International Journal of Engineering & Technology, 7 (4.20) (2018) 293-298

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



The Possibility of Using Navigation GPS Devices in the Survey Engineering

Haidar Abbas Neam Al_ dami*, Isaraa Riyadh Abdulridha

University of Al Qadisiyah / Engineering College, Road and transport Dep.
**Corresponding author Email: haidar.aldami@qu.edu.iq*

Abstract

As a result of the tremendous development in the field of computer technologies, communications and information revolution, new applications which has seen a tremendous development in terms of devices and technologies used in various applications such as a device Electronic Distance Measurement (EDM), Total Station, GPS (Surveyor and Navigational)… etc. In this study, five-ground control points (BM) were made to provide traverse, and these points observed by using three different navigation GPS devices, and observed by using TOTALSTATION device, and using spatial and statistical analysis functions in GIS. The study showed that the error in these devices is a random error varies from one device to another. In addition, it showed that the error varies from time to time. Cannot be determined the spread of readings to the observed point (by navigation GPS) in a particular direction or specific frame, as well as the central distance of the readings are changing from one device to another and from point to point.
The study recommends that should not be used navigation GPS devices in the survey work. In addition, re-survey all areas are observed or defined its borders by using this device (navigation GPS) by serving GPS devices with the required accuracy.

Keywords: GIS, Global Positioning System (GPS), observations, surveying, total Station

1. Introduction

science, which has seen a tremendous development in terms of devices and technologies used in various applications such as a device Electronic Distance Measurement (EDM), Total Station, GPS (Surveyor and Navigational)… etc.[1],[2].

All of these applications and modern technologies have made of space science enters many other sciences, but became a major part of them, which led to the emergence of new names trying to catch up with everything that develops in this area, such as the term (Geomatics).[3].

The navigation GPS enabled many people who have no relationship with Geomatics Engineering to use it in many joints of their lives. This application enables them to travel through the desert, sea, air, and return to their places of origin without any difficulties or problems by identifying the coordinates of origin and destination and reducing them. Further, it can be used draw the paths between the origin and the destination. This application also enables to save the names of places and names of the objects and calculate the distance between them and determine the time required to reach according to the speed of the specified path and determine their direction.[4].

However, it should be noted that GPS devices used in surveying applications differ from those of hand-held GPS (navigator) in terms of their prices, associated parts, the monitoring methods and the required calculations. It also requires the expertise and precision of the people employed (surveyors), [5].

And because of the need of these devices (surveying GPS) of the requirements and the inability of many institutions and companies to provide and desire to use these techniques, which led to the use of (GPS navigation) in surveying applications and the establishment of projects and try to use some mathematical and statistical methods to reach Acceptable results.

This has led to research in this area and to determine the points of strength and weakness, especially after the use of navigation GPS in surveying applications and construction of projects widely in almost all ministries, (As currently known in Iraq).

2. The principle of GPS:

The GPS (Global Positioning System) is a positioning system using a satellite called a global geodetic system or a global positioning system by receiving radio waves sent from satellites orbiting the Earth with a terrestrial receiver. The distance from the satellite to the receiver is obtained, and at the same time, based on the position information of the satellite sent from the satellite, the receiver Dimensional position (degree, longitude, height) of the system,[6].
GPS started development in the 1970s by the United States, and in 1993 formally started to be declaring in operation. Although it was develop for military use, it is also use for civilian use and is now being use by a large number of users in car navigation and mobile phones. There are no restrictions on time available for radio waves from satellites to reach, and if prepare even a GPS receiver can use it free of charge. [7].
The GPS satellite is a satellite that circles 20200 km over the period of about 11 hours, 58 minutes and 2 seconds. 24 aircraft are deployed in each of the six orbital planes and operated so that four or more satellites can be permanently observed from anywhere on the earth under a good geometric arrangement. GPS satellites are

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

equipped with atomic clocks using rubidium (Rb) and cesium (Cs), and transmit radio waves and signals to the ground with an extremely accurate cycle. 4 to 8 satellites can be observe at all times in the sky above elevation angle 15 degrees. The main specifications of GPS are shown in Table (1). [8], [9].

Table 1: Specifications of GPS satellites [10].

