An Assessment of RTK and PPK Solutions in a CORS Network

SN Lewis[1,#], PBA Fernando[1], MDEK Gunathilaka[1] and AND Perera[1]

[1]*Department of Surveying and Geodesy, Faculty of Geomatics, Sabaragamuwa University of Sri Lanka*

[#]1995snl@gmail.com

***Abstract**: Recently, Sri Lanka has developed a greater interest in surveying applications based on Continuously Operating Reference Station (CORS) technology. CORS Real Time Kinematic (RTK) can perform well through a good Global System for Mobile Communications (GSM) coverage area by receiving the corrections in real-time. It is very difficult when facing the GSM network coverage limitation issue in remote areas. As an alternative solution, Post Processing Kinematic (PPK) is a good solution to face that problem because it does not need a real-time data communication link for the correction signal when doing the survey. This study aims to compare the RTK and PPK solutions in a CORS network in Sri Lanka. Seven known points were selected near the Belihuloya area. The CORS reference station was the SULECO SUSL station. Position solutions were compared for both PPK and RTK methods with several sets of observations. According to the results, the horizontal variation of the PPK was accurate as the same as the RTK solution, which was below the 1cm mean difference. However, the vertical accuracy was lower than the horizontal accuracy in the PPK technique. This was around 10 to 15cm variations in the study area. In conclusion, both PPK and RTK techniques gave similar results in terms of horizontal accuracy in a CORS network. Therefore, the issues of real-time corrections transfer in a CORS network can be overcome by adopting PPK mode for the boundary and detail survey without interrupting the progress.*

***Keywords**: Accuracy Assessment, CORS Network, GNSS, PPK, RTK*

1. Introduction

Global Navigation Satellite System (GNSS) is the latest satellite-based surveying technique in the modern-day which mainly contribute to the worlds positioning and navigation applications. At the very beginning of the GNSS technology, it was not much accurate due to satellite orbit errors, satellite clock errors, signal delay errors in the troposphere and ionosphere, receiver noise errors, multipath, and so on (Karaim et al., 2018). End users have been moving to the new technology of GNSS to their ease of use in real-life applications by avoiding out-of-date technologies (Lilje, et al., 2009).

Continuously Observation Reference Stations (CORS) network, which installs permanent GNSS base stations with a network server is one of the present trends in which people are moving rapidly to use real-time accurate positioning (Lilje, et. al., 2009). It uses ground-located high accuracy GNSS receivers to obtain location data from GNSS receivers and it gives real-time corrections. This CORS Network combines the fixed base stations and creates a model to act as a Virtual Reference Station (VRS) for clients and decrease the base station distance to increase the position accuracy (Burns and Sarib., 2010). The raw data which are collected through high accuracy GNSS receivers, send lively to the control centre and corrections are processed in the control centre. Radio Technical Commission for Maritime Services (RTCM) corrections instantly broadcast as Network Transport of RTCM via Internet Protocol (NTRIP) to the rover receiver via General Packet Radio Service (GPRS). This Network covers a large area than a conventional single GNSS base station and it does not bias toward one station in this method. There should be at least three base stations to make the network. At present time this is very essential because the client can collect data only with one rover receiver and no more worries about setting up physical base stations (Janssen *et al.*, 2011).

When considering Sri Lanka, SLCORSnet of the Survey Department of Sri Lanka and the CORSnet of Suleco (Pvt) Ltd. provide the services of CORS network experience to the clients. It provides (Differential GNSS) DGNSS, single-base (Real Time Kinematic) RTK, (Network RTK) NRTK, and (Receiver Independent Exchange Format) RINEX data for post-processing applications. Both systems are still upgrading to give the best coverage in Sri Lanka.

RTK uses a carrier-based range to deliver positions with more precision. The distance between the base and the rover should not exceed 20 Km to maintain the high accuracy of the RTK solution (Shouny et al., 2017). CORS Network needs a good (GSM) network coverage to pass the correction data when using the CORS RTK method. In this method, corrections transmit through a GSM sim card from the CORS Network server to the rover. Sometimes it is not possible to maintain a good signal transferring between the CORS and the rover in real-time due to the limitation of GSM network coverage in remote areas in Sri Lanka.

