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A PROPOSED COST-EFFECTIVE APPROACH USING SMARTPHONES FOR CAPTURING DESCRIPTIVE DATA FOR GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

Nowadays, achieving precise positioning accuracy may be accomplished by using an expensive geodetic receiver (GNSS). Moreover, some applications do not need such exact positional precision. In recent times, smartphones have included Global Navigation Satellite Systems (GNSS) to determine their location, particularly for collecting descriptive data to update the attribute data of geographic information systems (GIS). This process does not require high levels of positional precision. The present study comprises two experiments. The first experiment is conducted in a small, unobstructed local region that provides optimal circumstances. Its purpose is to demonstrate the varying levels of precision in Global Navigation Satellite Systems (GNSS) for precise point positioning (PPP). Both single- and dual-frequency devices are used, and the International GNSS Service (IGS) correction is applied to highlight the fact that high accuracy is not necessarily required. Conversely, the second proposal proposes a cost-effective idea for an application that may be developed utilizing a smartphone to update attribute data instead of relying on a personal digital assistant (PDA) device and PPP. The accuracy ranges were determined by applying PPP, GNSS, and IGS adjustments. For single frequency, the range was 0.054 m to 0.330 m, while for dual frequency; it was 0.053 m to 0.280 m. The accuracy of location utilizing a single-frequency GNSS on a smartphone ranged from 1.2 m to 1.6 m, as shown by the revised descriptive data in GIS applications.

Keywords: (GNSS), precise point position (PPP), (GIS), international GNSS service (IGS), global position system (GPS), and personal digital assistant (PDA).

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1. INTRODUCTION

Precise point position PPP is a technique developed many years ago to get the accuracy of positioning for some applications that do not require high position accuracy within a few meters or decimeters without using any correction procedure. Also, with the development of positioning techniques and the many constellations, GNSS is used to improve the absolute coordinates without the need to connect with the base or reference stations [1]. In addition, the possibility of correcting errors caused by GNSS observations is reduced by using International GNSS Service (IGS) products such as the satellite orbits accessed, satellite clocks, earth rotation parameters, and atmospheric parameters. So, this adds a significant advantage to the use of the PPP method in terms of saving time and cost, ensuring commensurate accuracy, and applications that meet this accuracy, such as collecting and updating metadata information for medium-scale base maps for GIS [2]. Furthermore, the presence of more satellites from different constellations will help to increase the accuracy instead of using a single system only, achieving higher accuracy and lower convergence intervals through increased satellites. The four fully operated, independent Global Navigation Satellites from different organizations, such as GPS, GLONASS, the European Galileo, and BeiDou, are currently being implemented concurrently context when increasing the number of received satellite signals with good satellite geometry leads to better position accuracy.

Every system, including the ones mentioned above, works to have an independent estimate of the coordinates of points on the Earth's surface. The main reason for using global satellite navigation systems is occasionally based on working an independent way with military GPS or improving the accuracy by integration with it. The satellite geometry and strength help to eliminate or decrease some observation errors and dilution of precision. So, the increasing number of satellites with good distribution can help achieve good satellite geometry. Other than that, the ability of all available constellations to work with each other using multiple systems means increasing the visible satellite, the number of observations, and accuracy, as shown in Figure-1.

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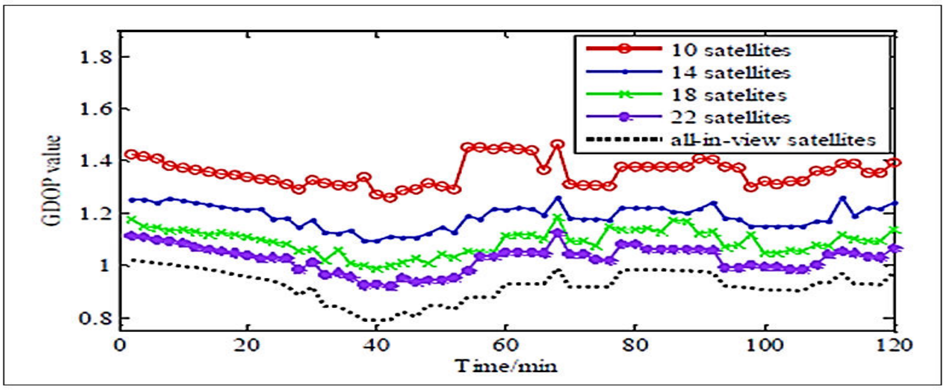

