ACCURACY ASSESSMENT OF UTP GPS CONTINUOUSLY OPERATING REFERENCE STATION FOR SIMULATED STRUCTURAL DEFORMATION MONITORING

By

Mohd Kamal Bin Mohd Yusof

21212

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

SEPTEMBER 2017

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CERTIFICATION OF APPROVAL

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Approved by,

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(AP DR. ABD NASIR MATORI.)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project entitled, “Accuracy Assessment of UTP GPS Continuously Operating Reference Station for Simulated Structural Deformation Monitoring", that the original work is by my own "Mohd Kamal bin Mohd Yusof" except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHD KAMAL BIN MOHD YUSOF

ABSTRACT

Accuracy is a degree of closeness a set of data from series of measurement to its true value and data set could be said as precise if the value is close to the average value of the quantity that being measured. Data measurement for any engineering applications cannot be perfect but the accurate data is important especially when it comes to the human safety. Recently Universiti Teknologi PETRONAS (UTP) has established a continuously operating reference system (CORS) which can be used by Global Positioning System (GPS) users to enhance the accuracy of their application. However, being new the accuracy performance has been assessed. Therefore, this study took the initiative to assess the accuracy of the CORS, in two variables which are baseline between CORS and users as well as amount of data used to provide the positioning. For the first variable, baseline between CORS and users were varied in the experiment set up, and the positioning accuracies of the users were observed. Similarly, for the second variable investigation, the amount of data processed to produce the positioning were varied and the positioning accuracy were observed. It was observed as the baseline between CORS and users increases, the accuracy of the users positioning decreases. On the other hand, as the amount of data used in the processing increases, the positioning accuracy of the users also improve.

ACKNOWLEDGEMENT

I, Mohd Kamal bin Mohd Yusof wants to address some heartfelt thanks and appreciation to all those involved directly or indirectly in my final year project, FYP until it finishes. A lot of knowledge, experience and achievements that I have while doing this FYP especially about the GPS itself, and in addition to carrying out a project that has been entrusted to me by my supervisor AP Dr. Abd Nasir Matori.

I also want to thank the Almighty for giving me the strength, healthy and opportunity for me and He gave as a grace for me to undergo this study and finish this final year project. I have learned various form of knowledge, especially in the field of Geomatics that connect with my field of study in civil engineering. With the opportunity and help that has given to me, a lot of new experience and knowledge that have opened my eyes about GPS and its contribution in the field of civil engineering especially when it comes to monitoring of the structure deformation.

Last but not least, my special appreciation to my supervisor, AP Dr. Abd Nasir Matori for entrusting me to carry out this project. Thank you for the very helpful assist and provide a guidance to me in terms of the knowledge about the global positioning system (GPS) and also about the project that I need to be done, solving the unknown information about how to carry out the test for this FYP project and in order to finish my degree. All the problems and concerns with the problem while carry out this project, he was able to be resolved with the clear explanation for the kind of problem.

Not to forget a very thankful and appreciation to the lab technician, Pn Suhaila bt Meor Hussin, technician for geomatics lab. She the one that really helping mu out throughout the whole project and also teaching me how to use the equipment. She also sacrifices her time to guide me to finish the test. With the help of Mr. Amir as a reference while I have a problem with the data during processing, he also helps

by giving a solution and also share the knowledge on how and why the problem occur during processing the data. I am really appreciating the help and guidance giving to me from both of them and only God know how to repay their kindness toward me.

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CHAPTER 1

INTRODUCTION

1.1: BACKGROUND

GPS or Global Positioning System is a system or network that sources from the orbiting satellite. The satellite will send a precise and exact detail of their position in the space back to earth. The navigation device that used to calculate the correct position, time and speed for the vehicle position are obtain the signal from the GPS receiver. At the height of the Cold War, the first GPS have been developed by the US military as an aid in its global intelligence effort. However, the used of GPS has been freely used to everyone and anyone with GPS receiver (Wikipedia, the free encyclopedia, 2017) and (GPS explained, 2017).

The most common used of GPS are to help the driver including air, water and land usage to get the best and smooth route from one place to the other places. Recent years, GPS or Global positioning systems have been increasingly used in order to monitor the structure deformations, particularly the deflections of long suspension bridges. The GPS can supply timely and accurate structural deformation information, with the presence of a strong satellite geometry or with the used of global navigation satellite system (GNSS).

In the structure engineering, the structure itself will be subjected with the certain loading and each structure have their own limitation to handle the loading. Loading for the structure are come from the weight of the structure itself and being added with permanent and variable loading. Not only have that, the environment also effected to the structure such as wind, earthquake, and soil sedimentation. For example, of the high-rise building, the wind is one of the most important thing that need to be consider during the design stage in order as low as possible the structure deformation (Teague, How, Lawson, & Parkinson, 2016). From the loading that being subjected to the structure, it will cause the deformation for the structure. The deformation is a part of the warning to the structure and it need to have an in-depth analysis for the structure as a safety precaution. The analysis and checking throughout the entire structure will take some time and at the same time the structure will continue to deform and when it comes to its limit the crack will appear as a second stage warning. From (Kaloop, Hu, & Sayed, 2015), they said that the large engineering structures are the king-plan for the socio- economic development of a nation. The carefully safety control are needed, since under excessive loading the structure might undergo failure, and will causing loss of lives and property.

Thus, in this large engineering works demand, the security of periodic monitoring of their deformations, which is the most relevant parameter to be monitored and which is essential to ensure their safety. The using of the GPS are one of the way to improve the safety precaution for the building or structure. The use of the GPS will help to monitor the deformation by using the coordinate. The changes of the coordinate for each structure can be calculated to know how much the structure being move. It also can be decided that the structure is still safe or not.

However, each structure should be monitor from time to time to make sure the safety of the structure and also the user are being under control. As we know, the GPS system also can have an error during data transmit between the satellite and the receiver. The system is needed to be make an assessment in order to get the higher accuracy for monitoring the structure deformation. At the University Technology of Petronas itself, we have our own GPS system, and from that, we will make an assessment to know the accuracy of the static system with the distance and time.

1.2: PROBLEM STATEMENT.

Deformation or deflection of a structure is the only single parameter affected by all the loads on the structural system and is an important critical parameter that would throw light in a significant measure on the structural behaviour of the body (Kaloop, Hu, & Sayed, 2015). From the statement, the structure deformation is one of the important aspect that need to be consider as a part of the safety factor. The deformation can be monitor by GPS system that being used widely using the coordinate from the top of the structure or building. The coordinate need to be monitor from time to time in order to check the different from the deformation occur.

Even though the GPS can provide a location, speed, altitude with a near-pinpoint accuracy, the system still has some error while the GPS receiver receive the signal from the constellation of satellite in orbit that need to be take into account. Most of the time, the error occurs because of the inaccurate time keeping by the receiver clock. Just a small difference between on-board clock of GPS receiver and the GPS time, distances that being calculated can be drifted. In order to know if it just a one-time error or permanent, we need to do an assessment for the GPS system by consider the distance from receiver and structure and the period of time.

1.3: OBJECTIVE

On this project, the main objective is to make an accuracy assessment of the UTP GPS system. The reason why this become the main objective of this project because to make sure the system that UTP have is the reliable one to be use around the UTP area. The important of this accuracy of GPS system is to make sure the data that being provided by the system can be used to analyse the safety of the structure around the UTP.

By doing that, the second objective of this project is to assess the effect of the distance to the GPS system accuracy at the V2 water tank as a centre point. This objective is being affected by the main objective because to know the distance of the building or structure that being monitor will not affect the data provided by the GPS system. In addition, the second objective is to know the maximum distance that UTP GPS system can provide with an accurate data. Therefore, we can provide another GPS system if the distance of the original GPS system that UTP already have is not enough to cover the whole UTP area.

The last but not least, our objective is to analyse the effect of observation time to GPS system accuracy. This object is to make sure that the observation time for structure deformation using GPS system does not affect the data provided by the GPS. This is because the deformation of the structure will take time to happen. During the time process, we must make sure that the system is in a good condition and can give an accurate data. If the data does not accurate enough, it will affect the user of the building and may be dangerous to be used.

1.4: SCOPE OF THE STUDY

This study focus on the assessment of the accuracy checking between of the UTP GPS system. Which is the reference point being at water tank near the café at village 2 will be used in this assessment. This study also makes an accuracy assessment with the distance of the structure. This is a part of the objective that need to be achieve in the end of this assessment and to know how the distance effect the accuracy of the UTP GPS system. In addition to the third objective is about effect of time during the observation. This is because, the system will keep going running in the real world and the deformation will be monitor from time to time and in order to have an accurate system to check the structure deformation, the time observation will be important in this assessment to know how it will be effected.

