TECHNOLOGY, CREATIVITY, IMPLEMENTATION

DIFFERENTIAL METHOD FOR ASSESSING THE EVENNESS OF THE ROAD SURFACE OF THE STREET AND ROAD NETWORK BY THE IRI INDEX

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Summary

The article investigates the use of the IRI index to assess the condition of the pavement of streets of different types within a settlement: main city and district roads, residential and industrial. The possibility of applying a differential system for assessing the evenness of the road surface is considered, which makes it possible to more accurately determine its condition in five gradations – from excellent to critical. Based on the results, a map of the district was built, which clearly demonstrates the distribution of the technical condition of its street and road network. This allowed us to identify problem areas, which will make it easier to optimize the planning of repair work and ensure efficient use of resources. The research provides a more comprehensive understanding of the factors contributing to pavement deterioration. Furthermore, the use of modern technologies, such as GIS systems and remote sensing data, facilitated the development of a dynamic model for monitoring road conditions in real-time.

Key words: pavement management systems, highway operations, structural and functional prediction of roads, pavement condition

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1. Introduction

The street and road network of the settlement is an important component of the urban infrastructure, which ensures transport connections, population mobility and economic activity. Its effective functioning depends on the condition of the road surface, which affects traffic safety, ease of movement and the duration of road operation. Regular monitoring and assessment of road conditions is key to maintaining them in good condition and timely maintenance.

One of the main indicators used to evaluate the quality of the road surface is the IRI (International Roughness Index), which allows you to determine the smoothness of the road and assess its impact on the comfort of drivers. However, traditional evaluation approaches are often limited to general categories of "good" or "bad", which do not take into account the degree of difference between individual road sections.

This article is aimed at improving the process of assessing the state of the street and road network of a settlement by implementing a differential assessment system based on IRI. This made it possible to analyze in more detail the technical condition of the road surface on streets of various types, to identify problem areas that need repair.

2. Theoretical part

In settlements, in accordance with *(DSTU 3587, 2022: 3)*, which regulates the requirements for the operational condition of highways under the conditions of ensuring road safety, there are no requirements for the uniformity of the road surface according to the IRI index for main streets of city, district importance and residential streets, and they are extended only to main roads (the maximum value should not exceed 3.1 m/km). According to *(DBN V.2.3-5, 2018: 2)*, such norms are available only for the capital type of road clothing on trunk roads of continuous traffic and its value should not exceed 2.0 m/km. This approach to determining the technical condition of the road surface makes it possible to apply only *the binary evaluation method*, comparing the measured IRI value with the requirement of the regulatory document. As a result of such an assessment, only two variants of the conclusion about the condition of the road surface of the highway type street are possible: "meets the requirements of the regulatory document" and "does not meet the requirements of the regulatory document", i.e. "satisfactory" or "unsatisfactory" (Fig. 1).

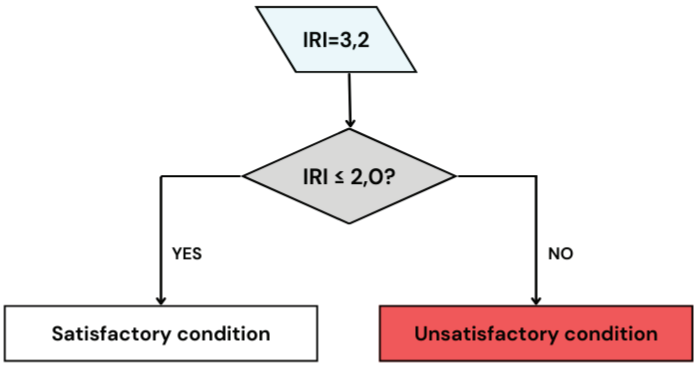


Figure 1 Algorithm of binary assessment of the technical condition of the road surface of the main street of continuous traffic

In addition, it is impossible to assess the state of the road surface of other types of streets, except for main roads.

The disadvantage of such an assessment is its limitation. It does not allow for gradations or degrees of difference between evaluated options, providing only two possible outcomes. The use of such an assessment method has a number of disadvantages:

1. Loss of nuance: Binary output cannot capture intermediate levels or degrees, which is important for more accurate evaluation.