Figure-1. Increasing the number of satellites decreases the GDOP, [3].

In recent times, several multinational smartphone manufacturers have launched devices that include the capability to capture code, carrier phase, and Doppler data for GNSS observation [4, 5]. Furthermore, there are many apps compatible with the Android operating system that are now accessible to observe a single frequency using a Global Navigation Satellite System (GNSS) to determine one's location. This is seen in Figure-2.

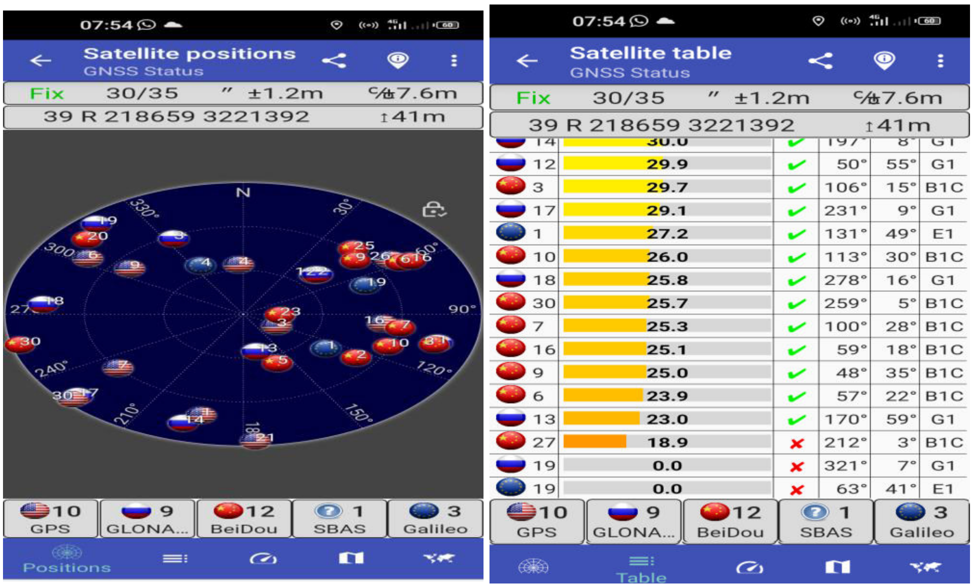

Figure-2. Android mobile application for determining the position using GNSS.

The map scale denotes the proportionate correlation between the length of the printed representation and its corresponding length in the actual field. The map scale indicates the degree of accuracy and amount of intricacy included in the map. Satellite imagery serves as a fundamental resource for acquiring a GIS base map. The ground sampling distance (GSD) or spatial resolution of satellite photos is directly correlated with the scale of the maps produced from these images. The relationship between the size of the map and the level of detail in the image may be seen in Table-1. Moreover, Table-2 illustrates the accuracy of many essential maps.

Table-1. The relationship between the map scale and the image spatial resolution [6].

Map scale (1: S)	1:1000	1:2000	1:5000	1:10000	1:25000
Ground Sampling Distance (m)	≈ 0.4	≈ 0.8	≈2	≈4	≈10

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Table-2. The accuracy of the basic scale [6].

