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RTK POSITIONING ACCURACY IN URBAN ENVIRONMENTS: A COMPARATIVE STUDY OF DIFFERENT GNSS RECEIVER GENERATIONS

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Abstract. *Real-Time Kinematic (RTK) positioning is one of the most widely used GNSS techniques for high-precision surveying and cadastral applications, providing centimeter-level accuracy in real time. Its performance, however, can be affected by urban environments, where signal obstruction, multipath effects, dense vegetation, and electromagnetic interference degrade positioning quality. This study evaluates RTK accuracy and reliability in urban conditions through a comparative analysis of two GNSS receivers from different technological generations: Trimble R10 and Hi-Target V200. Field experiments were conducted in Timisoara, Romania, during two independent observation sessions in March and April 2025. Four control points with varying environmental conditions, from open areas to locations affected by buildings and vegetation, were measured simultaneously using both receivers. RTK corrections were obtained via the Romanian permanent GNSS network, ROMPOS, using the NTRIP protocol. The analysis focused on X, Y, and Z coordinates, absolute coordinate differences, dispersion patterns, and satellite-related quality indicators, including satellite availability and PDOP values. The results show that both receivers achieved positioning accuracy better than 3.5 cm under all tested conditions. Trimble R10 demonstrated stability of the FIX solution, particularly in the vertical component, while Hi-Target V200 benefited from multi-constellation tracking. The findings highlight the importance of receiver hardware and processing strategies.*

Keywords*: GNSS, RTK positioning, urban environment, positioning accuracy, multi-constellation GNSS, PDOP*

INTRODUCTION

The continuous development of Global Navigation Satellite System (GNSS) technologies has had a major impact on surveying, geodesy, and cadastral applications, where high positioning accuracy and operational reliability are essential requirements. Among the available positioning techniques, Real-Time Kinematic (RTK) positioning has become one of the most widely adopted methods, as it is capable of providing centimeter-level accuracy in real time when differential corrections are applied from reference networks or permanent stations (Misra and Enge, 2012; Kaplan and Hegarty, 2017; figure 1).

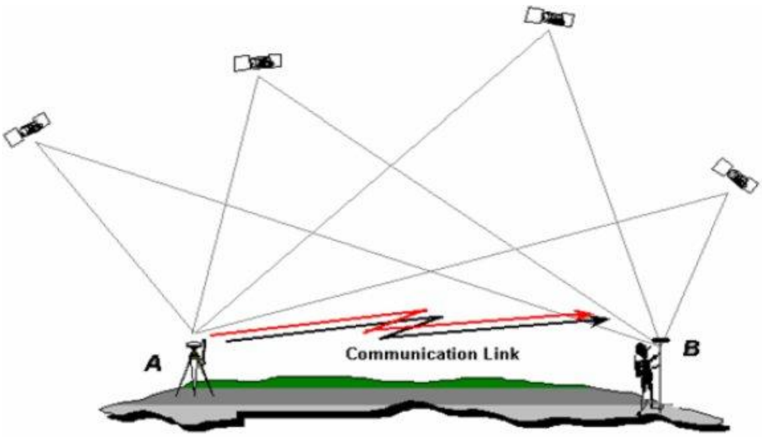

Figure 1. Real-Time Kinematic (RTK) surveying (https://canadiangis.com/guidelines-for-real-time-kinematic-rtk-surveying.php)

Despite its advantages, the performance of RTK positioning is strongly influenced by environmental conditions. Urban areas represent particularly challenging environments for GNSS applications due to the presence of tall buildings, narrow streets, dense vegetation, and various sources of electromagnetic interference. These factors often lead to signal obstruction, multipath propagation, reduced satellite visibility, and degraded satellite geometry, all of which can negatively affect positioning accuracy and solution stability (Seeber, 2012; Teunissen and Montenbruck, 2017; Wang et al., 2015; figure 2).

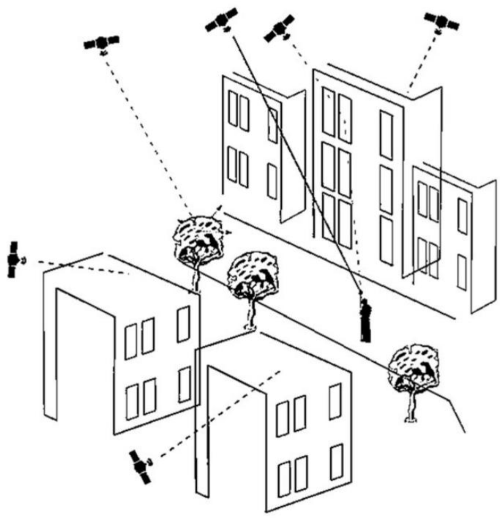

Figure 2. Global Navigation Satellite System positioning in urban environments (PARTSINEVELOS et al., 2020)

In recent years, the evolution of GNSS receiver technology has significantly improved RTK performance in such challenging conditions. Modern receivers are capable of tracking

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multiple satellite constellations, including GPS, GLONASS, Galileo, and BeiDou, as well as multiple frequencies. This multi-constellation and multi-frequency capability enhances redundancy, improves satellite geometry, reduces convergence time, and increases the probability of achieving a stable FIX solution in urban environments (Li, 2020; Zhang et al., 2018; Chen, 2022).

