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METHODOLOGY FOR OBTAINING CROSS-SECTIONAL ROAD SURFACE PROFILES USING LASER SCANNING DATA

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Road infrastructure is critical to the economy, providing mobility for people and cargo, and contributing to economic growth. Modern technologies, particularly 3D laser scanning, play a significant role in the monitoring, evaluation, and operation of infrastructure.

As part of this study, the AU20 laser scanning system was used to obtain transverse road surface profiles on a certain section of the Yerevan Tbilisi Highway. The scan data was processed in the ArmRef02 coordinate system. The main objectives of the survey are:

- develop a methodology to automatically separate the road surface from the 3D point cloud.
- Identify the pivotal and central axes of the path through spatial analysis.
- Compare the resulting profiles with the technical norms and suggest possible improvements.

The results showed that existing technical abnormalities have a negative impact on drainage efficiency and traffic safety. Adherence to local and international regulatory standards can contribute to improved road operation and sustainable development of transport networks.

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***Keywords*:** GNSS, LiDAR, MLS, field authentication, Tibetan Highway.

Introduction. Being advanced in transport networks not only facilitates logistical processes, but also promotes socio-economic interaction. Developed road systems are more important to emerging economies, because they ensure faster transport of products to market, reduce costs, and increase competitiveness. At the same time, developed regional infrastructure can eliminate inequalities between urban and rural areas, promoting economic inclusiveness [1]. In addition to economic impacts, road infrastructure also plays an important role in ensuring population safety and enhancing livelihoods. Effectively designed and maintained roads reduce the number of vehicle accidents, and the integration of modern technologies, such as 3D laser scanning, can ensure accurate and fast monitoring, contributing to sustainable infrastructure management. Laser scanning systems allow for high density in the scanning surface feature rendering process. With the

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use of laser scanning systems, it is possible to refrain from increasing the impact of human factors during the data collection phase, because with traditional hilarious methods, the naked eye may not notice clear boundaries for changing the characteristic of the rendered surfaces [2]. Thus, investment in road infrastructure development is seen not only as a catalyst for economic growth, but also as a long-term strategic goal aimed at ensuring safer, sustainable, and proportionate development. Using the laser scanning system, the object of monitoring the transport infrastructure was selected to obtain cross-section profiles of the road. The transverse slopes of the road surface provide:

- organizing road surface drainage;
- increasing the safety of vehicles traveling in the turnaround areas of the roadway;
- the longevity of the surface of the road.

This study was conducted using the AU20 laser scanning system for surveying a section of Yerevan's Tbilisi Highway, specifically the segment between Paruyr Sevak Street and the "Bypass Tunnel" Street. The study was based on the three-dimensional scanning data obtained by the "Center of Geospatial Technologies" LLC. Data retrieval and processing was performed in the ArmRef02 coordinate system.

The purpose of the work is to:

1. Development of a methodology for separating the object of study: ensure that the road surface is automatically separated from the cloud of 3D scanning points for efficient data processing.

2. Identification of the marginal and central axes of the road: develop a methodology to allow grouping of pickets along edge and central axes, ensuring their automatic classification and identification of the appropriate direction.

3. Comparison of broadband profiles with regulatory standards: create graphical models of profile sections based on grouped pickets; enter the data into a spatial database to enable further analysis and comparison.

Research Material and Methodology.

Development of the Methodology for Object Identification. The acquisition of the point cloud, which serves as the basis for assessing road surface damages in the study area, was carried out in two stages: field surveying and post-processing of the collected data (POS processing). In order to carry out the scanning process during the field recording process, two systems were combined with the AU20 LiDAR system and the GS18 GNSS rover. The GS18 GNSS (Global Navigation Satellite System) rover serves as a base-mode for the accumulation of static satellite data. Satellite static data is stored in RINEX format. The GNSS receiver of the AU20 LiDAR (Light Detection and Measurement) system is capable of connecting to the GS18 GNSS rover within a radius of 10 *km*, which is installed in the base mode. The data recorded by the rover installed in the base mode is the basis for the post-processing of the data generated by the scanning system. The AU20 LiDAR system during said operation, when a satellite connection is present, executes the inertial system. The inertial system startup process is followed by the original scanning process. Scan data after post-processing is obtained from a cloud of interconnected dots (Fig. 1) [3].