PPK is one of the solutions that is widely used in surveying and mapping to obtain high-precision or centimeter-accurate position data (Pirti, 2021). PPK technology does not require any real-time data communication between the base station and the receiver (Ahmed Fouad Metawi El-Shouny, 2008). Surveying with PPK technology could be the best option in the modern-day due to the use of the post-processing method with carrier phase signals when surveying challenging and low or limited GSM coverage areas.

According to the *opensingnal.com* website, they reported the 4G coverage of Sri Lanka by considering the four national mobile telecommunication operators; Airtel, Dialog, Hutch, and Mobitel. Opensignal.com have gathered data for 90 days from the start of October 2021 to December 2021 to analyse the data. The best service provider, Dialog is also providing 87% in coverage as shown in Figure 1 (Opensignal Limited, 2022).

Figure 1 : Network Coverage in Sri Lanka | Source: https://www.opensignal.com/reports/2022/02

The website, *nperf.com* provides details about the quality of your internet connection and collects a huge amount of data on mobile network coverage per year. It shows the main GSM service provider's network coverage in Sri Lanka using the collected data from 2020 (Figure 2) (Nperf, 2022).
Sri Lanka has several network service providers such as Dialog, Mobitel, Airtel, and Hutch and there is not fully covered entire Sri Lanka by any service provider according to the above online records.

CORS network is rapidly growing in the GNSS world due to its accuracy, reliability, and ease of use. A lot of end-users in Sri Lanka have moved to access CORS Network because of its benefits.

Figure 2 : Dialog GSM Coverage Maps in Sri Lanka |Source: https://www.nperf.com/en/map/LK/-/24443.Airtel/signal/?ll=7.976239853732186&lg=80.23452758789064&zoom=10

But there are not such end-users who have engaged with PPK solution, due to a lack of knowledge of the position accuracy of PPK over Sri Lanka. This research emphasizes the accuracy assessment between RTK and PPK in a CORS network in Sri Lanka.

2. Methodology

A. *Study Area*

The study was carried out over the Sabaragamuwa University premises located at Belihuloya which belongs to Ratnapura district in Sabaragamuwa province Sri Lanka as shown in Figure 3.

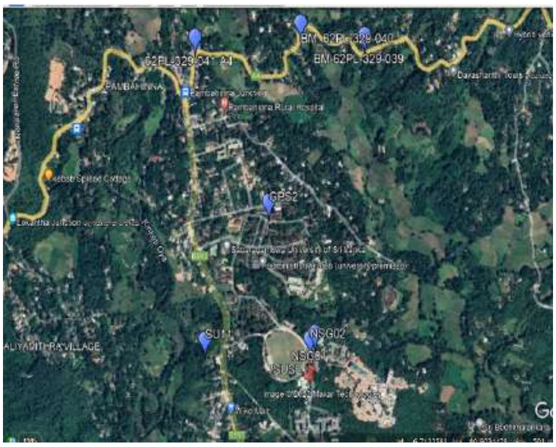

Figure 3 : Study Area

QQQQ. Methodology Flow Chart

Figure 4 explains the overall research methodology. Here, the priority was to collect the RTK and PPK data of the relevant stations around the study area and to compare the variation of the results.

As the secondary data, three survey department ground control points around the study area were obtained from the survey department of Sri Lanka (BM-62PL-329-039, BM-62PL-329-039, and BM-62PL-329-039). Previously established four ground control points (NSG1, NSG2, GPS2, and SU11) by the Faculty of Geomatics at the Sabaragamuwa University of Sri Lanka were also selected. These points were re-established by making a one-hour static observation using the same CORS Network base station (SUSL station).

RTK observations were taken for 10min, 5min, 1min, the 30s, and 5s time on the same station, and three data sets were obtained for each time interval for the statistical analysis. Similarly, the PPK observations were also taken for 10min, 5min, and 1min time intervals as three sets.