Scale (1: S)		500000	250000	100000	50000	25000	10000	5000	2000	500
Scale accuracy (m)	e_1= 0.1 mm	50	25	10	5	2.5	1	0.5	0.2	0.05
	e_2= 0.2 mm	100	50	20	10	5	2	1	0.4	0.1
	e_3= 0.4 mm	200	100	40	20	10	4	2	0.8	0.2

This study consists of two experiments. The first experiment focuses on comparing the accuracy of various Global Navigation Satellite Systems (GNSS) for precise point positioning (PPP) using the International GNSS Service (IGS) adjustment. Furthermore, in the subsequent stage, the smartphone gathers the coordinates of specific sites with a positional precision that aligns with medium-scale maps ranging from 1:5000 to 1:10000. These maps are generated using satellite pictures with a ground sample distance (GSD) ranging from 2.5 to 4 meters, and they are shown in Tables (1) and (2). The second experiment suggests a cost-effective method for an application that the authors recommend. This application may be used on an Android smartphone to gather data and update the GIS database with attribute data.

2. STUDY AREA AND DATA SOURCES

In the first experiment, points were used to make a locally closed traverse inside the 6-October branch of the National Research Centre (NRC). This was done with the World Geodetic System 84 zone 36R ellipsoids. This is seen in Figure-3. The Trimble R8 Model 4 GNSS GPS Receiver equipment, seen in Figure-4, was used for this investigation.

Figure-3. First experimental study area inside the NRC (UTM 36R-WGS84).

Figure-4. Trimble R8 Model 4 GNSS GPS Receiver.

The second experiment was conducted at the National Research Centre in Dokki, Cairo, Egypt. The data collection was carried out using reference ellipsoids from the World Geodetic System, specifically zone 36 R. This data was used to propose a design concept in the research work, as depicted in Figure-5. The coordinates and descriptive data from the field were obtained using a Samsung Note9 mobile device, as shown in Figure-6.

Figure-5. Second experimental study area inside the National Research Centre, Cairo, Egypt (UTM 36R-WGS84).

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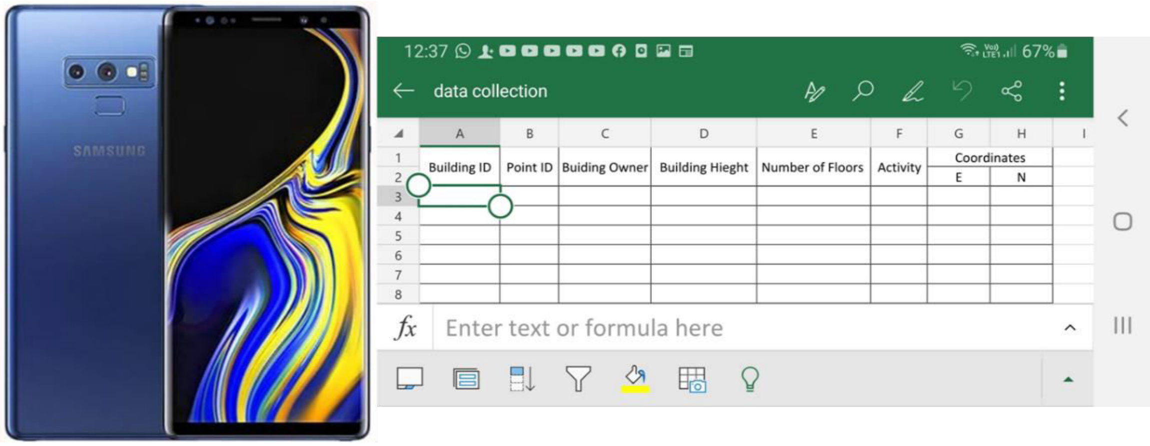

Figure-6. Smartphone data collections.

