ENGINEER

international scientific journal

SPECIAL ISSUE
E-ISSN
3030-3893
ISSN
3060-5172

A bridge between science and innovation

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

ENGINEER

A bridge between science and innovation

E-ISSN: 3030-3893

ISSN: 3060-5172

SPECIAL ISSUE

27-june, 2026

engineer.tstu.uz

TEXNIKA FANLARI DOKTORI, PROFESSOR MIRAXMEDOV MAXAMADJON MIRAXMEDOVICH TAVALLUDINING 80 YILLIGIGA BAG‘ISHLANGAN “SAMARALI QURILISH MATERIALLARI, KONSTRUKSIYALARI VA TEXNOLOGIYALARI” MAVZUSIDAGI XALQARO ILMIY-AMALIY KONFERENSIYASI ILMIY ISHLARI TO‘PLAMI

Toshkent davlat transport universiteti RAASN akademigi, O'zbekistonda xizmat ko'rsatgan yoshlar murabbiyi, texnika fanlari doktori, professor Miraxmedov Maxamadjon Miraxmedovich tavalludining 80 yilligiga bag'ishlangan, ilmiy ishlar to'plami nashr etilishi ko'zda tutilgan «Samarali qurilish materiallari, konstruksiyalari va texnologiyalari» mavzusidagi Xalqaro ilmiy-amaliy konferensiyani o'tkazishni rejalashtirmoqda.

M.M. Miraxmedov kompozitsion qurilish materiallarining polistruktura nazariyasini rivojlantirishga salmoqli hissa qo'shgan. Uning qurilish materialshunosligi sohasidagi ilmiy hissasi e’tirofi sifatida 1995-yilda Rossiya arxitektura va qurilish fanlari akademiyasining (RAASN) xorijiy a’zosi etib saylangan. M.M. Miraxmedov 6 ta monografiya, 200 dan ortiq ilmiy maqolalar va 25 ta ixtiroga mualliflik guvohnomalari muallifidir.

Ushbu konferensiyaning asosiy maqsadi - qurilish materialshunosligi, bino va inshootlarni loyihalash va qurilish sohasidagi ilmiy tadqiqotlar natijalarini, shuningdek, muhandislik ta’limini takomillashtirish yo'llarini muhokama qilishdan iborat.

Konferensiya ishida ishtirok etish uchun oliy o'quv yurtlari va ilmiy tadqiqot institutlari olimlari, O'zbekiston Respublikasi va xorijiy davlatlarning ishlab chiqarish vakillari, ilmiy tadqiqotlarda salmoqli natijalarga ega bo'lgan mutaxassislar taklif etiladi.

“Samarali qurilish materiallari, konstruksiyalari va texnologiyalari” mavzusidagi xalqaro ilmiy-amaliy konferensiyaning asosiy yo‘nalishlari quyidagilardan iborat:

1. Resurs va energiya tejovchi qurilish materiallari va texnologiyalari.
2. Atrof-muhitning transport infratuzilmasiga ta’siri va uni himoya qilish usullari.
3. Bino va inshootlarning qurilish konstruksiyalari: hisoblash va loyihalashning zamonaviy usullari.
4. Arxitektura, shaharsozlik va shahar muhitini rivojlantirish.
5. Qurilishni tashkil etishning innovatsion usullari va qurilish jarayonlari texnologiyalari.
6. Transport obyektlarini loyihalash va qurishda raqamli texnologiyalar hamda sun’iy intellekt.
7. Temir yo‘l transporti infratuzilmasi obyektlarini loyihalash, qurish va ekspluatatsiya qilish.
8. Zamonaviy muhandislik ta’limi tizimini takomillashtirish.

Mazkur konferensiya ilmiy hamjamiyatning turli vakillarini bir joyga jamlab, qurilish materialshunosligi sohasidagi zamonaviy muammolar va istiqbollarni muhokama qilish uchun qulay platforma vazifasini bajardi.

