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A New Approach to Determining Road Capacity

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ABSTRACT

The objective of the study is to analyse capacity of a road which depends on many factors. The formula underlying the regulatory methodology for determining capacity relates the actual capacity to the maximum capacity through the final capacity reduction coefficient, consisting of the product of seventeen partial coefficients.

According to this methodology, it is recommended to use no more than six partial coefficients in calculations while defining a set of these partial coefficients for each specific case. And this is where the problem of choosing the most significant partial coefficients arises.

One of the central streets of the city of Vladimir, Gorky Street, was chosen as the object of study.

The objective was achieved with the observation method and experimental studies of intensity of vehicle traffic on the considered street.

Several cross-sections were selected along the length of the street for measuring traffic intensity and composition of traffic flow during rush hour. The parameter being determined is the final coefficient of reduction in road capacity. It was calculated for each lane in the cross-section area. Then, its values were averaged over even and odd sides of the street, as well as along the length of the entire street.

This work uses, as an example, due to the small number of cross-sections, geometric interpolation with a Lagrange polynomial. Next, the maximum interpolation error was determined, and graphs were drawn of the dependences of the experimental and interpolated curves of the final coefficient of reduction in road capacity for even and odd sides of the street, as well as along the length of the entire street. For practical purposes, it is necessary to choose an interpolation method that will provide the minimum error. Thus, having a mathematically described curve, it is possible to determine the value of the final capacity reduction coefficient for any cross-section of the street.

The work has resulted in development of a methodology for experimental determination of road capacity, which allows one to determine the final capacity reduction coefficient for a specific, already existing road.

Keywords: *road, capacity, method of experimental determination of road capacity.*

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Текст статьи на русском языке публикуется в первой части данного выпуска.

INTRODUCTION

An analysis of scientific works and research in the field of road traffic management led to the conclusion that there is insufficient depth of work related to the road capacity [1; 2; 3].

The road capacity depends on a large number of factors [1, 2] [4]. The regulatory source for calculating road capacity is ODM 218.2.020–2012 [3]. The formula underlying the methodology for determining capacity connects the actual capacity with the maximum one through the final capacity reduction coefficient, consisting of the product of 17 partial coefficients [5]. According to this methodology, it is recommended to use no more than six partial coefficients in calculations [6] by defining a set of these partial coefficients for each specific case. And this is where the problem of choosing the most significant partial coefficients arises.

The *objective* of the work is to study the road capacity. One of the central streets of the city of Vladimir, Gorky Street, was chosen as the object of study.

Research *methods* included observation and experimental studies on the intensity of vehicle traffic on the considered street.

METHODOLOGY

Several cross-sections were selected along the length of the road, in which traffic intensity and composition of traffic flow during rush hour were measured.

The parameter being determined is the final coefficient of reduction in road capacity (β) [6]. It was calculated for each lane in the cross-section area. Then, its values were averaged over even and odd sides of the street, as well as along the length of the entire street.

This work uses, as an example, due to the small number of points on the β curve, geometric interpolation with a Lagrange polynomial. Next, the maximum interpolation error was determined and graphs of the experimental and interpolated curves β were plotted for even and odd sides of the street, as well as along the length of the entire street. For practical purposes, it is necessary to choose an interpolation method that will provide the minimum error.

Thus, having a mathematically described curve, it is possible to determine the value of β in any cross-section of the street.

In more detail, the methodology for experimentally determining the road capacity is as follows:

1. Collecting initial data:

1.1. Determining the number of cross-sections along the even ($К_E$) and odd sides ($К_{OD}$) of the street.

1.2. Determining the number of traffic lanes passing through each cross-section (n) [7, 8].

1.3. Determining maximum practical capacity (P_{max})[1].

1.4. Determining rush hour time (t_{rh}) [9; 10].

1.5. Determining observation time interval (Δt) [11; 12].

1.6. Determining the distance between cross-sections on the even and odd sides of the street ($x_0, x_1, \dots x_{Ke(Kod)-1}$).

2. Calculating vehicle traffic intensity (N) in each cross-section and its reduction [13–15].

3. It is assumed that the actual capacity is equal to the measured traffic intensity ($P = N$), since traffic intensity measurements were carried out during rush hour.

