World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

Check for updates

Investigations into the quality of final-product dual-frequency static PPP over fixing time using CSRS-PPP free online service: GPS Vs. GPS + GLONASS

Mustafa M. Amami *

Department of Civil Engineering, Benghazi University, Benghazi, Libya.

World Journal of Advanced Engineering Technology and Sciences, 2025, 17(02), 438-443

Publication history: Received 06 October 2025; revised on 20 November 2025; accepted on 22 November 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.17.2.1517

Abstract

The Global Positioning System (GPS) delivers precise, continuous, and globally accessible positioning and timing information through satellite-based measurements. Nevertheless, relying on a single satellite constellation imposes limitations related to satellite availability and geometric distribution, which can adversely affect the reliability of positioning, particularly in environments where visibility is reduced or satellite geometry becomes suboptimal. This study examines the performance of static Precise Point Positioning (PPP) as a function of fixing time using the Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service under two processing scenarios: GPS-only and GPS+GLONASS. The analysis was conducted under open-sky conditions where multipath effects are negligible. Dual-frequency GNSS data were collected from ten spatially well-distributed stations, each observed continuously for 24 hours. Static PPP solutions were generated for fixing intervals beginning at 1 hour and incrementally increasing to 24 hours. The 24-hour static PPP solution served as the reference for evaluating the accuracy and stability of all other solutions. The results show that utilizing GLONASS observations alongside GPS leads to notable improvements in solution reliability and overall positioning stability throughout the fixing intervals. These benefits are particularly clear during shorter observation durations, especially the first one hour where the absolute errors in N, H, 2D and 3D are reduced by (2.2, 3, 1.8 and 2.22 cm) with GPS+GLONASS, respectively. As for the Easting component, the absolute errors determined from the two constellations are very tiny and rounded about zero. The benefits of adding GLONASS to GPS can also be noted during the first several hours when PPP solutions are most sensitive to satellite geometry and convergence behavior. Although the enhancement in mean absolute positional accuracy becomes marginal for longer observation periods, the multi-constellation configuration significantly reduces the occurrence of outliers and decreases the dispersion of coordinate residuals across the Northing, Height, 2D, and 3D components. The results demonstrate that even under optimal open-sky conditions, where multipath is virtually absent, the integration of GLONASS contributes measurably to improving the robustness and reliability of Static PPP. In summary, although the improvement of integrating GLONASS with GPS in static PPP in the average absolute accuracy is marginal after long fixing time comparing to GPS-alone, the benefits are significant for the first a few hours, specially the first fixing hour where the 3D quality obtained via one-hour static dual-frequency PPP with GPS+GLONASS can be reached after 3 to 4 hours fixing time using GPS-alone.

Keywords: GPS; GLONASS; Precise Point Positioning (PPP); CSRS-PPP; Static Positioning; Fixing Time

1. Introduction

The Global Navigation Satellite Systems (GNSS), including the Global Positioning System (GPS) and Russia's Global Navigation Satellite System (GLONASS), are space-based positioning and navigation infrastructures that enable the determination of instantaneous position and velocity using passive range measurements [1]. These systems operate continuously under all weather conditions and provide high-accuracy, real-time global positioning and timing

* Corresponding author: Mustafa M. Amami

information [2]. GNSS satellites broadcast signals on two primary frequencies, each modulated with Coarse/Acquisition (C/A) and Precise (P) codes [3]. These signals support the derivation of pseudo-range and carrier-phase observations, which form the backbone of contemporary geodetic, surveying, and navigation applications [4].

The accuracy of GNSS positioning is influenced by several factors, including satellite geometry, atmospheric conditions, receiver performance, and signal environment [3]. Code-based positioning typically achieves meter-level accuracy, which is sufficient for low-precision applications such as vehicular navigation [5][6], drone operations [7][8], or the generation of low-accuracy ortho-mosaics and digital elevation models [9]. In contrast, high-precision applications, such as geodetic network establishment, structural deformation monitoring, and precision engineering, require centimeter-level accuracy. Such performance can be achieved through advanced techniques like Differential Carrier-Phase GNSS (DGNSS) and Precise Point Positioning (PPP) [3].