Comparative assessments of GNSS receiver performance under real urban conditions are therefore essential in order to quantify the practical benefits of technological advancements and to provide guidance for professional surveying applications. Several recent studies have emphasized that improvements in hardware design, antenna technology, and processing algorithms can lead to measurable gains in positioning accuracy; however, these gains are not always directly correlated with the number of tracked satellites or low PDOP values alone (Rajabi and Voosogh, 2021; Chen et al., 2019).

Within this context, the present study aims to evaluate the accuracy and reliability of RTK positioning in an urban environment by performing a comparative analysis of two GNSS receivers belonging to different technological generations: Trimble R10 and Hi-Target V200 (table 1).

Table 1

Summary comparison between GNSS equipment

Features	Trimble R10	Hi-Target V200
GNSS Constellations	GPS, GLONASS, Galileo, BeiDou	GPS, GLONASS, Galileo, BeiDou
Nr. Canale No. of Channels	440	965
RTK Accuracy (Horiz.)	±8 mm + 1 ppm	±10 mm + 1 ppm
Integrated Antenna	Yes	Yes
NTRIP Support	Yes	Yes
Acquisition Software	Trimble Access	Hi-Survey Road

The experimental measurements were carried out in the city of Timișoara, Romania, using real-time corrections provided by the national GNSS permanent network ROMPOS. By analyzing coordinate differences, solution stability, satellite availability, and PDOP values across different environmental conditions, this research contributes to a better understanding of RTK performance in complex urban settings and supports informed decision-making for future surveying and cadastral projects.

MATERIALS AND METHODS

The empirical analysis was carried out in Timișoara, Romania, where a set of four control points was selected in environments with varied visibility conditions: V1 (close to buildings), V2 (open space), A1 (dense vegetation), and A2 (semi-obstructed zone) (figure 3). These settings provide contrasting conditions for testing GNSS performance.

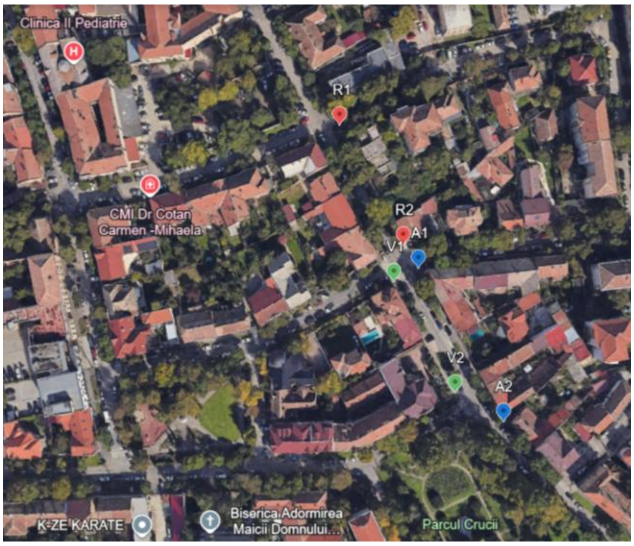

Figure 3. General map showing the location of the four measured points (V1, A1, A2, V2)

The GNSS receivers included in the study were Trimble R10 and Hi-Target V200, representing different generations of geodetic equipment. Trimble R10 integrates 440 channels and supports GPS, GLONASS, Galileo, BeiDou, and QZSS constellations, with an RTK accuracy of ±8 mm + 1 ppm horizontal and ±15 mm + 1 ppm vertical. The Hi-Target V200, with 965 channels, supports all major constellations and achieves RTK accuracy of ±10 mm + 1 ppm horizontally and ±15 mm + 1 ppm vertically. Both receivers are compact and designed for field applications (table 1).

Two observation sessions were performed: one in 7 March 2025, characterized by reduced vegetation and favorable weather, and one in 16 April 2025, with increased vegetation density. Both sessions used the ROMPOS network via NTRIP protocol for real-time corrections. Each control point was observed for at least 10 seconds after FIX stabilization. Coordinates were recorded in the STEREO 70 projection (ETRS89 datum) (table 2 and table 3).

