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THE USE OF LIDAR TECHNOLOGY - MOBILE MAPPING IN URBAN ROAD INFRASTRUCTURE

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Abstract: *The technical and technological progress achieved in the field of photogrammetry and teledection has resulted in remarkable advancements in various areas of activity, including topographic measurements. In what concerns detailed topographic measurements, typically performed with GNSS equipment and electronic total stations, the use of Mobile Mapping technology - LiDAR proves to be a significant advantage due to the reduction of working hours, the surveillance area coverage, and the complexity of acquired data. These measurements are performed with similar accuracy as any conventional equipment. To provide proof and test the proposed model, a section of the town of Lipova in Arad County was selected for investigation using mobile scanning equipment, specifically the Leica Pegasus: Backpack, in conjunction with a Leica Viva GS14 GNSS device. The Leica Pegasus: Backpack, a Mobile Mapping system, is a sensor platform designed for extreme ergonomic convenience. It combines five cameras providing a fully calibrated 360-degree view and two LiDAR sensors on an ultra-lightweight carbon fiber chassis. This system allows for extensive and efficient data collection both indoors and outdoors with a high level of accuracy and professionalism. Today, mobile mapping technology has become an indispensable part of our digital society. Using mobile devices and specialized applications, mobile scanning provides a fast, precise, and accessible method of recording and analyzing geographical information in real-time.*

Key words: *LiDAR, GNSS, INS, mobile mapping, Lipova*

INTRODUCTION

Leica Pegasus: Backpack is a high-performance mobile mapping solution developed by Leica Geosystems that has revolutionized the way urban space road infrastructure is mapped and managed [Miță et all 2020]. This technology enables fast and accurate geospatial data collection in real time [Șmuleac et all 2017, 2020, 2022], by utilizing a light wearable equipment [Casian et all 2019; Simon et all 2020], it offers the following advantages in urban infrastructure: fast data collection, detailed 3D model mapping, high-resolution panoramic imaging [Simon et all 2021], real-time data, efficiency and cost savings, monitoring modifications in the infrastructure [Masiero et all 2017].

Mobile mapping technology [Castagnetti et all 2016] has revolutionized mapping and road infrastructure management in urban environments [Fassi et all 2019], by providing precise data [Nocerino et all 2017], by succesfully saving significant time and costs for authorities and companies involved in managing these critical infrastructures.

The city of Lipova, located in Arad County in Romania [Bogdan et all 2014] has undergone a constant and continuous urban development regarding its infrastructure. To meet the growing needs of this community, mobile mapping technologies such as the Pegasus Backpack have become an invaluable resource. This high-performance equipment brings a considerable number of advantages to urban infrastructure mapping and management in Lipova, because it aids local administration and road infrastructure specialists in obtaining accurate and precise geospatial data with increased real-time efficiency.

Pegasus Backpack utilizes a combination of advanced sensors [Williams et all 2020], including a LiDAR laser scanning system, five spherical imaging cameras, a GNSS positioning unit and an inertial measurement unit IMU to collect accurate real-time data. The system can be assembled on the back of the operator [Rondeau et all 2015], similar to a backpack, allowing it to move freely on the ground, while capturing 3D data from different angles and viewpoints [Li et all 2020].

The Leica Viva GS14 is a high-precision GNSS receiver developed by Leica Geosystems, the world leader in geospatial technologies. It provides a complete solution for collecting real-time positioning data, using navigation satellites to provide accurate and reliable information about the position and movement of an object on the ground [Heikkila et all 2016].

The device is equipped with advanced GNSS technology, including a dual-frequency receiver, which allows for reception and signal processing from multiple constellations of satellites [Capra 2016], such as GPS-NAVSTAR, GLONASS, Galileo and BeiDou.

In conclusion, the utilization of this equipment represents a significant step in the modernization and improvement of city road infrastructure, ensuring an efficient, accurate and economical approach to its management. This technology is an invaluable resource for urban development and life quality improvement in the community of Lipova.

MATERIALS AND METHODS

The case study was conducted over 14 streets appertaining to the town of Lipova (Figure 1), Arad County. Lipova is a town located in the western part of the country, within the historical region of Crişana. Situated on the right bank of the Mureş River, Lipova lies at the foothills of the Zărand Mountains [Abrudan et all 2020], with an average altitude of approximately 110 meters above sea level. Topographically, the town of Lipova mainly resides on gentle rolling terrain, hills and plains [Țărău et all 2018].

