Journal of Science and Technology in Civil Engineering, HUCE, 2024, 18 (2): 86–98

STUDY ON THE POSITIONING EFFICIENCY OF GNSS RTK FOR ROAD PROFILE SURVEYS - CASE STUDY IN VIETNAM

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Article history:
Received 20/4/2024, Revised 24/6/2024, Accepted 25/6/2024

Abstract

Traditional topographic profile surveying requires numerous stages following mandatory procedures. Alongside that, the outdated traditional surveying equipment has reduced work efficiency during the surveying process. Currently, the Real Time Kinematic (RTK) method has been widely applied in the construction surveying field in Vietnam. However, this method, according to current technical standards, only allows topographic mapping at a scale of 1:1000 and without profile surveying. Although GNSS-RTK has been assessed to be very effective in construction surveys, there has not been a specific evaluation of the efficiency when topographic profile surveying. In this study, the experimental results with the Trimble R8S device applying RTK principles provided many solutions to increase productivity and efficiency in topographic profile surveying. The accuracy of this method has met the technical requirements for the current traditional technical standards in Vietnam. In addition, the advantages of the RTK technique have helped overcome the difficulties of traditional topographic surveying using a total station or theodolite and leveling devices, especially in terms of time and cost efficiency.

Keywords: topographical profile; GNSS-RTK data; Trimble R8S; digital level; elevation accuracy.

https://doi.org/10.31814/stce.huce2024-18(2)-07

1. Introduction

Thanks to the advantages of GNSS technology, the GNSS-RTK technique is widely applied in various survey fields. Applying the first field of geodetic works, the authors [1] evaluated that GNSS-RTK can replace traditional survey methods and can be confidently chosen for positioning in geodetic and mapping [2]. GNSS-RTK was used to georeference the entire survey in a unique and well-defined datum in an archaeological site [3]. Following GNSS-RTK plays a fundamental role in integrating a multitude of geospatial data, including total station, terrestrial laser scanning, and digital photogrammetry data, covering both underground and external survey areas. The authors [4] even suggest using smartphones with applications capable of utilizing Network Real-Time Kinematic (NRTK) GPS data technology for topographic surveys in areas where high precision is not required. Regarding the vertical accuracy of the RTK technique, the authors [5] experimented with 12 measuring points. The experimental elevations were measured by the RTK using the Trimble 5800 device and then compared with the results from the geometric leveling method using SOKKIA C4 automatic level. The experiment results showed a difference in the elevation determination between the two methods ranging from 2 to 10 cm, with a reliability of more than 95%. This opens the possibility of using RTK to replace the traditional methods (automatic level) in land surveying, especially in challenging terrain conditions. In the field of cadastral surveying by RTK, the authors [6] conducted experiments over a survey area of 120 points. To evaluate the RTK technique, the authors compared 3 experimental options. First, compare the coordinates at different times of the boundary points which were using

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the RTK determined from 3 reference points by the Topcon Hiper Pro device. Second, make the same comparison but using the Topcon GTS701 total station. Third, compare the results of the two devices above. The first experiment result shows a deviation in 360 coordinates (X, Y, Z) of 120 boundary points of about 2 cm horizontally and 5 cm vertically. In the second experiment, the measurement distance is no more than 300 m from the reference points to the boundary point. This case got a deviation of about a few millimeters for the horizontal and less than 1 cm for the vertical. Comparing the results of the two previous cases in the third option, the authors showed a difference of 5 cm horizontally and 10 cm vertically. They concluded that RTK can meet the requirements of the current technical standard in Turkey.

In the field of coastline research, GNSS-RTK measurements have been applied to determine changes in the elevation of the Arctic glacier surface [7] and determine the cross-shore profiles [8–10], as well as the topographic of coastline [11, 12]. In a hydrographic survey, the analysis of the RTK results [13] has proven that the system meets the positioning requirements for conducting hydrographic surveys in accordance with all IHO (International Hydrographic Organization) orders. Additionally, by evaluating data integration methods according to the IHO S-44 standard, Lewicka [14] studied the solutions to improve the integration of geospatial data in the hydrography field. Furthermore, the integration of GNSS-RTK enhances dry bathymetric data collected by UAVs and improves the wet bathymetry measure for the computations of conveyance within the Hydraulic models [15]. To survey the cross-section of rivers by RTK technique, the authors [16] used the Trimble 5700 GPS receivers with a horizontal accuracy of 10 mm + 1 ppm and an elevation of 20 mm + 1 ppm for position fixing, integrated with the SDH-13D digital echo depth sounder to determine the water depth. A comparison with traditional surveying by the Nikon DTM532 total station to measure 16 checkpoints showed that the results were within allowable errors (0.36 m horizontally and 0.1 vertically). In a similar study, Che Awang [17] noted that underwater survey data for topographical cross-section requires the accuracy of 3 main factors: tidal data, position, and depth value. Tidal readings are collected by tidal monitoring stations, topographic depth data is obtained by single- or multi-beam echo sounders and position data is collected using the RTK technique with centimeter precision.