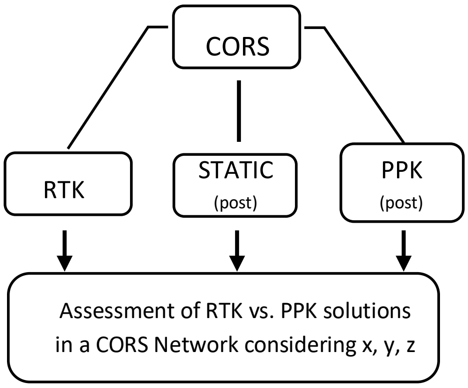

Figure 4 : Flow Chart Methodology

Figure 5 : Data Collection

Leica GS15 GNSS receiver and the Leica Infinity 3.0 post-processing software were used for the data acquisition and processing. Figure 5 shows the RTK and PPK field data acquisition procedure.

3. Results and Discussion

The result of the RTK and PPK solution in the SUSL CORS base station for East, and North coordinates and the height variation have been graphically represented in Figure 6 and Figure 7 graphs respectively. Most of the time horizontal coordinates have shown a similar variation and the vertical component variation shows considerable variation between the two solutions.

Figure 8 represent the Easting differences between RTK and PPK solutions. Figure 9 represent the Northing differences between RTK and PPK solutions, and Figure 10 represent the Height differences between RTK and PPK solutions. The mean differences between the PPK method and RTK method did not exceed 0.015m for the horizontal component (ΔE and ΔN) and 0.15m for the vertical component (ΔH).

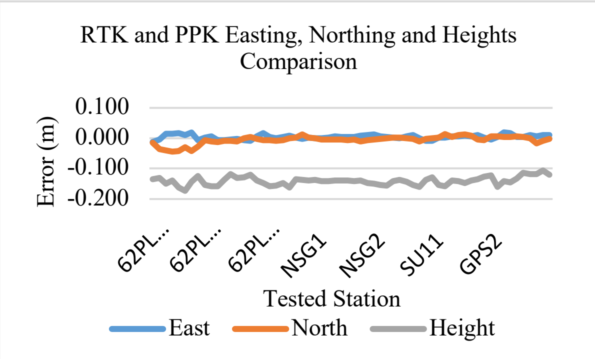

Figure 6 : RTK PPK North, East, Height Comparison | Line Graph

The standard deviation was 0.005m for ΔE and 0.07m for ΔN and 0.07m for ΔH components as shown in Figures 8,9, and 10. The best fit line has shown the variation of the difference between the RTK and PPK coordinates which is below 0.02m in the horizontal component and below 0.15m in the vertical component.

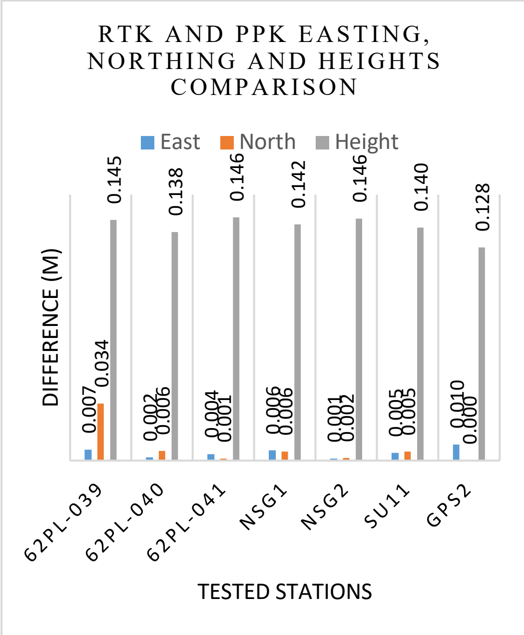

Figure 7 : RTK PPK North, East, Height Comparison | Average value in Bar Graph

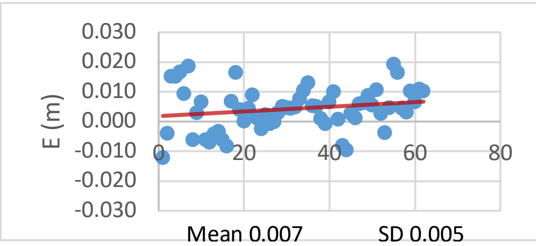

Figure 8 : Comparison of the coordinates of the test points for RTK vs PPK methods| ΔE