Fig. 1. Georeferenced point cloud obtained from scanning.

Using automated dot cloud grading and the Mobile Laser Scanning (MLS) toolkit, there is a limit to the inclusion of a hard road (Fig. 2).

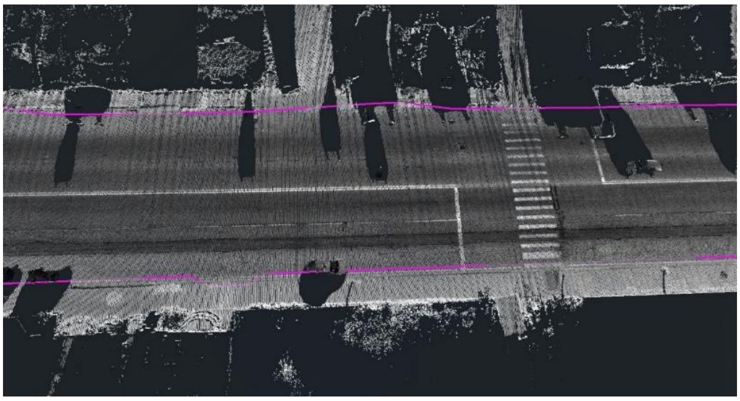

Fig. 2. Automatically extracted boundary of the rigid road surface.

In the automated separation process of the hard surface of the road, physical access to the entire area of the object being examined at the time of scanning is of great importance for the laser pulse released by the laser scanning system [3]. The example above clearly highlights the impact of "closed sections" in the process of separating the road surface boundary. The areas, where the cloud of dots is absent, the surface boundary has been corrected by mechanical interpolation [4].

Identification of the Marginal and Central Axes of the Road. The process of separating the road surface is followed by the process of identifying the edge and central axis of the above-mentioned section of highway. The separation of axes was done using a spatial data analysis toolkit for the IT software environment (Fig. 3). Picket points were obtained along the separated axes at an interval of 20 *m* (the number of picket points for the studied section is 73 on each axis). Picket points, the grouping of which was done by selecting points in a direction along a cross-section of the road, were the basis for obtaining cross-section profiles. In the process of obtaining profiles, the circumferential tilt of the object being examined was taken into account. After separating the edge and central axes and pickets of the examined section, an irregular triangulation network of the road surface limited to the Z values and edge axes of the indicated pickets was generated [5].