GNSS is widely used for estimating earthworks of construction and infrastructure projects. Its primary advantage lies in rapidly collecting data, thus simplifying operations and boosting efficiency [18]. Evaluating the technical accuracy of GNSS-RTK in calculating volumes compared with leveling [19] has shown that the difference of the DEM (Digital Elevation Model) is 5.2 cm, which corresponds to a difference in mass calculation within 3.68%–13.43%. This method is used to control the quality of global DEM when generating topographic profiles in flat and forest areas in Malaysia [20], and to support the calculating and designing of the correct longitudinal slope for forest/skid road construction or reconstruction projects [21]. In the other applications of engineering surveys, the research [22] has demonstrated the advantages of using RTK in the stakeout for highway construction projects. The stakeout points were redetermined by RTK and compared with their values from the design map. The authors calculated the execution time of 6 hours and achieved an accuracy of about 2 cm horizontally, and 3-4 cm vertically. Additionally, they highlighted some advantages of the RTK technique in the layout tasks, such as requiring only one reference point and no line of sight to the layout points. The authors also confirmed that the RTK technique is economically efficient compared to traditional methods. Enhancing RTK capabilities in surveying and staking out of road fields, the authors [23] studied the application of the CORS (Continuous Operational Reference Station) system. The CORS-RTK technique allows extending the distance between the measuring point (by Rover station) and the reference point (Base station) to tens of kilometers. Besides, it can adjust the measurement point using continuous data from many reference points, which helps to increase the accuracy and applicability of road surveying.

In Vietnam, the RTK technique has been around for about a decade, but the widespread application has only taken place in several years. For engineering surveying, there are currently some local or sectoral regulations on the RTK technique. For example, Decision 37/2017/QD-UBND of Hanoi capital allows the application of RTK for land surveying in areas where there is no cadastral map. Similarly, Circular 25/2014/TT-BTNMT of the Ministry of Natural Resources and Environment permits the RTK application on cadastral maps at scale 1:1000 in the agricultural region. Using Topcon-FC 200 device to evaluate the effectiveness of the RTK technique in cadastral surveying in Vietnam, the research [24] compared the results of the RTK with the Topcon OL 6006 total station. The two measuring methods were compared for cadastral mapping at a scale of 1:1000 in residential areas and a scale of 1:2000 in the garden and agricultural areas. The experiments indicated that the RTK technique does not meet the technical requirements for cadastral surveying on the 1:1000 scale but is comfortable on the 1:2000. Moreover, the advantage of the RTK is evident in its economic effectiveness due to time and manpower savings.

Applying RTK in Vietnam for engineering surveying, some studies give optimistic comments. Presenting a method for the coastal seabed topography by combining RTK and an echo sounder, the authors have experimented in a southern sea area of Vietnam and confirmed not only the superiority but also the applicability of RTK technology [25]. Tuan and Hiep [26] noticed that the CORS-RTK technique completely meets the necessary technical requirements for monitoring landslides and displacement of constructions. In another study, the authors affirmed that it is possible to improve the efficiency of geodetic work in the construction of super-high-rise buildings in Vietnam [27].

Despite the growing use of the RTK technique for various land surveying applications, including cadastral, topographic, and engineering surveys, Vietnam currently lacks specific technical standards or applications for RTK in topographical profile surveying. This research aims to address this gap by examining the topographical profile of line surveying using RTK and comparing it with traditional methods. In this article, we focus on the applicability of RTK for surveying road topographical profiles. The findings provide valuable technical insights for the construction surveying field, offering guidelines for efficient survey planning and on-site implementation. These results are significant not only for the geodetic community but also for a wide range of surveying engineering applications. Furthermore, they have educational value and practical benefits for both technical application and academic research.