DGNSS enhances positioning accuracy by employing simultaneous observations from a known reference station and an unknown rover receiver [10]. Forming single, double, or triple differences between observations effectively mitigates many common GNSS error sources, including satellite clock offsets and ionospheric delays [11]. Dual-frequency DGNSS systems can achieve millimeter-level precision, whereas single-frequency variants generally reach decimeter-level accuracy at a considerably lower cost [12]. Despite its strengths, DGNSS is constrained by the requirement for proximity to a reference station, limiting its usability on a global scale.

PPP emerges as a globally applicable alternative that provides high accuracy without requiring a local reference station. It employs precise satellite orbit and clock products, typically supplied by the International GNSS Service (IGS), along with sophisticated atmospheric and relativistic error models. PPP can deliver centimeter-level accuracy in both static and kinematic modes, although it typically involves longer convergence times compared to DGNSS. The Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service, developed by Natural Resources Canada (NRCan), is one of the most widely used free PPP processing platforms. It supports both static and kinematic datasets and yields coordinates referenced to the International Terrestrial Reference Frame (ITRF). Users can submit RINEX files from single- or dual-frequency receivers, and the service automatically applies precise ephemerides, clock corrections, and atmospheric modeling to produce high-quality solutions [13].

The performance of Static PPP is influenced by several parameters, including the number of available satellites, the surrounding multipath environment, the constellation used, the type and quality of the GNSS antenna [14], the ionospheric and tropospheric delay models, and the type of satellite ephemerides (ultra-rapid, rapid, or final). This study seeks to evaluate the benefits of augmenting GPS with GLONASS in Static PPP using dual-frequency observations collected under true open-sky conditions, and to analyze solution quality as a function of fixing time using the CSRS-PPP service with final precise products. This aspect warrants further investigation because most previous studies evaluated PPP performance at the final convergence epoch rather than examining accuracy progression at incremental hourly intervals. Furthermore, acquiring data in multipath-free desert environments and employing final ephemerides provides clearer insight into the intrinsic value of GPS+GLONASS integration without the confounding influence of multipath, poor satellite geometry, or lower-quality orbit products.

The present work will be followed by additional studies investigating multipath effects, the performance of integrated Kinematic PPP with MEMS-based INS and vision navigation, and the use of Kinematic PPP in UAV-based photogrammetry for precise determination of exterior orientation parameters, which play a crucial role in improving automatic image matching and reducing processing time compared to conventional workflows. Further details on related efforts undertaken at the University of Benghazi to enhance image-based navigation and matching performance can be found in [15] [19].

2. Objectives and methodology

The dataset used in this study was obtained through the Engineering Consultancy Office at Benghazi University from various projects conducted across Libya. Ten datasets were collected using a dual-frequency GNSS receiver operating in static mode under unobstructed open-sky desert conditions, with each observation session lasting 24 continuous hours. Each dataset was processed using two configurations: (1) GPS-only and (2) GPS + GLONASS, with fixing intervals initiated at 1 hour and increased incrementally up to 24 hours. The 24-hour static PPP solution was treated as the reference benchmark. For each fixing period, the static PPP coordinates were compared with the reference solution to compute the absolute positioning errors in Easting, Northing, Height, 2D (E+N), and 3D (E+N+H) components. The results from all ten stations were then statistically analyzed to identify and mitigate outliers and to derive the final accuracy metrics. Using datasets collected from geographically distributed locations across Libya enabled assessment of how satellite visibility and geographic distribution influence PPP accuracy and solution stability.

3. Results and Discussion

The average quality of N, H, 2D and 3D absolute differences in GPS-alone and GPS + GLONASS are shown in figures (1), (2), (3), and (4), respectively.