This project is to know that how the distance and time of observation does affect the accuracy data that being provided by the UTP GPS system. This project being assess using static method in order to determine the accuracy of UTP GPS system that being used to get the structure coordination in order check the structure deformation.

CHAPTER 2

LITERATURE REVIEW

The application or the use of GPS system have been widely used as a one tool in order to monitor the deformation of the structure (Doberstein, 2012). The main reason for using this system are to get a faster reaction and time to time data according to the structure information. Furthermore, it also improves the safety precaution for the building or structure user and it will help to reduce the causing loss live and property due to structure failure. (Radhakrishnan, 2014). As stated from (Celik, 2001)in the (Erol & Ayan, November 2008), early 1980's, they are using a conventional technique in order to measure the deformation in structures until it start moving to use a GPS as a measuring technique for engineering structure deformation. Most of the reason of using the GPS as a technique to measure the deformation of structure is only to get the higher accuracy. Especially for the high rise building that may be more difficult to measure it using the conventional way.

As mentioned by the (Erol and Ayan, 1999) has stated by the (Featherstone, 1998) and (Celik, 2001) about the benefit from the using GPS technique such as the higher accuracy and 3D positioning simultaneous. However, there is still imperfect about the GPS when it comes to the vertical positioning due to least accurately coordinate determine by the GPS. As we know, the GPS system also have the weakness and can cause some error while receive the data from the satellite due to obstacle such as being surrounded with a tall building. Because of that, as mention by the (Raziq, August, 2008) that there is limitation for monitoring the structure deformation including an inability to monitor small dynamic movement of the structure less than a centimetre. But, according to (Raziq, August, 2008), the advantages of this GPS are it can measure with ease the static, quasi-static and larger dynamic component.

There are a few purposes for structure monitoring using GPS technique such as allowing for the as-built performance to be checked between the design criteria by the responses GPS data (Radhakrishnan, 2014). It also can provide the opportunity to identify the unusual signal in term of loading condition or modified structure behaviour that can bring to the extreme case including structure damage and failure. (Wan Mohd Akib, 2014). Most of the using of the GPS to monitor the structure deformation are to make sure there is no other disaster or structure failure will be happened especially if the structure or building still being used. If this this happen, it will cause the major losses including the live and property losses. As stated in the (Abdel-Gawad, Mogahed, Abdel Mageed, & El-Maghraby, June 2014), the most important in deformation measuring is to avoid the structure failure.

According to the (Abdel-Gawad, Mogahed, Abdel Mageed, & El-Maghraby, June 2014), the GPS itself has a few positioning techniques such as static, stop and go, kinematic and real time kinematic (RTK). From all this technique, the static has the most an accurate and reliable technique, however the production of data is little bit slowly. (Accuracy and observation times, 2010) As we know, the GPS itself has their own deficiency in term of data provided (gisresources, 2014). There are a few reasons or the cause of the occurrence the error during GPS provide the coordinate data. As mention in the (Abdel-Gawad, Mogahed, Abdel Mageed, & El-Maghraby, June 2014) by the (Abdel Mageed Kh, 2006) about the error causes during GPS measurement. It can be divided into three parts, first is cause by the satellite in the satellite ephemeris, ununiformed satellite clock and effect of the termination selective availability in 2000 (Wubbena, Bagge, Seeber, Böder, & Hankemeier, 2016).

The second part is causing by the GPS receiver that start with the receiver clock that did not synchronise with the satellite clock and also cause by the receiver noise and variation at the antenna phase centre. The last part for the causing GPS error is the signal propagation error that happen due to tropospheric refraction, ionospheric refraction and multipath (Wubbena, Bagge, Seeber, Böder, & Hankemeier, 2016). Beside of that, the geometric location of the GPS as seen by the receiver also affect the error in accuracy of the computed GPS position (GPS Accuracy, 2017). Basically, the clearer the sky, the more accurate data can be obtained which is denoted as a dilution of precision.

CHAPTER 3

METHODOLOGY

The using of GPS in order to monitor the deformation of the structure is not a something new. Its already being implemented all around the world for example deformation monitoring of KOMTAR building in Penang, Malaysia, the Hong Kong's Tsang Ma Bridge and Humber Bridge in UK (Aziz et al.,2001; Behr et al.,1999; Cheng et al.,2002; Wong et al.,2001) as stated in Nisha, 2014. In this project, the main objective is to determine or to know how far or accurate the GPS system in the UTP in order to handle the monitoring of the structure deformation.

The methodology that will be use is by using a static method. This method being choose after a few discussions with the supervisor and lab technician and also a few researches which also recommended the static method to check the accuracy. Another reason is because the structure can be assuming as a static structure and it will not be moving from one place to another. It will be suitable in the assessment to use the static method and easier to make a comparison with the data that will be collected from the difference time and distance.

From this method, it will be requiring at least one (1) base station and two (2) station for one point to get the coordinate for each point station. Each station will be observer around two hours but still depending on the distance of the point station with the base station. The base station is the temporary base station where the station is already being analyse and fixed the coordinate with the UTP GPS system. All the equipment will be setting up at properly at the clear area to reduce disturbance from others. The weather also need to be consider during the test because of the equipment of the test cannot expose to the water.

Each equipment at a choosing station will be place without any disturbance during the running test and the equipment must be set up properly in order to get the reliable data. The coordinate that being collected with the rover will be analyse using Topcon software and the base point will be using the fixed coordinate that being analyse and connect with the UTP GPS system. This is because to make sure the coordinate that be obtain are correct and accurate. Any error during the test will be used to analyse the effect of the time and distance. Without the known coordinate as a base station, the point coordinate will not be accurate. Then the distance from each point with the base station will be obtain from the Topcon.

The most important on this project are the equipment is untouchable along the process being done. At the same time, the point station must be marked properly in order to get the same position for the next day process especially for the base station because that the only station will be use multiple time until finish the test. This is because, if the station not placed at the same position, the data that being collected will be error. This will be challenging for this project especially, to get the same spot and position for each structure and at the same time to make sure the equipment will not be touch by other.

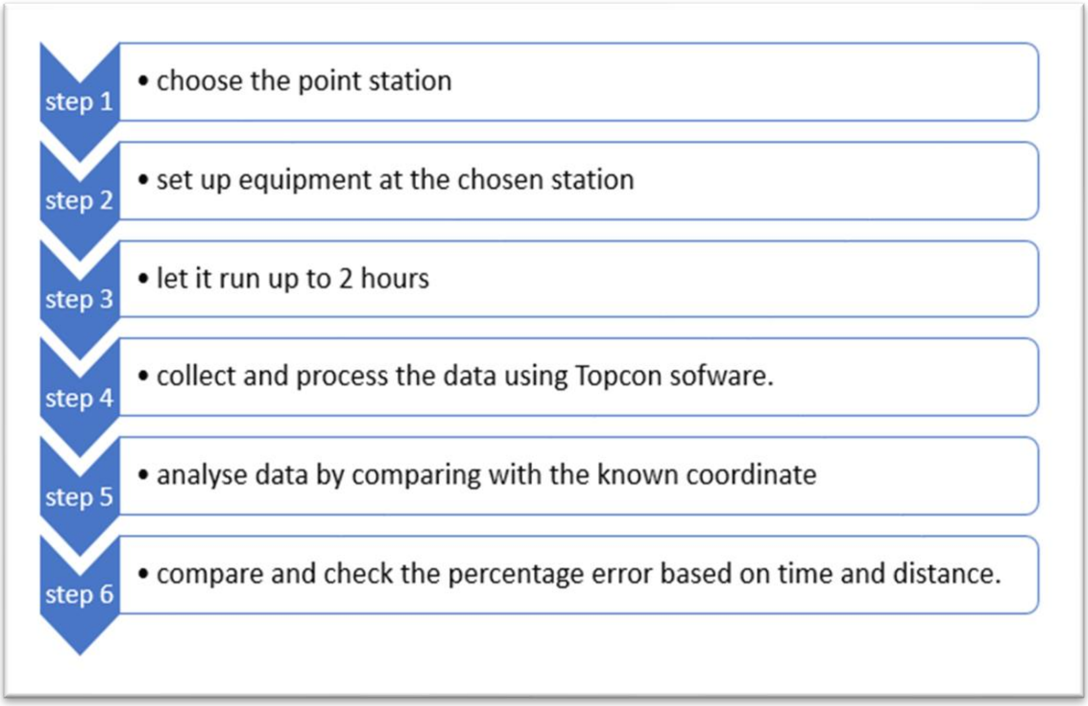

Figure 1: Procedure for accuracy assessment.

During the first time taking the data, area of parking block 13 being used. The first area might be too short but it only to make sure even the nearest distance still can give an accurate coordinate. It be one (1) base point with the red marking and another three (3) as a station with blue marking.