Number of satellites	24 (4 machines × 6 orbital plane)
Orbital radius	26561.7 km (sky approximately 20200 km)
Orbiting period	about 11 hours 58 minutes 2 seconds
Orbital inclination angle	55 °
Atomic clock with	rubidium, cesium

Recently, satellite-positioning systems targeting the entire Earth are progressing not only in US GPS but also in Russian GLONASS and European Galileo plan. Since the inclination angle of GLONASS satellite is 64.8 degrees and its inclination angle is larger than that of GPS satellites, if it can be used with GPS , the number of acquired satellites will increase dramatically in the middle and high latitudes area. In addition, although the system of the Galileo plan is independent of GPS and GLONASS, it is mutually compatible and aims for interoperation. For the arrangement of Galileo's satellites, 30 aircraft (3 of which are spare) satellites are supposed to be arranged at equal intervals on the orbital plane each having a tilt angle of 56 degrees. When the satellite of the Galileo plan is set at the lowest elevation angle of 15 degrees, the maximum visible number is nine. Since the maximum number of visible GPS satellites is 8, when using it with the satellite of the Galileo plan, use up to 17 positioning satellites.[11].

3. GPS radio waves and signals:

Radio waves transmitted from the GPS are two types of carrier waves, L1 wave (center frequency: 1575.42 MHz) and L2 wave (center frequency: 1227.6 MHz). Two types of digital signals are modulate and transmitted on these carrier waves. These are call C / A code (Clear and Acquisition) and P code (Precision).
These codes are irregular 0 and 1 series, and repeat the same pattern every cycle. Since this signal is call a code pattern and signals are transmit with different patterns for each satellite, the receiver can recognize the radio signal for each satellite. In addition, Co plays a role of a time mark, and using this as a marker measures the time required for radio wave arrival from the satellite to the receiver. Further, data called a navigation message (navigation message) is superimpose on the C / A code and transmitted to the L1 wave and the L2 wave. The contents are data such as satellite orbit information and satellite clock correction information. [12],[13].

4. Types of GPS positioning methods:

For GPS positioning, there is a single positioning using a single GPS receiver and relative positioning that uses two or more GPS receivers to eliminate errors. Singly positioning should receive the radio waves from four GPS satellites at the point where you are going to locate, and measure the distance to each satellite. The distance between the satellite and the GPS receiver is obtained by observing the propagation time from the satellite to the receiver and by multiplying the speed of light. In general, only the C / A code of the L1 wave can be use, so the accuracy obtained is as low as 2 to 50 m. On the other hand, in relative positioning, one receiver is installing at a known point and the other receiver is installing at a measurement point, thereby obtaining a baseline vector with high accuracy. Various positioning methods are use like differential GPS (DGPS), the RTK-GPS positioning, and the virtual reference point method…etc.[14],[15].

5. Error in GPS system:

Errors in the system can be divided into three categories.

1- Multipass

Among the radio waves reaching the antenna from GPS satellites, radio waves of low altitude satellites close to the horizontal line pass through the atmosphere of the ball over long distances, so that propagation errors may increase. As a result, the radio wave hits the feature and reflects it together with the directly received radio waves and it is receive, which becomes an error factor in distance measurement between the satellite and the antenna. [16].

2- Cycle slip

If the radio waves from the satellite are interrupting by an obstacle or the like, the phase measurement is interrupt and value is record by an integer, obstacles determine the integer value bias possible cyclic slips occur when passing under the roof, in a place surrounded by trees and near the building.

3- Other

Problems related to reception of GPS are other than multi pass and cycle slip. For example,

- Unjustified satellite clock
- The errors of controllers caused by operators, and these errors range from 1 meter to hundreds of kilometers.
- Errors caused by users (device settings, geodetic reference selection… etc.)

Noise errors and up to a meter limit.

6. Area of study:

The area of study chosen in the garage of the Faculty of Engineering, University of Al - Qadisiyah, Iraq, an open area free from buildings and trees to avoid possible signal errors within the Global Positioning System, on an area about 6500 m2, the ground control points (BM) were distributed in the form of a polygon. As shown in fig. (1).