2. Materials and Methods

2.1. Profiles surveying process in Vietnam

a. Local control network

Conventional topographic profile surveying always has requirements for the local reference/control points system and the surveying process following the technical standards. The purpose of the control points system is to accurately position the necessary direction and elevation control for the survey. Therefore, the control network must ensure accuracy, flexible layout, and ensure sight. The control points network is usually one level or two levels if the surveying line is too long. The geodetic control network in Vietnam is divided into 2 levels which are the national control network and the local control network. The national network is arranged by the accuracy hierarchy from the "0" order to the III order (for horizontal control network) [28] and from the I order to the IV order (for leveling network) [29].

As the requirement of the National technical standards [30], the local network has two levels which are measured and connected to the national network. There, the first level network has the task of determining the centerline and developing the second level which has the role of control of the topographic surveying. In addition, the technical standard [31] includes the detailed requirements for accuracy: (1) Error of position at 0.2 ÷ 0.3 mm multiplying to plan scale (M); (2) Error of altitude at 1/3 ÷ 1/4 of contour interval (h). For road surveys, the technical standards [32, 33] meet the needs of the local control network for the design and construction stages. In which, the elevation control network needs to be established with the required accuracy of $f_h \leq \pm 30\sqrt{L^{(km)}}$ (mm) with the measuring line length (L) has the unit of kilometer.

b. Profiles surveying

The construction line selection is conducted on a strip topographic map. The topographical profile then is a required process of determining the center line and surveying range in the work. The required accuracy is 0.2 mm multiplying M (M is the ratio of the longitudinal drawing and is usually equal to the scale of the strip topographical plan) and less than $1/4h$ (for elevation error) [31].

Based on the designed coordinates and control points, we carry out the center line determination. Minor adjustments of the centerline if necessary, help to minimize the volume of ground clearance, and achieve higher economic-technical factors. The center line is formed by the starting points, the endpoints, the vertices, the hectometer points, the curve points, and more precisely with detailed piles which are the generalized piles of the topographical longitudinal section. The traditional method used a total station or theodolite placed in the control points to stake out by the principle of the polar coordinate. This meets the difficulties of complex terrain conditions and suffers cumulative errors.

Following the center line stakeout will be the measurement of the topographical profiles. Longitudinal profile surveying is the measurement of the pile ground elevation. That helps to design the longitudinal slope of the route. During transversal profile surveying, the vertical sections are determined perpendicular to the centerline, which is essential for excavation calculation, adjustment, and construction. The traditional topographic cross-sectional measurement is done using leveling and tape or string so the work productivity often leads to inefficiency and the minor accuracy of distance measurements. In addition, it has also limitations in the case of steep terrains.

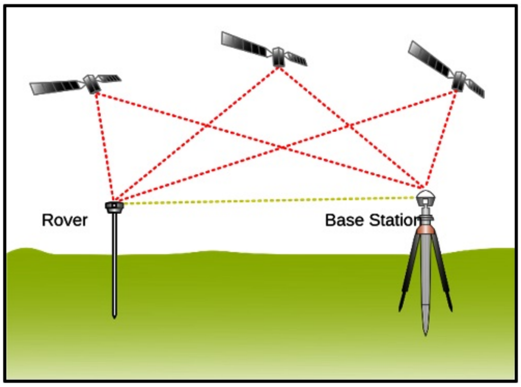
In brief, traditional surveying brings us to face some difficulties as follows: (1) Road center lines laying-out made by a total station is separate from topographical profiles surveying made by leveling; (2) Hard to manage and preserve landmarks in the site over time; (3) Meeting the requirement of the sight and the visibility for efficient control points.

2.2. Methodological Approach and Instrumentation

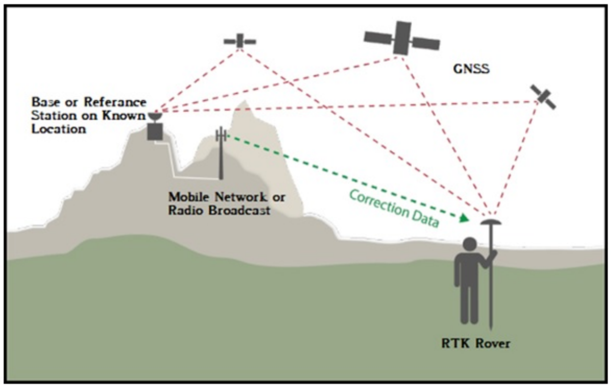
The potential of the RTK technique was investigated to address the challenges of difficulties of traditional topographical profile surveying. This study was divided into two main steps: first, developing an efficient methodology to integrate the staking out and surveying processes; second, conducting experiments to evaluate the elevation measured by RTK against technical standard requirements.

a. RTK methodological principle

The RTK methodological principle in Vietnam has two modes: Base single mode (Fig. 1(a)) and Network mode (Fig. 1(b)). The Base single mode involves placing the reference station at the control point. During operation, the Base receiver will calculate the pseudo and distance to each satellite at the same time. It then calculates the corrections for each reference satellite. When the mobile receiver (or rover) connects from the Base station by radio or mobile telephone and processes them separately the correction data, which corrects the coordinates and obtains the accuracy coordinates. This technique only uses one reference station to send correction information to the Rover, so the further away from the base station, the more the accuracy deteriorates. However, this mode is of great interest because it allows a very fast start-up.



