# Examples of using laser scanning as a support for traditional measuring methods in hard coal mining

*Mariusz* Koś[1], *Tomasz* Frycz[1], and *Sylwester* Kaczmarzewski[2*]

[1]KWK Knurów-Szczygłowice, 1 Dworcowa St., 44-190 Knurów, Poland
[2]Mineral and Energy Economy Research Institute, Polish Academy of Sciences, 7A Wybickiego St., 31-261 Cracow, Poland

**Abstract.** In recent years, the growing interest in new techniques for spatial data acquisition, processing and analysis has also found applications in surveying and geological departments, where it is used in the process of developing documentation. In the conditions of mining operations, surveying measurements must be carried out quickly, safely and with sufficient accuracy. The use of laser scanning allows the collection of a significant amount of data, which requires time-consuming processing, but is necessary for accurate modelling of objects in 3D. The legal basis for the use of laser scanning in mining is the acts that regulate activities in the field of surveying, geological survey documentation and technical standards for surveying. The process of implementing laser scanning in underground mining requires compliance with occupational safety regulations and technical standards, as well as proper training of personnel. The laser scanners used in practice are equipped with the SLAM algorithm, enabling precise measurement and point cloud generation. Appropriate software is crucial for processing and analysing the collected data. The use of laser scanning makes it possible to efficiently perform non-standard measurements, which contributes to streamlining work at mining facilities. However, to realize its full potential, it is necessary to train personnel and raise the level of use of this technology.

## 1 Introduction

In recent years, there has been a growing interest in new techniques for acquiring spatial data, as well as how to process, analyse and manage it. The dynamic development of modern measurement methods had also a positive effect on the surveying and geological departments of mining operations, which are eager and interested to use this fact in their daily work in the creation of surveying and geological documentation [1 – 3].

Laser scanning technology has emerged as a valuable tool in hard coal mining, complementing traditional measuring methods to enhance efficiency, accuracy, and safety in various aspects of mining operations [4]. By employing laser scanning devices, such as LiDAR (Light Detection and Ranging) scanners, miners can capture highly detailed and

* Corresponding author: skaczmarzewski@meeri.pl

precise 3D images of underground environments, including coal seams, tunnels, and surrounding geological structures [5 – 7]. This data provides comprehensive insights into the topography, dimensions, and conditions of the mine workings, facilitating better planning, monitoring, and management of mining activities [8 – 10].

Laser scanning supports traditional measuring methods by offering rapid and non-intrusive data collection capabilities, minimizing the need for manual measurements and surveys in hazardous or inaccessible areas of the mine [6, 11]. This not only saves time and resources but also improves safety by reducing miners' exposure to potentially dangerous conditions [12]. Furthermore, laser scanning enables the creation of accurate digital models and maps of the mine, which can be used for geological modelling, mine planning, and equipment optimization. These digital representations enhance decision-making processes and help identify potential risks or opportunities for improving operational efficiency and productivity [13 – 15].

Modern measurement technologies, such as laser scanning, are becoming increasingly indispensable in the mining industry due to the need to acquire large amounts of data on the geometry of objects under difficult measurement conditions [16, 17]. The introduction of laser scanning into mines enables the rapid acquisition of accurate information about mine workings and the technical infrastructure of the mine, with minimal measurement time. The technology has found application not only in measuring ground deformation, but also in inspecting the geometry of structures and objects with difficult access, such as retention tanks. Thanks to laser scanning, it is possible to quickly obtain full information about excavations, including measurements of the dimensions and cross-sections of corridor workings. Creating map documentation of workings based on laser scanner data is becoming common practice, enabling detailed analysis of the condition of the facilities and their compliance with the design documentation.

Surveying of mine workings must, above all, be done safely in the shortest possible time, with accuracy appropriate to the importance of the task. The number of observations acquired during a surveying session far exceeds the range needed to create traditional surveying and geological documentation. Therefore, the proper processing and extraction of information from the point cloud sometimes requires a considerable amount of work, which be discouraging. Unfortunately, this is the only way to optimally model an object in its three-dimensional space. Therefore, first of all, we should ask ourselves how, in what shape and with what accuracy the result of our work is to be presented [18 – 19].