The Practical Importance of QGIS Technologies in Engineering Geological Mapping

Sh.R. Khalimova[1][a], A.M. Karabaev[1][b]

[1]Tashkent State Transport University, Tashkent, Uzbekistan

Abstract: Engineering geological mapping is essential for infrastructure planning, geohazard assessment, and sustainable urban development, particularly in rapidly urbanizing regions. The growing complexity of spatial data requires efficient tools capable of integrating and analyzing diverse geological and terrain information. This study evaluates the practical importance of QGIS, an open-source Geographic Information System, for engineering geological mapping using Tashkent city as a case study. A structured and reproducible workflow was developed by integrating geological maps, Digital Elevation Models (DEMs), and field-based observations within the QGIS environment. DEM-derived morphometric parameters, including elevation, slope, aspect, and hillshade, were analyzed to characterize terrain conditions and assess construction suitability. Spatial overlay techniques were applied to combine geological and morphometric factors, enabling the identification of areas with potential geotechnical constraints. The results indicate that QGIS significantly enhances the accuracy, efficiency, and interpretability of engineering geological analyses. Three-dimensional visualization and thematic mapping improved the understanding of terrain morphology and spatial relationships between geological factors, supporting more informed engineering decision-making. Overall, the study confirms that QGIS is a robust, cost-effective, and flexible platform for engineering geological mapping in urban environments.

Keywords: Engineering geological mapping; QGIS; Digital Elevation Model (DEM); morphometric analysis; slope analysis; spatial overlay; 3D visualization; geotechnical risk assessment; urban geology

1. INTRODUCTION

Engineering–geological mapping plays an important scientific and practical role in the planning of modern infrastructure projects, the assessment of geological hazards, and the sustainable development of territories. Reliable information on subsurface conditions, lithological composition, geomorphological structure, and hydrogeological characteristics is a decisive factor in ensuring the safety, stability, and long-term performance of construction facilities [1]. Under conditions of rapid urbanization and the expansion in scale of engineering structures, traditional mapping methods increasingly limit the possibilities for comprehensive analysis of spatial data.

Geographic Information Systems (GIS) have marked a new stage in the collection, processing, and analysis of spatial data in engineering geology. In particular, the open-source QGIS (Quantum Geographic Information System) platform stands out due to its user-friendly interface, extensive analytical capabilities, and continuous development supported by an active user community [1, 2]. QGIS enables the creation of digital geological maps, the integration of data obtained from various sources, and the implementation of spatial analyses required for informed engineering decision-making [3, 4].

The widespread use of QGIS in professional practice and educational processes demonstrates its growing importance in engineering–geological mapping. Owing to its cost-effectiveness and high adaptability, it is increasingly being chosen by many organizations and research institutions as an alternative to licensed software solutions [7, 8]. This study is aimed at analyzing the practical significance of QGIS technologies in engineering–geological mapping, as well as their application potential, advantages, and limitations.

Literature review

Over the past decades, the use of Geographic Information Systems (GIS) in the fields of geology and engineering sciences has expanded significantly, becoming one of the principal scientific tools for digital geological mapping, geotechnical investigations, and the assessment of natural hazards [1, 11, 16]. According to the scientific literature, the transition from traditional paper-based mapping methods to GIS-based digital environments has enabled more accurate data representation, improved spatial consistency, and enhanced reproducibility of analytical results in engineering geology [12, 23]. This, in turn, has contributed to the development of a reliable scientific basis for engineering decision-making.

A number of studies emphasize that QGIS (Quantum Geographic Information System), as an open-source GIS platform, is capable of competing functionally with commercial software such as ArcGIS [8, 15, 17]. Researchers highly evaluate QGIS

[a] https://orcid.org/0000-0002-4753-390X
[b] https://orcid.org/0000-0002-9880-8547

for its analytical capabilities, data processing efficiency, and visualization quality, while particularly highlighting that its open-source ecosystem allows for flexible expansion in accordance with user needs [2, 10]. The absence of licensing costs is identified as a key factor driving the widespread adoption of QGIS by higher education institutions, governmental geological services, and engineering consulting organizations, especially in developing countries [7, 8, 16].