(a) Base single mode



(b) Network mode

Figure 1. Principle of RTK technique

The network mode is a technique that uses data from Continuously Operating Reference Stations (CORS). These stations are combined and formed into a network that implements several reference stations that surround a mobile receiver, thus creating a cell. The corrections were obtained from individual corrections stations of the cell. Thus, the quality of the corrections, which are sent to a rover, is more homogeneous and more stable than the base single mode. This technique also offers an advantage to increase the operating range of the rover stations.

b. Instrumentation and on-site process

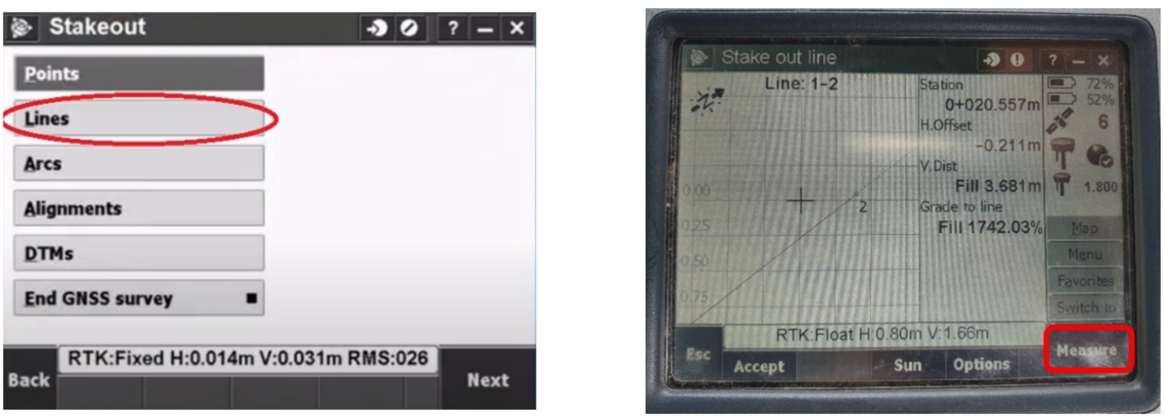
The GNSS-RTK Trimble R8S instrument was selected for fieldwork. This is a 2-frequency GNSS receiver with multi-satellite and good accuracy. The detailed parameters are described in Table 1.

In the RTK function, the Trimble R8S allows us to flexibly switch from stakeout the route determination mode to immediately measuring detailed points in the field. After importing the coordinate data of the design points into the handheld named TCS3 controller, the field process is performed with the stakeout modes, shown in Fig. 2(a). There are modes to stakeout points, lines, arcs, and alignments,... that permit us to easily locate the center line and control the surveying range. For example, in the Lines mode, after selecting the start and end points of the reference line (defined line), the screen will display the parameters such as the current position of the Rover; the distance from the Rover to the reference line; the distance from the Rover to the starting point, as shown in Fig. 2(b).

At each staked-out point, the surveying mode (the Measure button on Fig. 2(b)) could be implemented to measure and save the current coordinates. The set of obtained current points includes both horizontal coordinates and elevation values. The horizontal coordinates will be used to calculate the distances between the points, that is together with elevation values help us draw the topographical cross profiles. Moreover, on the handheld controller screen, we can also visually determine the perpendicular direction to the longitudinal profile as well as the surveying range during the topographical transverse profile surveying. This allows us to obtain more accurate and more reliable survey data.