An indispensable part of the measurement system is the appropriate software, thanks to which we will obtain a pre-planned effect. So far, the experience of JSW mines has shown the usefulness of the scanner in inventorying explosives stockpiles, scanning mining faces, taking situational and elevation measurements for the purpose of designing reconstruction, and measuring the straightness of belt conveyors or the volume of coal (stone) heaps. It should be borne in mind that the mobile laser scanner measurement technology has been introduced into mines relatively recently, and it will take some time for miners to become familiar and master the point cloud processing technology after its implementation at the next mining site is complete.

### 1.1 Legal basis for use of laser scanning

The use of laser scanning in mining is defined by the legal acts that regulate activities in the field of surveying, geological survey documentation and technical standards for surveying. This implies adherence to technical standards for surveying and documentation, as well as ensuring personnel safety and compliance with mining supervision standards. Accurate documentation and submission of measurement results to the state geodetic and cartographic archive is mandatory. Personnel responsible for taking measurements must be properly trained, and the implementation process is subject to supervision and quality control by the supervisory authorities. The implementation of laser scanning must also consider ensuring compliance with the Law on Surveying and Cartography and other legal acts regulating mining and surveying activities.

The key legislative documents in this area are:

– Ordinance of the Minister of Environment of October 28, 2015 on geodetic surveying documentation – based on §4 item 3, paragraph 1; §5 item 1, paragraph 2;

– Ordinance of the Minister of Internal Affairs and Administration of November 9, 2011 on technical standards for performing land surveying situational and altitude measurements, as well as developing and transferring the results of such measurements to the state geodetic and cartographic archive - based on Article 19 paragraph 1 item 11 of the Act of May 17, 1989. – Geodetic and cartographic law.

The Ordinance of the Minister of the Environment of October 28, 2015 on surveying and geological documentation provides an important legal basis, requiring the inclusion in the collected mining documentation of detailed information on the technologies used in the operation of the plant, including laser scanning. The provisions of §4(3)(1) and §5(1) and (2) impose an obligation to prepare detailed documentation on the geological characteristics of the site of measurements and surveys carried out, including potentially those obtained by laser scanning.

In turn, the Ordinance of the Minister of Internal Affairs and Administration of November 9, 2011 on technical standards for surveying, based on Article 19(1)(11) of the Act of May 17, 1989. – Geodetic and Cartographic Law, provides a general legal framework for geodesy and cartography in Poland. It establishes technical standards for the performance of situational and altimeter measurements, as well as the development and transmission of the results of such measurements. Regarding Article 19(1)(11) of the Act of May 17, 1989. - Geodetic and Cartographic Law, it should be assumed that its provisions may also apply to the use of laser scanning for mining geodesy, especially in the context of developing and transferring the results of measurements to the state geodetic and cartographic resource.

## 2 Methodology

The scanners used at the Knurów-Szczygłowice Mine, are handheld scanning units using the SLAM (Simultaneous Localization and Mapping) algorithm. Radio waves (invisible to the human eye) bounce off surrounding surfaces and return back to the sensor measuring the time wave needed to return to calculate the distance. Two inertial IMU systems have been built into the device, which measure the angles by which the scanning head has rotated and the accelerations it has undergone. All this information is passed to the SLAM algorithm and there the point cloud and trajectory of the scanner's route is generated.

**Fig. 1.** Mobile scanners from GEOSLAM [20] (from left: model: ZEB-Revo , ZEB-Revo RT, ZEB-Horizon).

Accuracy parameters of scanners:

| | |
|---|---|
| ZEB REVO-RT<br>43.200 pt/sec<br>Measurement accuracy 1 – 3 cm<br>Orientation accuracy 3 – 30 cm/10 min – 1 loop<br>Weight: 1 kg/6.3 kg (Zeb-Revo RT) | ZEB-HORIZON<br>300 000 pt/sec<br>Measurement accuracy 1 – 3 cm<br>Orientation accuracy 3 – 30 cm/20 min – 1 loop<br>– compatible with drone<br>Weight: 3.7 kg |

Compared to classical measurement techniques, the laser scanning method can measure incomparably more points, creating at the so-called point cloud. This way, after further processing, spatial model of the excavation is created from the raw observations.