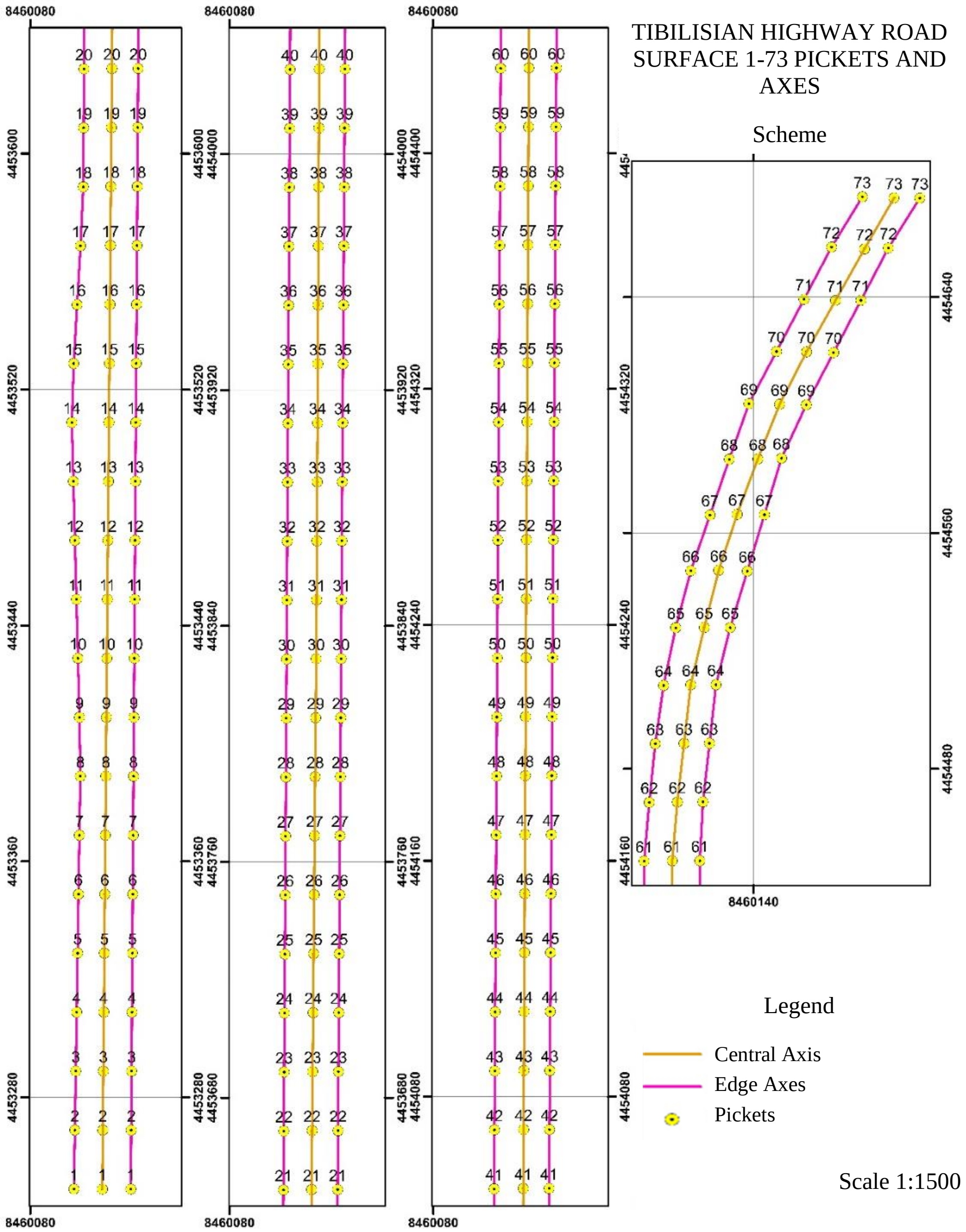

Fig. 3. Scheme of stakeout points and axes.

Since the creation of the triangulation network, cross-sectional profiles have been implemented according to the above-mentioned picket grouping logic to define the cross-sectional inclination features of the road surface. The graphical diagram of the profile sections as attribute data has been integrated into the pickets on the central axis. The central axis picket points contain attribute data for linearly projected distance, transverse inclination, and elevation differences from edge axis pickets (see Table). The picket grouping process was followed by the construction of profile lines with component points of the respective groups.

Attribute data characteristic of pickets (Arcmap attribute table)