The scientific literature extensively documents the effectiveness of QGIS in visualizing and interpreting complex geological data, including lithological units, networks of tectonic faults, stratigraphic boundaries, and hydrogeological objects [11, 12, 13]. The platform enables the integration of vector and raster data within a single environment, allowing geological maps to be analyzed together with digital elevation models (DEM), satellite imagery, and geotechnical borehole data [1, 6]. This capability ensures a comprehensive and systematic approach to engineering–geological assessments.

The extensive plugin ecosystem of QGIS further broadens its practical applicability. Scientific studies report the effective use of plugins such as GeoTrace, QGIS2threejs, as well as tools oriented toward geostatistical analysis and spatial modeling in engineering–geological research [2, 10, 24]. These plugins facilitate the identification of spatial orientations of geological structures, the assessment of slope stability, and the visualization of terrain morphology in both 2D and 3D environments [10, 18]. This is of critical importance for improving the understanding of geological processes and for the early assessment of engineering hazards.

Applied studies confirm the significance of QGIS in landslide susceptibility assessment, urban area planning, and the implementation of large-scale infrastructure projects [7, 9, 16, 18]. In landslide-prone areas, GIS-based modeling has contributed to the identification of high-risk zones by integrating geomorphological, geological, and climatic factors, thereby providing a foundation for the development of engineering measures aimed at risk mitigation [18]. Furthermore, studies conducted in the field of urban planning demonstrate that QGIS is effective in analyzing land-use dynamics, forecasting infrastructure demands, and implementing “smart city” concepts [16, 19].

At the same time, the literature also identifies certain limitations associated with the use of QGIS in engineering–geological mapping. Data accuracy and reliability remain among the primary challenges, as GIS analyses are highly dependent on the quality, resolution, and timeliness of input data [12, 20]. In addition, interoperability issues between GIS platforms and engineering software such as CAD and BIM often require complex format conversions, which may result in additional time and cost expenditures during project workflows [16, 20].

Another frequently cited challenge is the shortage of highly qualified GIS specialists in the fields of civil and geotechnical engineering [20, 21]. Although GIS technologies are widely taught in environmental and urban planning disciplines, their full integration into engineering education programs has not yet been sufficiently achieved in many regions. This situation indicates that, despite the significant technical and economic advantages of QGIS, its effective application requires systematic professional training, standardized data practices, and institutional support.

In summary, the existing literature confirms that QGIS technologies possess strong scientific and practical potential in engineering–geological mapping. At the same time, addressing issues related to data quality, professional training, and software interoperability emerges as a critical prerequisite for the more effective application of QGIS in engineering practice.

Data collection method

Engineering–geological mapping implemented using QGIS is based on the integration of spatial and non-spatial data. Commonly used data types include geological maps, digital elevation models (DEM), satellite imagery, field survey records, and GPS-based point observations [1, 6].

Data are typically collected from open geospatial repositories, national geological services, and field investigations. Prior to analysis, the data undergo preprocessing stages such as coordinate system standardization, data cleaning, and attribute verification. Quality control measures include the validation of spatial data through comparison with field observations and the verification of results using comparative analysis methods [1].

The integration of GPS technologies within the QGIS environment enables real-time positioning during fieldwork, thereby enhancing the accuracy and reliability of geological data collection [6]. This synergy between remotely sensed data and field-based observations provides a solid foundation for the effective implementation of engineering–geological analyses.