Table 1. Trimble R8S receiver specification [34]

Performance specification	Positioning performance
• Advanced Trimble Maxwell 6 Custom Survey GNSS chips with 440 channels • Future-proof your investment with Trimble 360 tracking • High-precision multiple correlators for GNSS pseudo-range measurements • Unfiltered, un-smoothed pseudo-range measurements data for low noise, low multipath error, low time domain correlation, and high dynamic response • Very low noise GNSS carrier phase measurements with < 1 mm precision in a 1 Hz bandwidth • Signal-to-Noise ratios reported in dB-Hz • Proven Trimble low elevation tracking technology • Satellite signals tracked simultaneously: - GPS: L1C/A, L1C, L2C, L2E, L5 - GLONASS: L1C/A, L1P, L2C/A, L2P, L3 - SBAS: L1C/A, L5 (for SBAS satellites that support L5) - Galileo: E1, E5A, E5B - BeiDou (COMPASS): B1, B2 • SBAS: QZSS, WAAS, EGNOS, GAGAN • Positioning rates: 1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz	• **Code differential GNSS positioning** - Horizontal: 0.25 m + 1 ppm RMS - Vertical: 0.50 m + 1 ppm RMS - SBAS differential positioning accuracy: typically < 5 m 3DRMS • **Static GNSS surveying** *High-Precision Static* - Horizontal: 3 mm + 0.1 ppm RMS - Vertical: 3.5 mm + 0.4 ppm RMS *Static and Fast Static* - Horizontal: 3 mm + 0.5 ppm RMS - Vertical: 5 mm + 0.5 ppm RMS • **Postprocessed Kinematic (PPK) GNSS surveying** - Horizontal: 8 mm + 1 ppm RMS - Vertical: 15 mm + 1 ppm RMS • **Real-Time Kinematic surveying** *Single Baseline < 30 km* - Horizontal: 8 mm + 1 ppm RMS - Vertical: 15 mm + 1 ppm RMS *Network RTK* - Horizontal: 8 mm + 0.5 ppm RMS - Vertical: 15 mm + 0.5 ppm RMS - Initialization time: typically < 8 seconds - Initialization reliability: typically > 99.9%



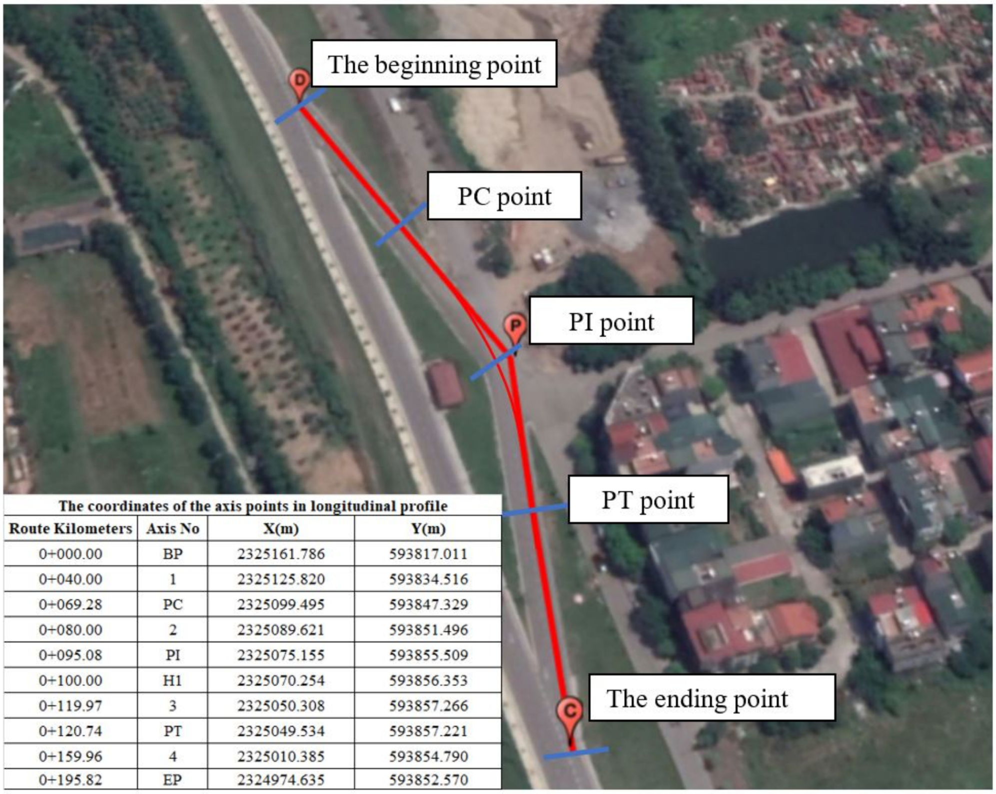
(a) Stakeout modes

(b) Stakeout line

Figure 2. Stakeout mode and an example of a stakeout line

2.3. On-Site experiment

For the experiment, we selected a section of dike road in Thach Ban ward, Long Bien district, Hanoi. This section has typical topographical characteristics of road constructions, such as large vertical and horizontal slopes, curves, and terrain features. It is approximately 196 meters long, with 5 cross profiles located at key points: the beginning point, PC (Point of Curvature at the beginning of the curve), PI (Point of Intersection of tangents), PT (Point of Tangency at the end of the curve), and the ending point, as shown in Fig. 3.



