Ability of RTK-Based GPS Measurement Method in High Accuracy Work in Geomatics Study

Nor Azme bin Nordin[1*], Noraishah Binti Mustapa[2], Asiah Binti Abdul Satar[3]

Department of Civil Engineering, Politeknik Sultan Haji Ahmad Shah
25350 Kuantan, Pahang, Malaysia
azme@polisas.edu.my
noraishah@polisas.edu.my
asiah@polisas.edu.my
*Corresponding Author

https://doi.org/10.24191/ajue.v17i4.16212

Received: 2 August 2021
Accepted: 3 September 2021
Date Published Online: 31 October 2021
Published: 31 October 2021

Abstract: Insfrastructure development require significant changes and transformation in Geomatics field for the upcoming decade. The use of new technology in Geomatics and surveying is essential and can be leveraged in many survey application that will help on building the nation towards a sustainable future. In the last 5 years, GNSS technology has been widely used and practiced to replace total station for survey work. Main factors that contributes to this busniness changes are the availability of much cheaper equipment with good technical capability in the market that helps surveyor to perform their work faster and more efficient. Global navigation satellite system services for accurate positioning has also rapidly increased and provide many option and solution for industry player or surveyor to choose. Combination of multiple global navigation satellite system providers such as GPS, GALILEO,GLONASS and BeiDOU has developed good satellite networks and increased numbers of available satellites for observation that improve absolute position accuracy. CHC i70 is among the best selling GNSS model on the market right now. The receiver can receive signal from GPS,GALILEO,GLONASS and BeiDOU simultaneously. This study will outline and focus on the capability of the RTK-Based method (30 second to 1 minute observation period) using CHC i70 instrument in high-precision measurement work. The research was done using the GPS calibration test site at Politeknik Sultan Haji Ahmad Shah (POLISAS) and was also practiced in the actual work for establishment of Temporary Bench Mark (TBM) along Jalan Melor to Ketereh, Kelantan. The result of the study found that RTK-Based method can meet the precision work that is permitted under 2cm accuracy. Studies show that the method of using RTK- Based is suitable for high precision work and improve the measurement time and work duration at field.

Keywords : Beidou, Chc and RTK-Based GPS and PDOP.

1. Introduction

Development of measurement technology and point positioning on earth is rapidly evolves as satellite systems are available around the world. The application of using measuring instruments has become easy and faster and the dream has become a reality. Nowadays, most of survey works has using Global Positioning System (GPS) equipment to replace Total Station. Faster survey time and minimal manpower has caused the use of GPS become more popular. The capability of GPS technology is fully supported by the establishment of a new satellite system, namely Beidou from China. The combination of Galileo, Glonass, Navstar GPS and BeiDou has completed satellite cycles in orbit and satisfy GPS user, especially land surveyor that allow them to do survey work easier and faster (Khomsin, etc al.2019). China not only launched their own satellite systems but had released high-tech GPS equipment. CHC equipment from China was used in this study. In the past years, it requires longer observation time to determine accurate and precise points on the ground. In the beginning of GPS technology, data observations require at least one day or more to complete. Then, static observation method was used and capable to perform data observation in less than an hour. However, sometimes the results not were not good and satisfied even though with longer observation time. This study is conducted to demonstrate the ability of RTK-Base GPS method in high accuracy work such as establishment of temporary bench marks at construction areas. Normally, first-class traverse survey is used with linear misclosure result greater than 1:8000 was used to determine northing and easting coordinates. Ideally, level equipment with misclosure of 0.012 √KM was used to determine elevation (PKUP.2009).

Lately, GPS/GNSS equipment has received significant increased in sales and almost all licensed land surveyors or freelances have at least one set of GPS equipment in their storage. Hence, the use of Total Station and leveling equipment's is no longer practical and only stored in the store or not being used at all. The proliferation of GPS devices in the market with affordable prices has made all users interested in owning such equipment. The question is whether the GPS equipment has really been able to change the entire system of land surveying work that all these while has been based on bearing and distance measurement.