4. Calculating β using the formula (1)[1]:

$\beta = P / P_{max}$,

where P is actual capacity, reduced cars/hour:

– for each lane in the cross-section ($\beta_1, \beta_2, \dots \beta_n$);

– for the even ($\beta_{1e}, \beta_{2e}, \dots \beta_{Ke}$) and odd ($\beta_{1od}, \beta_{2od}, \dots \beta_{Kod}$) sides of the street in each cross-section by averaging β over traffic lanes;

– for the entire street ($\beta_1, \beta_2, \dots \beta_{Kstreet}$) by averaging the values on the even and odd sides of the street in cross-sections.

5. Selecting a method for interpolating functions β ($\beta = f(x)$).

6. Drawing up a system of equations (SE) of interpolation and choosing a step (Δx).

7. Writing a computer program for solving the SE.

8. Drawing up experimental ($\beta_e = f(x)$) and interpolated ($\beta_{int} = f(x)$) curves β. Determination of error $\Delta\beta(x)$.

9. To obtain the capacity value at a street point $P(x)$, it is necessary to multiply the corresponding value of β by P_{max}.

10. Providing measures to reduce $\Delta\beta(x)$ and clarify β_e:

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[1] Tolkov, A. V. Improving traffic at intersections: Study guide. Vladimir, VLSU publ., 2018, 180 p. ISBN 978-5-9984-0852-6.

[2] Tolkov, A. V. Master's final qualifying work: Study guide. Vladimir, VLSU publ., 2021, 128 p. ISBN 978-5-9984-1403-9.

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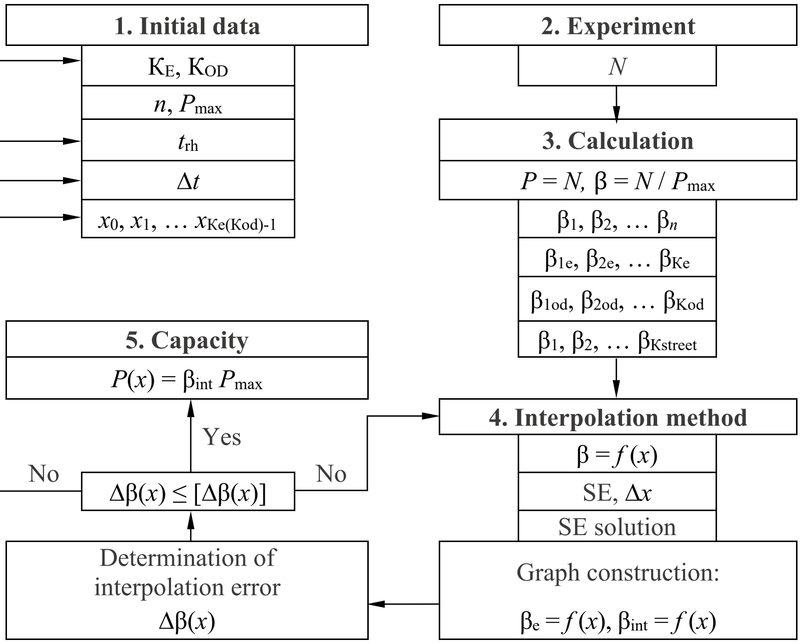
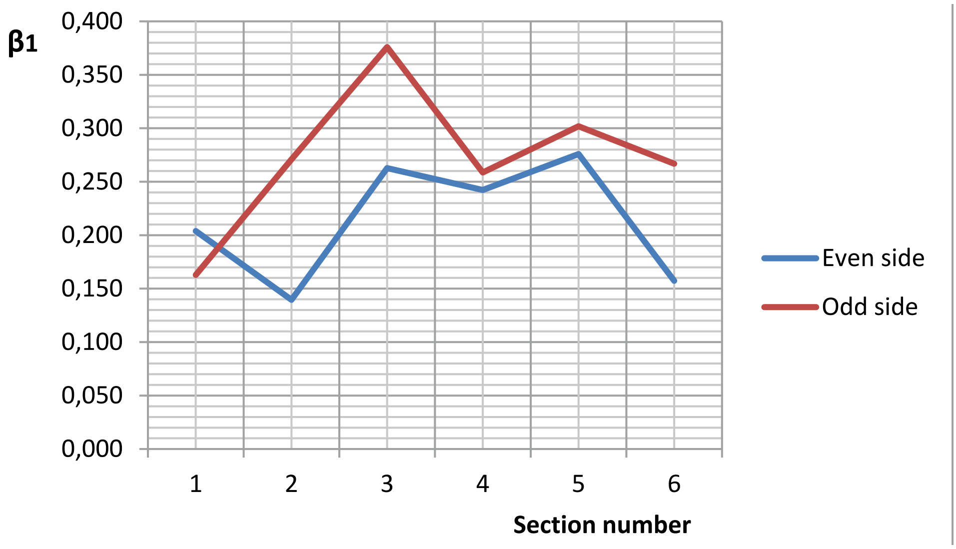


Pic. 1. Flow diagram of the methodology for experimental determination of road capacity [performed by the author].