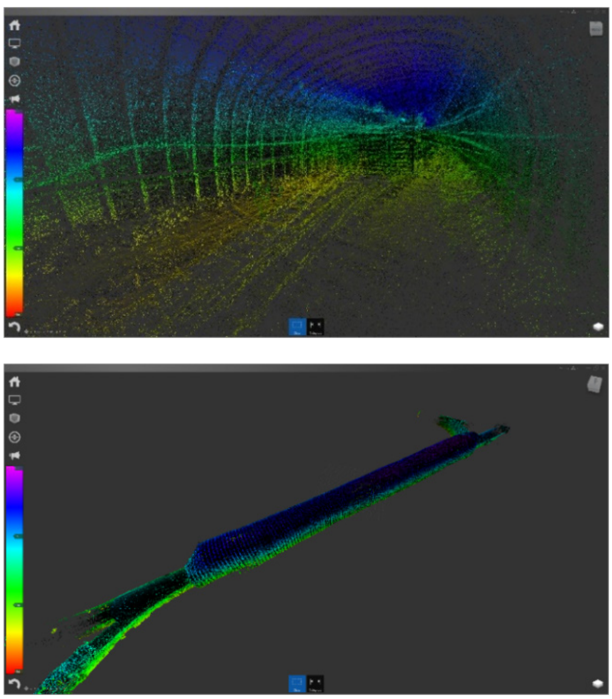

**Fig. 2.** Point cloud presentation presented in AUTODESK RECAP software.

With the help of the appropriate software and processing of the aforementioned cloud, one can obtain accurate data on the excavations, and measure lengths, widths, heights at each location. With so many observations, one can generate (Figs. 3 and 4) cross sections, longitudinal sections, measure volumes, surface areas after scanning the selected space only once.