Since 2015, GPS technology had evolved when China launched their third generation of BeiDou Navigation Satellite System (BDS). The first BDS-3 satellite was launched on March 30, 2015. On December 27, 2018, the BeiDou Navigation Satellite System began providing global services. It was said in 2016 that the Beidou-3 would achieve millimeter accuracy level (with post-processing). During that time China had begun promoting their GPS products that capable of detecting the entire existing satellite system such as Navstar GPS, Galileo, Glonass and BeiDou simultaneously. It affects DOP (Dilution of Precision). The availabilities of many satellites on space have certainly established good network and results on the GPS observation itself (Khomsin, etc al.2019).

Real-Time Kinematic (RTK) positioning is positioning that is based on at least two GPS receivers, a base receiver and one or more rover receivers. The base receiver takes measurements from satellites in view and then broadcasts them, together with its location, to the rover receiver(s). The rover receiver also collects measurements to the satellites in view and processes them with the base station data. The rover then estimates its location relative to the base. The observation of this RTK method just need a few second to get the best result compare the other method. Previously, static method was used for GPS observation to determine accurate survey result. Fast static method takes 15 minutes and static method takes between 1 until 1 day observation time. Survey result will be obtained after data post processing is completed. However, GPS RTK-base method has been widely used in engineering survey works such as topographic and boundary marking. Such works does not require high accuracy result but when it is used to obtain high-precision value such as the establishment of TBM, it raises question either the survey data can be accepted as final result.

2. Problem Statement

Long survey time and the need of many manpower for land surveying work is the main reason why many surveyors have used GNSS equipment to replace Total Station and leveling equipment. Linking theory and practice is where the problem in dealing with the data collection and analysis to achieve the best result . Transfers from one station to another require a line of sight, sometimes it is difficult for surveyors to make control trajectories. While the use of leveling tools is also not suitable for use on a hot afternoon. The readings on the level set will be affected by the hot heat from the road. Soil surveyors then look for alternatives to performing GPS static observations to move the coordinate and altitude values. However, this observation should be done with a time of at least 15 minutes for the fast static method and one hour and above for the static method. This is important for baseline calculations. However, this data cannot be obtained immediately because it needs to be processed first and known as post-processing. As satellite systems get better, the use of the RTK-Base method to make land survey work has become an option. However, many still doubt the ability of this method to be used fully in land survey work. The short observation period and less labor consumption will certainly make this method one of the best alternatives and a new breath in the world of measurement. Yet whether this method is worthwhile and meets the requirements of the actual measurement principle. The survey technique focused in this study is the use of RTK-Base method whereby only short observation time is required to obtain high accuracy data. 5 seconds, 20 seconds and 30 seconds observation time were used as observation time. Usually 3 to 5 seconds of observation time is required for topographic, levelling and detail survey work. Survey data and result of the work has been accepted by many parties because it meets the expected accuracy according to work specifications. However, for the establishment of TBM and setting out piling points that require high survey precision, its use is still in doubt and there is no specific study on such work was conducted using the RTK-Base method.

3. Objectives

The objectives of the study:

a. To evaluate the RTK-Base capabilities compared conventional method using the total station and levelling instruments in accuracy work.
b. To see the minimum time period that corresponds to the coordinates of the north, east and elevation (N, E, H) with higher accuracy

4. Scope of study

a. To perform 5 seconds, 20 seconds and 30 seconds GNSS RTK-Base observation at pillar (EDM Baseline Test) at POLISAS
b. To perform 30 seconds GNSS RTK-Base observation to establish temporary benchmark at Melor, Kota Bharu for road construction work along 4km distance
c. Perform survey observation using CHC i70 instrument as rover and CHC i50 as base
d. To process survey data using Civil Design and Survey (CDS ver.1.1) software

5. Method

Methodology works will include the process of calibration instruments itself, the process of field observation using Total Station, Levelling Instrument and RTK-Based as shown in Figure 1.

