h]	92,6	87,7	89,3	85,5	86,4	92,5	84,8	94,5	92,5	90,5
SD [-]	10,6	11,6	9,3	8,2	9,1	11,3	8,1	11,5	11,2	12,1
Voivodship roads										
	DW_1	DW_2	DW_3	DW_4	DW_5	DW_6	DW_7	DW_8	DW_9	
$V_{sr}$ [km/h]	80,9	80,2	80,4	75,9	74,4	75,9	73,1	72,5	72,9	
SD [-]	13,5	12,8	8,9	9,6	11,5	12,2	10,5	9,4	10,9	
Poviat roads										
	DP_1	DP_2	DP_3	DP_4	DP_5	DP_6	DP_7	DP_8	DP_9	
$V_{sr}$ [km/h]	77,6	90,5	77,5	79,8	74,8	70,6	81,8	66,9	76,0	
SD [-]	9,1	13,5	12,7	8,9	10,5	12,2	11,6	8,6	11,9	

National roads compared to voivodeship and powiat roads are characterized by better technical parameters. This situation gives drivers better conditions for faster driving, which was reflected in the registered average speed values. In the group of analyzed research sections, the highest average speeds were recorded on national roads and the lowest on powiat roads. The highest average speed in the group of national roads amounted to 92.6 km/h and was 14.5% higher than the highest average speed recorded on voivodeship roads (80.9 km/h) and only by 2.3% from the highest speed registered on roads district (90.5 km/h). In the case of powiat roads, a large spread of average speeds is noteworthy. The distribution between the maximum and minimum average segment speed recorded in the group of powiat roads amounted to 63.5% and was the highest. The lowest dispersion was recorded in the group of national roads (9.2%), and in the group of voivodeship roads the dispersion was slightly higher and amounted to 11.6%.

Fig. 1 presents a graph of average staple speeds including the road function. The figure clearly shows the differences between the averages depending on the functional class of the group of research sections. In order to determine the statistical significance of these differences, an analysis of variance was carried out, which resulted in confirmation of a very significant difference between means ( $p = .0000$ ). In subsequent analyzes, the impact of individual road parameters on average stall speeds was analyzed separately in the group of national, provincial and powiat roads.



