Experimental Work for Evaluation the Time Saving Between Different GPS Techniques for Makkah- Jeddah Region

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Abstract: Nowadays, there are available in technology, devices, Techniques such as GNSS and CORS and use the VRS techniques. Although for previous technology, some application just needs for the ordinary GPS techniques. So, the current research work is done by field experiments to assess the time saving and accuracy between GPS different techniques such as Stop & Go, Kinematic, and Kinematic ON THE FLY Techniques especially in mountain areas like MAKKAH region. There are three post-processed GPS kinematic techniques. These techniques are stop &go, kinematic, and kinematic on the fly techniques. Stop& go and kinematic techniques require the so-called initialization process, which must be repeated in each cycle slip due to satellite-signal blockage. This is a time consuming and practically reduces the surveying productivity. On the other hand, the kinematic on the fly technique does not require the initialization process. This leads to increase the surveying productivity. The current paper makes a comparative study between GPS stop &go, kinematic, and kinematic on the fly techniques, from points of view of accuracy, time elapsed for the initialization process, observation time for each surveyed point and the surveying productivity. The results supported by appropriate statistical tests showed that positional discrepancies between stop-go and kinematic techniques have mean value of 22 mm σ(S.D) of ± 7 mm. Also, the positional discrepancies between the stop& go and kinematic on the techniques are statically and practically insignificant, where the results showed that the positional discrepancy between the two techniques has a mean value of 22 mm with σ (S.D) of ± 2 mm. In this context, the kinematic on the fly technique is increasing the surveying due to using a recording data of about 3-seconds for each surveying point, and also because this technique does not require any initialization process which takes a lot of time especially in case of surveying near tree, road, mountains, and advertising frames specially when internet and communication with the CORS station is missed or disconnected. Finally, in case the issues to use RTK or VRS due to communication problems specially the regions within mountains areas such as MAKKAH in this situation the GPS kinematic on the fly technique is highly recommended to replace the stop-go and kinematic techniques, in all the surveying works of medium scale. Also, the distance between the surveyed point and the reference receiver does not affect the resulted coordinates for about 7 km.

Keywords: GPS; Kinematic Technique; Stop and Go Technique; Kinematic on The Fly Technique.

I. INTRODUCTION

GPS have a different post-processed techniques of data collection and processing, which can be employed with GPS. These techniques are static, rapid static, re-occupation, stop and go, kinematic, and kinematic on the fly [1]. Even though the GPS field procedures are different from one technique to another, the principle of planning, quality control and processing are the same. Static GPS technique is an accurate and reliable technique; however, it is relatively slow in production. Also, each one of other remaining techniques such as CORS, RTK, and VRS is representing a technological solution to the problem of obtaining high productivity, such as measuring many baselines in a small period of interval, however, with a relatively less accuracy than the static case, but sometimes there are some issues related to internet and disconnected problems. So, this current research is studying an alternative, techniques in case there are issues found to use the RTK or VRS techniques especially in mountain areas like MAKKAH region. Stop & go and kinematic techniques are suffering from the re-initialization process which happens when signal blockage is happened due to obstacles during the GPS surveying. There is Certainly that, the re-initialization process takes a lot of time, which affect the surveying productivity. Also, kinematic on the fly technique does not suffer from the re-initialization process, because this technique does not require an initialization process. These were the basic motivation behind the current study. Thus, the main objective of the current paper is to make a comparative study between GPS stop-go, kinematic, and kinematic on the fly techniques, from points of view of accuracy, time elapsed for the initialization process, and the surveying productivity. In this context, the different techniques of GPS post-processed kinematics techniques will be listed and described. The different methods used for the ambiguity resolution are briefly investigated. The methodology and point of investigation will be shown, including the explanation of the conducted field test. Finally, the results will be analyzed and statically examined, from which the final conclusions and recommendations are extracted.