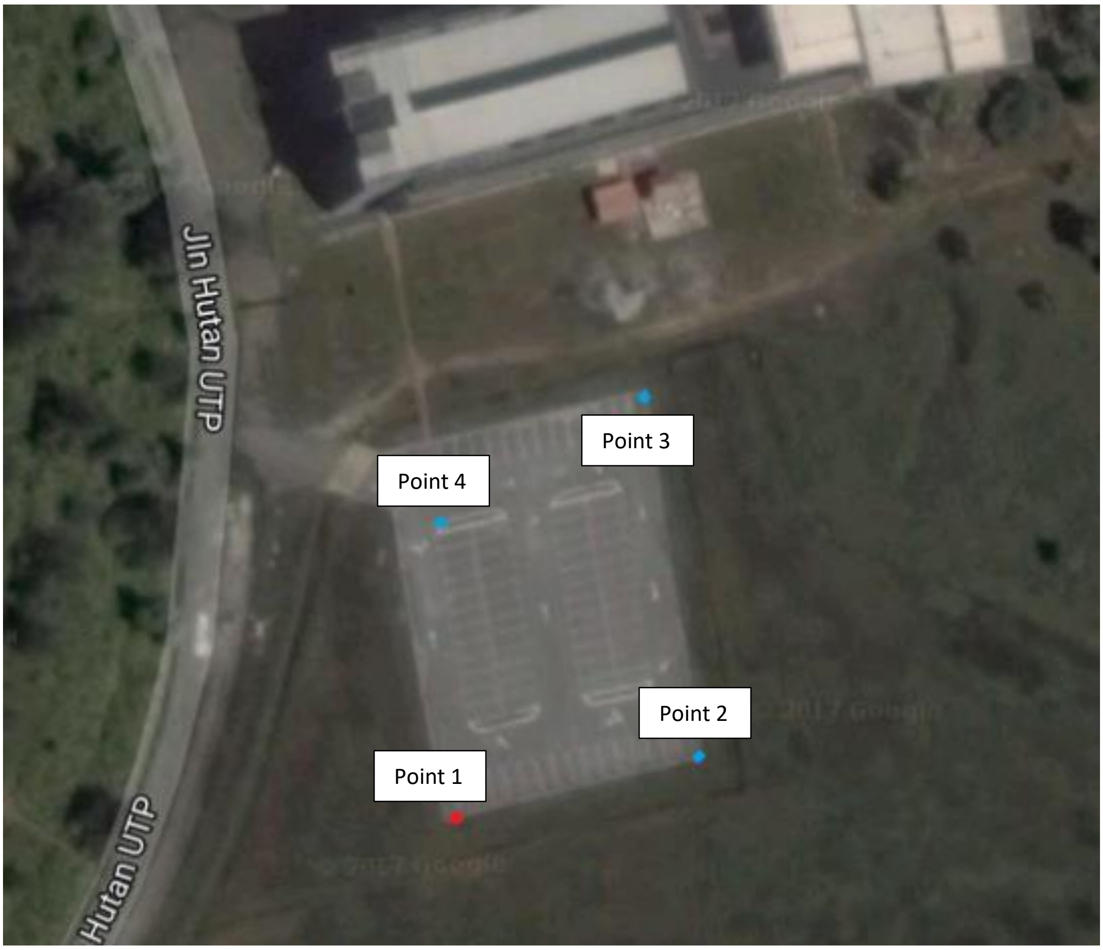

Figure 2: Chosen station at Block 13 parking area.

First of all, the base station as a point 1 need to be set up first then followed by the point 2 until the point 4. All the equipment need to be set up properly especially for the point 1 because it used a tripod. Another reason is to make sure it being place at the centre marking point. The rover must be place at the centre of the marking point and also need the make sure it flat by keep it the bubble in the circle. Before starting recording the data, the height of the base need to be recorded. Because of using the tripod, the height being measure using slant from the centre marking point until the rover marked point.

Figure 3: Set up equipment at point 1.

Figure 4: Bubble must be in the centre of circle area.

Same goes to the next three (3) point but the different is, it is using a bipod which is more easier and have a constant height of two (2) meter. Using the same step where it need to be place in the centre marking point and the bubble must be in the centre to make sure it flat at the top of the point.

Figure 5: Equipment set up for point 2, 3 and 4.

Figure 6: Bubble checking to make sure it flat.

After all the equipment being set up, the base station will be turn it on first to do a few set up before staring the recording. When everything is ready and the base start it recording, then the point 2, 3 and 4 can be turned on in order to start their recording coordinate data. While this rover is running, it cannot be disturbed or touch to prevent from it to move from the centre point. Only one (1) hour needed to record the data. When everything is done, the rover need to be shut it off before can take it to the lab to take the recorded data.

There are being separately by three (3) base line for this test which is the short base line, medium and long base line. The short consist six (6) station or point including the base station and one station for medium and another one for long base line. The reason behind the unequal station for each base line are because of the first section, which is the short base line, it being used to know the pattern of error occur for the different distance and effect of time observation. There is 4 points at the parking block 13 and another two-point station at convo fest parking area in front of village 4 hostel.

Figure 7: Point 5 & 6 at convo fest parking area.

Figure 8: Equipment set up for point 5.

Figure 9: Equipment set up for point 6.

3.1: FYP 1 Gantt Chart

Table 1: Project milestone for FYP 1.

Activity	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Selection of FYP project title														
Approval of FYP project title														
Research & study about the project														
Methodology discussion														
Preparation & submission of Extended Proposal														
Preparation of Proposal Defend														
Interim Report draft submission														
Final Interim Report submission														

Submit extended proposal

Presentation of proposal defend

Submit interim report (draft)

Submit interim report (final)

Project milestone

Planning progress

3.2: FYP 2 Gantt Chart

Table 2: Project milestone for FYP 2.

Activity	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Starting the project	■													
Collecting the project data		■	■	■ ★										
Analysis & compute the project data					■	■								
Prepared & submit Progress Report						■	■	■ ★						
Pre - SEDEX									■	■	■ ★			
Submission of Dissertation (draft final report)										■	■	■ ★		
Prepared & submit Technical Report											■	■ ★		
VIVA & submission of Project Dissertation													■ ★	

Finish collecting data

Submit progress report

Submit draft final report

Submit technical report

Submit final project

★ Project milestone

■ Planning progress

CHAPTER 4

RESULT AND DISCUSSION

4.1: RESULT

Based on the methodology that have been describe above, the test or the project have been done at the area of parking lot block 13 and convo fest parking area in front of hostel village 4. The area being choose as a first place and as a stepping stone before procced to the next location which is for the medium base line and for the long base line. During the first data recorded, there is no problem being identified because the equipment has already been set up according to the what it should be.   Then after the test is done and all the equipment have been send to the lab for the next process which is processing the data by using the Topcon software.

All the data being process and analyse. The result for six (6) station being tabulated as below.

4.1.1: Tabulated data.

Table 3: Result for short base line part 1.

point			1			2			3			4			5			6		
distance to point 1			0			39.282			46.123			71.602			1064.364			1088.03		
grid			484901.927	330211.686	33.71	484905.27	330250.824	33.817	484948.04	330210.688	33.606	484967.079	330241.393	33.401	485957.705	330384.006	33.852	485965.371	330465.189	33.57
time (minute)	10	grid	484901.927	330211.686	33.71	484905.27	330250.824	33.817	484948.04	330210.681	33.624	484967.077	330241.386	33.413	485957.688	330383.993	33.852	485965.36	330465.175	33.551
		error (m)	0	0	0	0	0	0	0	0.007	-0.018	0.002	0.007	-0.012	0.017	0.013	0	0.011	0.014	0.019
	20	grid	484901.927	330211.686	33.71	484905.27	330250.824	33.817	484948.039	330210.68	33.623	484967.08	330241.388	33.408	485957.695	330383.999	33.844	485965.361	330465.183	33.567
		error (m)	0	0	0	0	0	0	0.001	0.008	-0.017	-0.001	0.005	-0.007	0.01	0.007	0.008	0.01	0.006	0.003
	30	grid	484901.927	330211.686	33.71	484905.27	330250.824	33.817	484948.037	330210.682	33.623	484967.076	330241.388	33.418	485957.704	330384	33.849	485965.367	330465.186	33.562
		error (m)	0	0	0	0	0	0	0.003	0.006	-0.017	0.003	0.005	-0.017	0.001	0.006	0.003	0.004	0.003	0.008

Table 4: Result for short base line part 2.