2. METHODOLOGY

In this study, the methodology for applying QGIS technologies to engineering–geological mapping was structured around a systematic and reproducible workflow. The methodological approach comprises several key stages:

Stage 1. Data collection and preparation. Spatial and non-spatial data required for engineering–geological analysis were collected from open geospatial sources, national geological services, and the results of field investigations. These data included geological maps, digital elevation models (DEM), satellite imagery, geotechnical borehole data, and GPS-based point observations [1, 6]. All datasets were transformed into a unified coordinate reference system, attributes were verified, and data cleaning procedures were performed.

Stage 2. Integration of data into the QGIS environment. The prepared datasets were imported into QGIS in both vector and raster formats. At this stage, data obtained from various sources were integrated within a single environment, ensuring spatial compatibility and topological consistency [7]. This process provided a reliable spatial database for subsequent analyses.

Stage 3. Terrain and morphometric analysis. Based on the DEM, terrain parameters were calculated, including elevation, slope, and aspect, as these indicators are essential for assessing land suitability for construction and identifying geological hazards [1]. The morphometric analyses served as a fundamental basis for engineering decision-making.

Stage 4. Geological and structural analysis. Geological units, tectonic structures, and fault networks were generated as thematic layers. Using specialized QGIS plugins such as GeoTrace, structural elements were digitized, and their orientations and three-dimensional characteristics were evaluated based on the DEM [10]. This stage enabled a more in-depth analysis of the spatial structure of the geological environment.

Stage 5. Hazard assessment and thematic map production. Based on the analytical results, thematic maps illustrating hazard-prone areas (e.g., zones of low slope stability) were produced. Overlay analysis of multiple spatial layers was employed to identify areas posing engineering risks, and their spatial distribution was visualized [2].

Stage 6. Validation and visualization of results. The analysis outcomes were validated through comparison with field data and presented in a clear and interpretable form using visualization tools. Both 2D and 3D visualization techniques were applied to create maps suitable for use in the engineering decision-making process.

The selected workflow enables high spatial accuracy, efficient data integration, and reproducibility of geological analyses within the open-source QGIS environment. This approach serves as a reliable methodological framework for supporting scientifically grounded decision-making and the proactive assessment of hazards in engineering–geological mapping.

3. RESULTS AND DISCUSSION

The application of QGIS technologies in engineering geological mapping significantly enhanced the efficiency, accuracy, and interpretability of spatial analyses. DEM-based morphometric analysis provided a detailed representation of the terrain structure and elevation variability within the study area. As illustrated in Fig. 1, the spatial distribution of key morphometric parameters—such as elevation, slope, aspect, and hillshade—clearly reflects the geomorphological characteristics of Tashkent city. These parameters form the fundamental basis for engineering geological assessment and support the identification of terrain conditions relevant to construction suitability.

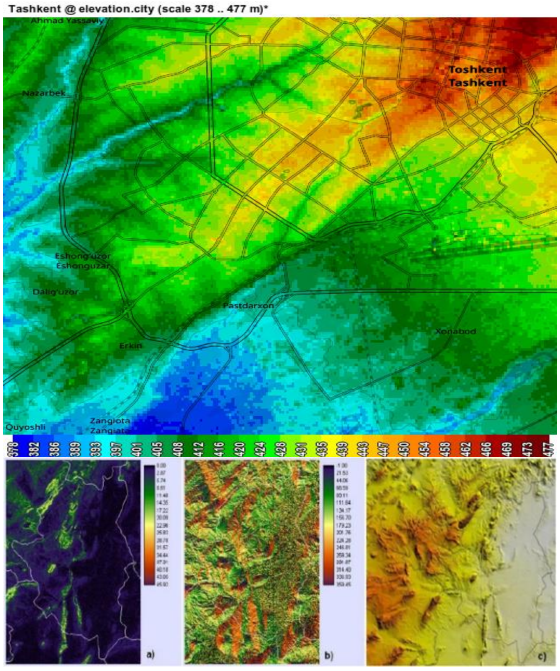
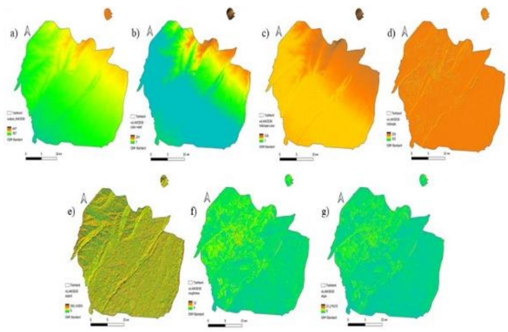