(a)



(b)

Fig. 1: (a) Shows the location of Al - Qadisiyah province within the map of Iraq, (b) Shows the area of study in the Faculty of Engineering, University of Al - Qadisiyah

7. Practical steps:

The research project carried out in three steps:

7.1 The first step:

Making and setting five ground control points (BM) in an open area of about 6,500 m 2 to avoid signal error, the ground control points made as (40 x 40) cm for the bottom base and 25x25 cm for the upper base, 40cm height and 30cm for the ground installation. A 15mm spiral screw was place in the middle of the upper base to installing the Total Station and measuring distances. As shown in fig. (2)



Fig. 2: (a) Shows ground control points (BM) manufactured, (b) Shows stabilized of ground control point (BM), (c) Shows distribution of ground control point (BM) in area of study.

7.2 The second step:

Monitoring by (GPS) for each point using three (GARMIN e trex venture) for five days. The three devices placed at each point of the (BM) for four consecutive hours and the horizontal coordinates (X, Y) recorded at different periods. The methodology explained in tables (2 - 6).

7.3 Third step:

The Total station is installing at each point of the ground control (BM) as an instrument station and observed other (BM). Input coordinates taken from the GPS device after the calculations and the extraction of Best Value in the Total Station of the point in instrument station. Set a point as (BS) for the monitoring process, a point on which the device depends on the base line to start from to monitor the remaining points. Conduct monitoring by directing the telescope to the reflector at the other points (BM) and reading coordinates.

8. Calculations:

After the process of making and setting the ground control points BM (first stage), the second stage started, the observations carried out using GPS devices for all the (BM) points and obtaining the data shown in tables 2 to 6, and then represent this tables in diagrams as shown in figures 4 to 8.

Table 2: The data of BM 1 that observed by GPS navigator devices, (I, II, III).

BM1											
I				II				III			
Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North
0 min	9	489792	3539913	0 min	6	489797	3539911	0 min	5	489792	3539912
1 min	11	489795	3539912	1 min	9	489797	3539913	1 min	5	489791	3539916
2 min	11	489793	3539914	2 min	8	489797	3539914	2 min	9	489791	3539917
5 min	11	489793	3539914	5 min	8	489795	3539913	5 min	9	489793	3539919
10 min	11	489793	3539912	10 min	8	489797	3539914	10 min	9	489792	3539916
15 min	10	489794	3539913	15 min	9	489797	3539914	15 min	9	489792	3539917
30 min	9	489792	3539910	30 min	10	489797	3539915	30 min	11	489795	3539916
1 hr	7	489793	3539912	1 hr	7	489798	3539919	1 hr	8	489791	3539915
2 hr	9	489794	3539914	2 hr	7	489800	3539918	2 hr	11	489790	3539920
3 hr	9	489791	3539913	3 hr	7	489792	3539916	3 hr	11	489789	3539916
4 hr	9	489795	3539915	4 hr	7	489786	3539916	4 hr	11	489790	3539915

Table 3: The data of BM 2 that observed by GPS navigator devices, (I, II, III).

BM2											
I				II				III			
Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North
0 min	8	489740	3539935	0 min	10	489738	3539936	0 min	7	489740	3539935
1 min	8	489739	3539937	1 min	9	489739	3539934	1 min	8	489742	3539937
2 min	9	489739	3539937	2 min	10	489738	3539935	2 min	10	489741	3539936
5 min	9	489738	3539936	5 min	10	489740	3539938	5 min	8	489741	3539937
10 min	10	489738	3539937	10 min	10	489739	3539939	10 min	9	489742	3539938
15 min	10	489738	3539937	15 min	8	489740	3539941	15 min	9	489741	3539938
30 min	9	489738	3539939	30 min	9	489737	3539938	30 min	8	489740	3539937
1 hr	10	489737	3539938	1 hr	8	489741	3539938	1 hr	9	489742	3539935
2 hr	9	489744	3539936	2 hr	8	489740	3539936	2 hr	9	489740	3539933
3 hr	11	489736	3539938	3 hr	10	489740	3539940	3 hr	9	489745	3539938
4 hr	9	489739	3539937	4 hr	9	489740	3539938	4 hr	10	489739	3539934

Table 4: The data of BM 3 that observed by GPS navigator devices, (I, II, III).