time (minute)	40	grid	484901.927	330211.686	33.71	484905.27	330250.824	33.817	484948.038	330210.685	33.622	484967.077	330241.39	33.411	485957.708	330384.003	33.846	485965.37	330465.187	33.577
		error (m)	0	0	0	0	0	0	0.002	0.003	-0.016	0.002	0.003	-0.01	-0.003	0.003	0.006	0.001	0.002	-0.007
	50	grid	484901.927	330211.686	33.71	484905.27	330250.824	33.817	484948.039	330210.687	33.62	484967.079	330241.392	33.404	485957.704	330384.004	33.854	485965.366	330465.186	33.578
		error (m)	0	0	0	0	0	0	0.001	0.001	-0.014	0	0.001	-0.003	0.001	0.002	-0.002	0.005	0.003	-0.008
	60	grid	484901.927	330211.686	33.71	484905.27	330250.824	33.817	484948.04	330210.688	33.606	484967.079	330241.393	33.401	485957.705	330384.006	33.852	485965.371	330465.189	33.57
		error (m)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5: Result for medium and long base line.

point			7			8		
distance to point 1			13485.369			21773.486		
grid			494407.754	339777.17	24.185	501867.926	343858.867	41.176
time (minute)	10	grid	494407.726	339777.15	24.192	501867.891	343858.84	41.211
		error (m)	0.028	0.02	-0.007	0.035	0.027	-0.035
	20	grid	494407.733	339777.157	24.204	501867.898	343858.848	41.197
		error (m)	0.021	0.013	-0.019	0.028	0.019	-0.021
	30	grid	494407.729	339777.151	24.207	501867.894	343858.841	41.202
		error (m)	0.025	0.019	-0.022	0.032	0.026	-0.026
	40	grid	494407.731	339777.149	24.201	501867.904	343858.842	41.194
		error (m)	0.023	0.021	-0.016	0.022	0.025	-0.018
	50	grid	494407.734	339777.152	24.204	501867.901	343858.845	41.196
		error (m)	0.02	0.018	-0.019	0.025	0.022	-0.02
	60	grid	494407.737	339777.154	24.192	501867.907	343858.85	41.189
		error (m)	0.017	0.016	-0.007	0.019	0.017	-0.013

4.1.2: Graphical data.

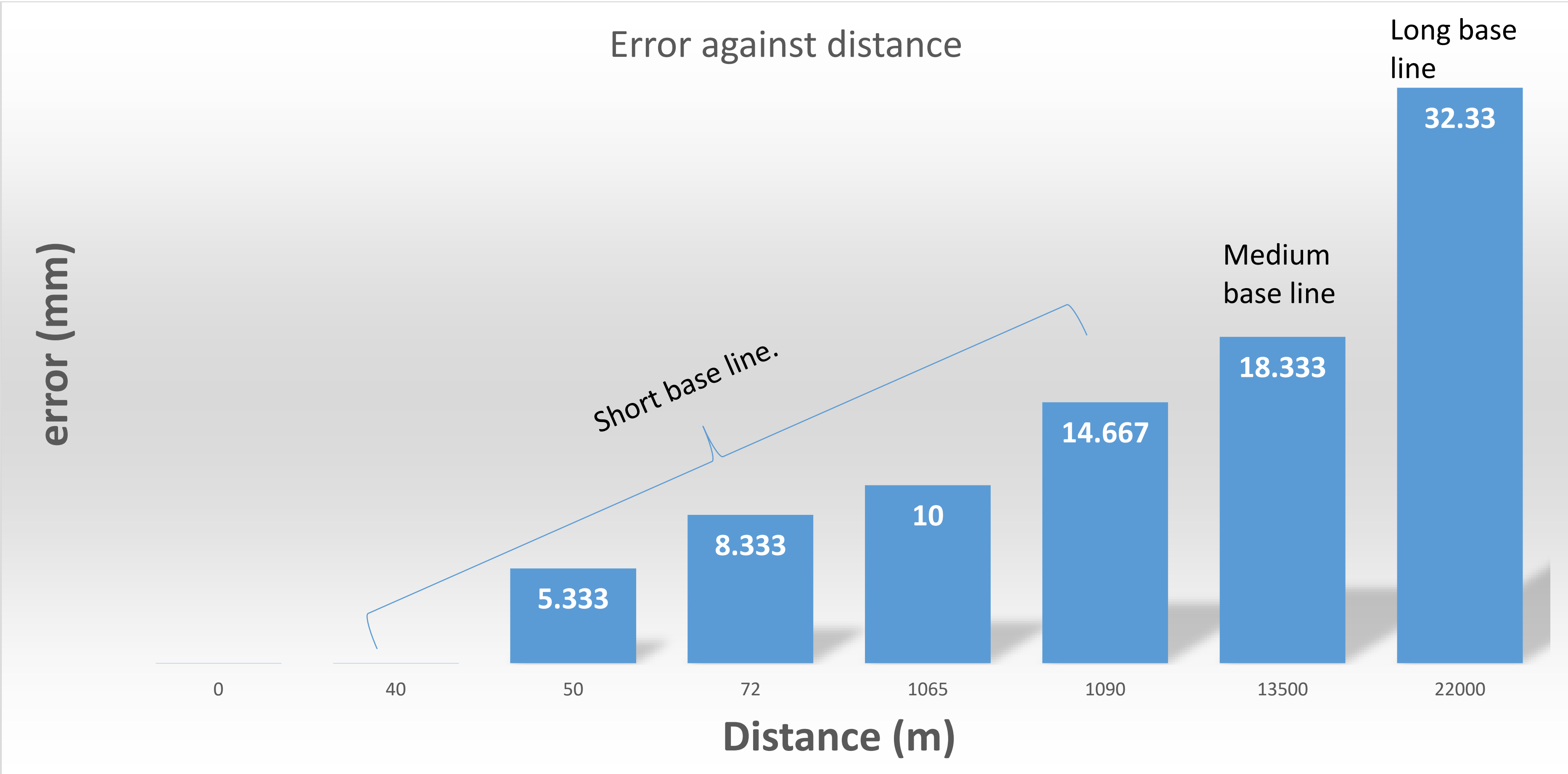

Figure 10: Graph of accuracy based on the distance.

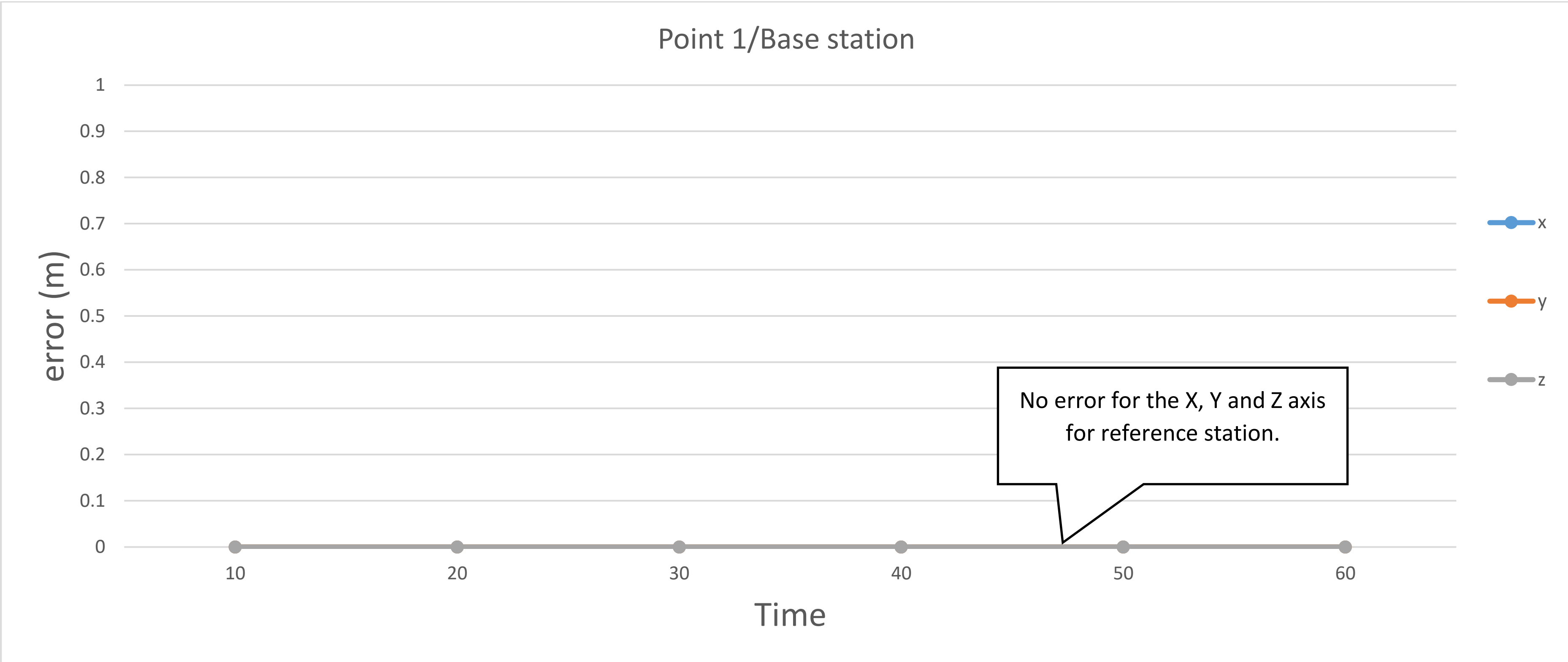

Figure 11: Graph error against time for base station.