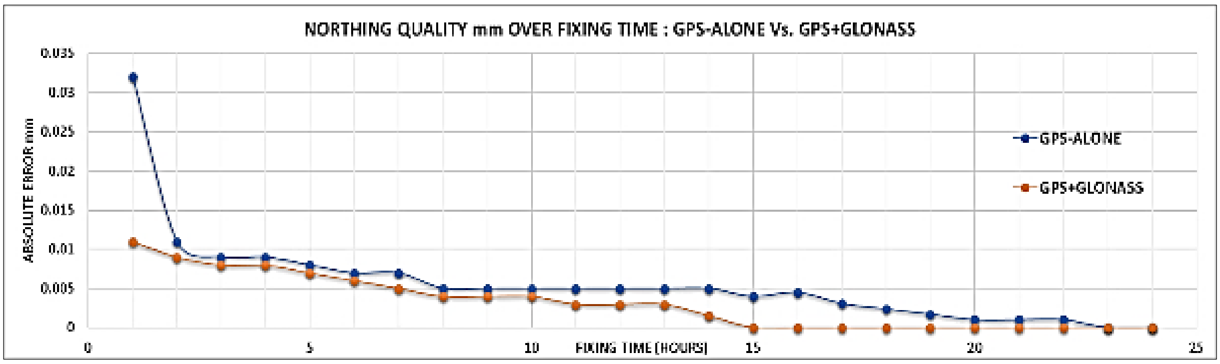

Figure 1 Northing Quality: GPS-alone Vs. GPS+GLONASS

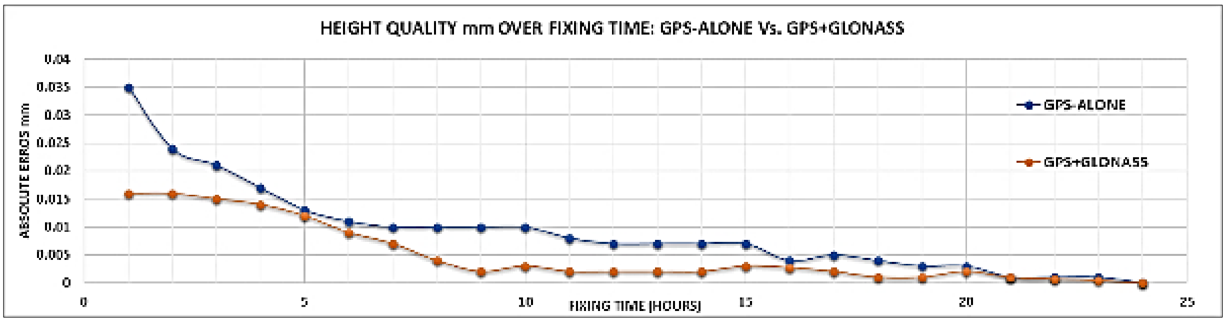

Figure 2 Height Quality: GPS-alone Vs. GPS+GLONASS

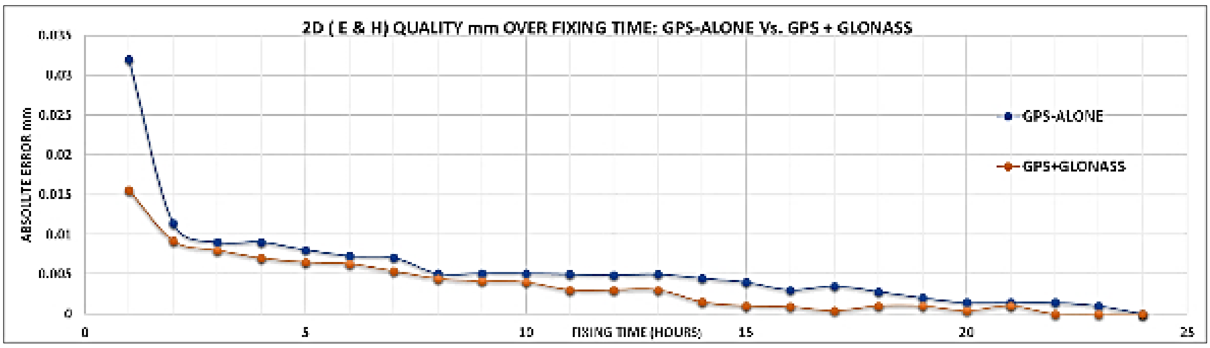

Figure 3 2D (E and N) Quality: GPS-alone Vs. GPS+GLONASS

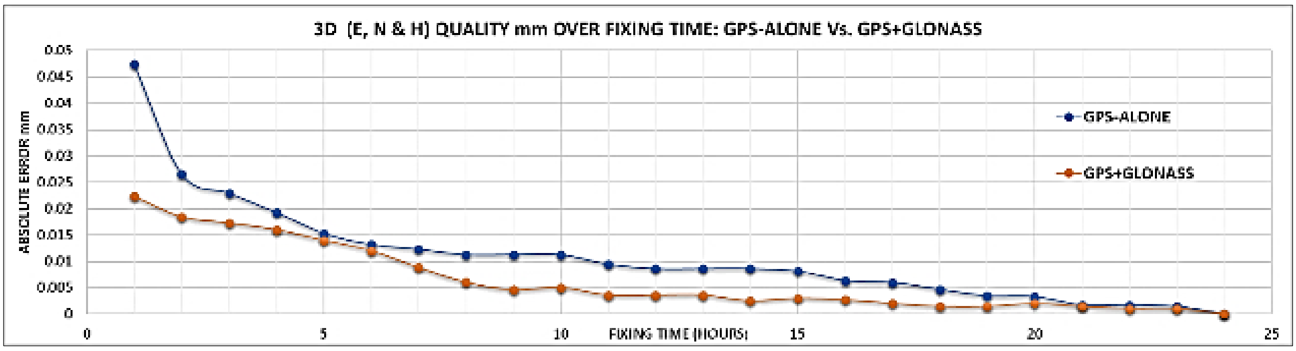

Figure 4 3D (E, N and H) Quality: GPS-alone Vs. GPS+GLONASS

The results indicate that incorporating GLONASS observations alongside GPS leads to notable improvements in solution reliability and overall positioning stability throughout the fixing intervals. The inclusion of the GLONASS constellation enhances satellite geometry, increases redundancy, and mitigates the impact of periods with reduced GPS satellite visibility. These benefits are particularly evident during shorter observation durations, especially the first one hour where the absolute errors in N, H, 2D and 3D are reduced significantly from (3.3, 3.5, 3.3 and 4.47 cm) for GPS-alone to (1.1, 1.5, 1.5 and 2.25 cm) for GPS+GLONASS, respectively. As for the Easting component, the absolute errors determined from the two constellations are very tiny and rounded about zero, which is expected due to the symmetrical distribution of the satellites in East and West directions in the sky. This symmetrical distribution is not possible in North and South directions, where there is an area that is clear from satellites in the North due to the satellite orbit inclination angle. This makes the errors in Northing components bigger than in Easting direction. In the case of GLONASS, the satellite inclination angle is bigger than that of GPS, which can reduce the area of no satellites and as a result, providing better results in Northing components. These benefits can also be noted during the first several hours when PPP solutions are most sensitive to satellite geometry and convergence behavior. Although the enhancement in mean absolute positional accuracy becomes marginal for longer observation periods, the multi-constellation configuration significantly reduces the occurrence of outliers and decreases the dispersion of coordinate residuals across the Northing, Height, 2D, and 3D components. Figure (5) shows the sky satellite distribution of 24 Hours for GPS and GPS+GLONASS.