2. Insufficient detail: With such an assessment, it is difficult to reflect more complex phenomena or differences between roads, which may lead to a simplification of the real situation, but does not provide sufficient detail.

Example: as a result of the evaluation of 2 roads, the average values of equality according to the IRI index were obtained:

Table 1

An example of an incorrect assessment of the state of the road surface

Road	IRI	Condition
Road A	3,2 m/km	Unsatisfactory
Road B	7,7 m/km	Unsatisfactory

1. **Road A**: has some minor defects, such as small cracks, peeling, but is generally in good condition.

2. **Road B**: has significant defects, such as potholes, deep ruts, which significantly affect the comfort and safety of traffic.

According to the binary method, both roads will be classified as "unsatisfactory" because they do not meet the criteria specified in the regulatory documents. However, this approach does not allow taking into account the difference in the condition of roads A and B. This leads to:

- **Lack of prioritization:** Road A needs less repair than Road B, but the binary method does not allow this conclusion. As a result, roads with different levels of damage may receive the same priority for repair, which can be inefficient in terms of resource utilization.
- **Incomplete picture:** operational services do not get a complete picture of the state of the roads. They cannot understand how problematic each of the roads is and what specific actions should be taken to improve them.
- Limitations in decision-making: In some cases, when several factors or criteria need to be considered, a binary approach may be too simplistic and will not provide enough information for an informed decision.

Thus, the binary road evaluation method leads to insufficient detail, which can negatively affect decision-making regarding road repair and maintenance and resource allocation. Because of these disadvantages, binary scoring is less suitable in situations where multivariate evaluation or analysis of complex situations is required. In such cases, using a scale that provides more gradations allows you to get a more accurate and detailed assessment.

Instead, it is proposed to use a differential method of assessing the evenness of the road surface according to the IRI according to the scale of technical conditions "excellent", "good", "satisfactory", "unsatisfactory" and "critical", taking into account the type of street. The limit values of such a scale are given in the table 2.

Table 2

Limit values of IRI for assessing the condition of the streets of populated areas

Type of street	Condition				
	Excellent	Good	Satisfactory	Unsatisfactory	Critical
Main streets of urban significance	IRI < 1,5	1,5 ≤ IRI < 3,0	3,0 ≤ IRI < 4,5	4,5 ≤ IRI < 6,0	IRI ≥ 6,0
Main streets of regional significance	IRI < 2,0	2,0 ≤ IRI < 4,0	4,0 ≤ IRI < 5,5	5,5 ≤ IRI < 7,0	IRI ≥ 7,0

Continuation of table 1

Residential streets	IRI < 2,5	2,5 ≤ IRI < 4,5	4,5 ≤ IRI < 6,0	6,0 ≤ IRI < 7,5	IRI ≥ 7,5
Industrial streets	IRI < 3,0	3,0 ≤ IRI < 5,0	5,0 ≤ IRI < 7,0	7,0 ≤ IRI < 8,0	IRI ≥ 8,0

The given data take into account the specifics and functional purpose of each type of street. They reflect general international approaches and world experience in assessing the state of the road surface in city conditions.

- **Main streets of urban importance** are the main transport arteries of the city, which provide the highest level of capacity and are associated with the most intense traffic.
- **Main streets of regional significance** are important streets within districts that also have a significant traffic load, but less than city arterials.
- **Residential streets** are streets located in residential areas with less traffic and more pedestrians.
- **Industrial streets** provide access to industrial zones; they may have a higher allowable IRI level due to higher loads and specific uses.

To determine the technical condition of the road surface using the differential method, an iterative approach is used, which consists in step-by-step determination of the range within which the determined IRI value is located (Fig. 2).