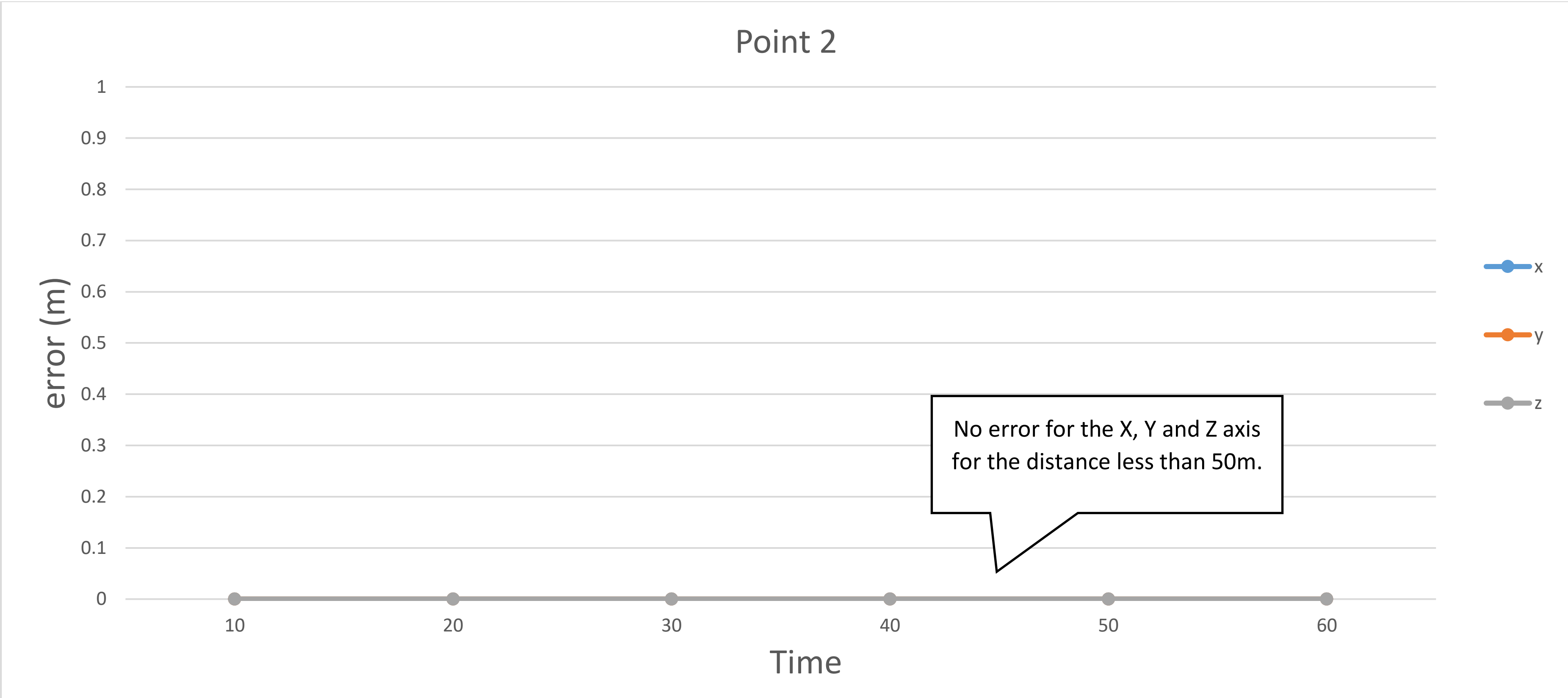

Figure 12: Graph of error against time for point 2 less than 40m.

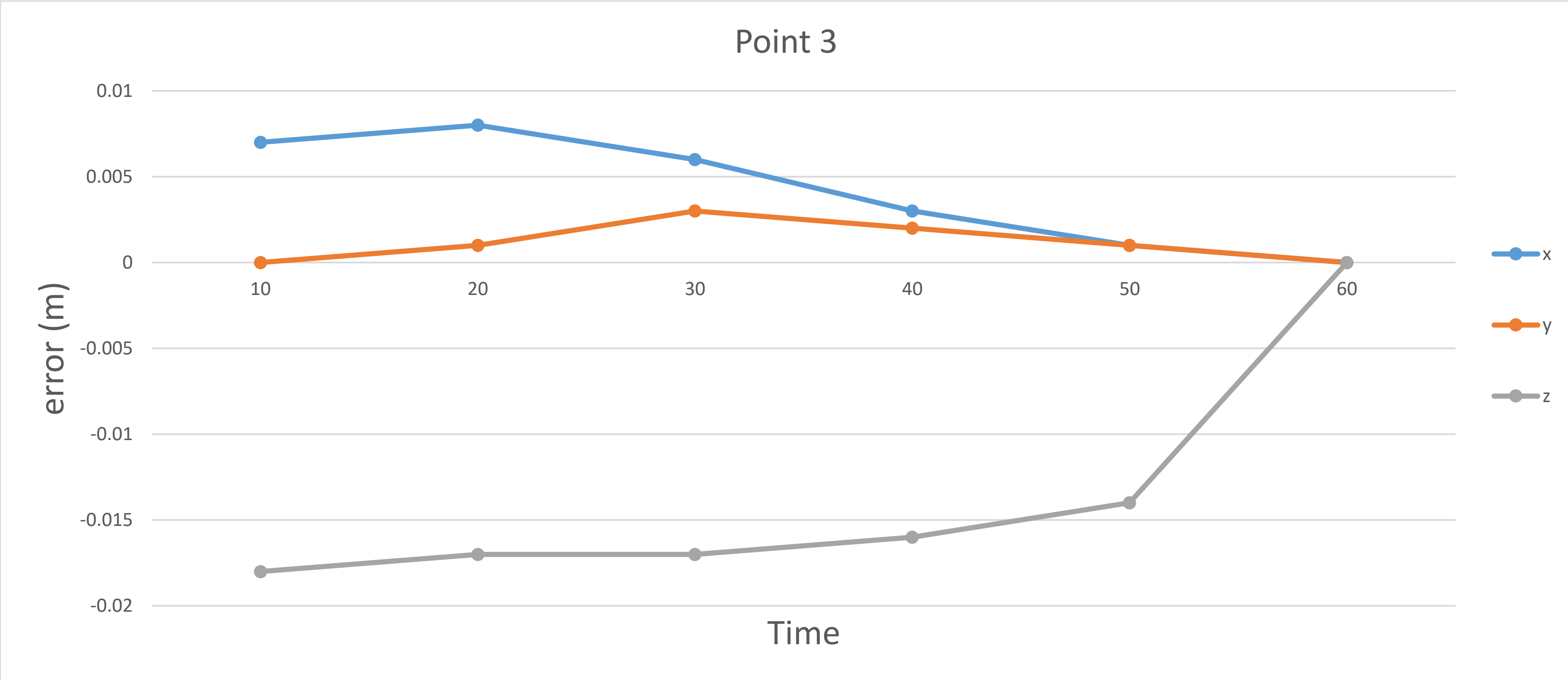

Figure 13: Graph of error against time for point 3 less than 50m.