	OBJ	Z_right	z_centre	Z_left	dist_left	dist_right	slope_left	slope_right
▸	36	1242.523	1242.664	1242.64	9.965	8.582	2.39	16.42
	37	1243.206	1243.352	1243.326	9.947	8.613	2.6	16.92
	47	1248.456	1248.601	1248.484	9.774	8.917	12	16.22
	58	1256.75	1256.959	1257.053	9.584	9.252	-9.79	22.69
	59	1257.509	1257.741	1257.889	9.566	9.283	-15.5	24.96
	60	1258.349	1258.529	1258.589	9.549	9.313	-6.23	19.38
	61	1258.92	1259.27	1259.377	9.532	9.347	-11.19	37.53
	62	1259.606	1259.893	1260.152	9.514	8.677	-27.22	33.13
	63	1260.203	1260.543	1260.894	9.751	8.622	-36.01	39.4
	64	1260.793	1261.093	1261.439	9.197	8.565	-37.65	34.94
	65	1261.188	1261.506	1261.795	9.653	8.781	-29.9	36.27
	66	1261.518	1261.799	1262.112	9.448	9.678	-33.14	29.05
	67	1261.72	1262.017	1262.331	9.163	9.24	-34.32	32.12
	68	1261.991	1262.297	1262.581	9.645	8.034	-29.41	38.11
	69	1262.192	1262.553	1262.798	10.378	9.022	-23.69	39.98
	70	1262.417	1262.768	1263.06	10.194	9.153	-28.59	38.41
	71	1262.759	1263.002	1263.309	10.671	8.61	-28.8	28.16
	73	1263.501	1263.695	1264.013	10.697	8.737	-29.69	22.23

Results and Discusion.

Comparison of Broad-Based Profiles with Regulatory Legal Documents. As part of the study, profiling cross-sections with grouped pickets were identified for the area under study on the Tibilisian Highway. Profile sections selected at intervals of 20 *m* have significant differences in graphic rendering. According to regulatory legal documents, which also serve as a legal basis for the justification and control of road construction projects, there are significant discrepancies in the cross-sectional surface of the roadway covered within the framework of the study. As a benchmark for permissibility and control of discrepancies, clear sliding technical norms have been adopted, which according to their intended purpose define the technical requirements for each road infrastructure. In this case, the object under study is a two-lane three-lane highway, with respect to which the guidelines for maintenance of technical norms state that from the central axis to the edge axes in the non-steep sections should have a cross-sectional inclination of 15–20‰ [6]. Comparing data from spatial analyses and cross-sectional profiles in the UATH environment, we have the following image.

Central Axis-left Edge Axis:

- (–37.6)–(–23.7)‰ Slope has: 64, 63, 67, 66, 65, 73, 68, 71, 70, 67, 72, 69 profile lines, the edge axis of the road surface in the mentioned sections has a higher height than the central axis, it corresponds to a transverse slope indicator of the length of the turning arc R up to 600 *m*, which should be up to 40‰.
- (–15.5)–(–0.3)‰ Incline: 59, 61, 58, 60, 10, 34, 33, 32, 31, 14, the profile lines of 58, 34, 33, 32, 35, 31, 14 and 10 do not comply with technical norms because they have a higher height than the central axis of said section.
- 0.8–15,1‰ Incline: 29, 36, 37, 30, 18, 40, 39, 45, 2, 22, 9, 23, 28, 12, 13, 25, 24, 26, 5, 6, 44, 21, 17, 41, 15, 52, 20, 27, 19, 46, 11, 8, 7, 55, 47, 57, 51, 42, 53, 56, 43, 48, 3, all of these profile lines have less incline than required by technical norms, which should be 15–20‰.
- 15.3–37.5‰ Incline: 16.38, 49, 50, 54.4, 1. The profile line 1 of these numbers has a slope of 37.5‰, which exceeds the norm.

Central Axis-right Edge Axis:

- (–45.3)–(–15.5)‰ Incline: 1, 2, 72, 3 profile lines.
- (–6.1)–6‰ Incline: 9, 6, 7, 4, 5, 8, 53, 13, 40, 10, 12, 15, 14, 52, 42. Profile lines whose numerical value does not comply with technical norms, these values should have been in the range of 15–20‰ inclines.
- 6.5–15.9‰ incline: 31, 23, 32, 41, 16, 51, 24, 11, 33, 43, 30, 25, 21, 35, 20, 46, 26. The profile lines of 39, 17, 18, 45, 29, 19, 22, 55, 34, 44, 38, 56, 57, 54, 28, 49, 50, 48, 27, whose numerical value does not comply with the technical norms, should have been included between the inclines of 15–20‰.
- 16.2–40‰ incline: 47, 36, 37, 60, 73, 58, 59, 71, 66, 67, 62, 64, 65, 61, 68, 70, 63 and 69 profile lines with indicators in line with technical norms, providing 15–20‰ in non-turning sections, and 40‰ in transverse incline norms up to 600 *m* long.