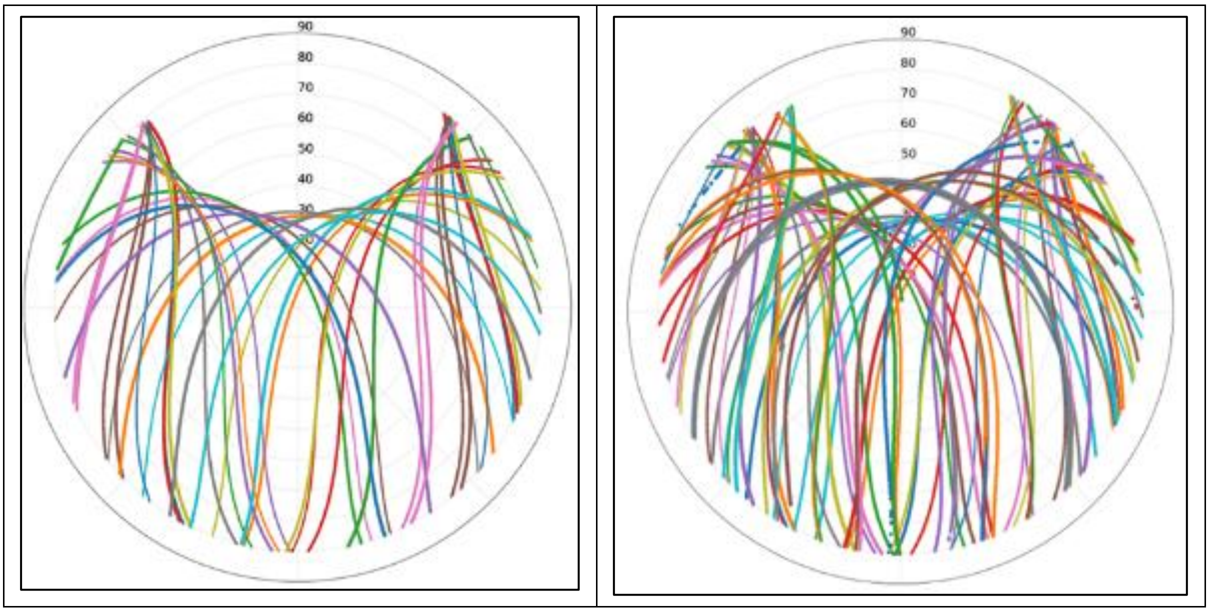

Figure 5 Satellite Sky Distribution: GPS-alone (left) Vs. GPS+GLONASS (right)

The results demonstrate that even under optimal open-sky conditions, where multipath is virtually absent, the integration of GLONASS contributes measurably to improving the robustness and reliability of Static PPP. These improvements can be attributed to the increased number of available satellites and improved satellite geometry, particularly during periods of reduced GPS satellite visibility, which contribute to better dilution of precision (DOP). The well-distributed satellite geometry can also help the ionospheric and tropospheric models for better estimation of delays. The other significant advantage of increasing the number of satellites is increasing the degree of free-dome in observations, which helps for deleting all observations that include high-residuals without effecting the quality of solution. This is beside the ability of dispensing satellites with very low-cut of angle which tend to have a noisy signal as it passes throughout longer atmosphere than the signals with high-cut of angles. Also, it can be noted that although the improvement of integrating GLONASS with GPS in static PPP in the average absolute accuracy is marginal after long fixing time comparing to GPS-alone, the benefits are significant for the first a few hours, specially the first fixing hour where the 3D quality obtained via one-hour static dual-frequency PPP with GPS+GLONASS can be reached after 3 to 4 fixing hours using GPS-alone.

4. Conclusion

This study investigates the impact of integrating GLONASS observations with GPS in static PPP over fixing time using the CSRS-PPP free online service under open-sky conditions with final precise ephemerides. Dual-frequency GNSS data were collected at ten spatially well-distributed reference stations, each observed continuously for 24 hours, and processed in static modes under two configurations: (1) GPS-only, and (2) GPS + GLONASS for fixing periods starting from 1 hour and increasing gradually by 1 hour until reaching 24 hours. The 24 hours static PPP results were used as the reference to assess the quality of all solutions. The results demonstrate that incorporating GLONASS observations alongside GPS leads to notable improvements in solution reliability and overall positioning stability throughout the fixing intervals. These benefits are particularly clear during shorter observation durations, especially the first one hour where the absolute errors in N, H, 2D and 3D are reduced by (2.2, 3, 1.8 and 2.22 cm) with GPS+GLONASS, respectively. As for the Easting component, the absolute errors determined from the two constellations are very tiny and rounded about zero. The benefits of adding GLONASS to GPS can also be noted during the first several hours when PPP solutions are most sensitive to satellite geometry and convergence behavior. Although the enhancement in mean absolute positional accuracy becomes marginal for longer observation periods, the multi-constellation configuration significantly reduces the occurrence of outliers and decreases the dispersion of coordinate residuals across the Northing, Height, 2D, and 3D components.

The results demonstrate that even under optimal open-sky conditions, where multipath is virtually absent, the integration of GLONASS contributes measurably to improving the robustness and reliability of Static PPP. In summary, although the improvement of integrating GLONASS with GPS in static PPP in the average absolute accuracy is marginal after long fixing time comparing to GPS-alone, the benefits are significant for the first a few hours, specially the first fixing hour where the 3D quality obtained via one-hour static dual-frequency PPP with GPS+GLONASS can be reached after 3 to 4 hours fixing time using GPS-alone.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Amami M. The Advantages and Limitations of Low-Cost Single Frequency GPS/MEMS-Based INS Integration. Global Journal of Engineering and Technology Advances. Feb. 2022; 10(2): 018-031.