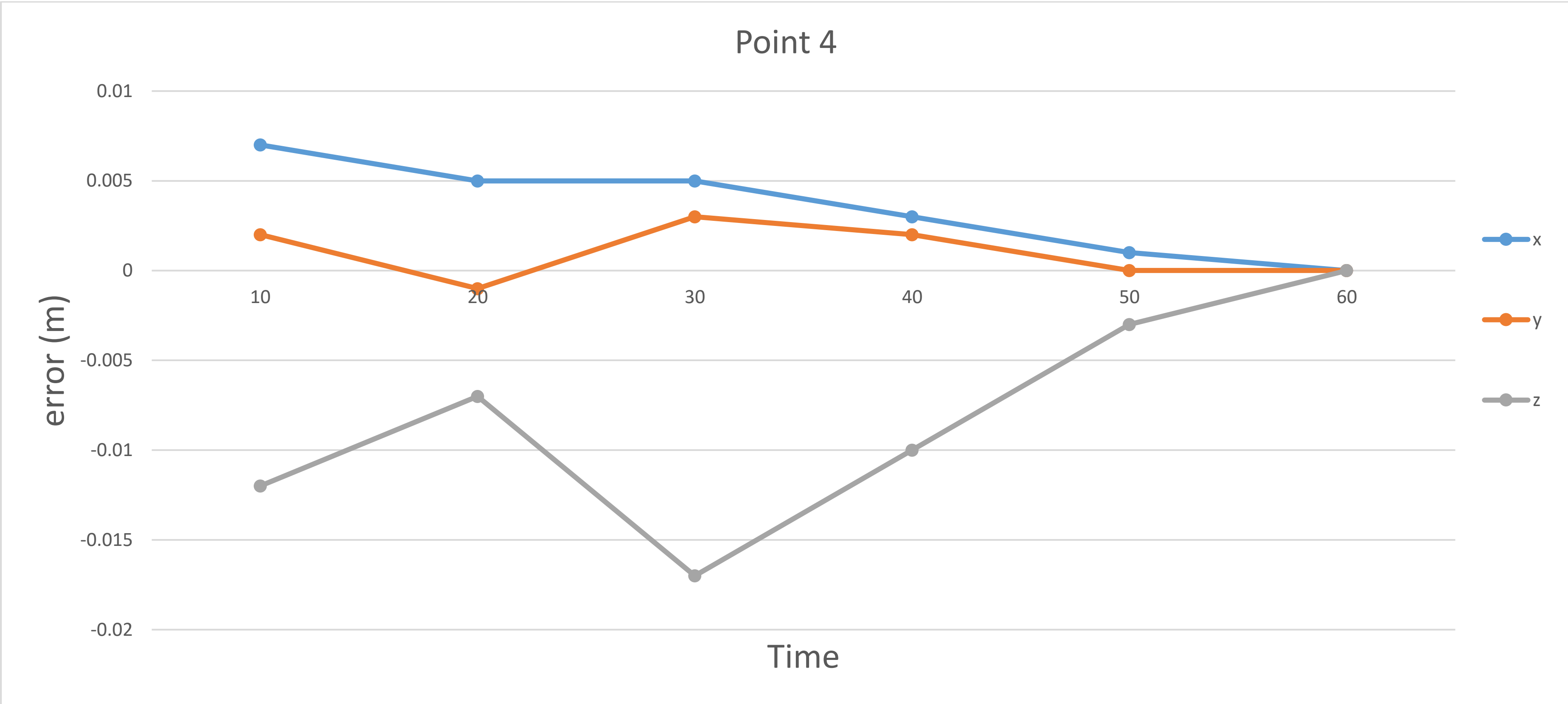

Figure 14: Graph of error against time for point 4 less than 100m.

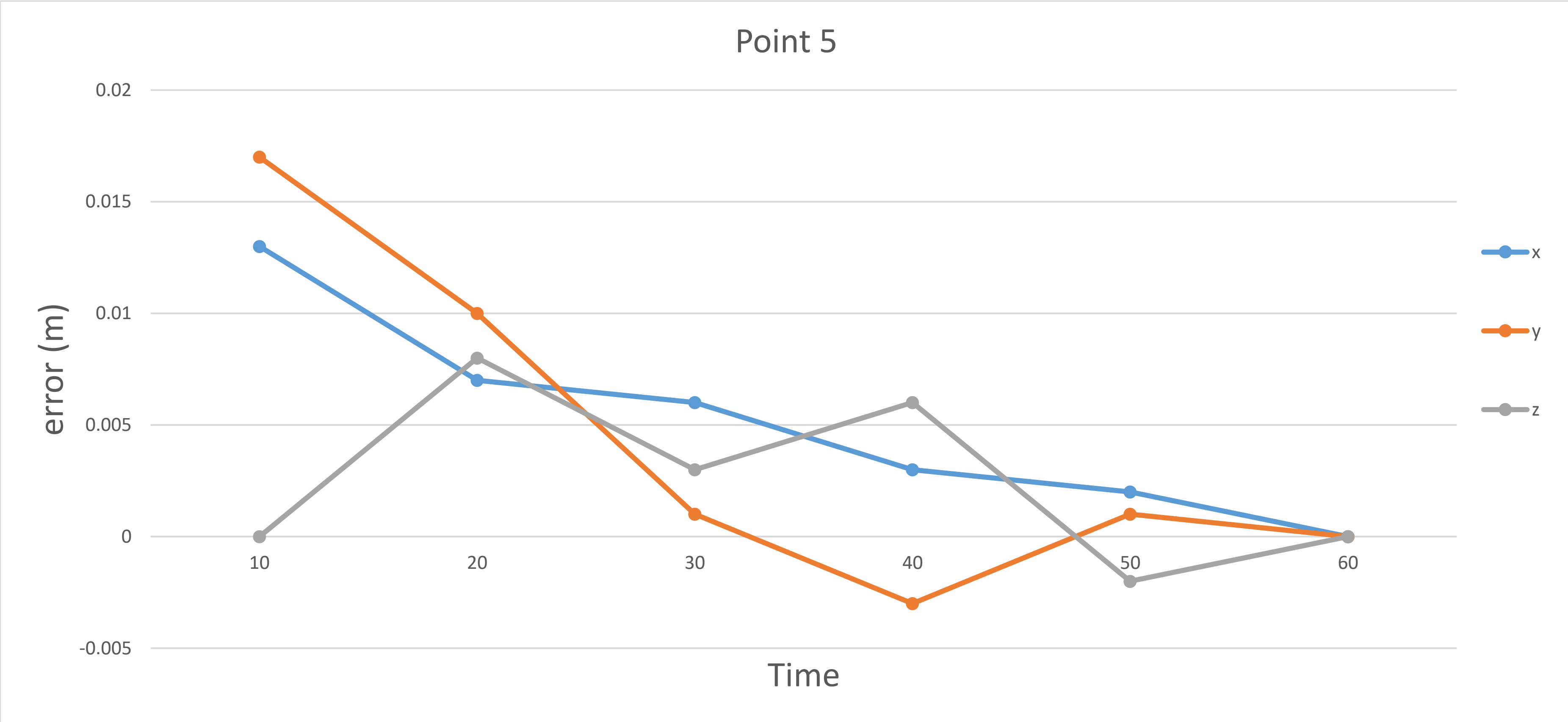

Figure 15: Graph of error against time for point 5 less than 1.2km.

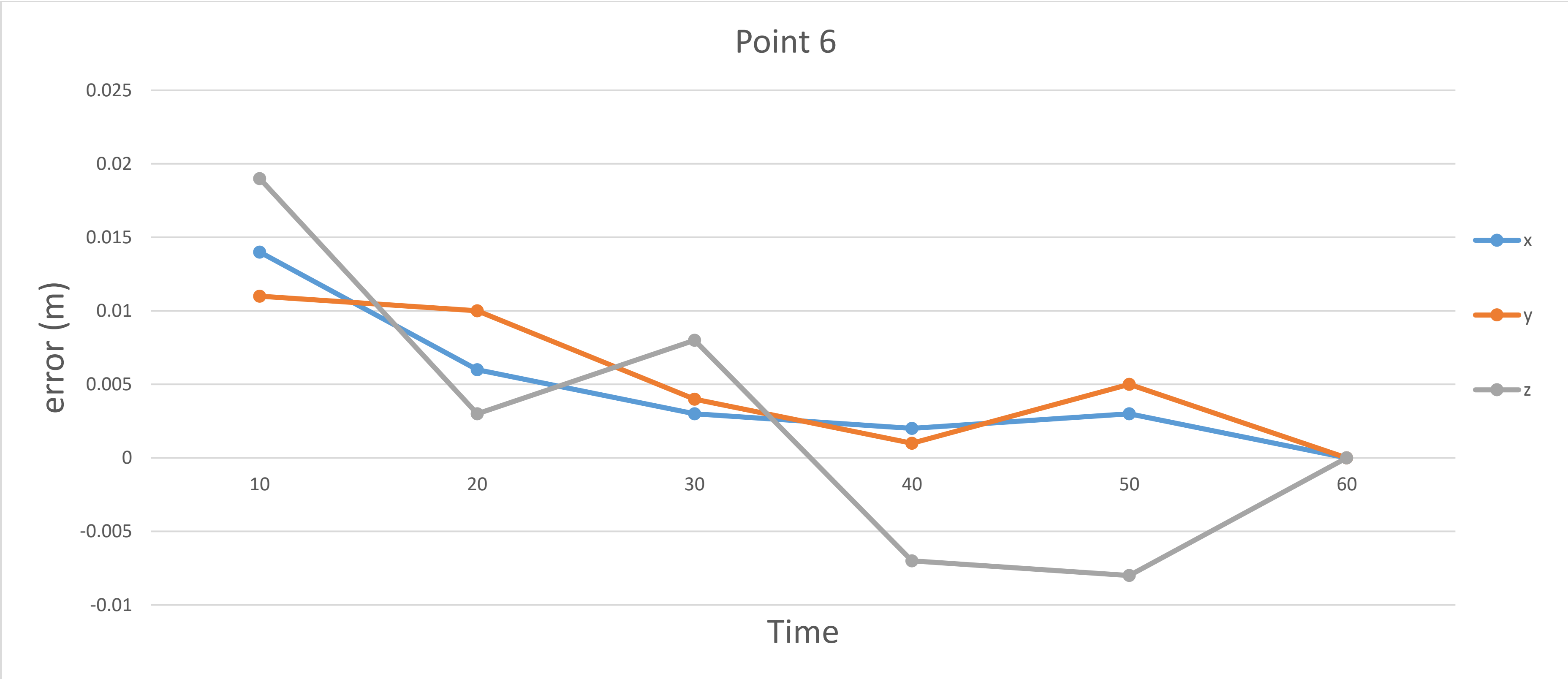

Figure 16: Graph of error against time for point 6 less than 1.2km.