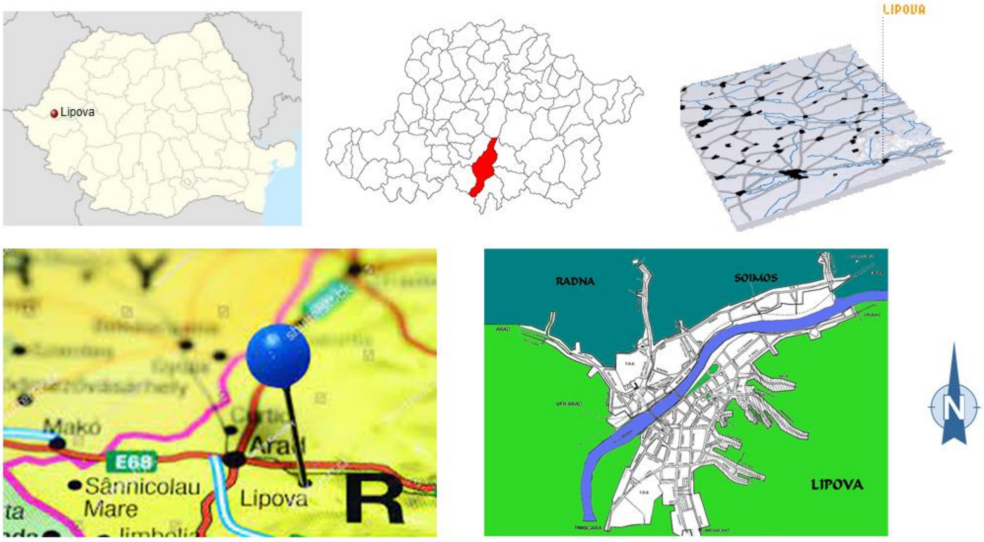

Figure 1. Location of the area of study

The methodology applied for this research involves going through several stages, synthetically presented in Figure 2.

Figure 2. Workflow

The model for using LiDAR - Mobile Mapping technology for detailed topographic surveys, both in urban areas and other locations, involves following the workflow below:

1. **Terrain recognition** to determine how many scans will be performed and where the master base station will be placed.
2. **Scanning the area of interest**. In this study, 14 individual scans were conducted, one for each street. The Leica Viva GS 14 equipment was used as the Master Base, recording Rinex data at one-second intervals throughout the scanning process.
3. **Determining control points**. After completing the scans, control points were collected from all the streets using RTK (Real-Time Kinematic) equipment, and these points were later verified on the cloud for points obtained during the previous scanning phase.
4. **Post-processing** was performed using Pegasus Manager software, and the accuracy was verified using NovAtel Inertial Explorer software.
5. **Obtaining topographic data**. After obtaining the cloud of points with the aid of the aforementioned post-processing step, information was loaded into Leica Cyclone software, where all the relevant features were extracted.
6. **Providing the final result**. The final result was processed using Autodesk AutoCAD Map 3D software, and the report was generated with the assistance of Leica Infinity software.

RESULTS AND DISCUSSIONS

Data acquisition was carried out using the Leica Pegasus Backpack equipment, in conjunction with a Leica Viva GS14 GNSS (Global Navigation Satellite System) device (Figure 3), which was used as the Master Base, recording Rinex data throughout the scanning process. In this case study, 14 individual scans were performed (Figure 4), one for each street. The entire scanning process lasted approximately 3 hours, during which all the elements of the investigated streets, with a coverage that captured of approximately 10 kilometers.

The mobile 3D laser scanning is conducted in two steps:

1. Placement and configuration of the reference station - located inside the Lipova stadium.
2. The second stage of mobile scanning is divided into:
   - Static initialization for 5 minutes: during which the equipment remains immobile in the position where it was placed to update the GNSS almanac and determine its location. Parameters for the cameras and image distances are set during this phase.
   - Dynamic initialization, for 2-3 minutes: during this phase, the equipment is moved continuously to activate the GPS/INS (Global Positioning System/Inertial Navigation System) system.
   - Proper scanning: the area of interest is patrolled with the mobile equipment operated by the operator.

- Finalizing the process: after data collection, the initializations are performed again, but this time in reverse order to complete the entire process accurately, first the dynamic initialization for 2-3 minutes, then static initialization for 5 minutes.