3. METHODOLOGY

This research aims to verify the concept that achieving a high level of precision is not essential for establishing location via the use of global positioning systems (GNSS) for GIS descriptive data. One will cite prior research [7, 8, and 9] that has examined the elements that affect the accuracy of monitoring, without going into detail about their unique findings in this study. Nevertheless, it is worth noting that the precision attained using the PPP approach is not necessary for gathering GIS descriptive data. PPP is a technique to get absolute coordinates that uses a pseudo-range (single/dual-frequency) carrier phase. In addition, some corrections can be used such as the satellite orbits accessed, satellite clocks, earth rotation parameters, and atmospheric parameters improve the accuracy of this technique. When working with static kinematics, the PPP method is very accurate, able to find the position within decimeters or centimeters, and it doesn't need to be connected to any reference stations. Currently, organizations like the International GNSS Service (IGS) and the European Space Operations Center (ESOC) are offering the aforementioned adjustments. The mathematical models for all accessible constellations of the multi-GNSS observations, namely GLONASS, GPS, BeiDou, and Galileo, are included as follows: -

$$P_j = \rho_j + C\,(dt - b_G{}^r) - cdT_j + d_j{}^{ion} + d_j{}^{trop} - c(B_G{}^S) + C[ISB_j] + \varepsilon_j \qquad \text{Equation 1}$$

$$\emptyset_j = \rho_j + C\,(dt - b_G{}^r) - cdT_j + d_j{}^{ion} + d_j{}^{trop} - c(B_j{}^S) + C[ISB_j] + [\lambda N_j + c(\delta j - d_j) - (\delta_j^S - d_j^S)] + \varepsilon_j \qquad \text{Equation 2}$$

Where:

j = another global navigation system (GLONASS, GALILEO, and BEIDOU);
dTG and dTJ = satellites clock error, for GPS and the other global navigation systems respectively, lumped with the ionosphere-free differential code bias, which can be obtained from the IGS-MGEX [10, 11].
$d^{ion}{}_j$ = ionospheric delay in meters;
$d^{trop}{}_j$ = the tropospheric meter-delay input;
$B^S{}_G$ and $B^S{}_J$ = bias terms, which represent the combined action of differential satellite code bias for GPS and the other global navigation systems respectively.

In comparison with the effects of other models, the estimated TEC model is used for accounting for ionosphere retardation ($d^{ion}{}_G$ and $d^{trop}{}_j$).

The standard SFPPP algorithm in the estimation process is therefore considered an unknown parameter.

In case use the high PPP use the above mention correction. The following section just shows the final results for the first and second

4. RESULTS AND DISCUSSIONS

The first fieldwork for this study project was conducted utilizing a geodetic GNSS receiver, namely the Trimble R8 Model 4 GNSS GPS Receiver, as seen in Figure-4. Table-3 displays the measurement model and the parameters for the first trial of this experiment: -

Table-3. Measurement model and the parameters for the field experimental of PPP statistic mode.

Estimator Observations	Signal selection	Sampling rate	Elevation Cutoff	Satellite Orbit & clock	Earth rotation parameter	Satellite antenna phase center	Receiver antenna phase center	Troposphere	Ionosphere
GNSS observations	GPS(L1/L2) GLONASS (L1/L2) BEIDOU (B1/B2) Galileo (E1/E5a)	15s	15^0	Fixed	Fixed	Corrected using MGEX and IGS values	Corrected	Saastamoinen model	Ionosphere-free linear combination

Table-4 displays the results obtained from the observations using IGS correction when the data are solved as a single frequency for the local traverse locations. Table 5 displays the observations obtained by applying IGS correction while solving the local traverse points as dual frequencies. Observations are collected only for GPS [12], as well as for GNSS (GPS+GLONASS+Galiileo BEIDOU) [9].

Table-4. GPS and GNSS standard division observations using IGS correction of the single frequency.