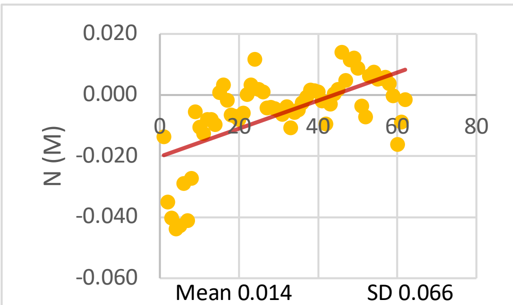

Figure 9 : Comparison of the coordinates of the test points for RTK vs PPK methods| ΔN

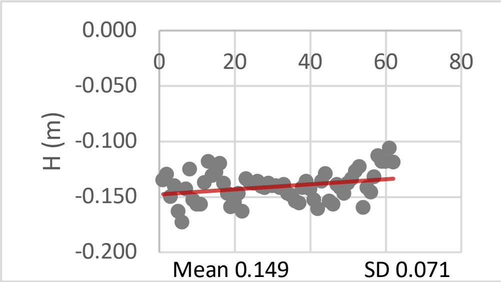

Figure 10 : Comparison of the coordinates of the test points for RTK vs PPK methods| ΔH

Then, a comparative analysis of a simple box and whisker plot was used to compare the difference between the RTK and PPK solution's northing, easting, and height variation as shown in Figure 11.

According to the analysis, horizontal variation of the PPK was accurate same as the RTK solution at sub-centimetre level i.e. below 1cm mean difference. Vertical accuracy was lower than horizontal accuracy i.e. it was closed to 10-15cm variations in the study area. According to the theories of Dilution of Precision (DOP) value, vertical direction accuracy is lower than the horizontal accuracy (Tahsin *et al.*, 2015).

As a secondary objective, obtained data was sorted as the observed time interval period of the Northing and Easting accuracy variations for both RTK and PPK solutions in a CORS network. Analyse was used to see the performance of the accuracy when changing the observation time period of each solution.

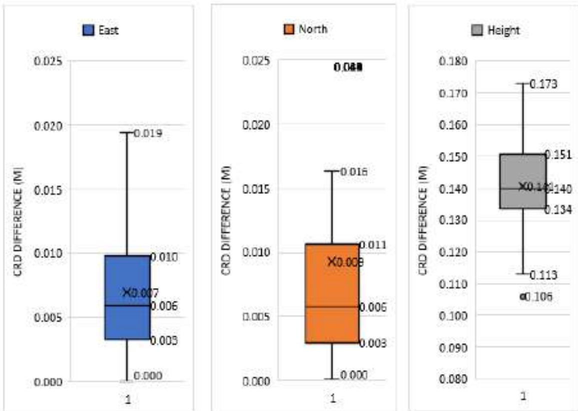

Figure 11 : Simple Box and Whisker Plot for E(left), N(middle), H(right) of RTK-PPK

Figure 11 illustrates the lower quartile, median and upper quartile of the Easting difference were 0.003m, 0.006m, and 0.010m respectively. The same statistics for the Northing difference were 0.003m, 0.006m, and 0.011m. Northing difference has some outliers i.e. a piece of data that is an abnormal distance from other points, in the data set. It was from only one set of data variations. 75% of the Easting and Northing variation is around the 0.01m range. The lower quartile, median and upper quartile values of the Height differences were 0.134m, 0.14m, and 0.151m. It is emphasized that 75% of the height variation is below the 15cm range.

Horizontal accuracy of the RTK solution was graphed to analyse the accuracy variation pattern according to the observation time period as shown in Figure 12. Horizontal accuracy of the PPK solution was graphed to analyse the accuracy variation pattern according to the observation time period as shown in Figure 13.