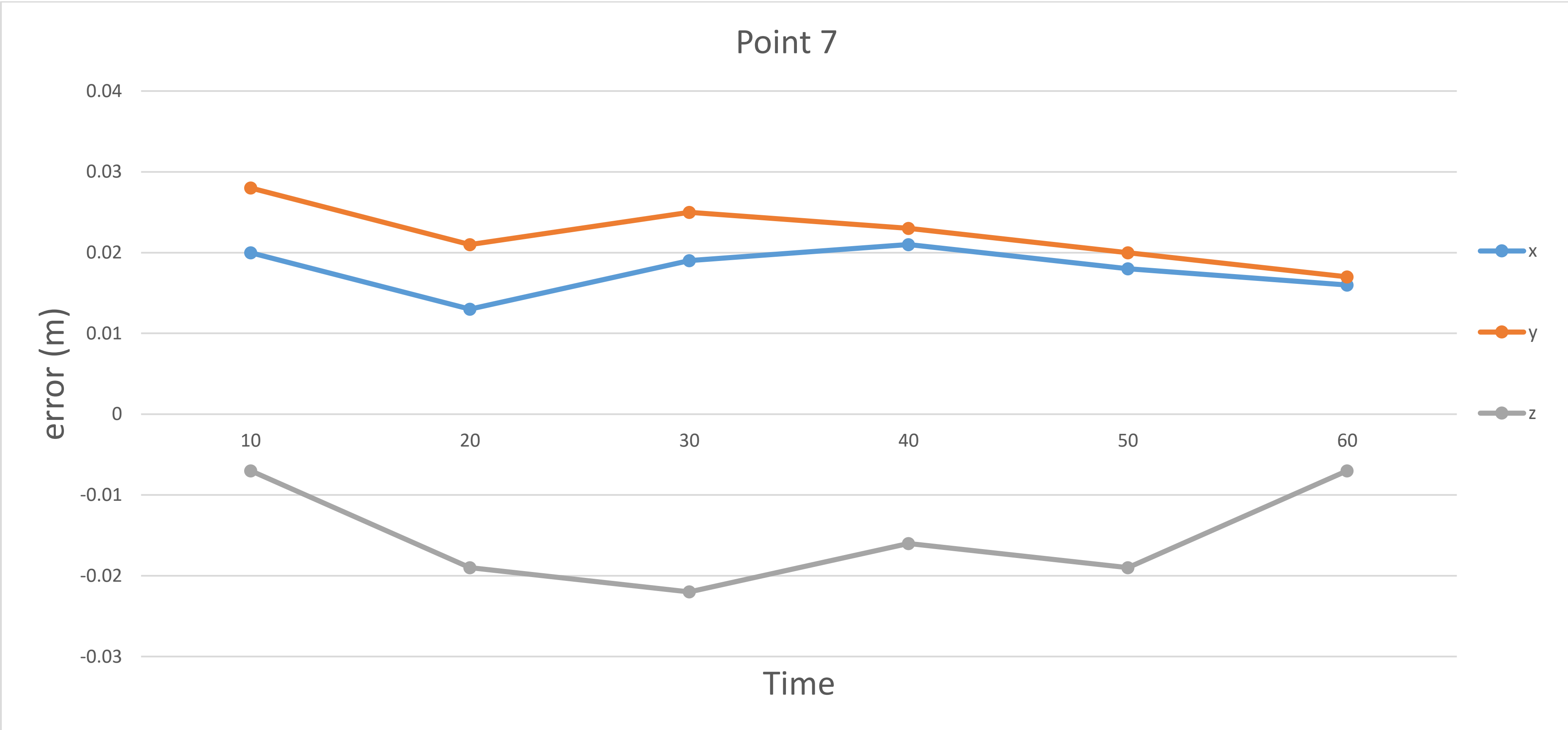

Figure 17: Graph of error against time for medium base line less than 15km.

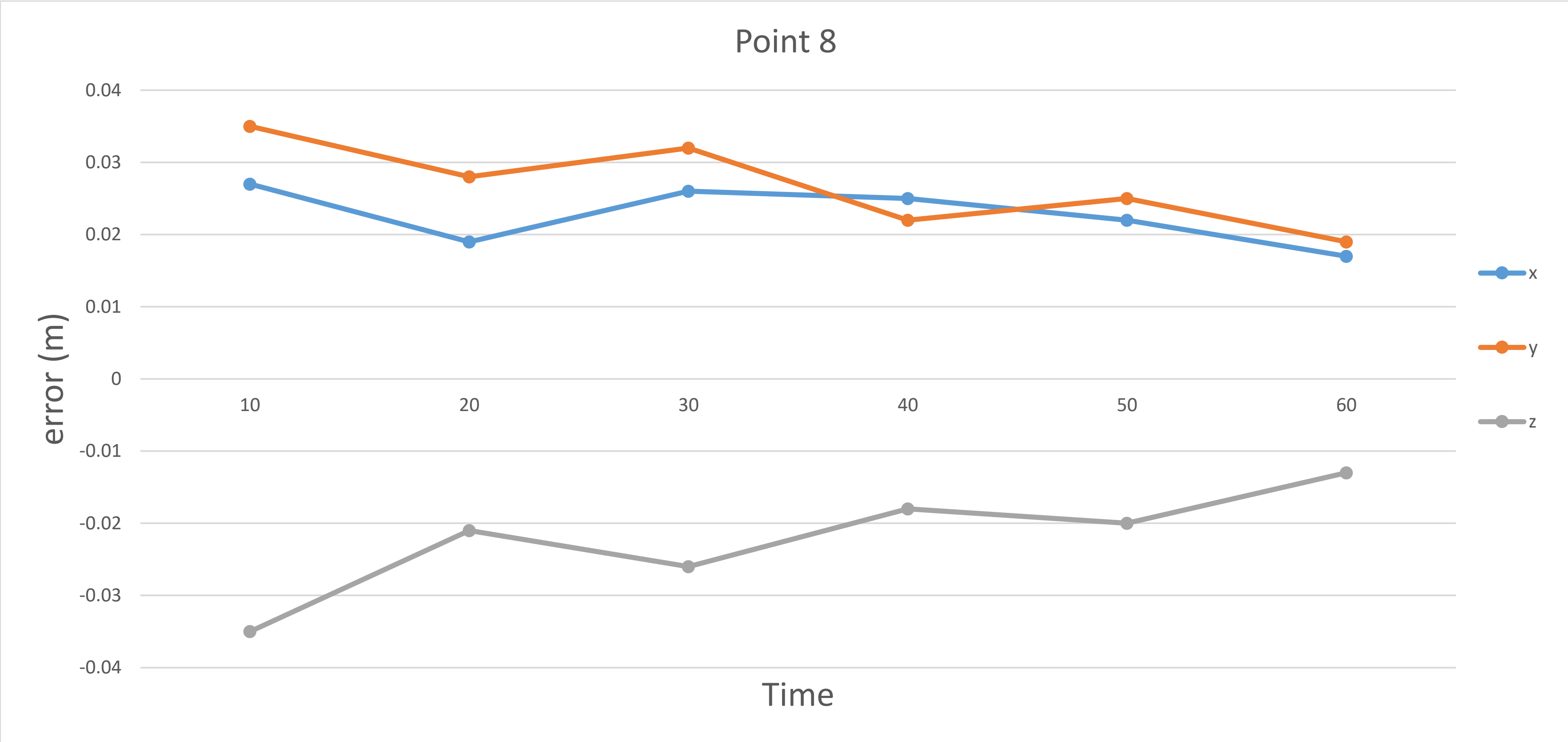

Figure 18: Graph of error against time for long base line less than 25km.