[2] Amami M, Smith M, Kokkas N. Low-Cost Vision Based Personal Mobile Mapping System. ISPRS- International Archives of The Photogrammetry, Remote Sensing and Spatial Information Sciences. 2014; XL-3/W1: 1-6.

[3] Hofmann-Wellenhof B, Lichtenegger H, Wasle E. GNSS global navigation satellite systems: GPS, GLONASS, Galileo, and More. 2007

[4] Amami M. Investigations into the integration of low-cost GPS/INS sensors. Libyan Journal for Engineering Research (LyJER). March 2017; 1(1): 2522-6967.

[5] Amami M. A Novel Design Concept of Cost-Effective Permanent Rail-Track Monitoring System. World Journal of Advanced Research and Reviews. March 2022; 13(3): 451-473.

[6] Amami M. Fast and Reliable Vision-Based Navigation for Real Time Kinematic Applications. International Journal for Research in Applied Sciences and Engineering Technology. Feb. 2022; 10(2): 922-932.

[7] Amami M. The Integration of Image-Based Navigation and GPS Carrier Phase Delta Positioning for Aerial Triangulation using Low-Cost Drones with Limited Number of Ground Control Points. Quest Journals. 2022; 7(5): 23-31.

[8] Amami M, EL-Turki A, Rustum A, EL-Amaari I, Jabir T. Topographic Surveying using low-cost amateur drones and 4K ultra-high-definition videos. Open Access Research Journal of Science and Technology. April 2022; 4(2): 072-082.

[9] Amami M, Elmehdwi A, Borgaa A, Buker A, Alareibi A. Investigations into utilizing low-cost amateur drones for creating ortho-mosaic and digital elevation model. International research journal of modernization in engineering technology and science. March 2022; 4(3): 2107-2118.

[10] Amami M. Enhancing Stand-Alone GPS Code Positioning Using Stand-Alone Double Differencing Carrier Phase Relative Positioning. Journal of Duhok University (Pure and Eng. Sciences). 2017; 20(1): 347 355.

[11] Amami M. The Integration of Stand-Alone GPS Code Positioning, Carrier Phase Delta Positioning and MEMS-Based INS. International Research Journal of Modernization in Engineering Technology and Science. March 2022; 4(3): 700-715.

[12] Amami M. The Integration of Time-Based Single Frequency Double Differencing Carrier Phase GPS/ Micro-Elctromechanical System-Based INS. International Journal of Recent Advances in Science and Technology. Dec. 2018; 5(4): 43-56.

[13] Amami M. Investigations into the quality of final-product dual frequency kinematic PPP in open sky using CSRS-PPP free online service: GPS Vs. GPS+GLONASS. Global Journal of Engineering and Technology Advances (GJETA). November 2025; 25 (2).

[14] Amami M. Testing Patch, Helix and Vertical Dipole GPS Antennas with/without Choke Ring Frame. International Journal for Research in Applied Sciences and Engineering Technology. Feb. 2022; 10(2): 933-938.

[15] Amami M. Comparison Between Multi and Single Epipolar Geometry-Based Filters for Optical Robot Navigation. International Research Journal of Modernization in Engineering Technology and Science. March 2022; 4 (3): 476-485.

[16] Amami M. Comparison Between Multi Epipolar Geometry and Conformal 2D Transformation-Based Filters for Optical Robot Navigation. International Journal for Research in Applied Sciences and Engineering Technology. March 2022; 10(3): 388-398.

[17] Amami M. Comparison Between Multi Epipolar Geometry and Affine 2D Transformation-Based Filters for Optical Robot Navigation. International Journal for Research in Applied Sciences and Engineering Technology. March 2022; 10(3): 399-409.

[18] Amami M. Speeding up SIFT, PCA-SIFT and SURF Using Image Pyramid. Journal of Duhok University, [S.I]. July 2017; 20(1): 356-362.

[19] Amami M. Multi and Single Epipolar Geometry-Based Filters Vs. Affine and conformal 2D Transformation-Based Filters. Global Journal of Engineering and Technology Advances. March 2022; 10(3): 032-051.