The coordinates of the axis points in longitudinal profile			
Route Kilometers	Axis No	X(m)	Y(m)
0+000.00	BP	2325161.786	593817.011
0+040.00	1	2325125.820	593834.516
0+069.28	PC	2325099.495	593847.329
0+080.00	2	2325089.621	593851.496
0+095.08	PI	2325075.155	593855.509
0+100.00	H1	2325070.254	593856.353
0+119.97	3	2325050.308	593857.266
0+120.74	PT	2325049.534	593857.221
0+159.96	4	2325010.385	593854.790
0+195.82	EP	2324974.635	593852.570

Figure 3. Experimental route and position of 5 cross-profiles

In the first step of the experiment, we connected the control point in the area, named RP-01 in Fig. 4, to the Vietnam national coordinate system VN2000. This control point served as the reference for the entire experiment. Using the design coordinates provided with the Trimble R8S, we employed the RTK Base single technique with the R8S to stake out the key points of the centerline and measure the coordinates (X, Y) and elevation (H_{RTK}) of these points for creating the longitudinal profile. Next, at these staked-out points, the handheld device of the Trimble R8S was used to determine the direction perpendicular to the centerline to measure the coordinates and elevations of the detailed points on 5 cross profiles, as shown in Fig. 5. Simultaneously, we measured the elevations (H_{tt}) of all those points using the electronic level Trimble Dini 03.

The experimental road chosen is a section of the Red River dike with a relatively steep terrain slope. Therefore, measuring the topographical profiles using the electronic level Trimble Dini 03 encountered many difficulties. In the following section, we present the experimental results and discussions on the advantages and disadvantages of the RTK Base single technique compared to the traditional method.

Figure 4. Position of control point RP-01

(a) By automatic leveling Dini 03

(b) By GNSS-RTK R8S Trimble

Figure 5. Topographical profiles measured by automatic leveling Dini 03 and by GNSS-RTK R8S

2.4. *Evaluate experimental result*

The electronic level Trimble Dini 03, with an accuracy of 0.7 mm/km, has been chosen as the standard for comparison with the results of RTK Base single measurements. The difference in results is calculated according to formulas (1) and (2).

$$\Delta H^i = H^i_{RTK} - H^i_{tt} \tag{1}$$

where H^i_{RTK} is the elevation measured by the RTK, H^i_{tt} is the elevation measured by the leveling and ΔH^i is the elevation deviation at the *i* point.

$$\begin{aligned} h_{RTK} &= H^i_{RTK} - H^c_{RTK} \\ h_{tt} &= H^i_{tt} - H^c_{tt} \\ \delta h &= h_{RTK} - h_{tt} \end{aligned} \tag{2}$$

In which h_{RTK} is the difference in elevation between the detailed and center points which were observed by RTK; h_{tt} is the difference in elevation between the detailed and center points which were by automatic leveling; δh is the relative deviation.

The accuracy of RTK measurement results is commonly assessed using error calculations such as MAE (Mean Absolute Error) and RMSE (Root Mean Square Error). These calculations are often performed according to formulas (3) and (4). Using MAE and RMSE helps evaluate the overall quality of the data obtained from RTK measurements.

$$MAE = \frac{\sum \left|\Delta H^i\right|}{n} \text{ or } MAE = \frac{\sum |\delta h|}{n} \tag{3}$$

$$RMSE = \sqrt{\frac{\sum (\Delta H^i)^2}{n}} \text{ or } RMSE = \sqrt{\frac{\sum (\delta h)^2}{n}} \tag{4}$$

where n is the number of elevation points.

3. Results and discussion

3.1. Results

The coordinates (X, Y) of the 41 detailed points obtained by Trimble R8s were used to calculate the distance between these points, rather than measuring with tape or string as in the traditional method. This use of the RTK technique increased time efficiency by more than threefold.

In this study, we acknowledge the horizontal positioning accuracy of the R8S within ± 10 cm, which meets the technical standards of traditional topographic profile surveying in Vietnam as mentioned in Section 2.1. Therefore, our primary focus will be on the elevation accuracy of the RTK technique.