Table 2

Coordinates obtained during the 7 March 2025 session
(Trimble R10 vs. Hi-Target V200)

Receiver	Point	X (m)	Y (m)	Z (m)
Trimble R10	**V1**	478399.743	206936.191	88.237
Hi-Target V200	**V1**	478399.711	206936.194	88.213
Trimble R10	**A2**	478333.831	206983.804	88.539
Hi-Target V200	**A2**	478333.835	206983.808	88.511
Trimble R10	**A1**	478405.364	206948.245	88.223
Hi-Target V200	**A1**	478405.356	206948.261	88.200
Trimble R10	**V2**	478345.678	206962.248	88.537
Hi-Target V200	**V2**	478345.680	206962.267	88.515

Table 3

Coordinated results for the session of April 16, 2025

Receiver	Point	X (m)	Y (m)	Z (m)
Trimble R10	V1	478399.699	206936.184	88.233
Hi-Target V200	V1	478399.731	206936.194	88.221
Trimble R10	A2	478333.848	206983.797	88.523
Hi-Target V200	A2	478333.812	206983.810	88.520
Trimble R10	A1	478405.366	206948.253	88.211
Hi-Target V200	A1	478405.341	206948.262	88.178
Trimble R10	V2	478345.675	206962.261	88.543
Hi-Target V200	V2	478345.669	206962.253	88.514

Subsequent analyses focused on computing absolute differences (ΔX, ΔY, ΔZ), evaluating dispersion, and statistical deviations across sessions (table 4 and table 5).

Table 4

Coordinate differences (ΔX, ΔY, ΔZ) between Trimble R10 and Hi-Target V200, 7 March 2025 session

Point	ΔX (m)	ΔY (m)	ΔZ (m)
V1	0.032	-0.003	0.024
A2	-0.004	-0.004	0.028
A1	0.008	-0.016	0.023
V2	-0.002	-0.019	0.022

Table 5

Coordinate differences (ΔX, ΔY, ΔZ) between Trimble R10 and Hi-Target V200, 16 April 2025 session

Point	ΔX (m)	ΔY (m)	ΔZ (m)
V1	-0.032	-0.010	0.012
A2	0.036	-0.013	0.003
A1	0.025	-0.009	0.033
V2	0.006	0.008	0.029

RESULTS AND DISCUSSION

The comparative analysis of RTK measurements obtained with the Trimble R10 and Hi-Target V200 GNSS receivers demonstrates that both instruments are capable of delivering reliable centimeter-level positioning accuracy in urban environments. Across the two observation sessions carried out in March and April 2025, the absolute coordinate differences between the two receivers remained below 3.5 cm for all measured points, confirming the robustness of RTK positioning even under constrained signal conditions. The close spatial agreement between the positions determined with the two receivers during both sessions is illustrated in figure 4, which presents the graphical representation of the measured points.

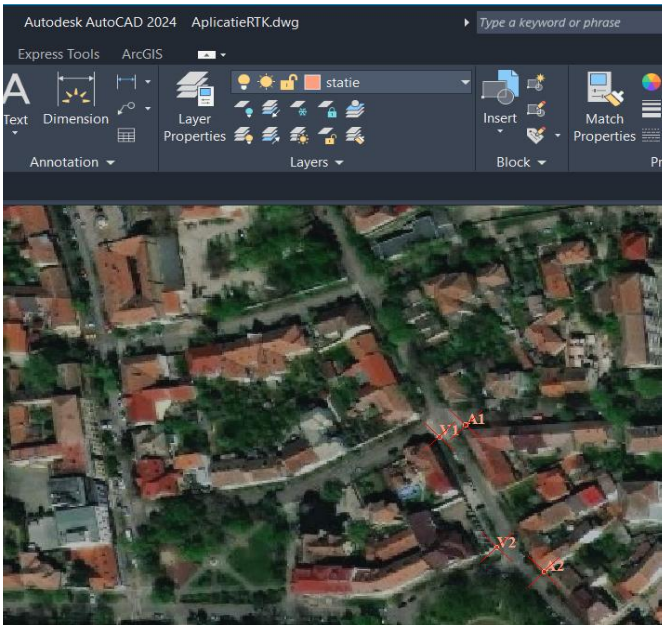

Figure 4. Reporting the points measured in the two sessions in AutoCAD

The horizontal components (X and Y) showed a high degree of consistency between the two receivers, with most differences remaining within the range of a few millimeters to approximately 2 cm. These results are consistent with findings reported in recent studies addressing RTK performance in urban environments, where horizontal accuracy is generally less affected by multipath and signal obstruction than the vertical component (Zhang et al., 2018; Wang et al., 2015). This behavior is clearly visible in the graphical comparison of coordinate differences presented in Figure 7, where the dispersion of the horizontal components is noticeably lower than that of the vertical component. The vertical component exhibited slightly larger deviations, which is a well-known characteristic of GNSS positioning due to satellite geometry and atmospheric effects (Teunissen and Montenbruck, 2017).