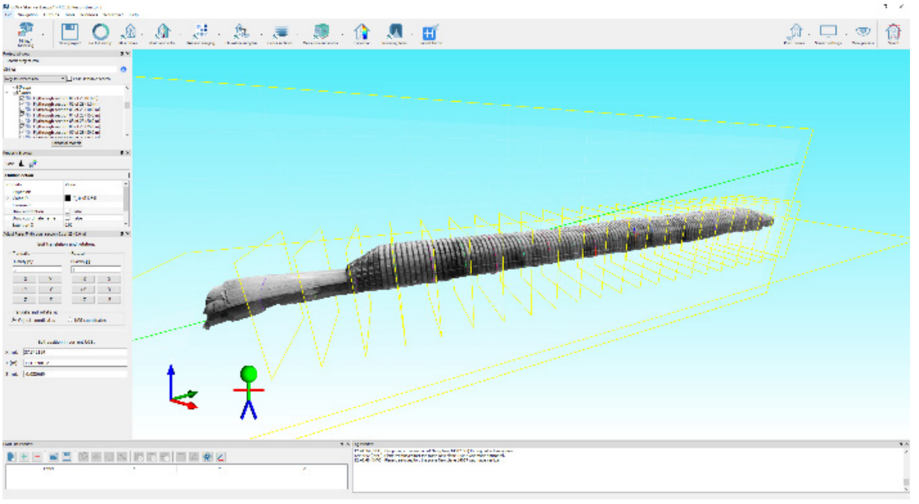

**Fig. 3.** Generating pit cross sections in JRC Reconstructor software.

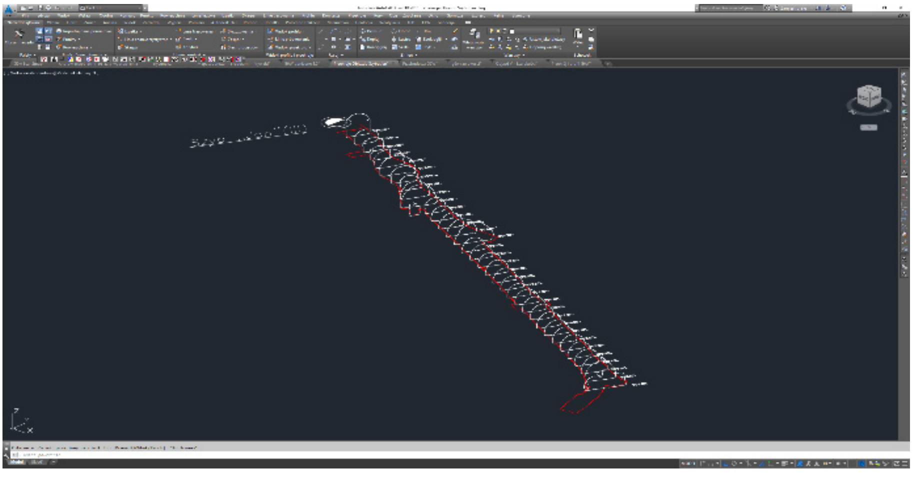

**Fig. 4.** Processing of excavation cross-sections in AutoCAD.

## 3 Results and discussions

The best use of modern measurement techniques is in non-standard tasks, ones that don't follow the regulations directly. In those the contractor could take measurements and process them according to his own needs and discretion. Often, unfortunately, this is the only possible way to learn or expand one's knowledge regarding the processing and use of such a huge number of observations as a point cloud. Unfortunately, the example presented below is not an atypical task but an ordinary situational-elevation survey in which modern surveying techniques were supported.

The measured site is an underground heading used for transporting materials and people by overhead railroads. Frequent traffic, stoppage of overhead railroads and movement of people in this excavation severely limited the execution of the tachymetric measurement. Therefore, authors decided to use the mobile hand scanner as the main measurement tool and the total station was used only to measure a few control elements. The measurement course of the mobile laser scanner was registered, i.e. the beginning and the end of the measurement loop were established (Fig. 5a), and the locations of the scanner's reference points as well as the location of the total station were determined (Fig. 5b).

*a* *b*

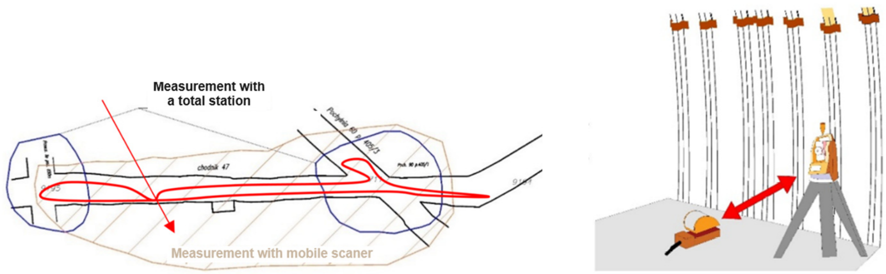


**Fig. 5**. Measurement sketch with trajectory design of the mobile scanner (a) and total station measurement point which is also a reference point (b).

The Geoslam hub software was used to process the point cloud and export it. The GeoSlamDraw software was used to analyse the point cloud, where first the transformation of the scanner's local coordinate system to the "Sucha Góra" system was performed (Fig. 6) and then cross-sections and projections were produced with the highest possible resolution (Fig. 7). The ability to use the transformation calculator in GeoSlamDraw software for each point cloud will avoid possible errors resulting from combining multiple point clouds simultaneously. This is important for the measurement of long headings, for which the quality and efficiency is determined by the measurement time.