In comparing the elevations of the 41 detailed points obtained by the electronic level Dini 03 (elevation Dini 03) and the GNSS-RTK Trimble R8S (elevation R8s), the results are presented in Table 2 and Fig. 6. Table 2 presents the 5 cross profiles, the names of the detailed points on each cross profile (denoted as MCi-i), their elevations, and their elevation deviations between RTK Base single (elevation R8s) and leveling method (elevation Dini 03). To better visualize these differences, the deviations are calculated using formula (1) and represented in the chart in Fig. 6. The largest deviations were observed at detailed points MC2-5 and MC4-5, with values of 6.5 cm and −5.9 cm, respectively.

The MEA and RMSE are used to evaluate the precision of the elevation obtained by RTK, as Eqs. (3) and (4), respectively. The MEA = 0.0143 m and RMSE = 0.0217 m satisfy the technical requirements of the topographical profile survey standards in Vietnam, which require less than 1/4 of the minimum elevation interval $h = 0.25$ m. This demonstrates that the RTK Base single technique has fully met the requirements for measuring topographic cross profiles in Vietnam.

According to another assessment way, using the elevation data in Table 2, we calculated the differences in elevation between the centerline points and the detailed measurement points on each cross profile using Eq. (3). In terms of comparing differences in elevation, the results of relative deviations shown in Fig. 7 indicate a similarity with MEA = 0.0157 m and RMSE = 0.0223 m. The largest discrepancies are 6.9 cm and −4.9 cm at the detailed point positions of MC2-5 and MC4-5, respectively.

These results demonstrated the stability in the quality of the measurement results of the RTK Base single technique in the experimental field.

Table 2. Elevation of detailed points and deviation between RTK Base single and leveling method

N^0	Cross-section position	Detailed points	Elevation Dini 03 (m)	Elevation Trimble R8S (m)	Elevation deviation (m)
1	1	1	9.804	9.821	−0.017
2	Beginning point	MC1-1	9.956	9.945	0.011
3		MC1-2	10.170	10.163	0.007
4		MC1-3	10.731	10.730	0.001
5		MC1-4	10.719	10.709	0.010
6		MC1-5	9.710	9.704	0.006
7		MC1-6	9.956	9.950	0.006
8	2	2	7.324	7.320	0.004
9	PC point	MC2-1	7.266	7.284	−0.018
10		MC2-2	7.555	7.595	−0.040
11		MC2-3	5.342	5.343	−0.001
12		MC2-4	4.191	4.221	−0.030
13		MC2-5	3.878	3.943	−0.065
14		MC2-6	7.380	7.388	−0.008
15		MC2-7	8.413	8.411	0.002
16		MC2-8	10.206	10.202	0.004
17		MC2-9	10.175	10.163	0.012
18		MC2-10	9.916	9.914	0.002
19	3	3	4.209	4.207	0.002
20	PI point	MC3-1	4.192	4.188	0.004
21		MC3-2	4.409	4.404	0.005
22		MC3-3	5.646	5.653	−0.007
23	4	4	6.557	6.547	0.010
24	PT point	MC4-1	6.449	6.393	0.056
25		MC4-2	5.017	5.009	0.008
26		MC4-3	3.880	3.884	−0.004
27		MC4-4	3.631	3.608	0.023
28		MC4-5	6.661	6.602	0.059
29		MC4-6	7.058	7.008	0.050
30		MC4-7	10.134	10.113	0.021
31		MC4-8	10.111	10.093	0.018
32		MC4-9	9.866	9.864	0.002
33	5	5	9.660	9.654	0.006
34	Ending point	MC5-1	9.804	9.793	0.011
35		MC5-2	10.006	10.003	0.003
36		MC5-3	10.772	10.760	0.012
37		MC5-4	10.753	10.744	0.009
38		MC5-5	9.592	9.603	−0.011
39		MC5-6	9.873	9.870	0.003
40		MC5-7	9.865	9.862	0.003
41		MC5-8	3.628	3.643	−0.015

3.2. Discussions

Based on the results presented in Section 3.1, the advantages of applying GNSS RTK techniques for road profile surveying are evident:

Utilizing the Trimble R8S GNSS-RTK system for measuring coordinates and elevation of detailed points significantly increased time efficiency by more than threefold compared to traditional methods