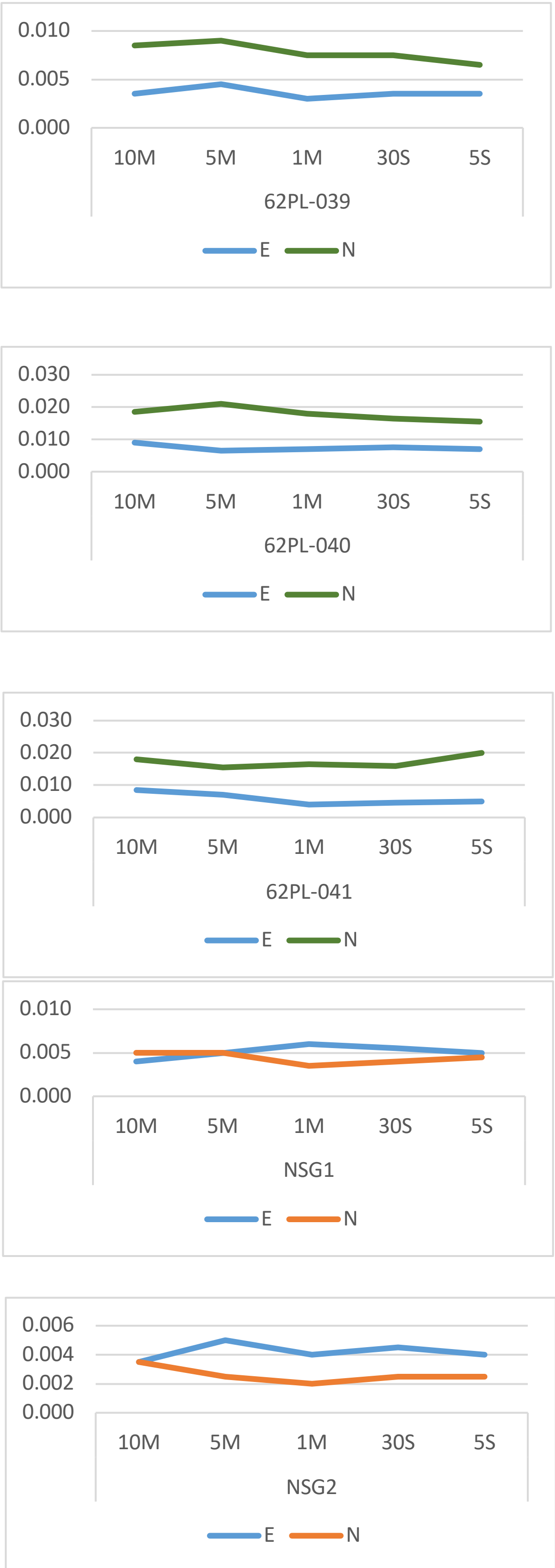

Figure 12 : RTK Position Accuracy Pattern considering the observation time interval