II. GPS POST-PROCESSED INEMATIC TECHNIQUES

GPS relative positioning uses at least two receivers simultaneously or more tracking the same number of satellites,

to determine their relative coordinate position. One of these receivers is selected as a reference station, (Base Station), which rest stationary at the site, with precisely known coordinates. The rover (another receiver), or remote receiver is of unknown coordinates. The rover may be settled or stationary, in this case static techniques, or rapid static technique, or the rover may be mobile, in this case the techniques are called kinematic techniques. The kinematic techniques are categorized into three types, which are: stop & go technique; kinematic technique, and kinematic on the fly technique, each one of these post-processed techniques will be discussed in the following sub-sections [2].
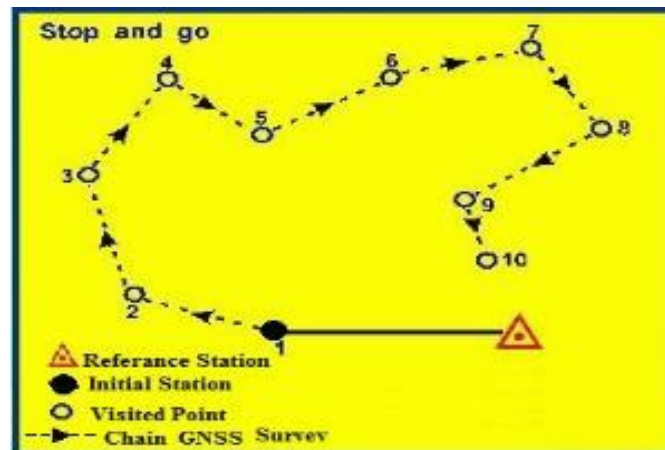
A. STOP AND GO TECHNIQUE

Figure 1: Field procedure of Stop & Go technique

The survey work is started by first determining the ambiguity parameters (initial integer ambiguity), a process known as receiver initialization. Usually, this is done in static mode. But there are many techniques can be used for solving the unknown phase ambiguities, which will be discussed later. When the ambiguity has been determined, the surveying work can be started. The rover will be moved from point to another, and is kept stationary at each point, to collect the data about 1 minute or less than 1 minute of phase data. In this procedure the cycle slip must be avoided so, it is very important that keeping the antenna continues to track the satellites, where, by this way, the resolved ambiguities are valid for the future phase observations. At what time, the signals are Stopped or obstructed, then the ambiguities have to be reinitialized [3]. The carrier phase data are processed in the double difference mode, to obtain the coordinates of the rover (unknown point) relative to the static base station. The path of the antenna isn't of interest, only the stationary points along this path which are visited by the receiver are important. It is recommended to repeat visits some of the previous occupied unknown surveyed points, or the initial point during the survey. Repeating the visit to some previously surveyed stations, gives more redundant observations, which will increase the reliability of derived unknown station coordinates, and also, helps to check of cycle slip. Revisiting of the initial point will help in processing the data backwards if any problems occur during processing data forwards [4].

The observation equation of the phase Pseudorange is:

$$\Phi = \rho + c(dt - dT) + \lambda\,N - d_{ion} + d_{trop} + d_{orb} + \varepsilon_\varphi \qquad (1)$$

Where:-

The stop & go technique is called by this name because the coordinates of the receiver are only of interest when it is stationary (the stop part), and the receiver continues to work while is being moved (the go part) from one stationary setup to the next. The implementation, of the stop and go observing technique, to determine the 3-d coordinates of any points along a certain path, is accomplished through three stages, namely: The ambiguity resolution, data collection from the roving receiver, as it's stops and kept stationary collecting data for 5-10 seconds rate of observations for a period about 30-60 seconds per each stop, and data processing to solve for the 3-d components of all baselines, between the fixed reference station and each occupied position along the path. Figure (1) shows the field procedure of stop and go technique.

The measured phase is indicated in meters by Φ, λ is the carrier wavelength,

N = The phase ambiguity,

ε_φ = The combined receiver and multipath noise,

c = About 3×10^8 m/s, (velocity light),

dt and dT = Satellite and clock errors for receiver respectively,

d_{ion}, and d_{trop}, = The error due to ionospheric, tropospheric refraction respectively, and

d_{orb} = The orbital error

The fundamental of the stop & go technique is the use of the double difference mode, to eliminate most of the encountered GPS biases, to fast ambiguity initialization. The double difference carrier phase observation equation for one baseline and two satellites is given by:

$$\nabla\Delta\Phi = \nabla\Delta\rho + \lambda.\nabla\Delta N - \nabla\Delta d_{ion} + \nabla\Delta d_{trop} + \nabla\Delta\varepsilon_\phi + \nabla\Delta\,d_{orb} \qquad (2)$$