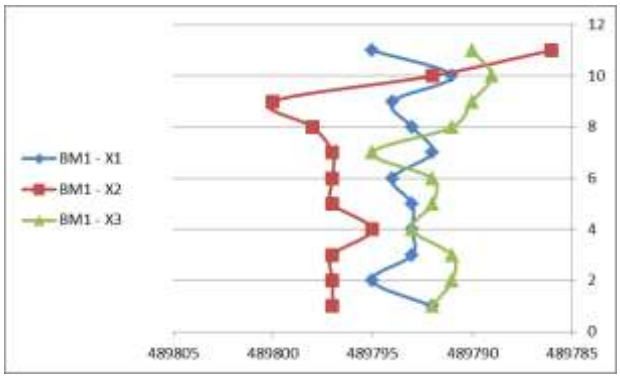
BM3											
I				II				III			
Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North
0 min	11	489752	3539977	0 min	10	489754	3539973	0 min	9	489757	3539973
1 min	9	489754	3539975	1 min	8	489756	3539974	1 min	11	489755	3539973
2 min	9	489754	3539972	2 min	9	489754	3539975	2 min	9	489756	3539974
5 min	10	489752	3539972	5 min	8	489753	3539972	5 min	9	489753	3539975
10 min	10	489755	3539971	10 min	8	489755	3539973	10 min	8	489755	3539976
15 min	8	489752	3539973	15 min	8	489755	3539972	15 min	8	489756	3539974
30 min	6	489751	3539974	30 min	7	489756	3539971	30 min	7	489758	3539974
1 hr	8	489752	3539973	1 hr	9	489755	3539976	1 hr	9	489756	3539975
2 hr	10	489753	3539971	2 hr	9	489756	3539978	2 hr	9	489759	3539979
3 hr	9	489756	3539978	3 hr	9	489753	3539977	3 hr	8	489751	3539970
4 hr	8	489758	3539979	4 hr	11	489752	3539974	4 hr	10	489759	3539976

Table 5: The data of BM 4 that observed by GPS navigator devices, (I, II, III).

BM4											
I				II				III			
Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North
0 min	9	489798	3539959	0 min	8	489791	3539965	0 min	8	489786	3539959
1 min	10	489795	3539960	1 min	8	489799	3539960	1 min	8	489787	3539958
2 min	10	489796	3539961	2 min	8	489795	3539958	2 min	8	489784	3539956
5 min	9	489794	3539961	5 min	9	489800	3539961	5 min	8	489786	3539960
10 min	9	489794	3539964	10 min	9	489794	3539964	10 min	8	489789	3539957
15 min	8	489796	3539961	15 min	9	489798	3539962	15 min	9	489796	3539960
30 min	8	489793	3539963	30 min	9	489797	3539961	30 min	7	489789	3539962
1 hr	10	489792	3539968	1 hr	9	489800	3539960	1 hr	8	489796	3539961
2 hr	9	489797	3539963	2 hr	8	489796	3539959	2 hr	9	489785	3539959
3 hr	8	489792	3539962	3 hr	8	489796	3539963	3 hr	7	489787	3539959
4 hr	8	489797	3539960	4 hr	8	489792	3539961	4 hr	7	489784	3539963

Table 6: The data of BM 5 that observed by GPS navigator devices, (I, II, III).

BM5											
I				II				III			
Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North	Time	No. Of Satellite	East	North
0 min	9	489772	3539946	0 min	9	489769	3539941	0 min	11	489773	3539946
1 min	9	489771	3539943	1 min	10	489769	3539941	1 min	10	489770	3539944
2 min	10	489773	3539940	2 min	10	489763	3539950	2 min	10	489769	3539944
5 min	11	489772	3539942	5 min	10	489770	3539948	5 min	11	489770	3539944
10 min	9	489770	3539944	10 min	10	489771	3539946	10 min	10	489771	3539942
15 min	11	489769	3539943	15 min	10	489769	3539946	15 min	9	489770	3539941
30 min	8	489772	3539942	30 min	9	489771	3539950	30 min	9	489770	3539944
1 hr	11	489769	3539942	1 hr	10	489771	3539946	1 hr	11	489769	3539945
2 hr	11	489768	3539944	2 hr	9	489773	3539944	2 hr	10	489769	3539946
3 hr	8	489769	3539945	3 hr	8	489760	3539943	3 hr	9	489768	3539948
4 hr	10	489777	3539945	4 hr	8	489770	3539941	4 hr	11	489773	3539945