Fig. 1. DEM-based morphometric analysis of Tashkent city including elevation, slope, aspect, and hillshade maps used for engineering geological assessment

Slope analysis derived from DEM data proved to be a critical factor in evaluating geotechnical constraints. The slope gradient map presented in Fig. 2 highlights areas characterized by varying slope classes, allowing the identification of zones with increased susceptibility to geotechnical hazards. Areas with higher slope gradients were recognized as potentially unfavorable for construction due to an elevated risk of slope instability, ground deformation, and related engineering challenges. This analysis demonstrates the importance of slope as a key indicator in engineering geological risk assessment.



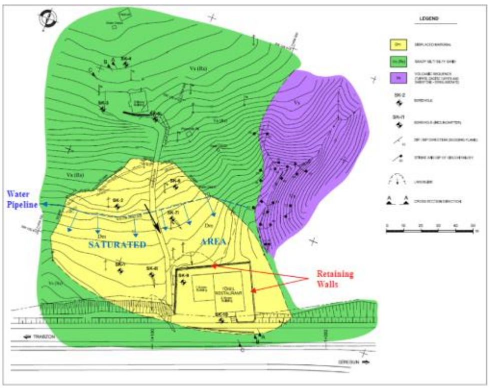


Fig. 2. Slope gradient map of Tashkent city derived from DEM data, highlighting areas with varying slope classes and potential geotechnical constraints

An integrated engineering geological evaluation was achieved through overlay analysis of geological units, structural features, and DEM-derived morphometric parameters. The resulting integrated map, shown in Fig. 3, provides a comprehensive spatial representation of hazard-prone and relatively stable zones across the study area. This integrated approach enables a more holistic understanding of subsurface and surface conditions, supporting informed decision-making in infrastructure planning and development.

Overall, the results confirm that QGIS offers a robust and flexible framework for engineering geological mapping. The combination of DEM-based morphometric analysis (Fig. 1), slope assessment (Fig. 2), and integrated spatial evaluation (Fig. 3) demonstrates the effectiveness of QGIS in analyzing complex geological environments. These capabilities contribute to improved risk identification, enhanced visualization, and scientifically grounded engineering decisions, reinforcing the practical value of QGIS in modern engineering geological applications.

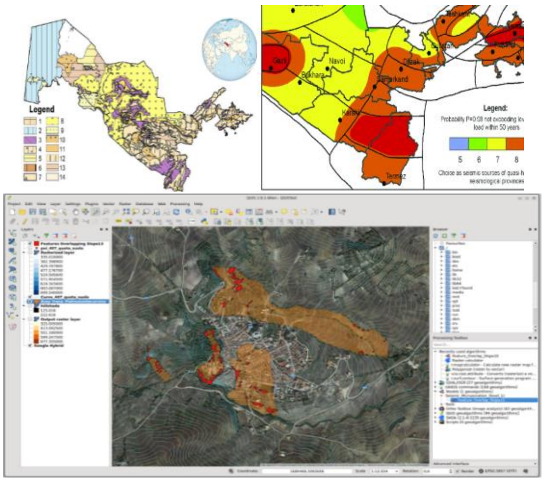


Fig. 3. Integrated engineering geological risk map of Tashkent city based on overlay analysis of geological units and DEM-derived terrain parameters

4. CONCLUSION

The results of this study demonstrate that QGIS technologies have significant practical value in engineering–geological mapping by effectively supporting spatial analysis, data integration, and visualization processes. As an open-source and economically efficient platform, QGIS provides extensive opportunities for making scientifically grounded decisions and ensuring sustainable infrastructure development in the fields of geology and engineering.