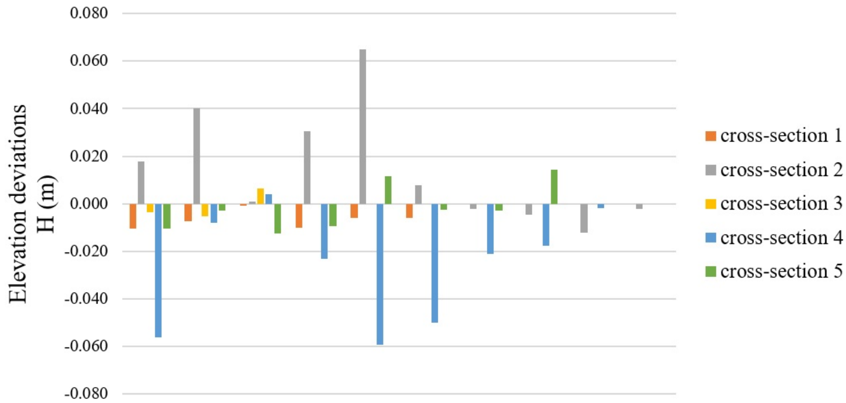


Figure 6. Elevation deviations of RTK Base single and Leveling

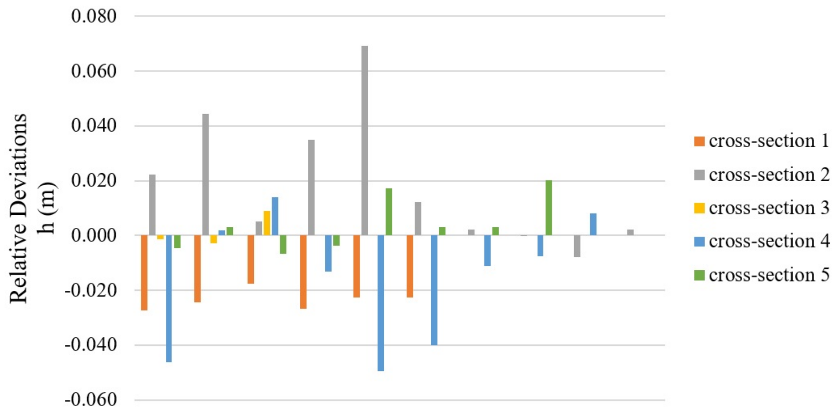


Figure 7. Deviations of difference in elevation deviations of RTK Base single and Leveling

involving tape or string measurements. This indicates a substantial advantage in terms of productivity and resource utilization.

Comparing the elevations obtained by the electronic level Dini 03 and the GNSS-RTK Trimble R8S revealed deviations, with the RTK technique demonstrating satisfactory performance. The MEA and RMS values indicate that the RTK Base single technique meets the technical requirements for measuring road cross profiles in Vietnam, showcasing its suitability for such applications.

The results suggest that the RTK technique offers a viable alternative to traditional methods for road profile surveying, offering improved efficiency and accuracy. Integrating RTK technologies into future survey projects could enhance overall surveying processes and results, leading to more reliable and precise geospatial data.

By combining the process of staking out centerline points and measuring road profiles, it becomes possible to simultaneously determine elevation and distances using the X, Y, and H coordinate systems. This approach proves more efficient than using a ruler or string, while also facilitating automatic data storage and quick verification of measurement reliability on-site. Consequently, this reduces errors and enhances safety in surveying tasks.

4. Conclusions

The RTK Base Single technique, a form of differential GNSS method, exhibits high positioning performance within 3 km of the base station, eliminating the need for alignment between control points. Consequently, it enables direct utilization of national control points without necessitating the establishment of a local control point network. Moreover, it seamlessly integrates both staking out and detailed point measurement processes during road profile surveying, thereby enhancing efficiency. Experimental results demonstrate a threefold reduction in centerline staking time compared to the conventional total station method.

The elevation accuracy achieved with the RTK technique in surveying road cross profiles reaches approximately ±6 cm, meeting current technical requirements in Vietnam. Its advantages effectively address challenges posed by traditional survey methods in complex terrain conditions, underscoring its applicability not only in road surveying but also in topographical profile surveying tasks in Vietnam.

Thus, the RTK Base Single technique offers significant time and cost efficiency for road profile surveying in Vietnam. The findings of this study are pertinent to the geodetic community and various surveying engineering applications, serving educational and technical purposes.

At present, Vietnam has established a national CORS system comprising 65 stations (VNGEONET), with plans underway to expand the network by incorporating an additional 90 to 100 NRTK-CORS stations in the future. However, it appears that the CORS system in Vietnam is primarily utilized for land management purposes. To further augment the application of the RTK technique in road profile surveying, continued consideration of the RTK CORS technique is warranted.

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