1. Values of average section speeds on the tested sections of non-urban roads

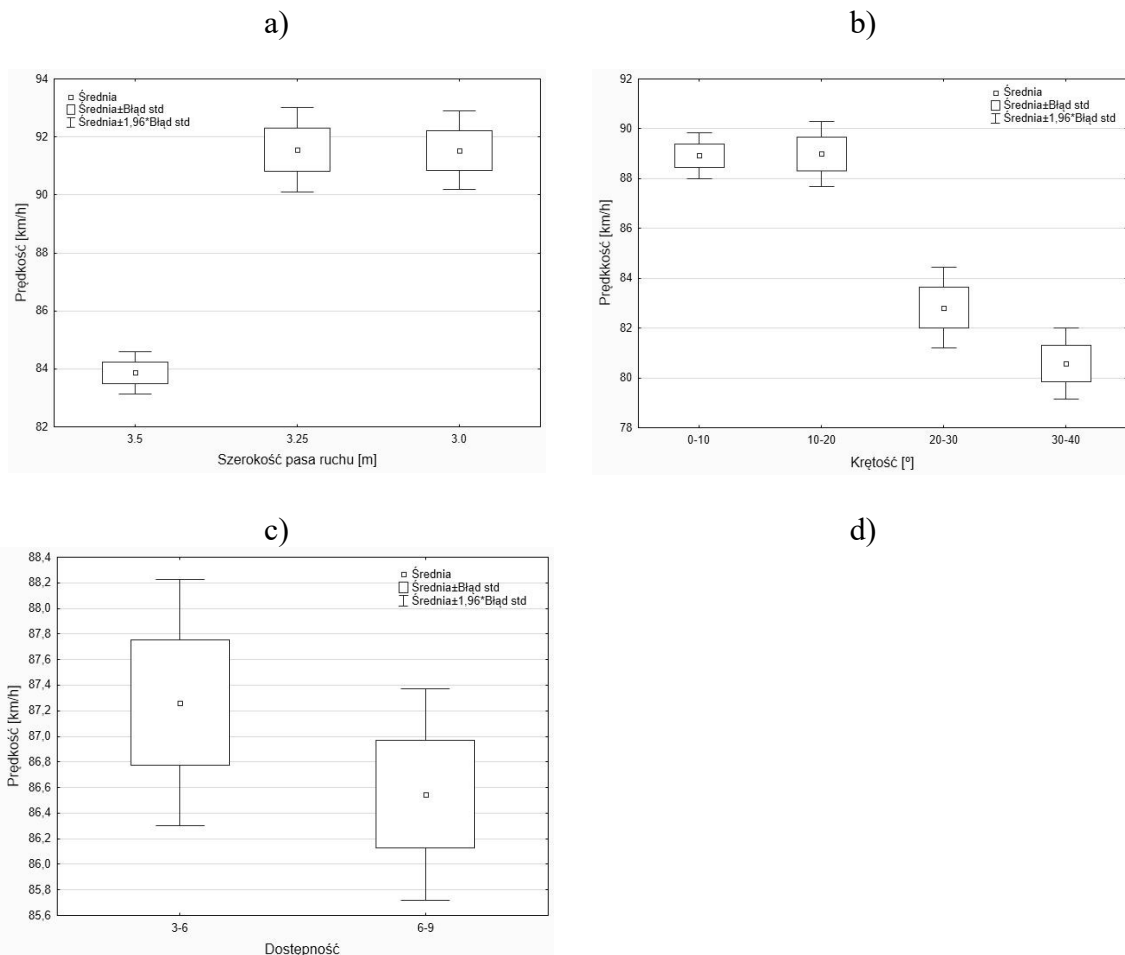
Figures 2 ÷ 4 present the results of statistical analyzes reflecting the impact of basic geometric parameters of the road on the average segment speed. The analyzes include lane width, roadside width, curvature, and road accessibility. In the case of national roads, the influence of the width of the ground shoulders was not analyzed due to its fixed value of 1.5 m.

Figures 2a and 2b show that in the case of national roads, the average segment speed significantly depends on the width of the lane and the road's curvature. In both of these situations a very high significance of the influence of the width of the lane was obtained (level  $p = .0000$ ). Analyzing the impact of the width of the lane, it can also be seen that in the case of roads with a lane width of 3.25 m and 3.0 m, the average speeds remain practically on the same level and, what is characteristic, it is a higher level compared to roads with a lane width 3.5 m. Analyzing road curves (Fig. 2b, 3c and 4c) and its influence on the average segment speed from the presented drawings clearly shows that the roads of lower technical classes are characterized by higher curvature. In the case of national and provincial roads, the increase in curvature above 20o considerably decreases the mean segment speed. In addition, two homogeneous groups can be distinguished, whose homogeneity was confirmed in the