Floor plans for spatial analyses and profile sections featuring profile lines and picket groups by numbering, road surface with irregular triangulation grid and horizontal 10 *cm* drop, as well as a map of surface slopes (see Figs. 4 and 5). Taking into account the results of the survey, we can conclude that the technical norms of the architectural construction of road infrastructure and their maintenance, not only ensure the longevity of the operation of these infrastructures, but also guarantee the enhancement of the safety concept, the reduction of the workload, the increase of the risk of natural disasters. Specifically, a designated section of the Tbilisi highway, which has a longitudinal inclination due to terrain features, is often flooded due to inefficient drainage systems and transverse surface inclinations. This in turn, leads to the intense degradation of the hard cover and the formation of waterholes. By maintaining technical standards and increasing the efficiency of operation, vehicle carrying capacity is increased, reducing the balancing and longevity of traffic jams in inclement weather conditions [1].

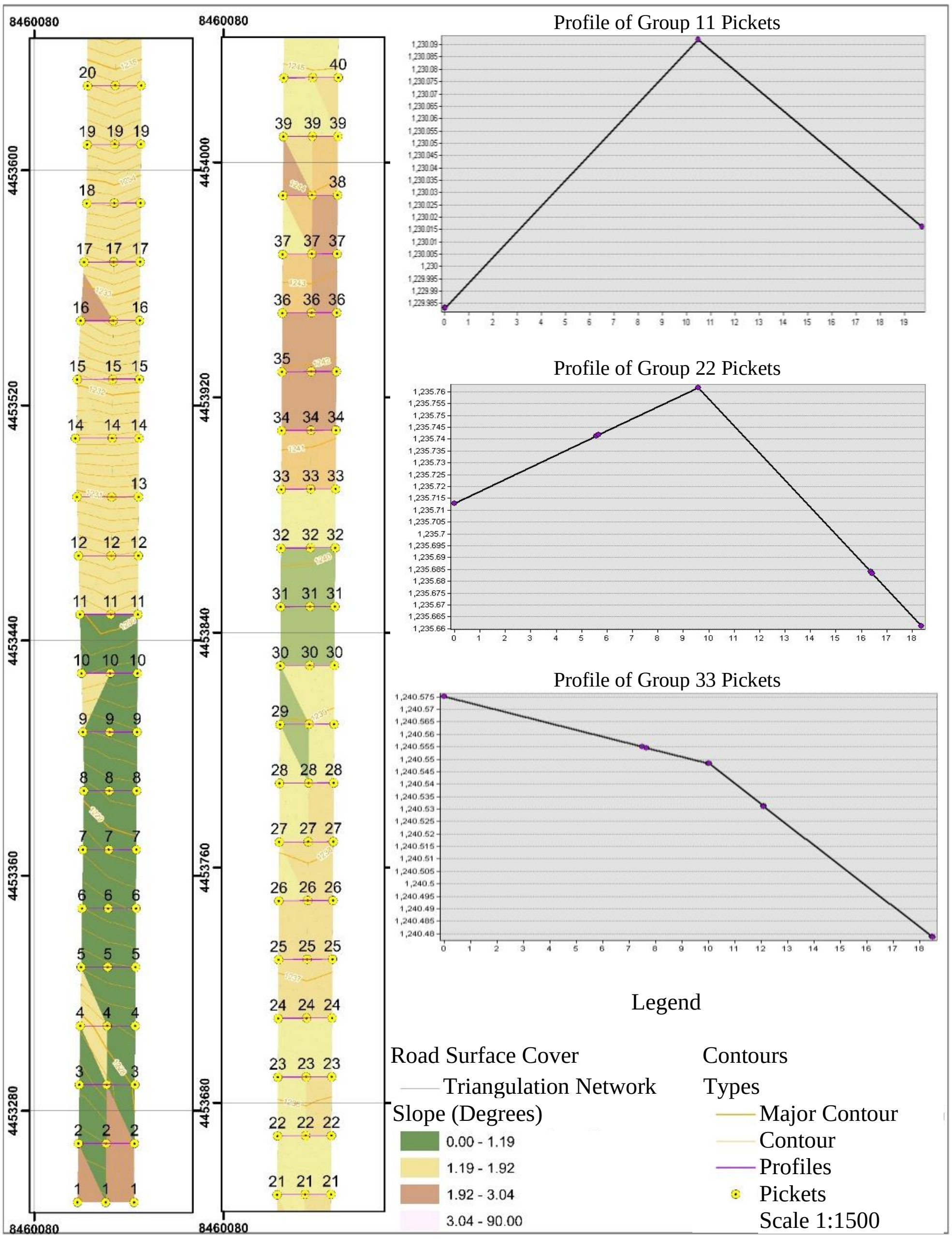

Fig. 4. Plan of elevation data for the surface cover of stakeout points 1–40.

Conclusion and Recommendations. Significant areas of the highway surface have impairment of the necessary technical conditions, and their correction will promote the effective organization of drainage in the specified roadway and increase traffic safety. Graphs of the profile sections identified during the study and access to the digital layers are provided with the following reference to the literature list [7].