Points	GPS (S.D m)				GNSS (S.D m)			
	X	Y	Z	Position	X	Y	Z	Position
1	0.0408	0.0491	0.0457	0.0784	0.0392	0.0486	0.0458	0.0774
2	0.0601	0.0702	0.0577	0.1089	0.0315	0.0399	0.0333	0.0608
3	0.0817	0.0815	0.0951	0.1516	0.0396	0.0725	0.0411	0.0923
4	0.0561	0.0502	0.0455	0.0880	0.0313	0.0346	0.0268	0.0538
5	0.3550	0.3225	0.1606	0.5058	0.2061	0.2297	0.1239	0.3326
6	0.0698	0.0506	0.0396	0.0949	0.0443	0.0448	0.0308	0.0701
7	0.0544	0.0553	0.0500	0.0923	0.0592	0.0587	0.0479	0.0961

Table-5. GPS and GNSS standard division observations using IGS correction of the dual frequency.

Points	GPS (S.D m)				GNSS (S.D m)			
	X	Y	Z	Position	X	Y	Z	Position
1	0.0397	0.0482	0.0449	0.0769	0.0364	0.0459	0.0434	0.0729
2	0.0563	0.0658	0.0541	0.1021	0.0268	0.0356	0.0293	0.0533
3	0.0642	0.0640	0.0747	0.1175	0.0326	0.0399	0.0338	0.0616
4	0.0515	0.0460	0.0417	0.0807	0.2790	0.0300	0.0233	0.2816
5	0.2618	0.2423	0.1183	0.3758	0.1392	0.1553	0.0839	0.2248
6	0.0683	0.0495	0.0387	0.0928	0.0376	0.0370	0.0266	0.0591
7	0.0524	0.0535	0.0483	0.0891	0.0487	0.0506	0.0403	0.0810

The second phase of fieldwork for this study involves using an Android application designed for observing and calculating location using a single-frequency GNSS [13], as seen in Figure-2. The measurement observations for local traversal sites for this experiment are shown in Table 6 and Figure-7.

Table-6. GNSS standard division's observations using the smartphone single frequency.

Points	GNSS Position Accuracy (S.D m)
1	1.2
2	1.4
3	1.5
4	1.4
5	1.6
6	1.4

7	1.4

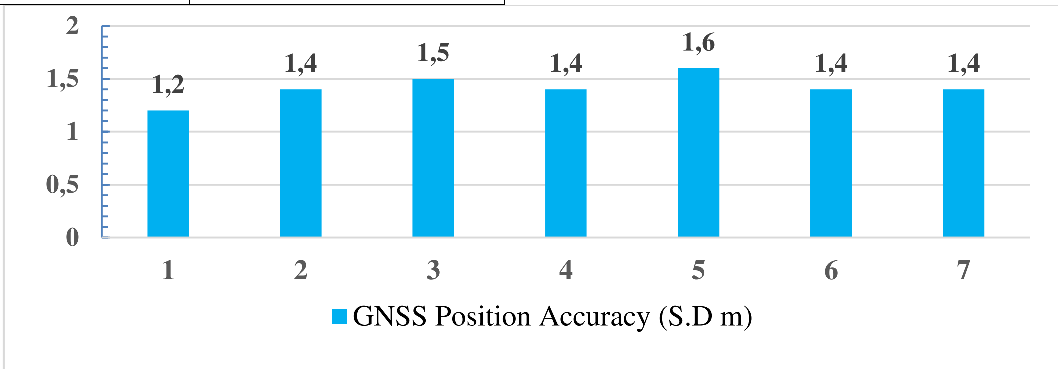

Figure-7. GNSS standard division's observations using the smartphone single frequency.

Based on the results mentioned above, it can be deduced that there is a negligible difference (accurate to the millimeter) between single and dual frequency at local traverse points seen for less than one hour when using IGS correction. From an economic and accuracy standpoint, using smartphones to estimate locations for gathering descriptive data is sufficient for GIS applications at a medium-scale map [14].