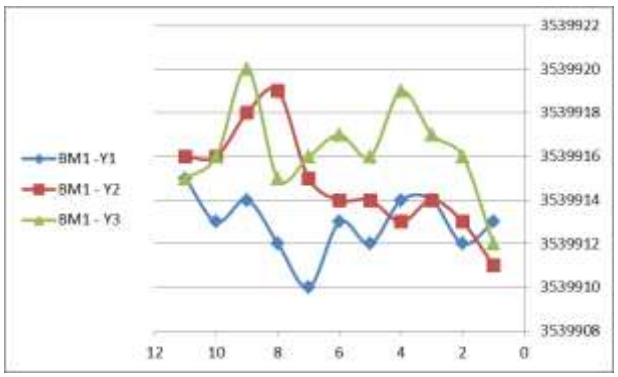
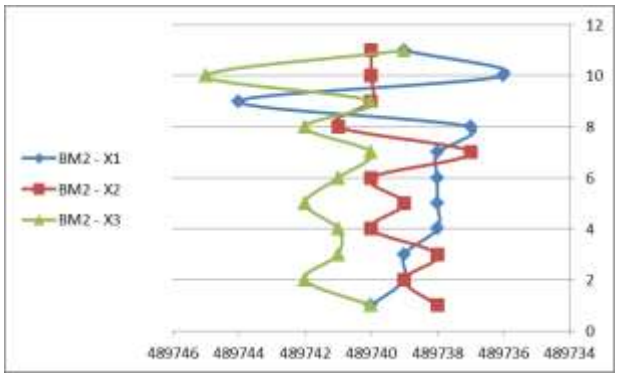


Fig. 3: BM 1 observed by GPS navigator devices (I, II, III), in X and Y coordinates.



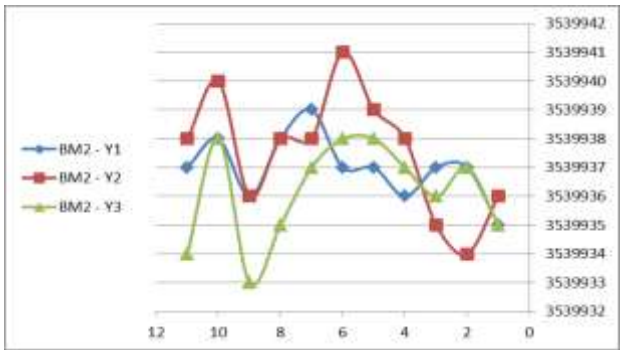
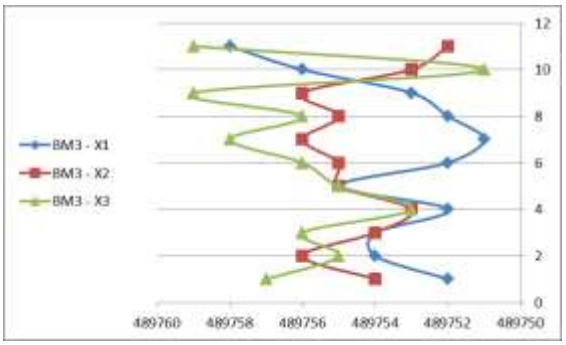


Fig. 4: BM 2 observed by GPS navigator devices (I, II, III), in X and Y coordinates.



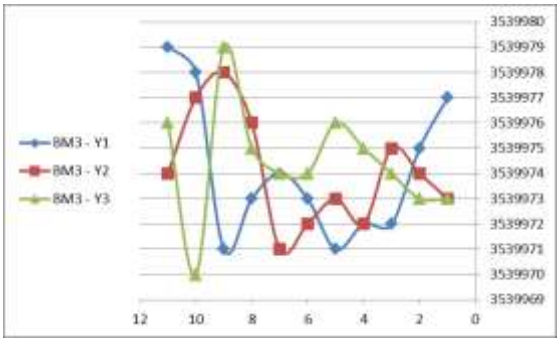
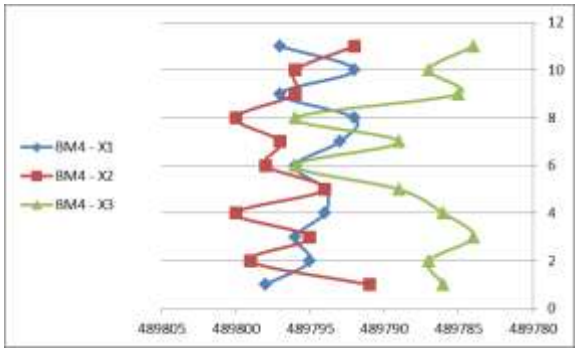


Fig. 5: BM 3 observed by GPS navigator devices (I, II, III), in X and Y coordinates.