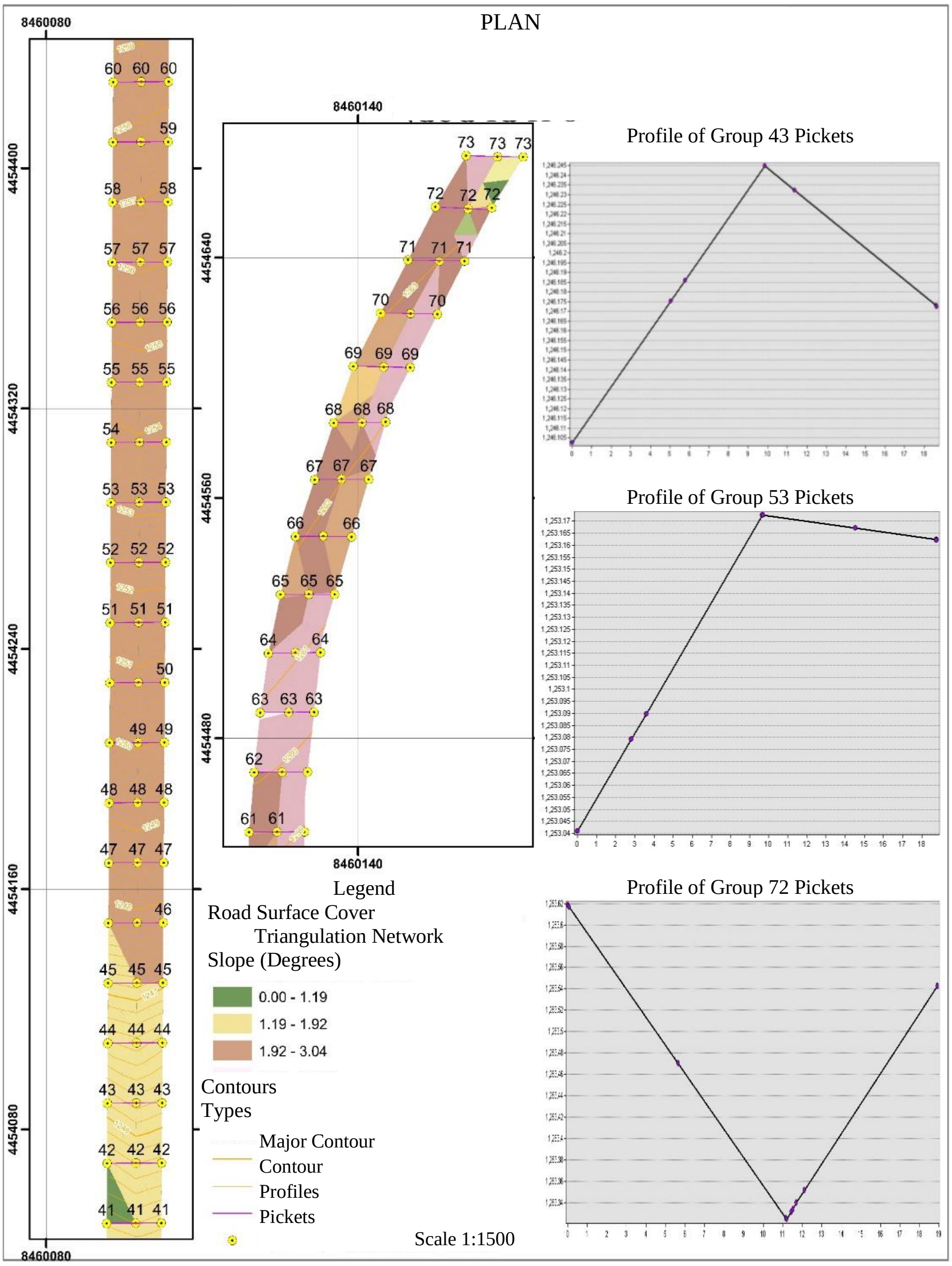

Fig. 5. Plan of elevation data for the surface cover of stakeout points 41–73.

Based on the results identified during the study, the following recommendations are proposed to ensure compliance with the technical standards of transverse profiles of road infrastructure surfaces:

1. Conduct phased monitoring of road infrastructure surface coverings (at most every two years).

2. Align the quality control standards for surface renewal works with technical requirements that are as close as possible to the construction phase during renovation activities.

3. Implement control measures on freight traffic to prevent the movement of trucks exceeding the permissible load limits.

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REFERENCES

1. Park H.S., Lee H.M., et al. A New Approach for Health Monitoring of Structures: Terrestrial Laser Scanning. *Computer-Aided Civil and Infrastructure Engineering* **22** (2007), 19–30. https://doi.org/10.1111/j.1467-8667.2006.00466.x