The satellite clock error dt, and receiver clock bias dT, can be eliminated, by using this type of receiver to satellite double difference mode. So, this observation equation is repeated for each baseline and each pair of observed satellites. The number of points that can be determined in one session depends on the number of available receivers. The number of new established points is directly proportional to the number of available receivers, whereas, the longer observing time period, the higher obtained accuracy. Usually, the range of accuracy for static survey, is normally 3–10 mm + 1–2 ppm [5].

The static surveying is usually applied in high accuracy surveying projects, such as establishing new geodetic networks, densification of existing first order control networks or lower order network, crustal movements, and structural deformation.......ect[6].

B. KINEMATIC TECHNIQUE

The aim of the GPS kinematic observing technique is to determine the position of the antenna while it is in motion (in case the RTK not available). The main difference between stop and go and kinematic techniques, is that in Kinematic technique, the coordinates of roving receiver are calculated at all points separated by pre-specified time interval, along the survey trajectory, whereas, in stop and go technique, the coordinates of the roving receiver are calculated at selected points. There is a great similarity between both the kinematic and stop & go techniques which is the ambiguity must be determined during the initialization step before starting the survey, and the ambiguity must be reinitialized if a cycle slip occurs during the survey work [7]. The field procedure of Kinematic technique will be shown in figure (2).
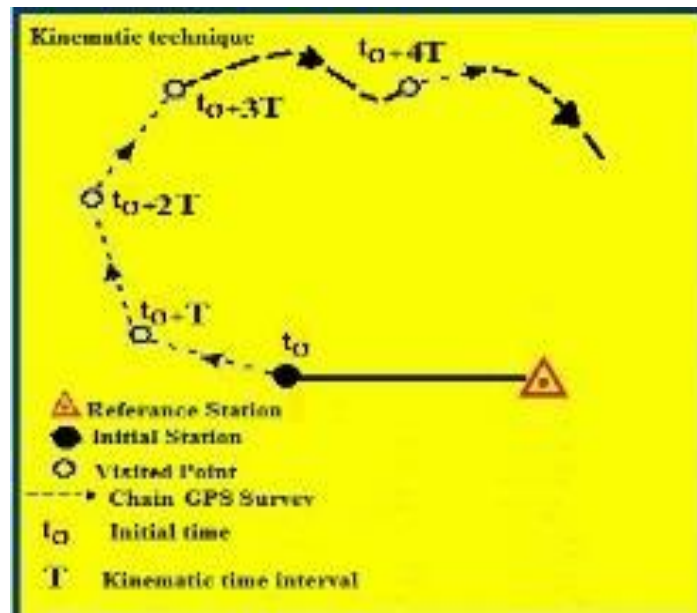

Figure 2: Field procedure of Kinematic technique

The field experiment work steps of the GPS kinematic technique, observation is carried out by setting receiver on a base reference station (a known reference point) and a rover receiver on an arbitrary specific point. An adequate data from at least 4 satellites must be collected to ensure ambiguity resolution, which may be resolved by any one of the three methods which will be discussed in the following section. Thereafter the rover receiver can start moving and begins the survey work, where, the observations are taken a certain time interval. As mentioned before, when the receiver is being in motion, at least four satellites have to be tracked continuously and no loss of lock happens. Nevertheless, if any obstructed is occurring for the receiver (underpass for example), or there are less than four satellites in view being tracked, the ambiguity resolution has to be resolved again. So, care should be taken in the field, during the planning stage, such that no obstacles exist Through the survey path, which may cause loss of data [8]. In General, the expected path accuracy is slightly less than static survey due to the increased number of unknown parameters to be estimated. Typically, a precision of 10 to 20 mm+1 ppm can be achieved. Kinematic technique is the most productive technique in determining a great number of points in a short time (in case the RTK techniques is not available especially in the Holy MAKKAH region through the Mountains). So, this technique can be used in the determination of moving object route, such as, road and highway surveys, position of boats and airplanes……. etc. [9].