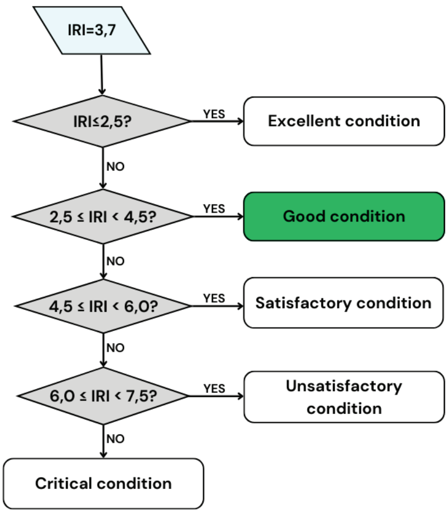


Figure 2 Algorithm of differential assessment of the technical condition of the road surface of a residential street

3. Experimental part

Data collection

As part of the research, a survey of the street and road network of the Troyeschyna housing estate in the Desnianskyi District of Kyiv was carried out. During the survey, the

IRI was determined in forward and reverse directions on 26 streets, of which 2 streets of the main type of urban significance, 4 streets of the main type of district significance, 16 streets of residential type of district significance and 4 streets of industrial type (Table 3)

The IRI was determined using a smartphone accelerometer and the RoadLab PRO software complex. During the survey, the vehicle's trajectory is plotted on an interactive map and divided into sections, the average length of which is 110 m, and a KML (Keyhole Markup Language) format file is created, which allows you to record GPS coordinates and to bind of the IRI. to specific sections of the road.

Table 3

Classification of the studied streets

Type of street	List of streets	
Main streets of urban significance	R. Shukhevycha Ave. R. Reagan Str.	
Main streets of regional significance	Chervonoi Kalyny Ave. M. Zakrevskyi Str. H. de Balzac Str. Myloslavska Str.	
Residential streets	Budyschanska Str. V. Vysots'kogo Blvd. Hradynska Str. Desnyans'ka Str. Kashtanova Str. M. Lavrukhina Str. Liskivska Str. Radosynska Str.	K. Dan'kevycha Str. O. Ekster Str. O. Kurinnoho Str. S. Lyfarya Str. V. Beretti Str L. Bykova Blvd. Arkh. Nikolajeva Str. Radunska Str.
Industrial streets	Pukhivska Str. Elektrotekhnichna Str. Melyoratyvna Str. Kraynya Str.	

This approach provides detailed cartographic visualization of research results, which greatly simplifies further analysis and planning of repair works. As a result of the survey, the IRI was determined for 851 segments, and the total length of the surveyed roads was 93.4 km.

Data visualization

After data collection, the resulting KML files were processed in Google Earth and Data Analyst OpenAI services. They were cleaned of false values, organized and analyzed, and the affiliation of each segment of the street on which it was measured was determined. This made it possible to visualize the collected GPS coordinates and accurately determine the condition of the road surface for each segment. After that, the data were integrated into maps showing the technical condition of roads according to the IRI. This approach not only made it possible to identify the most problematic areas, but also provided the possibility of further analysis and planning of repair works based on the obtained results. The obtained information became the basis for a detailed analysis of the distribution of the technical condition of the road network of the settlement.

Figure 3 Cartogram of IRI values, Troyeshchyna, Desnyansky district, Kyiv, as of September 2024, built by the RoadLab Pro software complex and processed in Google Earth

As a result of the survey, the IRI was determined for 851 sections, which allowed to obtain accurate data on the technical condition of each section of the road. Fixing the GPS coordinates of each segment of the street made it possible to clearly determine the geolocation of the segments of the street-road network and tie the results of the analysis to specific areas. This provides a reliable information base for further research and monitoring of the condition of roads in real conditions of urban infrastructure, in particular, allowing to compare different sections by their location and condition of the surface. As a result of this approach, it became possible to accurately match each segment of the road with its actual location, which ensures high accuracy in identifying problem areas. Thanks to the use of geolocation data, it is easy to determine in which parts of the district the condition of the road surface is the worst. On the basis of the analysis, a detailed summary table was created, which contains information about the types of investigated streets, the length of the investigated areas, and the assessment of the technical condition based on the average values of the IRI (Table 4).