Trimble R10 demonstrated greater stability of the FIX solution, particularly in the vertical dimension, suggesting that antenna design and internal processing algorithms play a significant role in mitigating multipath effects. This behavior can be observed by comparing the receiver performance under different environmental conditions documented in figure 5 (March 7 session) and figure 6 (April 16 session), where Trimble R10 maintained a stable FIX solution despite changes in vegetation and shading. This observation aligns with recent research indicating that positioning quality is not solely dependent on the number of tracked satellites or favorable PDOP values, but also on receiver-specific processing strategies (Rajabi and Voosogh, 2021; Chen et al., 2019).

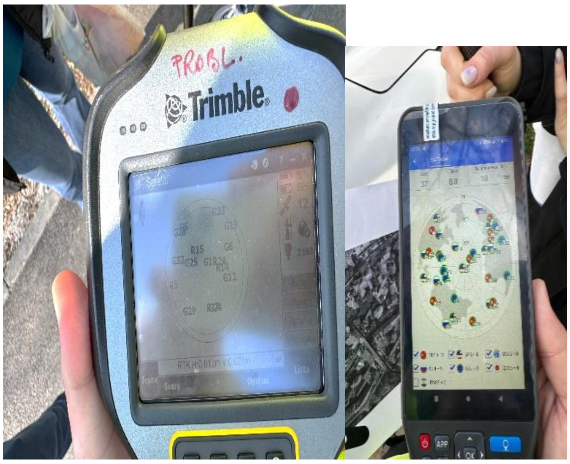

Figure 5. The session on March 7 (in point V1)

In contrast, the Hi-Target V200 consistently tracked a higher number of satellites and achieved lower PDOP values, reflecting improved satellite geometry due to its multi-constellation and multi-frequency capabilities. However, these advantages did not always translate into superior positional accuracy, especially under conditions of dense vegetation observed during the April session. The impact of environmental obstruction on solution quality during this session is illustrated in Figure 6, confirming that urban GNSS performance is influenced by a complex interaction between environmental conditions, receiver hardware, and data processing algorithms (Li, 2020; Chen, 2022).

Figure 6. The session on April 16 (in point V1)

Seasonal variations also played a measurable role in positioning performance. During the March session, when vegetation density was reduced, both receivers achieved stable FIX solutions with minimal dispersion (figure 7). In the April session, increased foliage and shading resulted in slightly higher coordinate dispersion, particularly on the vertical axis, as reflected in the comparative graphical analysis (figure 7). Nevertheless, all deviations remained within acceptable limits for standard surveying and cadastral applications, reinforcing the suitability of RTK techniques for urban measurements when appropriate survey planning is applied.

Figures 7. Graphical representation of coordinate differences (ΔX, ΔY, ΔZ) for 7 March and 16 April 2025 sessions

From a practical perspective, both receivers are appropriate for general surveying and cadastral activities. For high-precision applications, such as engineering monitoring or deformation studies, methodological refinements including repeated measurements, extended occupation times, and post-processing (PPP/PPK) are recommended. These findings align with broader academic discussions on GNSS resilience in constrained environments (SEEBER, 2003; TEUNISSEN, 2017).

CONCLUSIONS

This study assessed the performance of Real-Time Kinematic (RTK) GNSS positioning in an urban environment through a comparative analysis of two geodetic receivers from different technological generations, namely Trimble R10 and Hi-Target V200. The experimental results obtained from two independent measurement sessions confirm that both receivers are capable of delivering reliable centimeter-level positioning accuracy under real urban conditions.

The analysis showed that horizontal and vertical coordinate differences remained below 3.5 cm for all tested points, demonstrating the robustness of RTK positioning even in the presence of buildings, vegetation, and partial signal obstruction. Trimble R10 exhibited greater stability of the FIX solution, particularly in the vertical component, which is critical for high-precision surveying applications. In contrast, Hi-Target V200 benefited from multi-constellation and multi-frequency tracking, resulting in a higher number of observed satellites and lower PDOP values, although these advantages did not always translate into superior positional accuracy.

From a practical perspective, the findings indicate that both receivers are suitable for standard surveying and cadastral tasks in urban environments. For applications requiring enhanced vertical accuracy or higher reliability under constrained conditions, careful survey planning, optimal observation timing, and, where necessary, repeated measurements are recommended. Overall, the study confirms that modern RTK GNSS technology remains a dependable solution for urban positioning, supporting its continued use in professional surveying and geodetic practice.

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