Fig. 1 Research workflow

Moreover, figure.1 shows the workflow which include planning for the overall work from literature review until the conclusion based on the results and discussion (Damio,2016). The technique selected is suitable and appropriate in establishing the data collection and analysis in order to answer the research objectives (Teoh & Parmjit, 2019). The data processing is adequate and in line with objectives of the research and able to justify the results for the analysis.

6. Planning

The main criterion for this study is based on selection of GNSS equipment that are commonly used and popular among land surveyors. Regardless of the price, it is sufficient to get accurate observation result. In this study, CHC GNSS model; CHC i50 and CHC i70 were selected. Firstly, the equipment shall be calibrated and certificate of fitness shall be produced by the supplier to ensure survey equipment is in good condition prior observation. The certificate issued as shown in the Figure 2 below.

eVRS Calibration Certificate

Receiver SN 1045074

Date Calibrate: Wednesday, November 2, 2020
Next Date Calibrate: Thursday, November 2, 2021
10:05:22 AM

891223-01-5595
PUSATTOLSRMBNPDHNSS

Pillar	Reference Coordinates			Observed Coordinates			Differences (m)		
	Lattitude	Longitude	Ellipsoidal Height (m)	Lattitude	Longitude	Ellipsoidal Height (m)	Lattitude	Longitude	Ellipsoidal Height
P001	2° 37' 38.63973"	101° 53' 14.69251"	59.548						
				2° 37' 38.63952"	101° 53' 14.69245"	59.525	0.006328	0.001841	0.023044
				2° 37' 38.63944"	101° 53' 14.69280"	59.521	0.008703	0.008653	0.027017
				2° 37' 38.63955"	101° 53' 14.69245"	59.495	0.005409	0.001811	0.053031
P003	2° 37' 36.61172"	101° 53' 12.15928"	57.498						
				2° 37' 36.61132"	101° 53' 12.15891"	57.484	0.012038	0.011132	0.014067
				2° 37' 36.61129"	101° 53' 12.15885"	57.455	0.012931	0.012965	0.043040
				2° 37' 36.61124"	101° 53' 12.15884"	57.475	0.014421	0.013241	0.023021
P005	2° 37' 32.15132"	101° 53' 6.58663"	61.414						
				2° 37' 32.15189"	101° 53' 6.586120"	61.384	0.017104	0.015317	0.030021
				2° 37' 32.15082"	101° 53' 6.586110"	61.374	0.015028	0.015611	0.040171
				2° 37' 32.15089"	101° 53' 6.586140"	61.378	0.012905	0.014721	0.036044

Fig. 2 GPS Calibration Cert.

GPS/GNSS (EDM Baseline Test) calibration site at POLISAS was selected for this study. The calibration site was established by Geodesy section, JUPEM Pahang for all users at east-cost area. Established coordinate value from JUPEM as per shown in figure 3 below.

Koordinat GDM2000@Revised2006								Cassini Geocentric	
Stesen	Latitud			Longitud			Ell.Height	Utaraan	Timuran
P001	3	51	33.42700	103	18	44.08643	28.259	16475.379	97477.573
P002	3	51	34.37162	103	18	44.33363	28.249	16504.406	97485.170
P003	3	51	35.78907	103	18	44.70445	28.247	16547.962	97496.566

Fig. 3 Established value by JUPEM Pahang

7. Technique and Instruments

The first step in this study is to perform GNSS RTK-Base observations on the calibration pillar located at POLISAS. There are 3 pillars, pillar one (POO1) is used as the base station. Pillar 2 (P002) and pillar 3 (P003) will be observed by the rover. CHC i50 device will be set as base station as it receives satellites than the CHC i70. While the rover will use CHC i70 device. Result comparison based on observation time will be made for each pillar by comparing the observation value with known value fo the pillars. *LandStar* 7 software (Figure 4) will be used as observation medium as it comes with this GNSS CHC equipment. Next is to perform a 30 -second observation for the purpose of establishing a TBM along 4 km roads in Melor, Kota Bharu. TBM value from total station and levelling equipment are readily available. Thus, observation values comparison will be made based on those values.