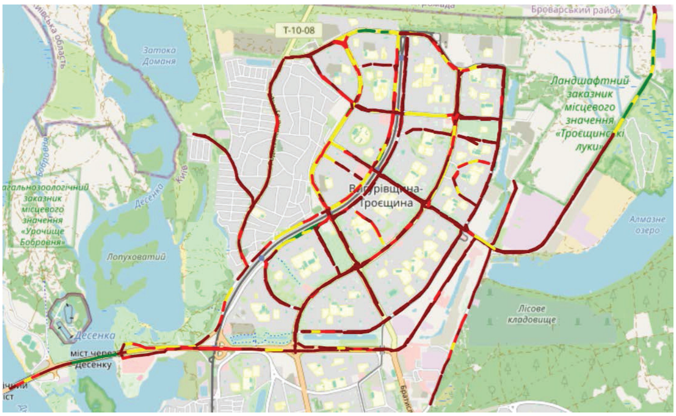
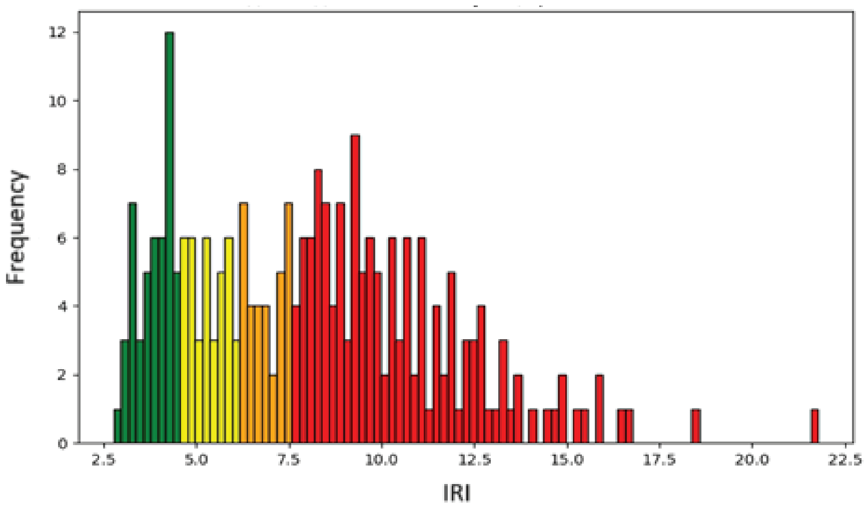
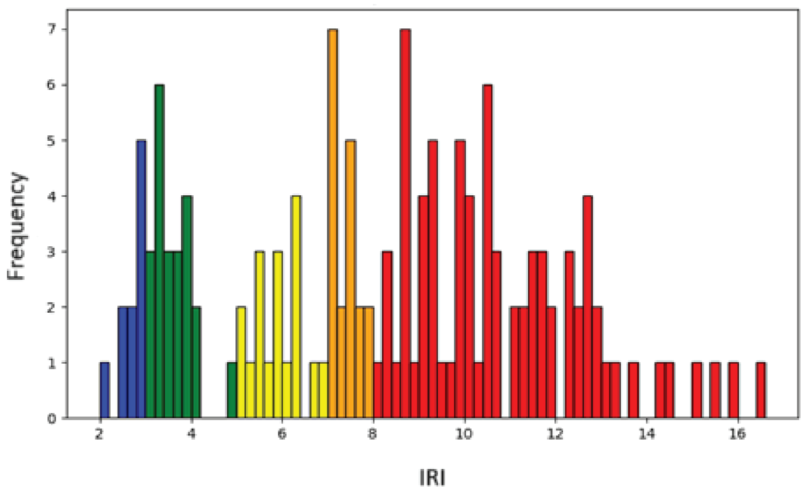