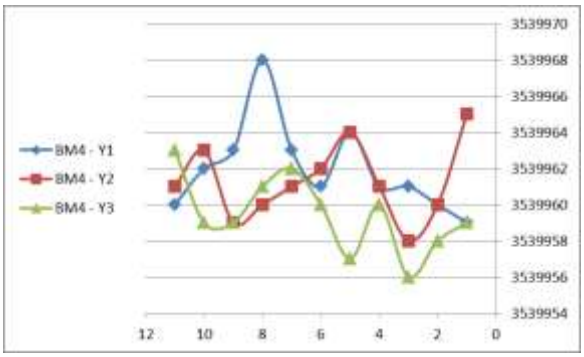
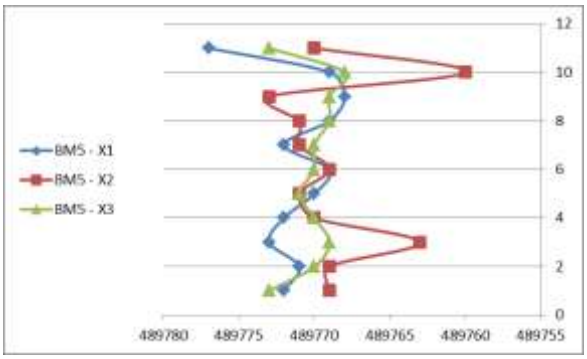


Fig. 6: BM 4observed by GPS navigator devices (I, II, III), in X and Y coordinates.



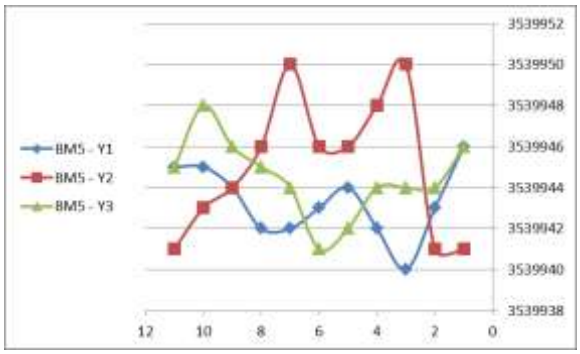


Fig. 7: BM 5observed by GPS navigator devices (I, II, III), in X and Y coordinates.

Then setting out the observed values (coordinates) in the GIS program to show the relationship between them as a real coordinates as shown in Fig. (8), and use the equations of the statistical and spatial analysis for purpose of determining the direction of the spread values as shown in fig. (9).



Fig. 8: represent the X,Y coordinates values observed by navigation GPS devices (blue I, red II, green III) let fall in the GIS program.

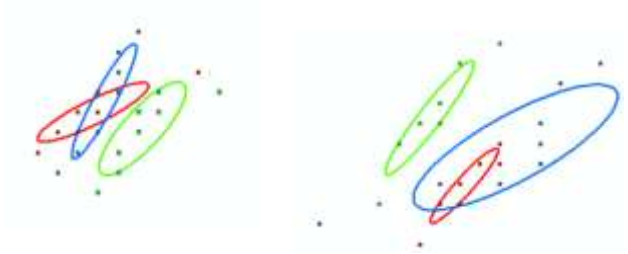


Fig. 9 direction of the spread values for the X, Y coordinates values observed by navigation GPS devices (blue I, red II, green III) let fall in the GIS program for BM1 & BM2.

For applying the third stage, the statistical equations below applied to extract the best value of the points to three devices and input to TOTALSTATION as the initial coordinates of the instrument station and back sight point, this result as shown in tables 6 to 11.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \ldots\ldots \quad (1)$$

Where:
n = The frequency of measurement for the variable
xi = the measurements to (n) of the variables

$\bar{x}$ = Average = the best value for the variable

$$\delta_{x_i} = \pm\sqrt{\frac{\sum_{i=1}^{n} V_i^2}{n-1}} \quad (2)$$

Where:

$$\sum_{i}^{n} v_i^2 = v_1^2 + v_2^2 + \ldots\ldots + v_n^2$$

v_i = Residual error in measurement

$$v_i = x_i - \bar{x}$$

δ_{xi} = The standard error of one of these measurements

$$\delta_{\bar{x}} = \pm \frac{\delta_{xi}}{\sqrt{n}} \ldots\ldots\ldots\ldots\ldots (3)$$

Where:

$\delta_{\bar{x}}$ = The standard error of the mean.