2. Han J.-Y., Guo J., Tsai M.-J. Automatic Reconstruction of Road Surface Features by Using Terrestrial Mobile Lidar. *Automation in Construction* **58** (2015), 165–175. https://doi.org/10.1016/j.autcon.2015.07.017
3. Hovsepyan E.M. Comprehensive Assessment Roadside Injuries through High-Resolution Three-dimensional Laser Scanning. *Proc. of YSU. Geol. and Geograph. Sci.* **58** (2024), 95–103. https://doi.org/10.46991/PYSU:C.2024.58.2.095
4. Kukko A., Kaartinen H., et al. Multiplatform Mobile Laser Scanning: Usability and Performance. *Sensors* **12** (2012), 11712–11733.
5. Riveriro B., Gonzalez-Jorge H., et al. Laser Scanning Technology: Fundamentals, Principles, and Applications in Infrastructure. In book: *Non-Destructive Techniques for the Reverse Engineering of Structures and Infrastructure*. CRC Press, London, UK (2016), 7–33. https://doi.org/10.1201/b19024-4
6. *Interstate Standard. Public Roads. Rules for Designing Highways*. GOST R52399-2022.
7. https://drive.google.com/drive/folders/1bEzXSJu8M5KwA04ZjBlMIZcYSJQ4P-GD?usp=drive_link