Figure 4 Cartogram of IRI values processed in Data Analyst OpenAI

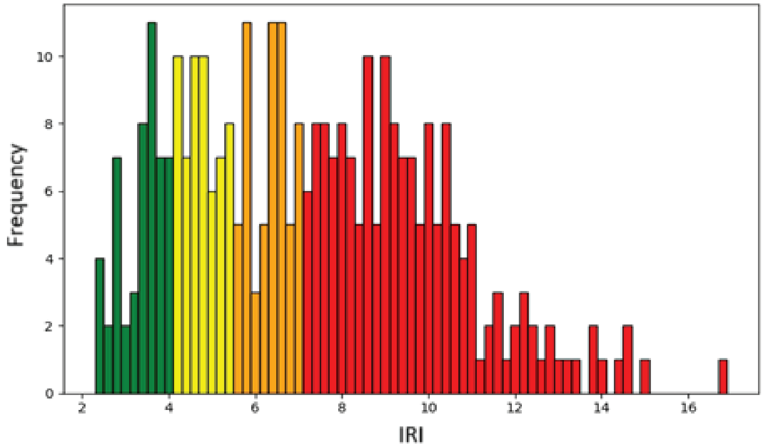
Since the streets have a considerable length and consist of sections repaired in different periods, using different materials and with different technical characteristics and, accordingly, have a different technical condition, diagrams were additionally constructed (Fig. 5-8) showing the distribution of these sections by values IRI. In the table 5 and the histogram of technical condition (Fig. 9) shows data on the length and share of sections of all technical conditions from excellent to critical for each street.



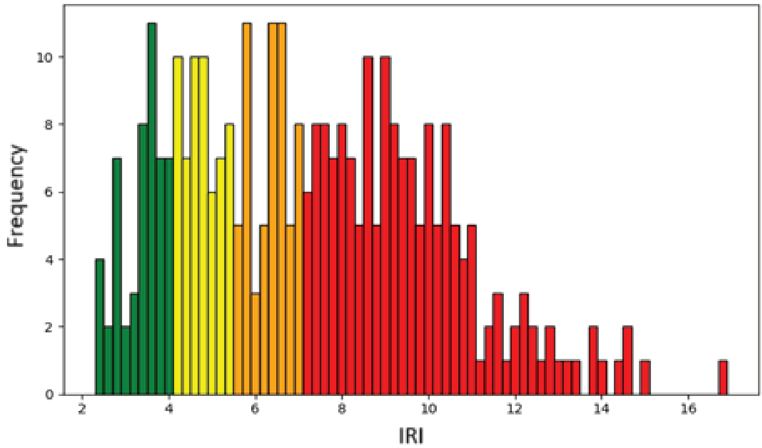
Figures 5 IRI distribution graph for residential streets



Figures 6 IRI distribution graph for industrial streets



Figures 7 IRI distribution graph for main streets of regional significance



Figures 8 IRI distribution graph for Main streets of urban significance

4. Conclusions

The application of the IRI differential evaluation system significantly improved the quality of the analysis of the state of the street and road network within the settlement. Instead of simplified approaches, a more accurate system was proposed, which provides an opportunity to better understand which sections of roads need urgent repair, and which can be included in the plan of preventive works. Based on the results, a cartogram and graphs of IRI distribution were built, which clearly demonstrate the distribution of the condition of roads, which makes it possible to ensure the effective use of resources through optimal planning of repair works.

Table 4

Summary table of the results of the determination of equality according to the IRI indicator of the street and road network of Troyeschyna in Desnyanskyi district of Kyiv