4.1 Second Experimental Suggestion Concept for Application a GIS Location-Based Mobile

This experiment focuses on proposing the creation of a mobile application for the Android platform that utilizes GPS/GNSS mobile sensor data to construct a GIS location-based system. Additionally, the application will include the display of map position information. Furthermore, it establishes a connection between geographical characteristics and the integrated spatial mobile database. The proposed method aims to achieve cost-effective data collection by using portable devices equipped with GPS/GNSS sensors, namely smartphones, which are widely accessible to the general public. These devices would be used for collecting GIS base-map data in this particular area. Figure-8 depicts the proposed functions of the idea for the application, which were implemented to gather data and update the base map for ArcGIS.

4.1.1 Results of the second experimental suggestion

The second experiment aimed to ascertain the coordinates selected in front of the buildings of the National Research Centre. The necessary data for each building was recorded, as seen in Figure-6, and then imported into a database using ArcGIS software version 10.8. Furthermore, the use of smartphone applications for determining coordinates shows, that the precision of the location (1.6m) is sufficient for effectively gathering building data, as depicted in Figures (9, and 10).

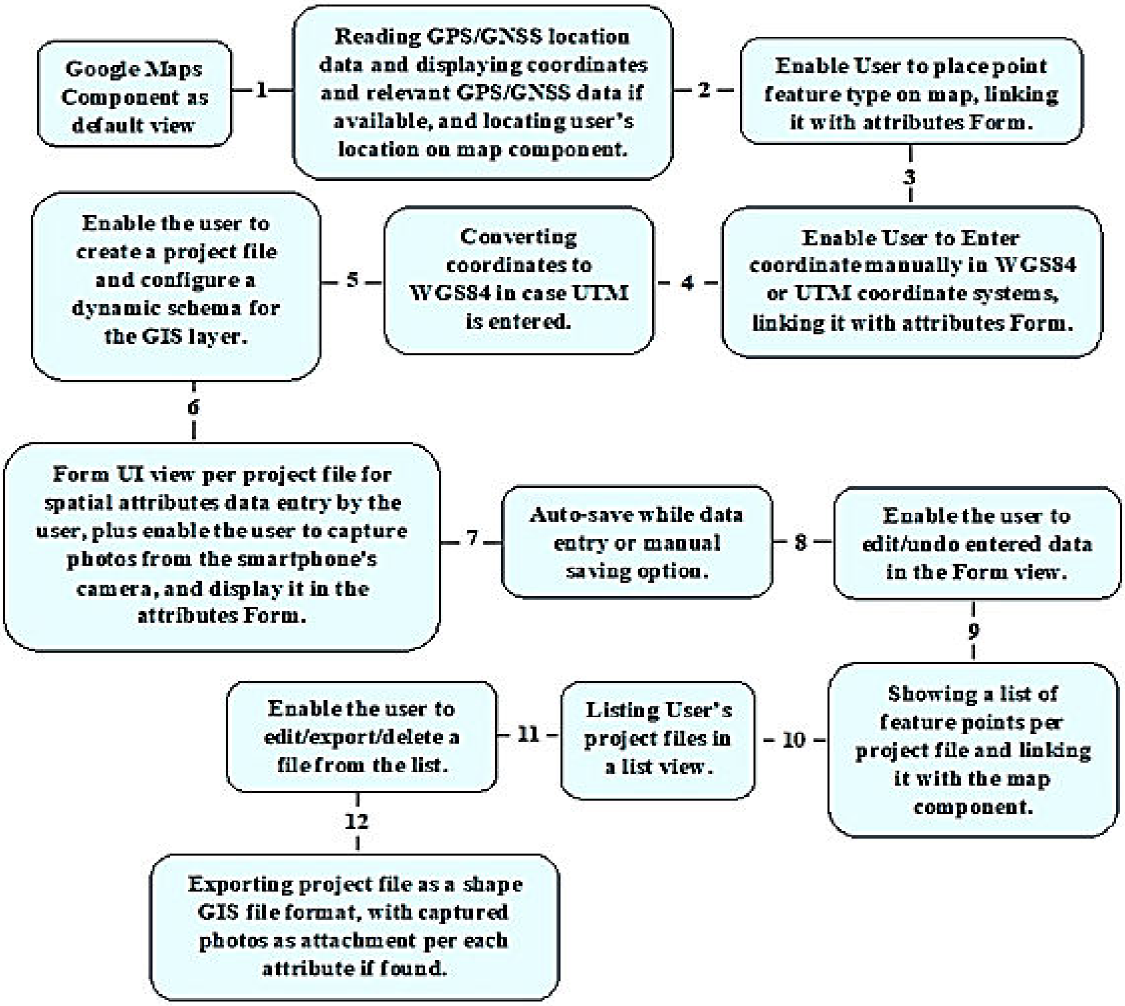

Figure-8. Diagram of the suggested functions of the GIS data collection application.

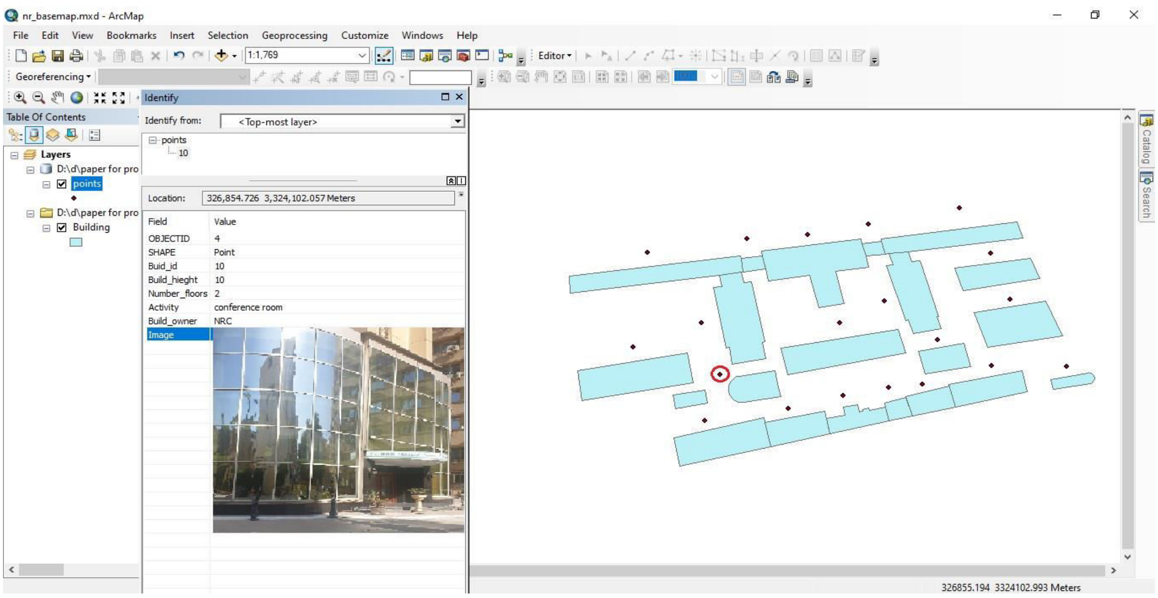

Figure-9. Example of data collection related to the new conference building.