C. KINEMATIC ON THE FLY TECHNIQUE

Kinematic on the fly technique provides the path of a moving receiver without the necessity of static initialization. The moving receiver can be moved directly from the first observations onwards. The following requirements are essential for kinematic on the fly technique [10]:

1. Using Dual frequency data.
2. A minimum of five satellites are tracked from the first epoch.
3. Good geometry or low GDOP values.
4. No cycle slips or loss of lock during the first 200 seconds.
5. A maximum distance of about 10 km between the reference and rover receivers.

In this technique (Kinematic on the fly) is carried out by putting a receiver on base station reference at a known reference point and a rover receiver on the first point on the path to be surveyed. The rover can be working without any initialization process, where the observations are taken by pre-set time interval. Figure (3) shows the field procedure of kinematic on the fly technique. Kinematic on the fly technique has an advantage of saving time in the initialization process and every re-initialization process due to loss of lock. This will surely increase the surveying productivity[11].
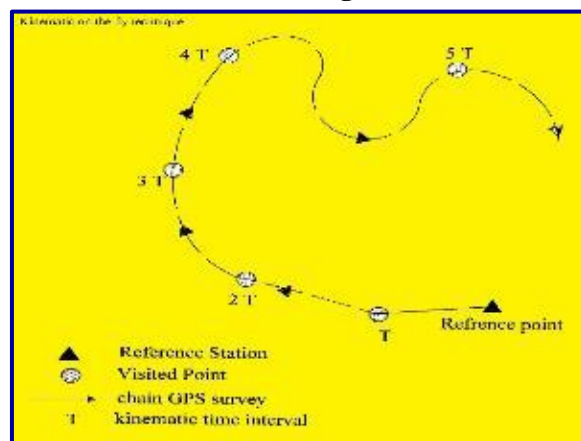
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Figure 3: Field procedure of Kinematic on the fly technique

III. RESOLUTION OF THE AMBIGUITY

When tracking GPS satellites, there are two different types, measurements can be performed. One of them is the Pseudorange and the other is a carrier phase measurements. Usually, the accuracy of Pseudorange measurements can reach, in the best cases, the sub-meter accuracy. But, the carrier phase measurements, is representing very accurate range measurements between the orbiting satellites and the ground receivers, [12]. From the previous mentioned, the carrier phase measurements are more accurate than Pseudorange. The initial measurements of the carrier phases of the signals received by a GPS receiver, as it starts tracking the signals, are undetermined, or ambiguous, by an integer number of carrier wavelengths. A GPS receiver has no way of counting the number of the complete cycles of the incoming signals. The best it can do is the measurement of the fractional part of the signal, and then it keeps track of the phase changes, [13]. The initial integer number of complete cycles between the satellite and the receiver is known as ambiguity, and it is usually denoted as (N). The problem of the resolution of the carrier beat phase ambiguities can be classified into the two distinct parts of ambiguity estimation and ambiguity validation problems. The estimation process is the problem of finding optimal estimators for the unknown ambiguities. The validation problem is concerned with the testing of the quality of the estimated phase ambiguities. The validation part is of importance in its own and quite distinct from the estimation part. One will always be able to compute a solution for the required ambiguities, whatever its quality. Therefore, the main task of the validation part is to study whether the quality of the computed ambiguities is acceptable for the final GPS position solution or not [14]. The static GPS technique, where a long time of observations is allowable, the Classical method for ambiguity resolution is applied. The Classical method is depending on combining phase and code data [15]. The basic idea here is based on performing code measurements, until the noise level of the code solution becomes less than half the wavelength of the used carrier wave. Then, the phase measurements can be used, along with the obtained code solution to resolve the required phase ambiguity sets using the wide-lane linear combination, which produces a signal of wavelength of approximately 86 cm. Once the ambiguities are resolved correctly, ambiguities of original signals can be determined easily, if the ionospheric effect properly modeled or eliminated. Concerning the GPS kinematic techniques, there are two ambiguity resolution methods. Stop and go, and Kinematic GPS techniques, a method for ambiguity resolution called Fast Ambiguity Resolution Algorithm FARA is commonly used. On the other hand, for ON THE FLY technique, a method for ambiguity resolution called ON THE FLY(OTF) is used. Each one of the mentioned two methods will be discussed below.