Verification results will be analyzed to provide confident among users that RTK-base method is reliable to provide high accuracy survey result.

Fig. 4 Instrument and software used during observation *CHC i50, CHC i70 and LandStar 7*

8. Field Observation

Figure 5 below shows survey observation at EDM Baseline Test pillar at POLISAS. While Figure 6 shows observation made on TBM 1 Melor. BM 0017 located 200m from calibration site was used as bench mark for this study. Please refer Figure 7.

Fig. 5 *Pillar 1*

Fig. 6 *TBM 1 Melor*

Fig. 7 *BM 0017*

9. Data Processing

Upon completion of each measurement work, the survey data will be sent to telegram application in the form of CSV Comma Delimeted File. This will simplify the processing work because the data stored in this Ascii format is much easier to be accessed and can be opened through Excel software. Civil Design & Survey software (Figure 8) is used to display the details of the observations data in graphical form and ease data analysis to be performed. Data is first transferred into database for data analysis and visualization.

Fig. 8 *Civil Design & Survey Software (CDS)*

10. Result, Analysis & Discussion

The observation results at pillar stations in Table 1 shows that readings of at least 20 seconds is required to obtain a good reading value. According to the high-precision measurement criteria, the readings at N, E and H must be less than 5 mm and it is found that 30 seconds are required to achieve result as per criteria as shown in Table 2. However, this result does not depict the true measurement result because of short baseline and the distance between Base and Rover is only around 35m to 75 m only. A short baseline calculation will often give good value. In addition, the pillar area is a GPS/GNSS calibration site where the sky visibility is 90 percent and above.

Table 1. Comparison observation at EDM Baseline Test POLISAS

Observation	Pillar 1			Pillar 2			Pillar 3		
	N	E	H	N	E	H	N	E	H
True Value	16475.379	97477.573	28.259	16504.406	97485.17	28.249	16547.962	97496.566	28.247
Observed At 5s	16475.379	97477.573	28.259	16504.397	97485.187	28.259	16547.925	97496.565	28.252
Difference (meter)	0	0	0	0.009	-0.017	-0.01	0.037	0.001	-0.005
Observed At 20s	16475.379	97477.573	28.259	16504.398	97485.184	28.249	16547.945	97496.564	28.246
Difference (meter)	0	0	0	0.008	-0.014	0	0.017	0.002	0.001
Observed At 30s	16475.379	97477.573	28.259	16504.407	97485.169	28.248	16547.964	97496.562	28.247
Difference (meter)	0	0	0	-0.001	0.001	0.001	-0.002	0.004	0

Data analysis from GPS RTK-Base observation results on the pillars shows that observation time of 30s has given the smallest values different and can be accepted as the ideal observation time for the RTK-Base method. Next, Root Mean Square Error analysis was calculated and shown as per Table 2.

Table 2. Difference observation time interval at EDM Baseline Test POLISAS

Observation for 5 Second							
Pillar	Time	ΔN	ΔE	ΔH	ΔN^2	ΔE^2	ΔH^2
Pillar 2	5s	0.009	-0.017	-0.01	0.000081	0.000289	0.0001
Pillar 3	5s	0.037	0.001	-0.005	0.001369	0.000001	0.000025
				RMSE	0.026925824	0.012041595	0.007905694
Observation for 20 Second							
Pillar	Time	ΔN	ΔE	ΔH	ΔN^2	ΔE^2	ΔH^2
Pillar 2	20s	0.008	-0.014	0	0.000064	0.000196	0
Pillar 3	20s	0.017	0.002	0.001	0.000289	0.000004	0.000001
				RMSE	0.01328533	0.01	0.000707107
Observation for 30 Second							
Pillar	Time	ΔN	ΔE	ΔH	ΔN^2	ΔE^2	ΔH^2
Pillar 2	30s	-0.001	0.001	0.001	0.000001	0.000001	0.000001
Pillar 3	30s	-0.002	0.004	0	0.000004	0.000016	0
				RMSE	0.001581139	0.002915476	0.000707107