Table 7: The data of BM 1 that observed by TOTALSTATION for best values coordinates that extract from GPS navigator devices (I, II, III)

	I			II		II	
BM1	Calc HD	59.545		Calc HD	60.858	Calc HD	54.072
	Obs HD	54.992		Obs HD	54.985	Obs HD	54.996
	DHd	-4.553		DHd	-5.782	DHd	0.925
		X	y	x	y	X	Y
	BM.2	489742.9	3539935.14	489744.74	3539935.33	489740.35	3539936.52
	BM.3	489758.26	3539970.36	489758.91	3539971.1	489754.36	3539972.3
	BM.4	489800.39	3539957	489801.43	3539959.07	489796.97	3539960.55
	BM.5	489775.26	3539941.82	489776.8	3539943.08	489772.4	3539944.47

Table 8: The data of BM 2 that observed by TOTALSTATION for best values coordinates that extract from GPS navigator devices (I, II, III)

	I			II		II	
BM2	Calc HD	39.941		Calc HD	39.574	Calc HD	41.009
	Obs HD	38.427		Obs HD	35.441	Obs HD	38.426
	DHd	-1.515		DHd	-1.133	DHd	-2.583
		X	y	x	y	X	Y
	BM.1	489789.69	3539916.37	489789.99	3539916.22	489792.41	3539916.23
	BM.3	489753	3539972.64	489754.03	3539973.03	489754.99	3539972.03
	BM.4	489795.53	3539960.6	489796.39	3539960.4	489797.71	3539960.54
	BM.5	489770.86	3539944.67	489771.49	3539944.79	489773.25	3539944.31

Table 9: The data of BM 3 that observed by TOTALSTATION for best values coordinates that extract from GPS navigator devices (I, II, III)

	I			II		II	
BM3	Calc HD	43.095		Calc HD	43.651	Calc HD	35.505
	Obs HD	44.198		Obs HD	44.249	Obs HD	44.154
	DHd	1.104		DHd	0.598	DHd	8.649
		X	y	x	y	X	Y
	BM.1	489789.74	3539917.45	489790.02	3539917.02	489783.17	3539913.08
	BM.2	489738.98	3539938.56	489739.43	3539938.68	489736.16	3539941.5
	BM.4	489795.93	3539961.68	489796.73	3539961.12	489795.96	3539955.76
	BM.5	489771.17	3539945.89	489771.73	3539945.68	489769.06	3539943.93

Table 10: The data of BM 4 that observed by TOTALSTATION for best values coordinates that extract from GPS navigator devices (I, II, III)

	I			II		II	
BM4	Calc HD	49.121		Calc HD	46.457	Calc HD	43.313
	Obs HD	44.674		Obs HD	44.652	Obs HD	44.695
	DHd	-4.448		DHd	-1.806	DHd	1.382
		X	y	X	y	X	Y
	BM.1	489793.3	3539917.36	489795.71	3539916.74	489791.54	3539914.9
	BM.2	489740.56	539933.062	489742.6	3539930.92	489737.37	3539942.58
	BM.3	489751.32	3539969.98	489752.41	3539968.1	489743.94	3539962.46
	BM.5	489771.82	3539943.73	489773.55	3539942.37	489767.25	3539938.69

Table 11: The data of BM 5 that observed by TOTALSTATION for best values coordinates that extract from GPS navigator devices (I, II, III)

	I			II		II	
BM5	Calc HD	32.965		Calc HD	30.406	Calc HD	30.157
	Obs HD	33.063		Obs HD	33.061	Obs HD	32.969
	DHd	0.098		DHd	2.655	DHd	2.812
		X	Y	x	y	X	Y
	BM.1	489788.7	3539914.16	489788.05	3539917.03	489790.23	3539917.01
	BM.2	489738.6	3539936.99	489736.7	3539936.87	489738.45	3539935.41
	BM.3	489754.42	3539972.04	489750.37	3539972.84	489751.13	3539971.65
	BM.4	489796.42	3539958.16	489793.13	3539961.44	489794.17	3539961.52