Է. Մ. ՀՈՎՍԵՓՅԱՆ

ՃԱՆԱՊԱՐՀԱՅԻՆ ՄԱԿԵՐԵՎՈՒՅԹԻ ԼԱՅՆԱԿԻ ԿՏՐՎԱԾՔՆԵՐԻ ՊՐՈՖԻԼՆԵՐԻ ՍՏԱՑՄԱՆ ՄԵԹՈԴԱԲԱՆՈՒԹՅՈՒՆԸ ԼԱԶԵՐԱՅԻՆ ՍԿԱՆԱՎՈՐՄԱՆ ՏՎՅԱԼՆԵՐԻ ԿԻՐԱՌՄԱՄԲ

Ամփոփում

Ճանապարհային ենթակառուցվածքների որակն ու տեխնիկական համապատասխանությունը կարևոր դեր են խաղում տրանսպորտային ցանցերի արդյունավետության և անվտանգության ապահովման գործում: Սույն հետազոտության շրջանակում ուսումնասիրվել է ճանապարհի լայնակի կտրվածքների պրոֆիլների ստացման մեթոդաբանությունը՝ 3D լազերային սկանավորման տվյալների կիրառմամբ:

Ուսումնասիրվող տարածքում AU20 լազերային սկանավորման համակարգով իրականացվել է ճանապարհային մակերևույթի հետազոտություն, որի արդյունքում ստացված տվյալները մշակվել են ArmRef02 կոորդինատային համակարգում:

Հետազոտության նպատակներն են.

• մշակել ավտոմատացված մեթոդաբանություն 3D կետերի ամպից ճանապարհի մակերևույթի առանձնացման համար:

• Բացահայտել ճանապարհի եզրային և կենտրոնական առանցքները տարածական տվյալների անալիզի միջոցով:

• Համեմատել ստացված պրոֆիլները տեխնիկական նորմերի հետ և գնահատել դրանց համապատասխանությունը:

Վերլուծության արդյունքում հայտնաբերվել են լայնակի թեքության շեղումներ, որոնք խաթարում են ջրահեռացման արդյունավետությունը և նվազեցնում ճանապարհային անվտանգության մակարդակը: Տեխնիկական նորմերի խախտումները հանգեցնում են մակերևույթի ջրահոսքի անհամաչափության, ինչը նպաստում է ծածկի քայքայմանը և տրանսպորտային միջոցների կառավարման ռիսկերի աճին:

Э. М. ОВСЕПЯН

МЕТОДОЛОГИЯ ПОЛУЧЕНИЯ ПОПЕРЕЧНЫХ ПРОФИЛЕЙ ДОРОЖНОЙ ПОВЕРХНОСТИ С ИСПОЛЬЗОВАНИЕМ ДАННЫХ ЛАЗЕРНОГО СКАНИРОВАНИЯ

Резюме

Качество и техническое соответствие дорожной инфраструктуры играет важную роль в обеспечении эффективности и безопасности транспортных сетей. В рамках данного исследования изучена методология получения поперечных профилей дорожной поверхности с использованием данных 3D-лазерного сканирования.

На исследуемом участке было проведено исследование дорожной поверхности с применением системы лазерного сканирования AU20, а полученные данные обработаны в координатной системе ArmRef02.

Цели исследования:

• разработать автоматизированную методологию для выделения дорожной поверхности из облака 3D-точек.

• Определить краевые и центральные оси дороги с использованием пространственного анализа данных.

• Сравнить полученные профили с техническими нормативами и оценить их соответствие.

В результате анализа выявлены отклонения поперечных уклонов, которые нарушают эффективность дренажа и снижают уровень дорожной безопасности. Несоответствие техническим нормативам приводит к неравномерному стоку воды на поверхности, что способствует разрушению покрытия и увеличению рисков управления транспортными средствами.