The RMSE value for the 30s reading indicates the level of accuracy and data obtained are reliable to be used in high-precision work. Table 3 below shows the results of observations on 6 TBMs for road construction works from Melor to Ketereh Kota Bharu while Figure 8 shows a graph of differences in observation data at TBM Jalan Melor Ketereh Kota Bharu. The first findings found that there was a relatively large difference in value in TBM 2 (Northing and Easting Value) and also in TBM 6 (Easting and Height). However, the observation values in other TBMs give good and acceptable result. A more detailed study was done in the field and found that TBM 2 was located under a large thicket of trees. This is because the surveyor who did the traverse and levelling had placed the TBM on the grounds that he thought the area was dimmer and a safer.

Table 3. Comparison Observation at TBM Jalan Melor, Ketereh Kota Bharu

		Northing	Easting	Height
TBM 1	Traversing and levelling	8091.45	13262.64	9.042
	GPS Observation 30s	8091.461	13262.64	9.043
	Difference (meter)	-0.011	-0.004	-0.001
TBM 2	Traversing and levelling	8052.912	13237.57	9.337
	GPS Observation 30s	8052.936	13237.64	9.333
	Difference (meter)	-0.024	-0.064	0.004
TBM 3	Traversing and levelling	7060.063	13645.57	9.949
	GPS Observation 30s	7060.062	13645.58	9.945
	Difference (meter)	0.001	-0.005	0.004
TBM 4	Traversing and levelling	6051.102	14043.07	9.82
	GPS Observation 30s	6051.113	14043.07	9.813
	Difference (meter)	-0.011	0.001	0.007
TBM 5	Traversing and levelling	6026.832	14046.99	9.71
	GPS Observation 30s	6026.852	14046.98	9.72
	Difference (meter)	-0.02	0.003	-0.01
TBM 6	Traversing and levelling	4963.085	14580.6	8.966
	GPS Observation 30s	4963.076	14580.57	9.026
	Difference (meter)	0.009	0.035	-0.06

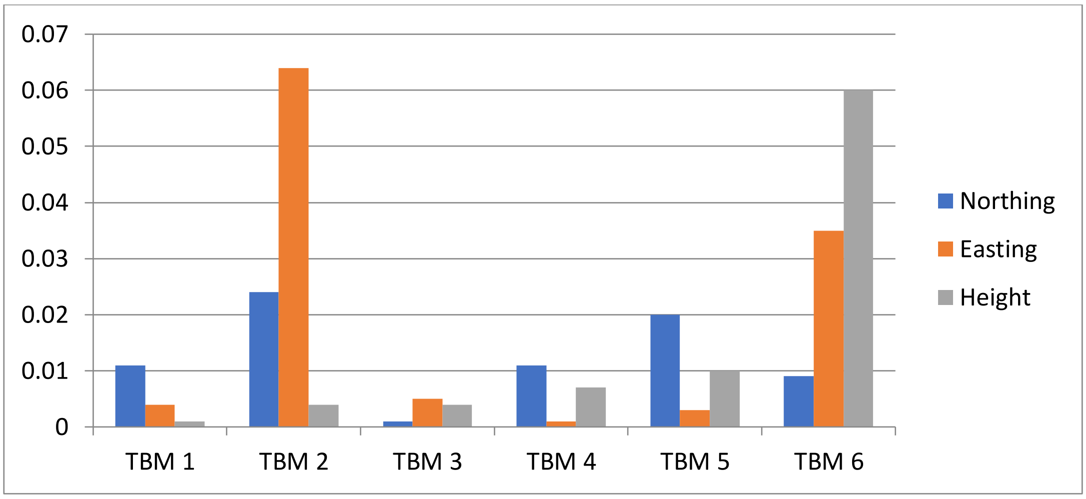

Fig. 9 Graf shows data observation differences at TBM Jalan Melor Ketereh Kota Bharu

Table 4 shows the PDOP (Position Dilution of Precision) and VDOP (Vertical Dilution of Precision) readings in TBM while Figure 9 shows the graph of PDOP and VDOP readings in TBM Jalan Melor Ketereh Kota Bahru. PDOP and VDOP readings in the TBM 2 area were also found to be relatively high compared to the readings at other locations.