Figure 3. Leica Pegasus: Backpack and Leica Viva GS14 (Master Base) – Lipova Stadium

A modernization project is an initiative that involves improving the infrastructure of a specific street or road segment in a city or locality [Martens et all, 1997]. Topographic surveys are an integral part of the process of street modernization projects. This type of survey presupposes the process of collecting geospatial data to create an accurate representation of the terrain and existing infrastructure [Paunescu et all, 2020]. This topographic data is essential for the proper design and execution of street modernization refurbishment. This is how topographic surveys can be involved in such a project:

Initial Assessment: in the initial evaluation phase, topographic surveys are conducted to obtain precise data on terrain configuration, elevations, slopes, groundwater levels, and other characteristics of the area. This data helps identify potential issues and develop an appropriate modernization plan.

Design: in the design phase, topographic data is used to develop detailed plans for the modernization of the targeted streets. These plans include changes to the street alignment, asphalt layer thickness, the location of infrastructure (such as sewerage and underground networks), as well as details related to drainage and flood prevention.

Execution: as construction work begins, topographic data is used to guide machinery and equipment during construction. This ensures that the work is carried out according to the plans and specifications, thereby avoiding errors.

Quality Control: topographic surveys can be used to check the quality of the work performed during and after the project's completion. This data can help identify any deviations from the initial plan and correct them.

Data Management and Updates: the topographic data collected during the project can be stored and updated for use in the long-term maintenance and management of the modernized street.

Therefore, topographic surveys are an important component of street modernization projects, contributing to more efficient and precise planning, construction, and road infrastructure management.

Street modernization projects are essential for improving urban infrastructure and enhancing road safety along with the residents' comfort. These projects can vary significantly in scale and complexity, but generally aim to bring significant benefits to the local community.

Figure 4. Streets under the scanning process

Replacing traditional topographic surveys with mobile mapping technologies, such as LiDAR scanning [Aksamitauskas et all, 2016], and high-resolution imaging can offer significant advantages in modernization projects. Here are some of the benefits of using mobile mapping technologies instead of traditional topographic surveys:

Increased Efficiency and Speed: mobile mapping technologies enable the rapid collection of field data. A vehicle or, in this case, an individual equipped with LiDAR scanning equipment and cameras can record geospatial data as they move, eliminating the need for manual point-by-point measurements.

High Accuracy: mobile mapping technologies provide precise and detailed data, allowing for extremely accurate 3D models of the terrain and existing infrastructure.

Large Data Volumes: mobile mapping technologies can collect a large amount of data in a relatively short time, providing a comprehensive view of the targeted area. This can be valuable for modernization projects that require detailed coverage.

Cost Reduction: while the initial costs of mobile mapping equipment may be high, it can provide long-term savings by eliminating manual labor costs, including personnel expenses and the time required for traditional topographic surveys.

Safety: the use of mobile mapping technologies can reduce risks for personnel on the field, as it reduces the need to be in high-traffic areas or interact with vehicles.

Easy Updates: data collected with mobile mapping technologies can be easily updated and revised as the project progresses or requirements change.

Detailed Analysis: mobile mapping technologies provide data that allows for detailed analysis of the terrain and existing infrastructure, aiding in informed decisions during planning and design.

Processing was carried out using Pegasus Manager software, and the accuracy was verified using NovAtel Inertial Explorer software.

Pegasus Manager (Figure 5) is specialized in managing and processing data obtained during mobile mapping data collection, such as LiDAR scans and photo images. Processing often requires specialized knowledge in cartography and mobile mapping technologies. However, the software offers a wide range of tools to provide the assurance of accurate and efficient data processing, thus the collected data are transformed into valuable information for the purpose of planning and managing infrastructure projects as well as any other types of projects.

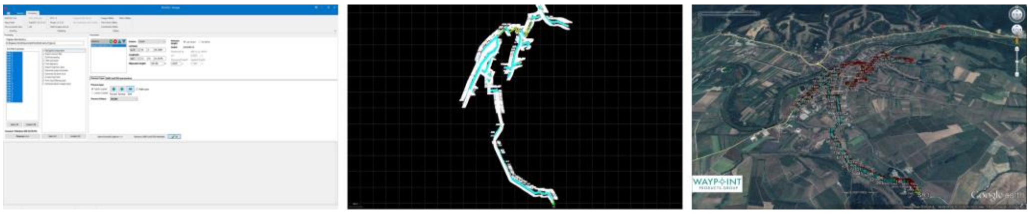

Figure 5. Data Processing

NovAtel Inertial Explorer (Figure 6) is a specialized software for correcting trajectories and analyzing inertial data obtained during mobile data collection, such as data from the Leica Pegasus Backpack equipment. Correcting the trajectory is a crucial step in data processing to achieve precise and consistent results.