At the same time, the integration of QGIS with artificial intelligence, machine learning, the Internet of Things (IoT), and cloud-based GIS platforms has the potential to further enhance its role in predictive modeling, automated analysis, and collaborative geological research in the future. This, in turn, will contribute to safer and more sustainable decision-making in engineering practice.

REFERENCES

[1] Erharter G., et al. Geological Maps with QGIS: A New Guideline for Digital Geological Mapping. 2023. Available as PDF.

[2] Hatari Labs. 5 Best QGIS Plugins You Should Know About. Available at: https://hatarilabs.com/ih-en/5-best-qgis-plugins-you-should-know-about

[3] Boxer G. Using QGIS in Mineral Exploration. Draft Report, 2023.

[4] Krumm C. Q1 2023: 3 Maps I Made Using QGIS 3.30 & the Lessons I Learned. LinkedIn Pulse, 2023. Available at: https://www.linkedin.com/pulse/q1-2023-3-maps-i-made-using-qgis-330-lessons-learned-claire-krumm

[5] QGIS in Mineral Exploration. Using QGIS for Geological and Mineral Exploration Applications. Available at: https://qgis-in-mineral-exploration.readthedocs.io/en/latest

[6] Mergin Maps. Open-Source Geological Mapping with the British Geological Survey. Available at: https://merginmaps.com/case-studies/open-source-geological-mapping-with-british-geological-survey

[7] GIS Cloud. GIS Mapping and the Benefits of Online Solutions. Available at: https://www.giscloud.com/blog/gis-mapping-and-benefits-of-online-solutions

[8] ialeUK. Mapping and the Benefits of QGIS. Available at: https://iale.uk/mapping-and-benefits-qgis

[9] Erharter G.H., Steinbichler M., Eder M., Hintersberger E., Jaeger D. A New Guideline for Geological Maps with QGIS // Austrian Journal of Earth Sciences. 2023. Vol. 116. P. 147–150. https://doi.org/10.17738/ajes.2023.0008

[10] QGIS Plugin Repository. GeoTrace: Geological Structure Tracing and Orientation Analysis Plugin. Available at: https://plugins.qgis.org/plugins/GeoTrace

[11] Hatari Labs. Open Webinar: How to Make a Geological Map with QGIS (April 27–29, 2021). Available at: https://hatarilabs.com/ht-en/open-webinar-how-to-make-a-geological-map-with-qgis-apr-27-29-2021

[12] Encardio Rite Group. GIS in Civil Engineering: Applications, Benefits, and Future Trends. Available at: https://dev.encardio.com/blog/gis-in-civil-engineering

[13] Bedrock Engineering. Viewing Geotechnical Data in QGIS. Available at: https://bedrock.engineer/guides/viewing-qgis

[14] QGIS Geo Mapping Masterclass (Video). Available at: https://www.youtube.com/watch?v=py78PmQNURA

[15] GIS for Geologists. Why Learn to Use QGIS? Available at: https://www.gisforgeologists.com/pages/why-learn-to-use-qgis

[16] Encardio-Rite. GIS in Civil Engineering: Applications, Benefits, and Future Trends. Available at: https://dev.encardio.com/blog/gis-in-civil-engineering

[17] Forr M.B. Why QGIS Still Matters, Even If You're Beyond the Basics. LinkedIn Post. Available at: https://www.linkedin.com/posts/mbforr_why-qgis-still-matters-even-if-youre-beyond-activity-7381523739336937472-iJZV

[18] Mathew B.V., Jayakrishnan R., Chandran A., Pranav A., Rishikesh V.S. GIS-Based Landslide Mapping and Analysis Using QGIS: A Study in Palakkad, Kerala // International Journal of Engineering and Management Research. 2025. Vol. 15, No. 1. P. 142–150. https://doi.org/10.5281/zenodo.15070403