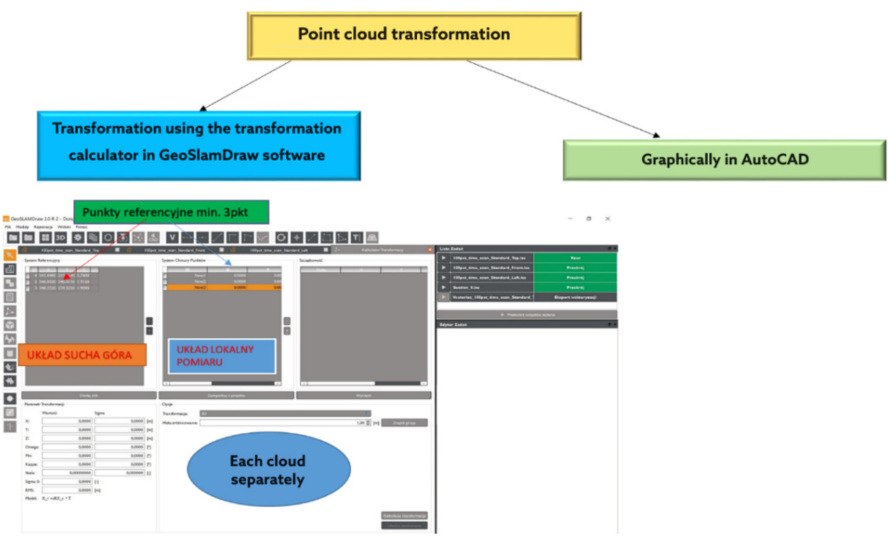


**Fig. 6.** Transformation using the transformation calculator in GeoSlamDraw software.

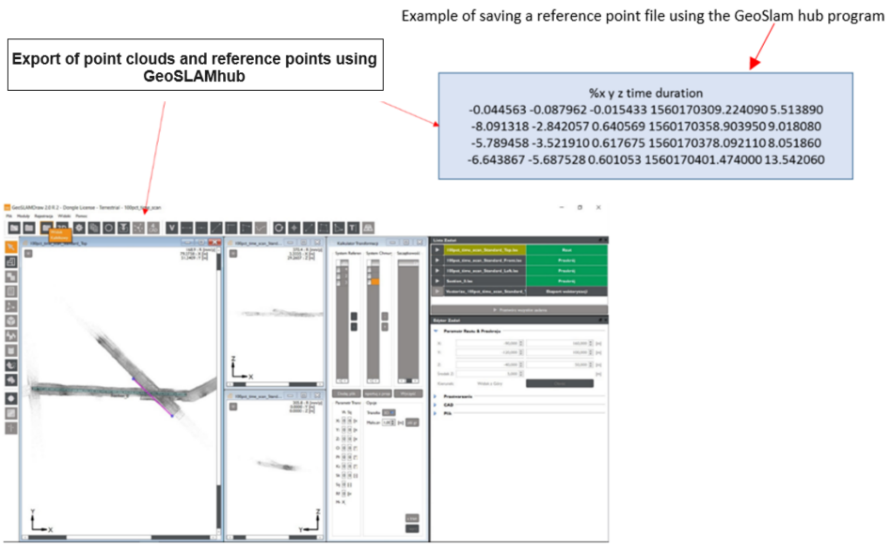


**Fig. 7.** Processing and analysing a point cloud with GeoSlamDraw [20].

The results of both measurements, i.e. laser scanning in the form of raster images, along with the pickets calculated in the surveying software, were loaded into AutoCAD. The next step was to compare and vectorise the raster image to the form shown in the figure below (Fig. 8).

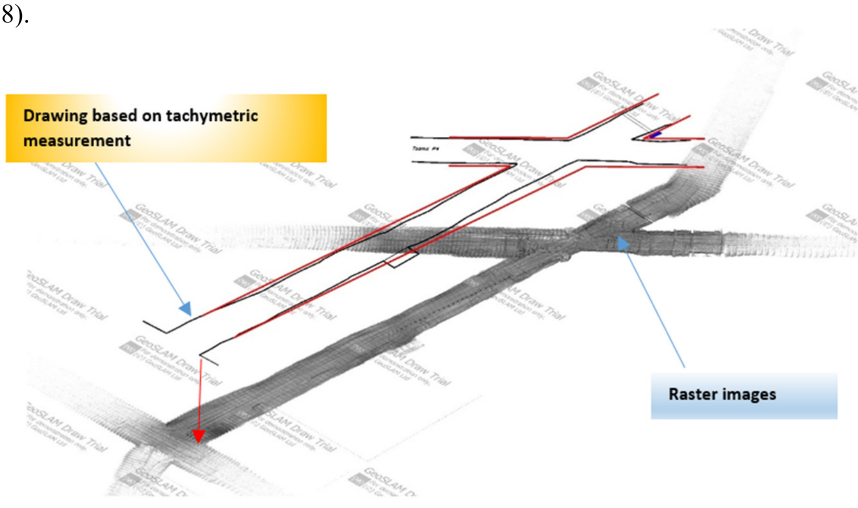


**Fig. 8.** Raster image projection with drawing made on the basis of tachymetric measurement in isometric system made in AutoCAD software.