№	Street	Number segments	Total length segments, m	Average IRI value, m/km	Minimal IRI value, m/km	Maximum IRI value, m/km	Mode of IRI values, m/km	Median values IRI, m/km	Condition according to the average value of IRI
1	R. Shukhevycha Ave.	75	8268	6,15	2,29	12,35	4,46	6,04	Critical
2	R. Reagan Str.	43	4785	6,38	3,17	11,01	3,17	6,39	Critical
3	Chervonoi Kalyny Ave.	84	9484	7,43	3,07	13,43	4,06	6,95	Critical
4	M. Zakrevskyi Str.	74	7922	9,07	4,24	16,72	8,55	8,94	Critical
5	H. de Balzac Str.	124	13598	6,18	2,30	14,59	9,48	5,59	Unsatisfactory
6	Myloslavska Str.	50	5464	6,78	2,34	15,07	2,34	6,46	Unsatisfactory
7	Budyschanska Str.	3	319	11,72	8,32	14,96	8,32	11,87	Critical
8	V. Vysots'kogo Blvd.	8	834	7,35	4,15	15,79	4,15	6,28	Unsatisfactory
9	Hradyns'ka Str.	10	1058	7,56	4,19	10,59	4,19	8,01	Critical
10	Desnyans'ka Str.	24	2582	10,67	7,56	15,86	7,56	10,87	Critical
11	Kashtanova Str.	14	1550	10,65	4,78	18,40	4,78	10,69	Critical
12	M. Lavrukhina Str.	7	727	7,55	3,00	11,95	3,00	6,79	Critical
13	Liskivs'ka Str.	22	2527	7,23	4,19	11,50	4,19	7,13	Unsatisfactory
14	Radosyns'ka Str.	33	3566	8,72	5,92	12,18	8,70	8,69	Critical
15	K. Dan'kevycha Str.	12	1321	11,41	7,24	14,81	7,24	11,38	Critical
16	O. Ekster Str.	19	2101	6,99	3,26	15,42	3,26	4,65	Unsatisfactory

Continuation of table 4

17	O. Kurinnoho Str.	14	1503	7,38	4,93	12,64	4,93	6,42	Unsatisfac-tory
18	S. Lyfarya Str.	34	3780	9,04	3,91	16,77	3,91	8,87	Critical
19	V. Beretti Str	9	989	4,82	3,19	6,93	3,19	4,65	Satisfactory
20	L. Bykova Blvd.	5	541	4,88	4,23	5,78	4,23	4,73	Satisfactory
21	Arkh. Nikolajeva Str.	10	1210	11,40	7,21	21,75	7,21	10,03	Critical
22	Raduns'ka Str.	34	3684	6,77	4,27	4,31	4,39	2,77	Good
23	Pukhivska Str.	76	8231	6,65	2,00	12,70	3,09	7,12	Satisfactory
24	Elektrotekhnichna Str.	30	3365	10,71	5,98	15,50	11,71	10,88	Critical
25	Melyoratyvna Str.	17	1868	8,06	5,00	14,58	5,00	7,51	Critical
26	Kraynya Str.	20	2102	10,11	3,92	16,50	3,92	10,64	Critical

Table 5

Distribution of the condition of the road pavement and the length of sections along the streets

Street	Excellent		Good		Satisfactory		Unsatisfactory		Critical	
	1*	2**	1	2	1	2	1	2	1	2
1	2	3	4	5	6	7	8	9	10	11
Main streets of urban significance										
R. Shukhevycha	0	0,0%	628	7,6%	1527	18,5%	1889	22,8%	4224	51,1%
R. Reagan	0	0,0%	0	0,0%	1296	27,1%	803	16,8%	2686	56,1%
Main streets of regional significance										
Chervonoi Kalyny	0	0,0%	561	6,0%	1997	21,4%	2346	25,1%	4431	47,5%
M. Zakrevskyi	0	0,0%	0	0,0%	215	2,7%	1089	13,7%	6618	83,5%
H. de Balzac	0	0,0%	3313	24,4%	3421	25,2%	2358	17,3%	4506	33,1%
Myloslavska Str.	0	0,0%	1084	19,8%	1197	21,9%	711	13,0%	2472	45,2%
Industrial streets										
Pukhivska	1136	13,6%	2172	26,0%	769	9,2%	870	10,4%	3397	40,7%
Elektrotekhnichna	0	0,0%	0	0,0%	217	6,4%	384	11,4%	2764	82,1%
Melyoratyvna	0	0,0%	0	0,0%	560	30,0%	765	41,0%	543	29,1%
Kraynya	0	0,0%	101	4,8%	515	24,5%	0	0,0%	1486	70,7%
Residential streets										
V. Beretti	0	0,0%	334	33,8%	443	44,8%	212	21,4%	0	0,0%
L. Bykova	0	0,0%	219	40,5%	322	59,5%	0	0,0%	0	0,0%
Budyschanska	0	0,0%	0	0,0%	0	0,0%	0	0,0%	319	100,0%
V. Vysots'kogo	0	0,0%	208	24,9%	108	12,9%	213	25,5%	305	36,6%
Hradyns'ka	0	0,0%	215	20,3%	107	10,1%	104	9,8%	632	59,7%
K. Dan'kevycha	0	0,0%	0	0,0%	0	0,0%	0	0,0%	1321	100,0%
Desnyans'ka	0	0,0%	0	0,0%	0	0,0%	0	0,0%	2582	100,0%
O. Ekster	0	0,0%	1004	47,8%	112	5,3%	104	5,0%	881	41,9%
Kashtanova	0	0,0%	0	0,0%	328	21,2%	108	7,0%	1114	71,9%
O. Kurinnoho	0	0,0%	0	0,0%	452	30,1%	518	34,5%	533	35,5%
M. Lavrukhina	0	0,0%	316	43,5%	0	0,0%	104	14,3%	307	42,2%
S. Lyfarya	0	0,0%	335	8,9%	151	4,0%	416	11,0%	2878	76,1%
Liskivs'ka	0	0,0%	108	4,3%	716	28,3%	641	25,4%	1062	42,0%