Pic. 2. Distribution graph of β1 by first lanes of the street [performed by the author].

– increase in the number of cross-sections (*clause 1.1*);

– increase in observation time (*clause 1.4*) [14; 15];

– decrease in Δt (*clause 1.5*);

– more accurate measurement of distances between cross-sections (*clause 1.6*);

– selection of the exact interpolation method (*clause 6*).

The flow diagram of the technique is shown in Pic. 1.

RESULTS

As an example, a study of Gorky Street in the city of Vladimir is described. The number of cross-sections under consideration (six were selected, located in the area of stopping points (SP)) and traffic lanes, the values of the maximum practical capacity, the results of measuring vehicle traffic intensity and the calculation of β by lane are shown in Table 1.

The distribution graph of β along the first lanes of the street is shown in Pic. 2.

Table 1

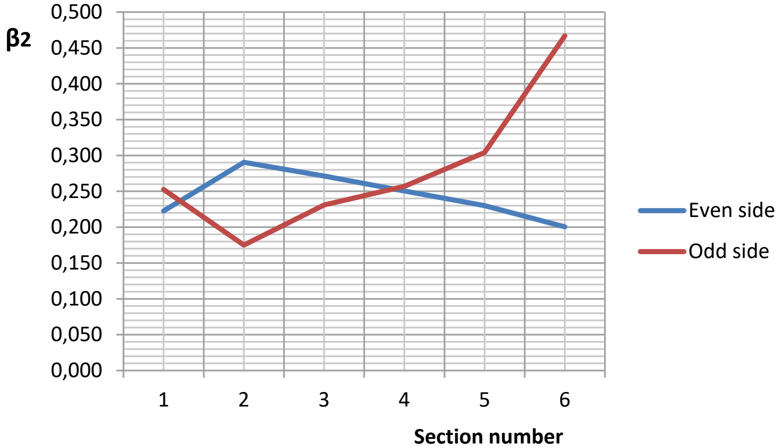
Calculation of β per lanes [performed by the author]

SP	Side of the street	Number of a lane	P_{max}, passenger cars/hour	P, red. cars/ hour	β
1st r.Sodyshka	Even	1	2300	204	0,089
		2	2300	734	0,319
		3	2300	512	0,223
	Odd	1	2300	142	0,062
		2	2300	607	0,264
		3	2300	581	0,253
2nd Gastello street	Even	1	2200	307	0,140
		2	2200	639	0,290
	Odd	1	2200	596	0,271
		2	2200	385	0,175
3rd VLSU	Even	1	2200	578	0,263
		2	2200	597	0,271
	Odd	1	2200	827	0,376
		2	2200	508	0,231
4th Lenin square	Even	1	2200	533	0,242
		2	2200	551	0,250
	Odd	1	2200	569	0,259
		2	2200	565	0,257
5th Vspolie	Even	1	2200	607	0,276
		2	2200	506	0,230
	Odd	1	2200	664	0,302
		2	2200	669	0,304
6th Yurievskaya zastava	Even	1	2200	346	0,157
		2	2200	441	0,200
	Odd	1	2200	587	0,267
		2	2200	1027	0,467