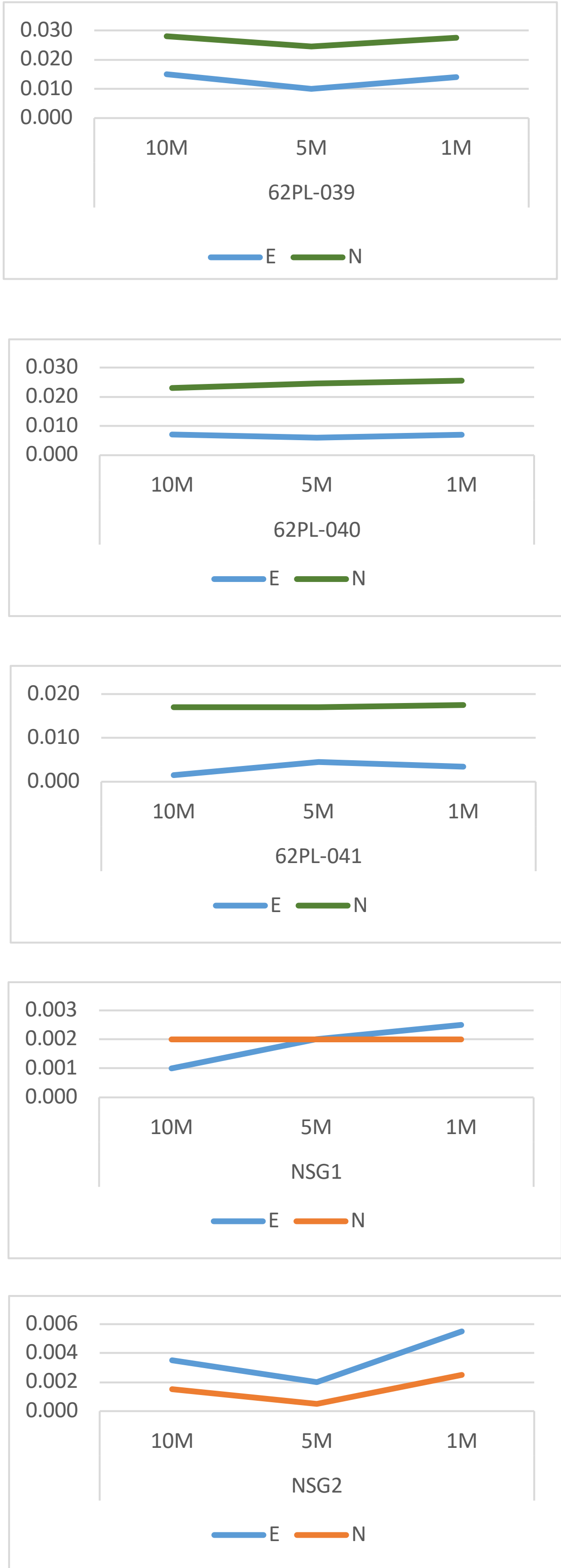

Figure 13 : PPK Position Accuracy Pattern considering the observation time interval

Figures 12 and 13 illustrate the RTK and PPK northing and easting accuracy pattern considering the observation time interval. Most of the time, the number of epochs were 601 for 10min, 302 for 5min, 61 for 1min, 31 for the 30s, and 7 for 5s. According to the graphs, the obtained position accuracy of both solutions was not biased by the observation time interval period in GNSS observations in the study area.

4. Conclution and Discussion

RTK solution is the most suitable solution when comparing the PPK method according to the final results of the research. Although PPK solution has also performed the same as the RTK maintaining a good horizontal accuracy i.e.75% of the Easting and Northing variation is around the 1cm range. Considering the vertical component of the assessment, that has a low accuracy for both solutions when comparing the horizontal accuracy. The mean value ΔH of RTK was 6.4cm and 8.1cm for PPK solution and both solution average variation was nearly 14cm.

As a sub-objective, obtained data was collected for comparing accuracy pattern according to the observation time intervals. Results were not good enough to get a clear idea of the accuracy variation with the number of epochs of the signal. Because figure 12 and 13 does not show the accuracy enhancement when increasing the observation time period.

Comparing the results, PPK has performed the same as the RTK in horizontal accuracy in a CORS network. It would be a good solution to use in a low GSM coverage area to solve the problem of correction transferring in real-time a CORS network. The final results of the research have justified the importance of understanding the concept of PPK solution replacement for RTK in the Belihuloya region through a CORS network.

Due to the practical difficulties, this study was limited only to the Belihuloya region, only SUSL CORSnet base station and suggested to do the test for the other parts of the country to get a better picture of the entire CORS network performance.

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Author Biographies

Mr. SN Lewis is a final year undergraduate of a BSc Hons in Surveying Sciences (Hydrographic Surveying) with FIG/IHO/ICA Category B certification at the Faculty of Geomatics, Sabaragamuwa University of Sri Lanka. This paper is based on his final year research project. His research interests include Hydrography and GNSS technology.

Ms. P.B.A. Fernando is a final year undergraduate of a BSc (Hons.) Surveying Sciences in Hydrographic Surveying with FIG/IHO/ICA Category B certification at the Faculty of Geomatics, Sabaragamuwa University of Sri Lanka. Her research interests are in Hydrography, Oceanography and, GPS technologies

Dr. MDEK Gunathilaka is a senior lecturer at the Faculty of Geomatics, Sabaragamuwa University of Sri Lanka. His research interests include Hydrographic Surveying and Spatial Sciences.

Mr. AND Perera is a senior lecturer at the Faculty of Geomatics, Sabaragamuwa University of Sri Lanka. He was the former Chief Hydrographer of the National Hydrographic Office in Sri Lanka. His research interests include Data Acquisition instrument development, Seabed classification, and Satellite-derived bathymetry