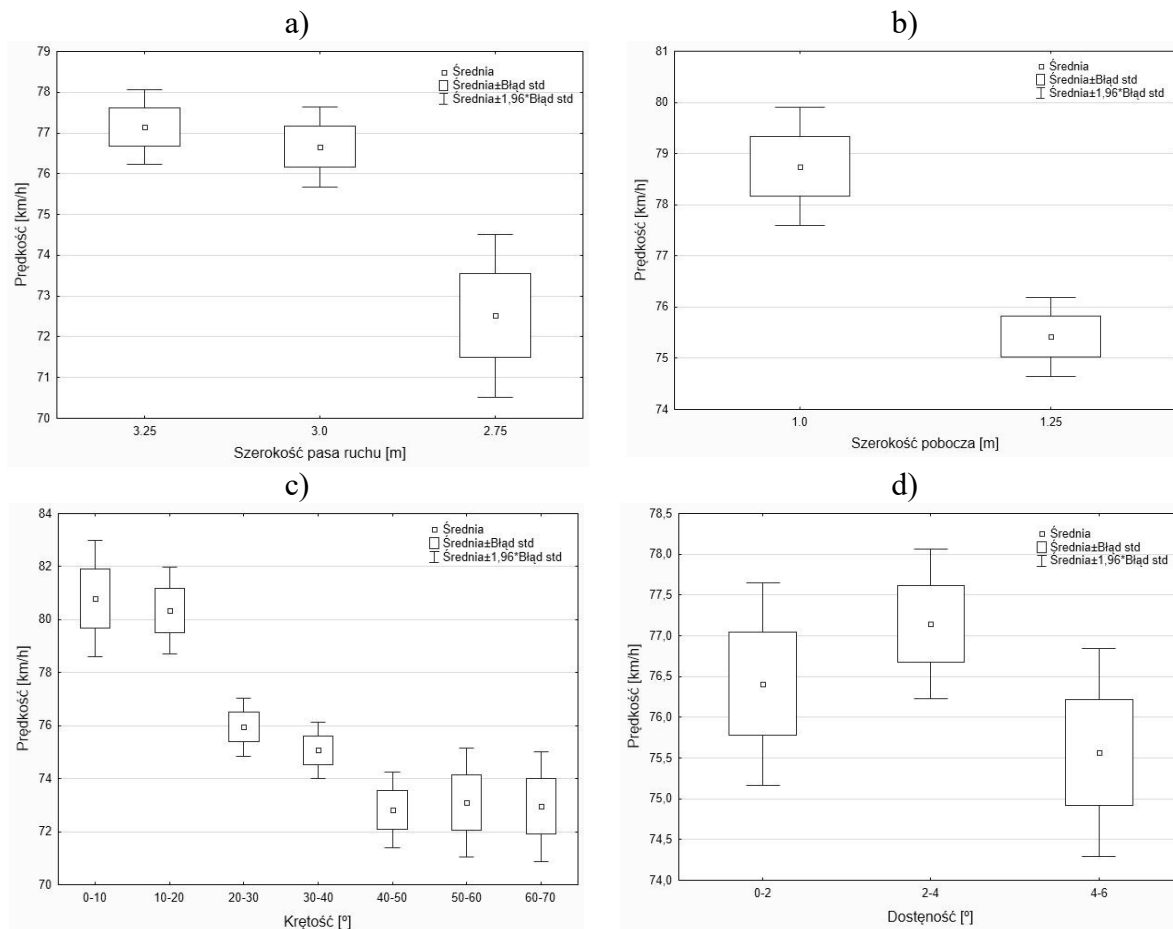
*Post-hoc* RIR Tukey test. The first group consists of roads with curvature up to 20o, and in the second group, there are roads with curvature above 20o. You can also notice the effect of road availability on the decrease in average speed (Figure 2c) but it is statistically insignificant ( $p=0.27919$ ).

Road availability does not have a significant impact on the average segment speed in the case of voivodship roads ( $p = 0.12937$ ). A very significant influence was found in the case of the width of the lane and ground shoulder as well as the road's curvature (at the level  $p$  correspondingly equal to  $p = .00056$  and  $p = 0.0000$ ). The influence of curvature on the segment speed in the case of provincial roads is similar to that on national roads. The increase in curvature above 20o translates into a significant decrease in speed, and the analyzed sections, based on the *Post-hoc* RIR Tukey test, can be assigned to two homogeneous groups (Figure 3c). One group consists of roads with a curvature of 0 ÷ 20o, and the other group with a curvature of 20 ÷ 40o.