Since the GNSS signal worked excellently throughout the entire period, there was no need for trajectory adjustments using the SLAM (Simultaneous Localization and Mapping) algorithm. The average scanning accuracy was 3 cm. For better control, ground control points were used, determined through the RTK (Real-Time Kinematic) method.

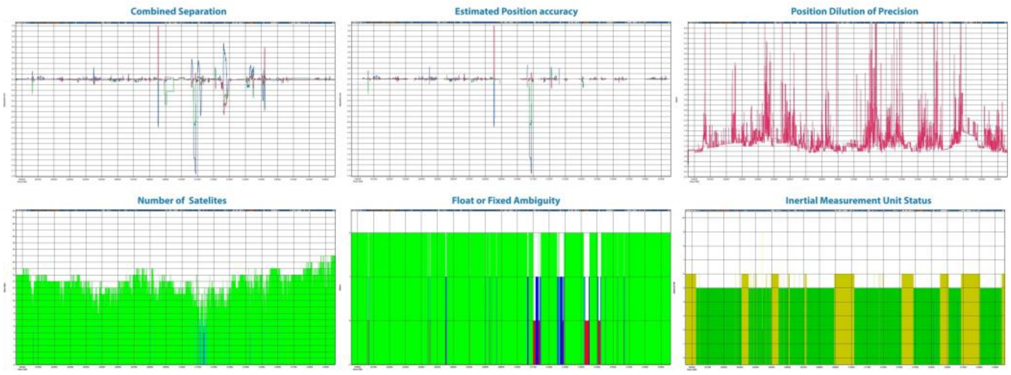

Figure 6. Quality Control

Pegasus Manager allows us to a fast and accurate quality check of the data acquired from the mobile mapping system (Figure 7). It displays the captured mission and enables users to seamlessly navigate through images and point clouds. The application enables us to take measurements from images and LiDAR data and create reports by combining GIS information with images and LiDAR data.

Data Import: The first step is to import the data collected with the Leica Pegasus Backpack into the Pegasus Manager software. This can include LiDAR scans, photo images, GNSS data, and any other associated data.

Data Correction: Pegasus Manager can perform corrections and alignments to ensure data accuracy. This may involve corrections for distortions, adjusting the data accordingly with the known control points, or recalibrating sensors to ensure precise data.

LiDAR Data Processing: The software allows us to process and extract features from LiDAR data. This can include creating 3D terrain models, identifying objects, or generating data for elevation points.

Photo Image Processing: Photo images can be processed and used to create panoramic images or to identify and extract significant features such as traffic signs or manhole covers.

Exporting Processed Data: Once processing is complete, Pegasus Manager enables us to export the processed data in various formats for use in other applications or for sharing with other users. In this particular case, the export was done in *las* files.