Table 4. PDOP and VDOP readings at TBM Jalan Melor Ketereh Kota Bharu

TBM	Bacaan PDOP	Bacaan VDOP
TBM 1	1.20599997	1.078144312
TBM 2	1.573000026	1.097178221
TBM 3	1.164000034	0.974231541
TBM 4	1.251000047	1.037890196
TBM 5	1.210000038	0.998729169
TBM 6	1.332000017	1.309392071

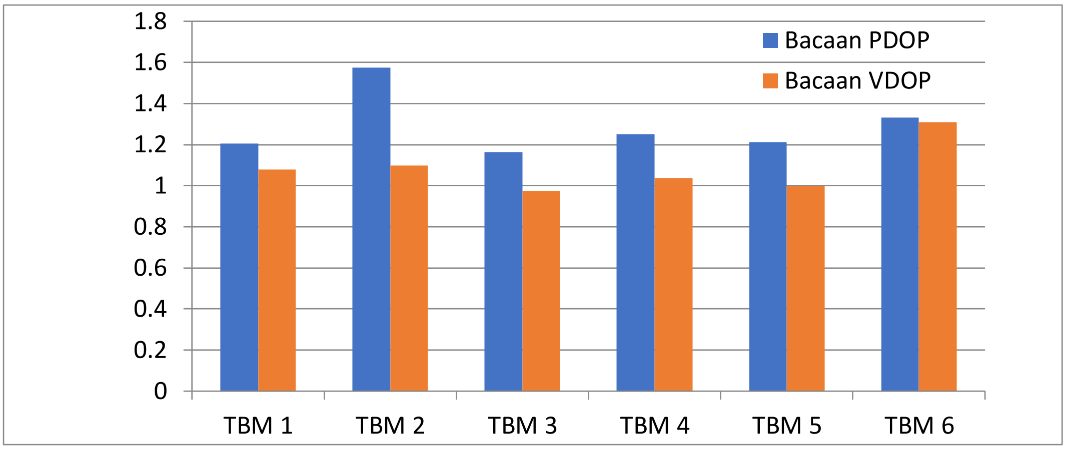

Fig. 10 PDOP and VDOP readings at TBM Jalan Melor Ketereh Kota Bharu

Referring to Figure 10, another set of observations was performed observe the effects of canopy interference on PDOP and VDOP readings. Readings are made on six points that have different conditions. First at open area, second is in a tree -covered area (which differs in terms of its canopy coverage) and third is under an electrical transmission line. Based on Table 5, it is clear that if survey is performed under a tree whose canopy is quite high it will affect the PDOP and VDOP readings even if at that particular time the GPS signal is 'fixed'.

Table 5. PDOP and VDOP readings

Station	PDOP reading	VDOP reading
Field	1.365703106	0.556979477
Trees 40% ke 60 % canopy	1.551386118	0.621282637
Trees 10 ke 30 % canopy	1.297574639	0.552715898
Field	1.371986508	0.556718647
Under transmission line	1.193597674	0.51383239
Under transmission line	1.195724249	0.513992608

As shown in Table 5, DOP (Dilution of Precision is a term used to describe the strength of the current satellite configuration, or geometry, on the accuracy of the data collected by GPS receiver at the time they use it. Therefore, PDOP can be describe as 3D positioning where HDOP is a Horizontal of DOP and VDOP is a Vertical od DOP. With GPS receivers, when satellite is grouped together in the same area of the sky, the satellite geometry is considered to be weak (*higher DOP value*). When satellites are evenly spread through the sky, their geometry is considered strong (lower DOP value). Then our positional accuracy will be better and give good result. It described survey condition during observation at TBM 2 and TBM 6. Figure 11 and Figure 12 explained what it means by PDOP (Mohd Hafiz Yahya & Kamarudin, 2008).