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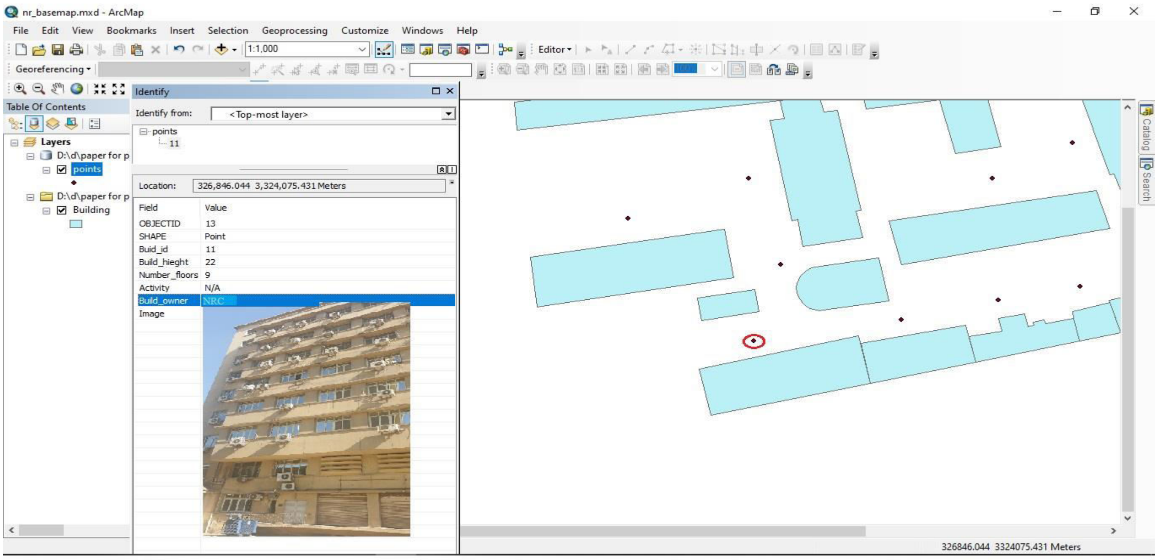

Figure-10. Example of data collection related to the Genetic Engineering building.

5. CONCLUSIONS

After, this study the results obtained can be concluded with the following recommendations.

a) The use of a single-frequency geodetic surveying receiver for GPS only using IGS correction is given the accuracy from 0.0408 m to 0.355 m in the X direction, from 0.0491m to 0.3225 m in the Y direction, from 0.0457m to 0.1606 m in the Z direction and position from 0.0784 m to 0.5058 m.

b) The use of a single-frequency geodetic surveying receiver for GNSS constellation, using IGS correction is given the accuracy from 0.0392 m to 0.2061 m in the X direction, from 0.0486 m to 0.2297 m in the Y direction, and from 0.0458m to 0.1239 m in the Z direction and position from 0.0608 m to 0.3326 m.

c) The use of a dual-frequency geodetic surveying receiver for GPS only using IGS correction is given the accuracy from 0.0397 m to 0.2618 m in the X direction, from 0.0482 m to 0.2423 m in the Y direction, and from 0.0449 m to 0.1183 m in the Z direction and position from 0.0769 m to 0.3758 m.

d) The use of a dual-frequency geodetic surveying receiver for GNSS constellation, using IGS correction is given the accuracy from 0.0364 m to 0.0.2790 m in the X direction, from 0.0459 m to 0.1553 m in the Y direction, and from 0.0434 m to 0.0839 m in the Z direction and position from 0.0591 m to 0.2816 m.

e) The using of GNSS constellation improves the accuracy of PPP more than using GPS only in both using single or dual frequency.

f) As expected, the result of dual frequency is better than the single frequency.

g) The use of single-frequency relevant GPS/GNSS data available through the smartphone with a time duration of less than 1 minute is given an accuracy of less than 2 m (from 1.2 m to 1.6 m).

h) The accuracy of position coordinates using GPS/GNSS via the smartphone is sufficient for data collection for GIS applications.

i) The proposed concept for a base to design a system is characterized as a low-cost system and fast method that achieves sufficient accuracy for updating the descriptive data of medium-scale GIS base maps.

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The National Research Centre (NRC) provided the devices that were used in the research and allowed experimental work inside the NRC branches.

LIST OF ABBREVIATIONS

GNSS	Global navigation satellite system
GIS	Geographic Information System
PPP	Precise Point Position
IGS	International GNSS Service
PDA	Personal Digital Assistant.
S.D.	Standard Deviation.
WGS 84	World Geodetic System 1984.
UTM	Universal Transverse Mercator.

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