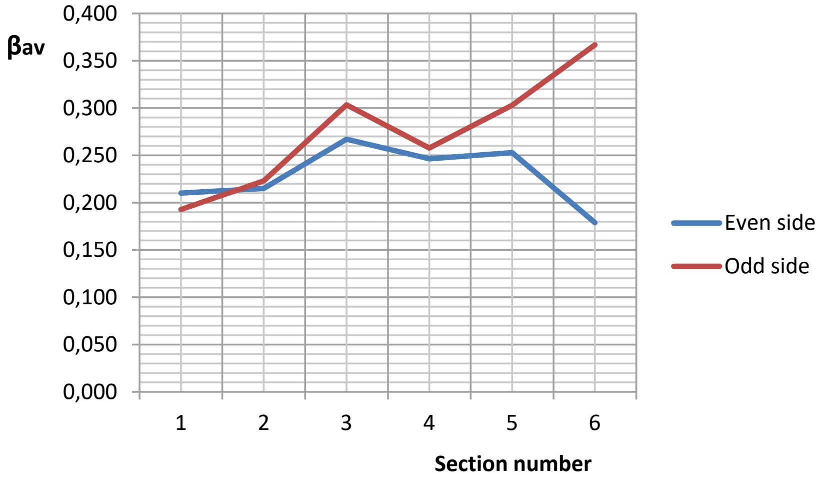
Table 2

Initial data for the system of interpolation equations [performed by the author]

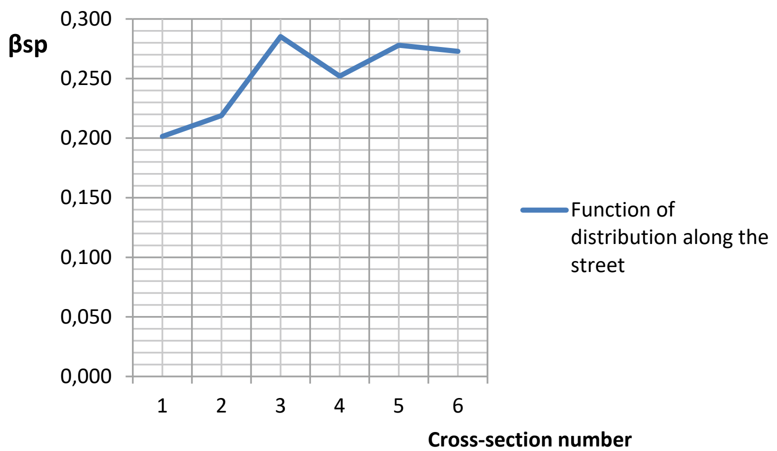
Along the entire street					
x_0	x_1	x_2	x_3	x_4	x_5
0,00 km	0,53 km	0,95 km	1,60 km	2,15 km	2,65 km
β_1	β_2	β_3	β_4	β_5	β_6
0,201	0,219	0,285	0,252	0,278	0,273



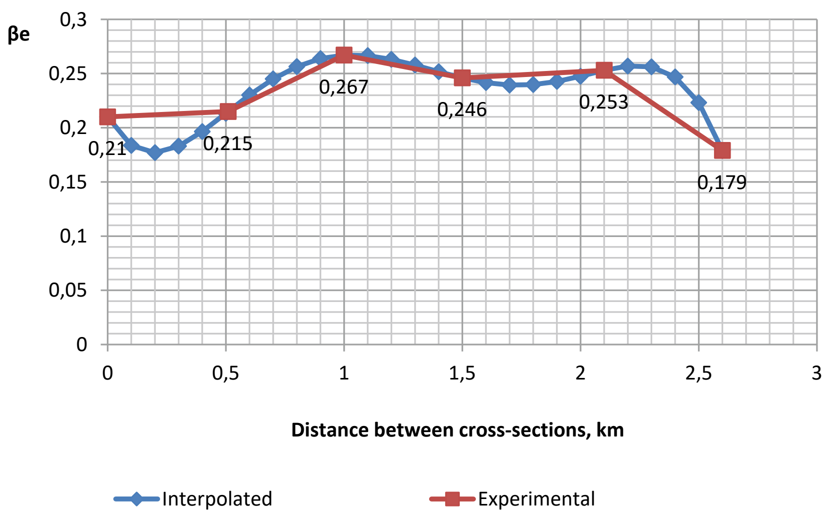
Pic. 3. Distribution graph of β2 by second lanes of the street [performed by the author].