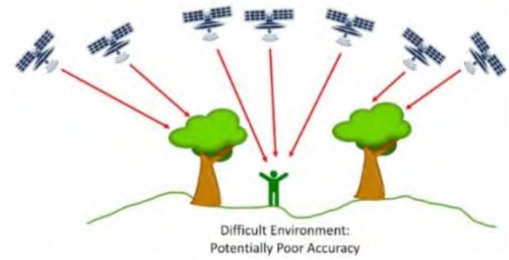

Fig. 11 Poor PDOP

Fig. 12 Good PDOP

The observations must follow the standard set by the supplier in order to optimize the ability of measuring the distance that can be reached by the rover from the base station position. Moreover, RTK-Base method is the best alternative in high-precision work but should follow all the guidelines as shown in the results shown. If this method is questionable, the work must record point with known coordinates and altitude. Moreover, when the survey work is finished, they have to re-observe the same point for confirmation.

11. Conclusion

In conclusion, consideration must be taken seriously when undertaking GPS observations using RTK-Base method. Therefore, the observation must be performed in an area with good sky visibility and not under the canopy (90 % sky visibility). Observations must also be made in accordance with the specifications set by the equipment manufacturer that is based on the ability of the distance that can be reached by the rover from the base station position. RTK-Base method can be used as the best alternative in high-precision work but should follow all the guidelines. If users still doubt to use this method, they should start the work by recording a point with known coordinates and altitude and when the survey work is finished, they have to re-observe the same point again for verification. It is sufficient to perform GPS observation for a period of 30 seconds to obtain high accuracy results. The average observation value was acceptable for high-precision works that require accuracy below than 2 cm and the RTK-Base method can replace the previous GPS measurement methods and can also replace the conventional method. PDOP value during survey observations must be considered. For the RTK-Base method, the PDOP reading must be as low as possible and close to 1 meter. Land surveyors and GPS users shall pay attention at PDOP or VDOP value in order to achieve high accuracy survey result.

12. References

Abdullah, M., Misran, N., Ariff, M., & Abdullah, M.F. (2010). *Perbandingan Ralat 'Multipath' bagi Data Cerapan GPS Stesen MASS dan Stesen RTK.*

Damio, S. M. (2016). Q Methodology: An Overview and Steps To Implementation. *Asian Journal of University Education. Volume 12 Number 1*

Ghazali S S. (2008). Linking Theory and Practice: The Case of TESL Trainee Teachers. *Asian Journal of University Education. Volume 4 Number 2*

Gumilar, Bramanto, B., Kuntjoro,W., Abidin,H.Z., & Trihantoro,N.F. (2017). *Contribution of BeiDou Satellite sysyem for long baseline GNSS Measurement in Indonesia*

Hasan,H.(2015). Penggunaan GPS Dalam Kerja-kerja Semakan Garis Dasar EDM

Khomsin, Anjasmara,I.M.,Pratoma,D., & Ristanto,W. (2019). *Accuracy analysis of GNSS (GPS,Gloanass and Beidou). Observation for positioning.*

Musa,T. A., & Asillam, M.F. (2019).Near real time ionospheric monitoring system over Malaysia using GPS Data: My-Iono Service, *Journal of Physics Conference Series 1152(1):012016*

Olivart,J.M., Salinas,D.M., & Sanchnez, J. (2020). *Full Real-Time Positioning and Attitude System Based on GNSS-RTK Technology*

Pekeliling Ketua Pengarah Ukur dan Pemetaan Bil 6 (2009) : *Garis Panduan Amalan Kerja Ukur Kadaster Dalam Persekitaran eKadaster*

Roberts,G.W.(2018). *Accuracy analysis of GPS/BDS relative positioning using zero baseline measurement*

State Council Infomation Office China (2016).*China Beidou Navigation Satellite System*

Teoh S H, Parmjit S (2019). A Practice in a Research Methodology Class. *Asian Journal of University Education Vol. 15 No. 3*

Yahya, M.H., & Kamarudin,M.N. (2008). *Analysis of GPS Visibility and Satellite-Receiver Geometry Over Different Latitudinal Regions*