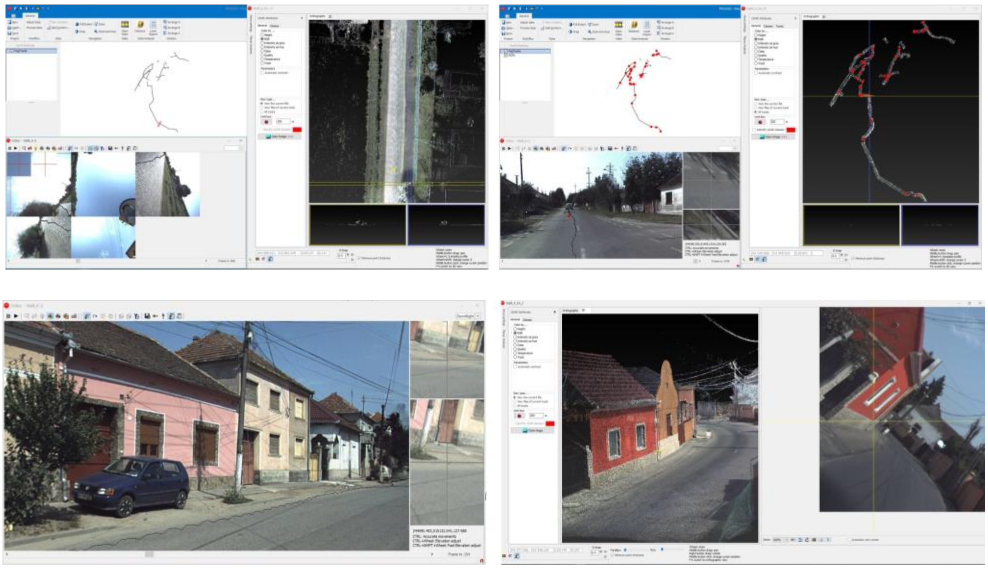

Figure 7. Obtaining 3D Point Could

After obtaining the 3D point cloud as a result of processing, the project was imported into Leica Cyclone software, from which all tracked elements were extracted (Figure 8). Cross-sectional profiles for the road were created, and all characteristic features of a topographic survey were extracted.

The software allows us to segment the data based on specific objectives or areas of interest. This can include identifying and separating terrain, buildings, trees or other objects.

After extracting the relevant data, Cyclone enables us to export the processed data in various formats, such as geospatial file formats or formats compatible with other applications. Taking into consideration the continuation of the use of AutoCAD, the exported file was in *dxf* format.

Mobile mapping technology not only enables the precise and detailed capture of data, it also provides the analysis and evaluation of data for planning, risk assessment/management, and scenario modeling purposes. The final result was finished using Autodesk AutoCAD Map 3D software, and the report was generated using Leica Infinity software (Figure 9).