One can use the result of the measurement in the form of already processed point cloud for further work related, for example, to designing the optimal route of an overhead rail or conveyor belt. For these purposes, one can use cross-sections made in GeoSlamDraw software, on which one can present the outline of the excavation along with its movement extremes (Fig. 9).

 https://doi.org/10.1051/e3sconf/202452601025

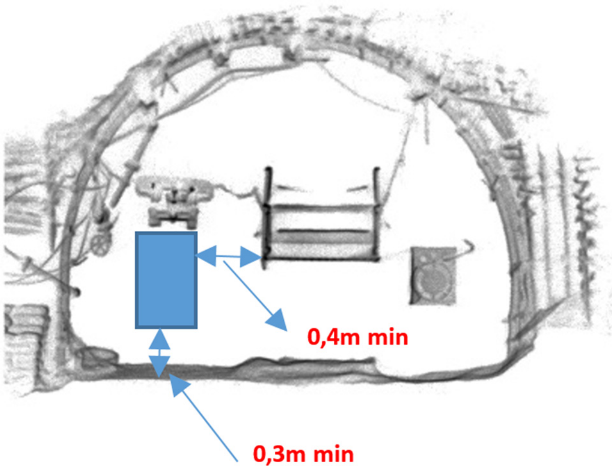


**Fig. 9.** Drawing showing the movement outline along with the heading outline.

Point cloud analysis shows that laser scanning is an effective tool for creating spatial models of mine workings. The measurement process is relatively simple, and the data obtained are very accurate, allowing precise representation of the geometry of the workings. Such models can then be used for sensitivity analyses of numerical calculations and for improving methods of modelling air flows in mines. Thus, the use of laser scanning can be important for improving mine safety by supporting engineers in many areas - from excavation convergence studies to optimization of ventilation network model parameters.

## 4 Conclusions

The article emphasizes the significant utility of modern measurement techniques, particularly in scenarios deviating from standard regulations. Despite the prevalence of conventional situational-elevation surveys, the work illustrates a case involving an underground heading for material and personnel transportation via overhead railroads. Challenges such as frequent traffic and limited accessibility necessitated innovative measurement solutions.

Spatial images of the workings represent the imminent future, and certainly the measurements obtained by these methods can improve the work of many departments within mines (such as measurements of the dimensions of the workings, inventory for reconstruction, measurements to observe the deformation of the workings, and straightness measurements). It is certainly worthwhile to train personnel in the field of this technology, so that the results obtained from the work are utilized in their entirety, which now is the biggest challenge in mines as well as in plants cooperating with mines.

During the implementation of 3D measurements, the surveying and geological departments are typically the only ones at the mine equipped with software capable of processing such large amounts of information. Consequently, the product of the work remains a map, either in digital or analog form, drawn up in accordance with current standards.

Utilizing a mobile hand scanner as the primary tool, supplemented by a total station for control elements, the authors successfully captured the site's intricate details. The Geoslam hub and GeoSlamDraw software facilitated point cloud processing, transformation, and analysis, enabling the creation of detailed spatial models. Integration with AutoCAD further facilitated comparison, vectorization, and utilization of the data for various purposes, such as designing optimal routes for infrastructure within the excavation.