[19] QGIS Plugin Repository. Geology Plugins for QGIS. Available at: https://plugins.qgis.org/plugins/tags/geology

[20] Encardio. GIS in Civil Engineering: Applications, Benefits, and Future Trends. Available at: https://www.encardio.com/blog/gis-in-civil-engineering

[21] New Zealand Geotechnical Society (NZGS). Geotechnical Investigations Using QGIS Software. Available at: https://www.nzgs.org/event/geotechnical-investigations-using-qgis-software

[22] Mittal A., Pandey G., Siddiqui N.A., Mondal P., Molokitina N.S. QGIS: An Effective Tool in Assessing the Quantity and Quality of Groundwater Resources // Water Supply. 2025. Vol. 25, No. 1. P. 48–64. https://doi.org/10.2166/ws.2025.004

[23] Perret J., Jessell M.W., Bétend E. An Open-Source, QGIS-Based Solution for Digital Geological Mapping: GEOL-QMAPS // SSRN Electronic Journal. 2024. 27 p. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4814451

[24] Carroll Engineering. Enhancing Civil Engineering with GIS Models. Available at: https://www.carrollengineering.com/enhancing-civil-engineering-with-gis-models

INFORMATION ABOUT THE AUTHORS

Sh.R. Khalimova	Tashkent State Transport University, the Department of Urban infrastructure engineering and artificial intelligence E-mail: xalimova_sh@tstu.uz Tel.: +998 95 833 01 37 https://orcid.org/0000-0002-4753-390
A.M. Karabaev	Tashkent State Transport University, the Department of Construction of Buildings and Industrial Structures Tashkent State Transport University, the Department of Urban infrastructure engineering and artificial intelligence E-mail: karabaev_a@tstu.uz Tel.: +998 95 957 19 51 https://orcid.org/0000-0003-3691-1079

CONTEXT / MUNDARIJA

V. Soy, U. Shermukhamedov, A.Babaev , N. Mukhammadiev, G. Malikov
Analysis of The Influence of Loading Time and Technological Factors on the Deformation of Long-Term Creep of Lightweight Concretes……………………………………………………………..124

E. Urazxanova, K. Markabaeva
Passive Cooling Strategies in Residential Architecture of Hot-Dry Uzbek Cities: A Design-Screening Model……………………………128

G. Dosjanova
Technological Efficiency of Modular Green Roof Systems for Operated Flat Roofs in Nukus Conditions…………………………131

Sh. Khalimova, A. Karabaev
The Practical Importance of QGIS Technologies in Engineering Geological Mapping…………………………………………………135

J. Sodikov, K. Musulmanov, A. Adizov
Integrating Roadside Greening and Urban Microclimate into Pedestrian Accessibility Assessment: A Case Study of Tashkent City ………………………………………………………………140

K. Lesov, Sh. Tadjibaev
Resource-Efficient Designs and Organizational-Technological Solutions for Reinforcing the Subgrade in Sandy Soils…………….147

U. Dosmetov
Management of Transformation Processes in the Railway Industry of Uzbekistan: Problems, Solutions, and Initial Results……………152

S. Djabbarov, N. Kodirov
Forecasting the Fatigue Life of Rails R65 Using Digital Technologies and Artificial Intelligence…………..158

Kh. Umarov
Positive and Negative Aspects of Organizing Heavy-Duty Train Traffic in Increasing the Carrying Capacity of Uzbekistan's Railway Network……………………………………………………………….164

P. Begmatov, F. Eshonov, Sh. Jonkobilov
Assessment of Rail Reliability on Metro Tracks…........................169

U. Ergashev, Sh. Makhamadjonov
Research of Foreign Experiences in Planning Railway Track Repairs Based on Diagnostic Data…...173