4.2: DISCUSSION

From the result that have been analyse with the table and the graph, the test for accuracy assessment have been achieved. Based on that, for the error that effect from the different distance can be seen a pattern which is the error increasing along with the distance increase also as state by the (Piyasena & Perera, 2014). (Jie, Li, Weiming, & Lifeng, 2013) have state that the error increasing with the baseline distance are causes from the reduction of public synchronous satellites, troposphere and ionosphere error correlation that can affect the three-dimensional error.

In the other word, the maximum distance can be use d from this reference station is more than twenty (20) km according to the (The Official Website for The State of New Jersey, 2008). From (GPS Accuracy, 2017), in term of the maximum error or the maximum accuracy can be given from the GPS is about 5m less than 7.8m. This limit of the accuracy is being used as a benchmark for this test and as the result obtained, up to less than 25km, the accuracy or the error of the GPS data still below the limit and can be consider as accurate data with an error less than 50mm.

In term of the observation time, there are a few studies that have stated about the time observation needed for the different distance. Study from (Geosystems, 2000) have state that the base line distance less than 5km only need around 10 minutes for the data observation, distance less than need 25minutes and base line with the distance up to 20km only need 40 minutes observation. In the other study have stated that the time needed for static observation is 30 minutes for distance less than 1km, 1 hour for distance below 5km and around 90 to 120 minutes needed to observe a base line with the distance up to 20km. (Accuracy and observation times, 2010).

From the result, the time observation needed is one (1) hour for the short base line with the distance below 2km and need at least 2 hours for the medium and long base line with respective distance of 13km up to 22km. This is because, the graph for medium and long base line with 1 hour observation time have shown that the data up until 60 minutes does not enough or in the other word is not accurate. Need to take consideration also, the error for all the base line are still below the limitation and then, the data are still can be used for other requirement.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1: CONCLUSION

Base on the result and analysis that have been done for all the distance base line, it can be conclude that in term of the distance that affect the accuracy of the GPS data is can be true because, from the result, it shown the error pattern that occur in this assessment is increase along with the increasing of the distance and for the higher distance, it could be less accurate for the system. Although the error is increase, it still does not pass the limit of the maximum accuracy of GPS system that is around 5km. In the other hand, for the time observation, it seems to have a connection with the distance observation. This is because as the distance increase, the error is increase also and same goes to the time observation needed for the system to observed an accurate data. The distance that below 5km seem to have at least 1 hour observation and the distance more than 10km need more than 1 hour.

For the aim of this project was also to be able to achieve the objective that need to make an identification about the accuracy of the UTP GPS system. With the result that have been stated above, the objective of this assessment has been achieved. The main objective is to assess the accuracy of the UTP GPS system can be concluded as an accurate at least for the distance up to 22km base on this assessment test. Which means, the error from the data observation is still can be consider as accurate because it does not exceed the limit of 5km accuracy.

The assessment for the effect of distance with the accuracy data also proven with the result where the increasing distance of observation point or station from the base station is effect the GPS system to give an accurate data. The error data seem to have a constant pattern which is it will be increase along with the increasing of distance. The result still has the same conclusion where the data still can be use because of the error still below the limitation.

The last objective is the assess the effect of time observation to the accuracy data. This last objective also been achieved with the proven data and graph. A necessary time observation is needed to get an accurate data from GPS system because as the result shown that, it takes at least 1 hour minimum to get an accurate data for the distance less than 2km and the observation of 1 hour for the medium and long base line is not sufficient enough to get an accurate data.

Lastly, the conclusion is that the distance from observation point to the base station is the main factor that can affect the accuracy data from the GPS system. From the distance, it will affect the time observation needed for the GPS system to provide an accurate data. In order to have an accurate data, the distance from the base station need to be determine and along with the time observation for at least 2 to 3 hours for the distance below 25 km and need more for the higher distance.

5.2: RECOMMENDATION

At the end of this project, there are a few recommendations that need to be address in here which is it can be used to improve the assessment result and the whole project. The first one is about the distance, it could be make the higher distance comparison such as 5km,15km,25km,35km and 45km in order to assess the error either it still below the limit or it already passing the limit and also the result can be shown the maximum distance of the UTP GPS system. Secondly, is about the time observation, it would be a necessary thing to have an observation during night time and day time to have a comparison and to know either night and day time effect the accuracy of the data. For the third recommendation, according to this assessment is to have a comparison between two methods about the accuracy data. As being state in a (Abdel-Gawad, Mogahed, Abdel Mageed, & El-Maghraby, June 2014) and (Celik, 2001) that the static technique is more accurate than other method.

In term of the using this monitoring system in the real world. It should be implemented to the whole structure in Malaysia to have a GPS system for structural deformation monitoring. This is because this system can be part of a safety equipment for the building. There is a lot of project that being construct at hilly area especial for residential purpose. With the high-risk area to have a landslide, it would be a better protection that can be used at least to save a people life. The authorize agency in Malaysia can make a new regulation about this system to be implemented at least for the project that have a possibility to be involved in landslide area.

REFERENCE

[1] *Wikipedia, the free encyclopedia*. (25 June, 2017). Retrieved from Wikipedia, the free encyclopedia: https://en.wikipedia.org/wiki/Global_Positioning_System

[2] *GPS explained*. (2017). Retrieved from Mio: https://eu.mio.com/en_gb/global-positioning-system.htm

[3] Teague, E. H., How, J. P., Lawson, L. G., & Parkinson, B. W. (2016). *GPS AS A STRUCTURAL DEFORMATION SENSOR.* Stanford CA: Department of Aeronautics and Astronautics.

[4] Kaloop, M. R., Hu, J. W., & Sayed, M. A. (2015). Bridge Performance Assessment Based on an Adaptive Neuro-Fuzzy Inference System with Wavelet Filter for the GPS Measurements. *Geo-Information*, 2339-2361.

[5] Doberstein, D. (2012). Chapter 2: Introduction to the Global Positioning System. In D. Doberstein, *Fundamentals of GPS Receivers: A Hardware Approach* (pp. 23-39). Springer Science+Business Media, LLC.

[6] Radhakrishnan, N. (2014). Application of GPS in structural deformation monitoring: A case study on Koyna dam. *Journal of Geomatics*, 48-54.

[7] Erol, S., & Ayan, T. (November 2008). An Investigation on Deformation Measurements of Engineering Structures with GPS and Levelling Data Case Study. *Internationa; Symposium on Modern Technologies*, 6-13.

[8] Celik. (2001). Advantages Deformation Monitoring using GPS Technique. *Journal of Geomatic*, 35-38.

[9] Raziq, N. (August, 2008). *GPS Structural Deformation Monitoring:.* Melbourne: The University of Melbourne.

[10] Wan Mohd Akib, W. (2014). High Rise Building Deformation Monitoring With GPS. *Department of Geomatic Enginnering*, 35-41.

[11] Abdel-Gawad, P. K., Mogahed, D. M., Abdel Mageed, D. M., & El-Maghraby, E. M. (June 2014). Evaluation and Accuracy Assessment of Static

GPS Technique in Monitoring of Horizontal Structural Deformations. *Journal Of Modern Engineering Research (IJMER)*, 12-18.

[12] *Accuracy and observation times.* (2010). Retrieved from NPTEL: http://nptel.ac.in/courses/105104100/lectureB_13/B_13_10Accuracy.htm

[13] gisresources. (10 February, 2014). *GIS Resources*. Retrieved from GIS Resources.com: https://www.gisresources.com/gps-surveying-techniques_2/

[14] Wubbena, G., Bagge, A., Seeber, G., Böder, V., & Hankemeier, P. (2016). *Reducing Distance Dependent Errors for Real−Time Precise DGPS Applications by Establishing Reference Station Networks.*

[15] *GPS Accuracy*. (December, 2017). Retrieved from GPS.GOV: https://www.gps.gov/systems/gps/performance/accuracy/#how-accurate

[16] Piyasena, N., & Perera, G. (2014). *ERROR PATTERN RECOGNITION OF STATIC GPS OBSERVATION WITH CHANGE OF PDOP, BASELINE AND OBSERVATION DURATION.* Sri Lanka: University of Sri Lanka.

[17] Jie, Z., Li, F., Weiming, T., & Lifeng, G. (2013). *Cross-ocean GPS long distance rapid static positioning methods.* Wuhan: Wuhan University.

[18] *The Official Website for The State of New Jersey.* (8 March, 2008). Retrieved from CHAPTER 4 GPS SURVEYS: http://www.state.nj.us/transportation/eng/documents/survey/Chapter4.shtm

[19] Geosystems, L. (2000). *General Guide to Static and Rapid-Static.* Heerbrugg: Leica Geosystems AG.