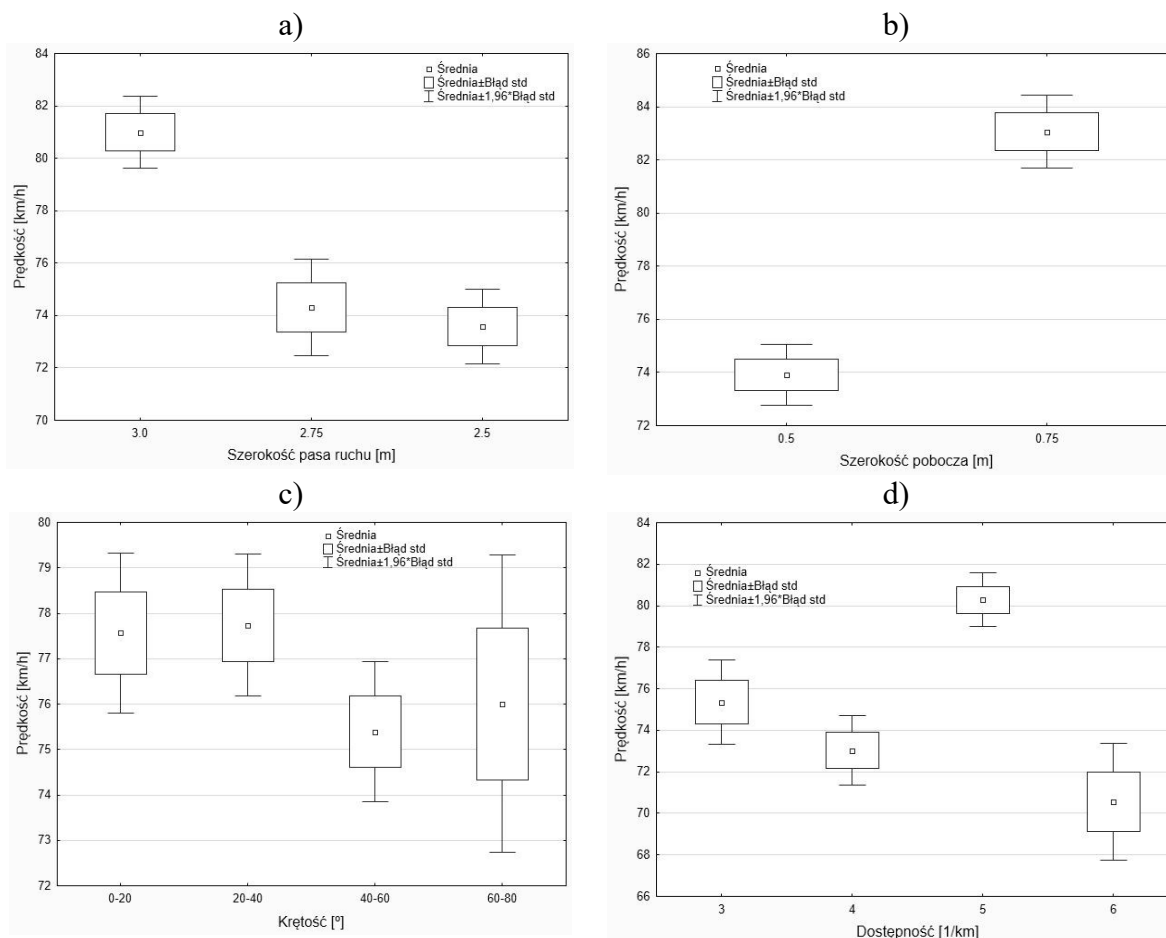
Analyzing the impact of the considered parameters on the average segment velocity on powiat roads, based on the analysis of variance, a very significant effect of the width of the lane (Figure 4a), shoulder width (Figure 4b) and availability (Figure 4c) was found - in each of these cases  $p= .0000$ . In contrast to the other research sections, no significant influence of the road's curvature was found ( $p=.14177$ ).



2. Dependence of mean section speed on national roads from a) lane width b) road curvature c) road accessibility



3. Dependence of mean sectional speed on provincial roads from a) width of the lane b) width of the shoulder c) curvature of the road d) road accessibility



4. Dependence of mean sectional speed on poviata roads from a) lane width b) roadside width c) road curvature d) road accessibility

## Conclusions

The article presents the results of section speed measurements carried out on non-urban sections of national, provincial and poviata roads. The aim of the research was to determine the significance of the impact of selected road parameters on the segment speed of vehicles. As a result of the tests and analyzes carried out, it was found that:

- in the case of national roads, the sectional speed of vehicles significantly depends on the width of the lane and the road's curvature, and does not depend on the accessibility of the road,
- in the case of voivodship roads, the sectional speed of vehicles significantly depends on the width of the lane and ground shoulder and the curvature of the road, and does not depend on the accessibility of the road,
- in the case of poviata roads, the sectional speed of vehicles significantly depends on the width of the lane and ground shoulder and the accessibility of the road and does not depend on its swollenness.

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