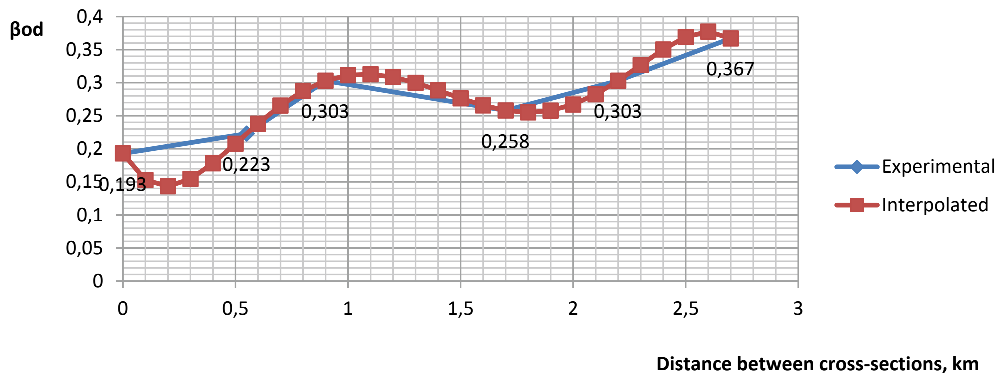
Pic. 4. Distribution graph of the coefficient βav on even and odd sides of the street [performed by the author].



Pic. 5. Distribution graph of the coefficient βsp along the entire street [performed by the author].



Pic. 6. Comparison of experimental and interpolated curves βe on the even side of the street [performed by the author].



Pic. 7. Comparison of experimental and interpolated curves β_{od} on the odd side of the street [performed by the author].

The distribution graph of β along the second lanes of the street is shown in Pic. 3.

The distribution graph of averaged β on the even and odd sides of the street is shown in Pic. 4, and the distribution graph for the entire street is shown in Pic. 5.

The work, due to the small number of points on the β distribution curve, applied geometric interpolation using a Lagrange polynomial.

The initial data for compiling a system of interpolation equations are the distances between cross-sections along the length of the street, and also the values of β corresponding to these cross-sections (Table 2).

Further, to automate the calculations, programs were written in MATLAB.

A comparison of the experimental and interpolated β curves on the even side of the street is shown in Pic. 6.

The error is $\Delta x_{max} = |x_{int} - x_{exp}| = 0{,}043$ (21,3 %).

A comparison of the experimental and interpolated β distribution curves obtained on the odd side of the street is shown in Pic. 7.

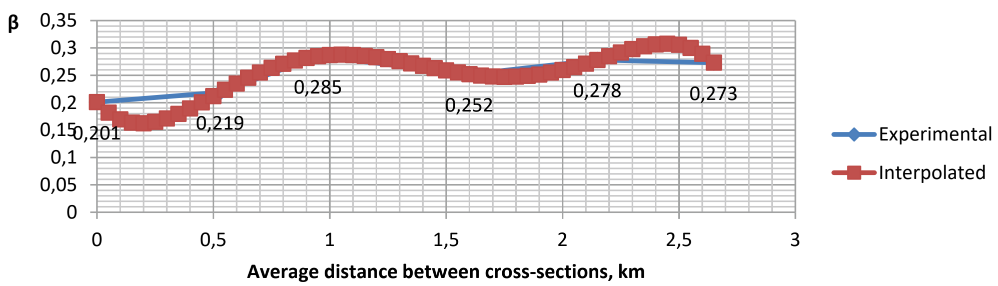
The error is $\Delta x_{max} = |x_{int} - x_{exp}| = 0{,}0617$ (30,0 %).

A comparison of the experimental and interpolated β distribution curves obtained along the length of Gorky Street is shown in Pic. 8.

The maximum interpolation error is $\Delta x_{max} = |x_{int} - x_{exp}| = 0{,}0477$ (22,7 %).

CONCLUSIONS

A methodology has been developed that allows one to determine the final capacity reduction coefficient of a particular road (street) under specific road conditions and the composition of the traffic flow. This indicator is defined as the ratio of the actual road capacity to the maximum practical capacity. The essence of the technique is to obtain the actual distribution curve of the final capacity reduction coefficient along the length of a particular road and compare it with the curve obtained using the interpolation method (mathematical description of the actual curve). The criterion for accuracy of the technique is the interpolation error. Having



Pic. 8. Comparison of experimental and interpolated curves β, obtained along the length of Gorky Street [performed by the author].

a mathematically described curve, it is possible to determine the value of the final capacity reduction coefficient for any cross-section of the street.

Recommendations have been developed to reduce the error of the methodology, aimed at increasing the number of cross-sections (observation points) along the length of the road, increasing the total time of observation of traffic flows (to obtain a larger volume of data), reducing the time interval for recording vehicles (to obtain a more accurate image of changes in the intensity of traffic flows over time), choosing a more accurate method for measuring distances between cross-sections and the interpolation method.

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