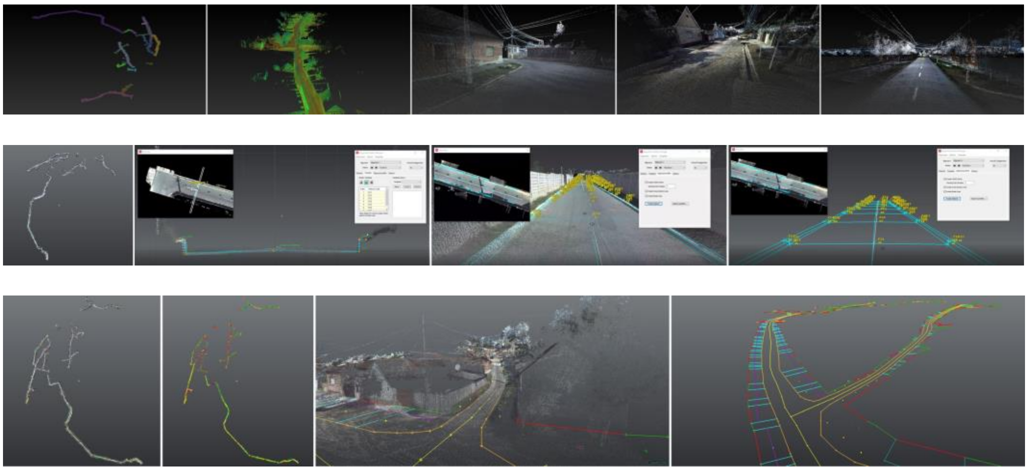

Figure 8. Extracting relevant data in Leica Cyclone

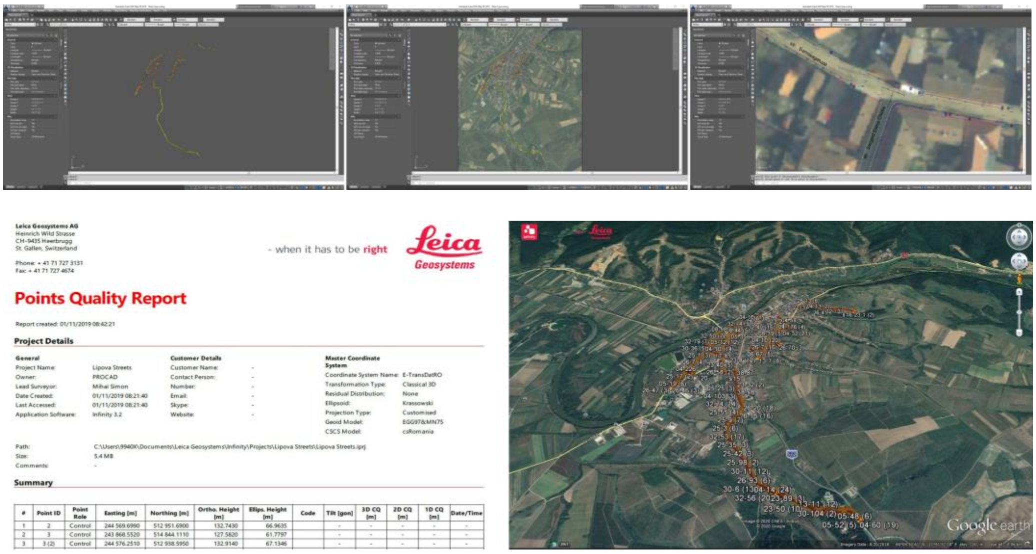

Figure 9. Topographic plan and report

The modernization of the local streets under analysis, with a length of 10 kilometers, is socially and economically significant for the respective locality. Work execution will considerably improve the technical condition of the respective public roads, thereby upgrading traffic comfort and safety.

The road element layout, longitudinal profile, and cross-section were designed according to the beneficiary's requirements expressed in the design theme and respecting the inventory of the public domain (Figure 10).

The designed route follows the existing path with faithful precision, remaining on the location of the existing access roads.

Longitudinal Profile:

In the longitudinal profile, the slopes range from 0.01% to 14.71%, as the roads are located in a hilly area. The vertical alignments and design grade will correspond to a design speed of 25 km/h.

Transversal Profile:

Road platform: ………………….….5.0 m
Roadway:…………………………...4.0 m
Shoulders: ………………………... 2 x 0.50 m
Width of protected/unprotected ditches: 0.40 m

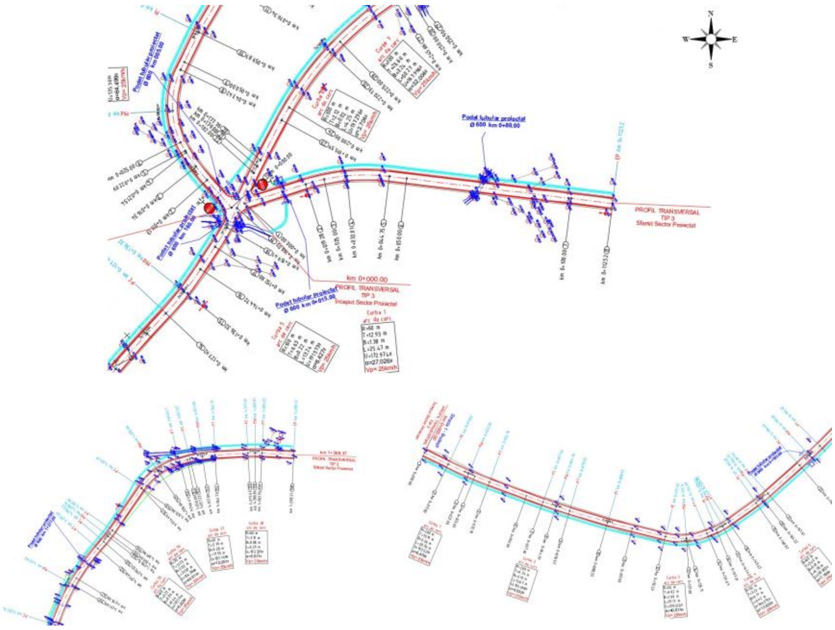

Figure 10. Situation plan after the road design

CONCLUSIONS

In conclusion, road refurbishment involves a series of important steps and aspects that contribute to improvement of the road infrastructure in a city or locality. These projects can be complex and require careful planning and execution to ensure success. Traditional topographic surveys have been used in the past to collect the necessary field data, but mobile mapping technologies have become an attractive option, offering a range of advantages in terms of efficiency, precision, and time and resource savings.

Precise and detailed geospatial data can be obtained by using mobile mapping technologies. These can be essential for the design, construction, and management of road refurbishment. However, it is important to assess the specific project requirements and consider the initial costs and resources required to decide if mobile mapping technology is the most suitable solution.

Regardless of the method used for collecting topographic data, road refurbishment remains a vital process for improving urban infrastructure, road safety, and the quality of life in local communities. This process involves careful planning, design, construction, and maintenance to ensure long-term good and safe road conditions.

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