9. Conclusion

By tracking the data extracted from the study in different stages, and when tracking the data in tables 2 to 6, and seeing its behavior through the figures 4 to 8, we note, that the values observed in these devices are (random values) variable from one device to another, and from time to time. When using the statistical equations from 1 to 3 to obtain the best value (most probable value), note that these values are different from device to another in the same point as shown in Figures (10 and 9). When using the GIS program, the distribution of the random values observed for the same point varies from one device to another. After extracting the best value of the points allocated for each GPS receiver separately and input them as initial values in the TOTALSTATION device, and observed the remaining points relative to these values, there is no corresponding between the values extracted from the relative monitoring using TOTALSTATION device and the most probable values extracted from all GPS devices. Finally, we can get the following:

1- The study showed that, the error in the navigation GPS devices is a random error varies from one device to another.
2- The study showed that, cannot be specified the error in BM as a reference and observed another point on it.
3- The study showed that, cannot be determined the direction of scatter readings to the observed point (by navigation GPS) or specific frame, as well as the central distance of the readings are changing from one device to another and from point to point.
4- The study recommends that should not be used navigation GPS devices in the survey work. In addition, re-survey all areas are observed or defined its borders by using this device (navigation GPS) by serving GPS devices with required accuracy.

References

[1] James Bao-Yen Tsui, " Fundamentals of Global Positioning System Receivers: A Software Approach", Wiley & Sons, Inc.,2000.
[2] Wang, Y., Forman, G., & Wei, H., "Mining large-scale GPS streams for connectivity refinement of road maps". The Computer Journal,2015.
[3] Mario A. Gomarasca," Basics of Geomatics", Springer Dordrecht Heidelberg London New York,2009.
[4] J.Parthasarathy, " Positioning and Navigation System Using GPS", International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Volume XXXVI, Part 6, Tokyo Japan 2006
[5] Chen YQ and XF He," Contribution of Pseudolite observations to GPS precise surveys". KSCE Journal of Civil Engineering, 2008.
[6] Akbar, M. Thakkar, D. Jones, K. Adom, and N. Rashidi, " GPS Satellite Precision Global Surveying", IAJC-IJME International Conference, 2008.
[7] Norsuzila Ya'acob, Siti Sarah Saaiddutdin, Azita Laily Yusof and Nani Fadzlina Naim," Bluetooth GPS Application Based on Latitude and Longitude FOR Child Tracking Model", ARPN Journal of Engineering and Applied Sciences, 2017.
[8] Ali Pirsiavash, " Basic Concept of GPS and Its Applications", IOSR Journal Of Humanities And Social Science, Volume 21, Issue 3, 2016.
[9] Panos Psimoulis," Potential of Global Positioning System (GPS) to measure frequencies of oscillations of engineering structures", Journal of Sound and Vibration,2008.
[10] US Army Corps of Engineers, "NAVSTAR Global Positioning System Surveying", Washington, DC 20314-1000, manual No. 1110-1-1003,2003.
[11] Ali Pirsiavash, Ali Broumandan, Gérard Lachapelle and Kyle O'Keefe, "Galileo E1/E5 Measurement Monitoring - Theory, Testing and Analysis", European Navigation Conference, 2018.
[12] Arvind Roy," Ionospheric Affects on GPS Signals", International Journal of Advanced Research in Electronics and Communication Engineering, Volume 6, Issue 6, 2017.
[13] Charles S. Carrano, Keith M. Groves, William J. McNeil, and Patricia H. Doherty," Scintillation Characteristics across the GPS Frequency Band", 25th International Technical Meeting of the Satellite Division of the Institute of navigation, 2012.
[14] Xingxing Li, Maorong Ge, Hongping Zhang, Jens Wickert, " A method for improving uncalibrated phase delay estimation and ambiguity-fixing in real-time precise point positioning", Journal of Geodesy, Volume 87, Issue 5, 2013.
[15] Nelson Acosta & Juan Toloza," Techniques to improve the GPS precision", International Journal of Advanced Computer Science and Applications, Vol. 3, No.8, 2012.
[16] James R. Wright, "GPS Composite Clock Analysis", International Journal of Navigation and Observation, 2008