## References

1. Janus, J. (2016). Zastosowanie skaningu laserowego do budowy modelu numerycznego wyrobiska górniczego. *Prace Instytutu Mechaniki Górotworu PAN*, *18*(3), 27-34.
2. Marciniak, B. (2016). Narzędzia wspomagające proces projektowania obudowy wyrobisk podziemnych w warunkach kopalni "Bogdanka". *Wiadomosci. Górnicze*, *67*(2), 108-114.
3. Sobczyk, E. J., Galica, D., Kopacz, M., & Sobczyk, W. (2022). Selecting the Optimal Exploitation Option Using a Digital Deposit Model and the Ahp. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4047752
4. Zalevsky, Z., Buller, G. S., Chen, T., Cohen, M., & Barton-Grimley, R. (2021). Light detection and ranging (lidar): Introduction. *Journal of the Optical Society of America A: Optics and Image Science, and Vision*, *38*(11), LID1-LID2. https://doi.org/10.1364/josaa.445792
5. Richert, M., & Dudek, M. (2023). Risk Mapping: Ranking and Analysis of Selected, Key Risk in Supply Chains. *Journal of Risk and Financial Management*, *16*(2), 71. https://doi.org/10.3390/jrfm16020071
6. Dyczko, A. (2023). Real-time forecasting of key coking coal quality parameters using neural networks and artificial intelligence. *Rudarsko-Geološko-Naftni Zbornik*, *38*(3), 105-117. https://doi.org/10.17794/rgn.2023.3.9
7. Killinger, D.K. (2014). Lidar (light detection and ranging). *Laser Spectroscopy for Sensing*, 292-312. https://doi.org/10.1533/9780857098733.2.292
8. Dudek, M. (2017). The analysis of the low-cost flexibility corridors. In *2017 IEEE International Conference on Innovations in Intelligent Systems and Applications* (pp. 478-483). Gdynia, Poland: Gdynia Maritime University. https://doi.org/10.1109/inista.2017.8001207
9. Baltiyeva, A., Orynbassarova, E., Zharaspaev, M., & Akhmetov, R. (2023). Studying sinkholes of the earth's surface involving radar satellite interferometry in terms of Zhezkazgan field, Kazakhstan. *Mining of Mineral Deposits*, *17*(4), 61-74. https://doi.org/10.33271/mining17.04.061
10. Polyanska, A., Pazynich, Y., Sabyrova, M., & Verbovska, L. (2023). Directions and prospects of the development of educational services in conditions of energy transformation: the aspect of the coal industry. *Polityka Energetyczna – Energy Policy Journal*, *26*(2), 195-216. https://doi.org/10.33223/epj/162054
11. Polyanska, A., Pazynich, Y., Poplavska, Z., Kashchenko, Y., Psiuk, V., & Martynets, V. (2024). Conditions of Remote Work to Ensure Mobility in Project Activity. Lecture Notes in Mechanical Engineering, 151-166. https://doi.org/10.1007/978-3-031-56474-1_12
12. Galica, D., & Sypniowski S. (2012). Deposit model as a first step in mining production scheduling. (2012). *Geomechanical Processes During Underground Mining – Proceedings of the School of Underground Mining*, 231-247. https://doi.org/10.1201/b13157-39
13. Koch, G.J. (2006). Using a Doppler light detection and ranging (lidar) system to characterize an atmospheric thermal providing lift for soaring raptors. *Journal of Field Ornithology*, *77*(3), 315-318. https://doi.org/10.1111/j.1557-9263.2006.00058.x
14. Lee, Y., Woo, H., & Lee, J.-S. (2022). Forest Inventory Assessment Using Integrated Light Detection and Ranging (LiDAR) Systems: Merged Point Cloud of Airborne and Mobile Laser Scanning Systems. *Sensors and Materials*, *34*(12), 4583. https://doi.org/10.18494/sam4100
15. Choi, H., Song, Y., & Jang, Y. (2019). Urban Forest Growth and Gap Dynamics Detected by Yearly Repeated Airborne Light Detection and Ranging (LiDAR): A Case Study of Cheonan, South Korea. *Remote Sensing*, *11*(13), 1551. https://doi.org/10.3390/rs11131551
16. Turumbetov, T. (2022). Integrated monitoring for the rock mass state during large-scale subsoil development. *Frontiers in Environmental Science*, (10), 852591. https://doi.org/10.3389/fenvs.2022.852591
17. Nurpeissova, M., Rysbekov, K., Levin, E., Derbisov, K., & Nukarbekova, Zh. (2021). Study of slow motions of the earth surface. *Vestnik KazNRTU*, *143*(5), 3-9. https://doi.org/10.51301/vest.su.2021.i5.01

18. Strach, M., & Zaczek-Peplinska, J. (2017). *Zastosowanie technologii naziemnego skaningu laserowego w wybranych zagadnieniach geodezji inżynieryjnej*. Warszawa, Polska: Oficyna Wydawnicza Politechniki Warszawskiej, 217 s.
19. *Skanowanie laserowe 2018*. Retrieved from https://geoforum.pl/dodatek/7/3434/skanowanie-laserowe-2018
20. *GeoSlam.*(2024). Retrieved from http://geoslam.com