Continuation of table 5

Arkh. Nikolajeva	0	0,0%	0	0,0%	0	0,0%	113	9,3%	1097	90,7%
Radosyns'ka	0	0,0%	0	0,0%	115	3,2%	870	24,4%	2581	72,4%
Raduns'ka	0	0,0%	2266	61,5%	1205	32,7%	213	5,8%	0	0,0%

* – in this row, in cells 1 – the length of the site, m

** – in this row, in cells 2 – proportion, %

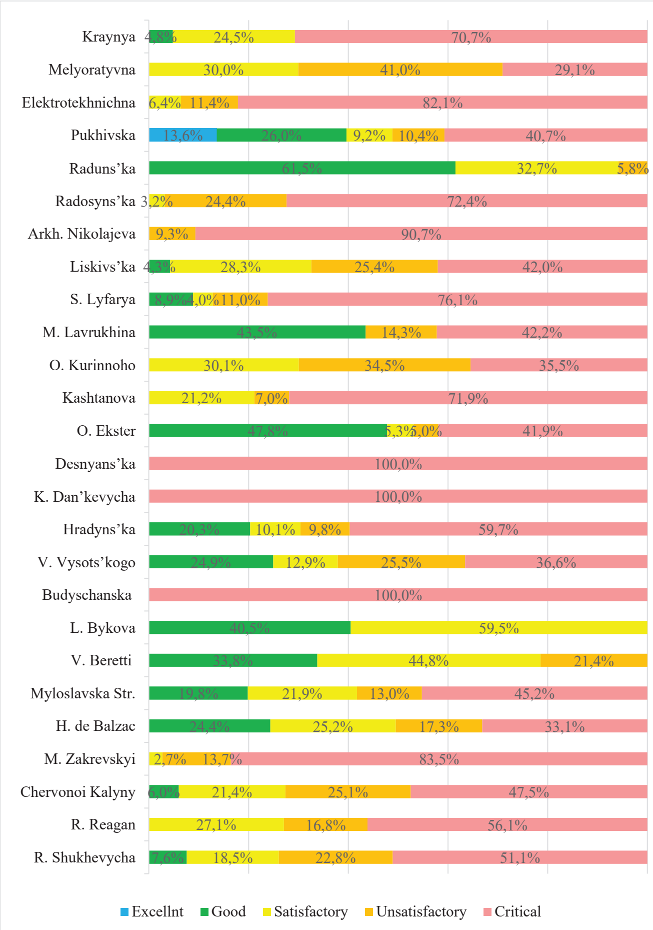


Figure 9 Histogram of the condition of the street and road network of Troeshchyna Desnyanskiy district of Kyiv as of September 2024.

The results of the study were applied in a research project 2023.04/0097 "Creation of a technology and a system of operational analysis and management of cement-concrete pavement condition of critical infrastructure objects based on spectral photoinformational images".

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