A. FARA ALGORITHM FOR AMBIGUITY RESOLUTION

FARA method is based on testing many combinations of ambiguity sets, or positions representing the ambiguity, within a certain pre-determined searching space. Further, the searching space is usually centered at a certain initial estimate of the ambiguity set or the position, and could be either the mathematical space or a physical space [16]. The process of searching the integer ambiguities is carried out by applying certain procedures such as, a validation and avoidance criteria to the ambiguities (or positions) being tested. FARA can be applied on (Stop & go), and kinematic techniques. There are three filed methods can be applied in order to speed the search domain, and consequently reduce the time elapsed for initialization. The first method is depending on the static occupation for a short baseline, so both reference and roving receivers, observe simultaneously in a static mode (remember that at least four common satellites or more, for a period from 10 to 20 minutes to resolve the baseline) components as well as solving the ambiguity [15]. The second method is depending on occupying a known baseline, so, the initialization can be done by occupying a previously known baseline. Simply, by setting both receivers on the two known ends of the baseline. This is the case, since with double difference mode, the atmospheric biases and orbit uncertainty are greatly eliminated, and therefore, it takes only less than 2 minutes of common data to resolve the ambiguities [17]. The third method is depending on the antenna swap, so, it is to change the geometry of the antennas instead of waiting long periods until a change in satellites occurs. The two receivers are setting and fixed to collect the data (two points few meters apart) for about one-minute by tracking the same satellites. The antennas of the two receivers are swapped (carefully interchanged),

that is, the receiver first antenna is placed where the receiver second antenna had been, and vice versa.

After one-minute again of collecting observation data, the antennas are swapped again. The length between the two receivers needs not to be known. However, during the swap procedure, care should be taken, to maintain contiguous lock on minimum of four satellites and not to disturb the tripods while solves the integer cycle ambiguity and baseline vector [18].

B. OTF AMBIGUITY RESOLUTION

On the fly (OTF) is an advanced technique developed to determine the initial ambiguity while the rover in motion, which is used mainly in the GPS kinematic on the fly technique. The satellite and receiver clock biases will be removed by this technique (OTF). Also, the orbital errors, as well as the atmospheric biases, will be greatly reduced. A smoothing algorithm using the phase observations can be applied to beat of affected of the multipath and the relatively high noise of the code observations[19]. The main concept of this smoothing technique is based on using the phase measurements to smooth the relatively imprecise code observations. The mathematical expression of such smoothing algorithm is:

$$P(t_i)_{sm} = \omega.P(t_i) + (1-\omega)(P(t_{i-1})_{sm} + \Phi(t_i) - \Phi(t_{i-1}))$$
(3)

Where:-

$P(t_i)_{sm}$ = The smoothed code observation at epoch t_i ,

$P(t_{i-1})_{sm}$ = The smoothed code observation at epoch t_{i-1} ,

$P(t_i)$ = the observed code at epoch t_i ,

$\phi(t_{i-1})$ and $\phi(t_i)$ = the phase observation in range units at

epoch t_{i-1} , and t_i. and

ω = a time dependent weight factor.

For the first epoch i=1, the weight is set ω =1, thus, the full weight is given for the measured code. For consecutive epochs, the weight of the code phase is continuously reduced, and thus, emphasizes the influence of the carrier phase data. Practically, a reduction of the weight by 1%, is found to be superior in case of kinematic survey with epoch interval 1-second. In such a case, after 100-seconds, only the smoothed value from the previous epoch, is considered.

The covariance matrix of the unknown ambiguities can be represented geometrically to form a confidence region around the estimated real values of the ambiguities. Based on statistical evaluation, only one point is selected as the most likely candidate for the integer ambiguities. Once the ambiguities are correctly resolved, a final adjustment solution is performed to obtain the rover coordinates at cm accuracy level [1].

IV. METHODOLOGY

The methodology this current research work, will be based on the analysis of the behavior of the discrepancies in the 3-d Cartesian coordinates of the tagged points along a certain surveyed path. In this contest, there will be two sets of discrepancies.

1) The first set is the discrepancies between the 3-d coordinates of 19 points surveyed by stop and go technique, and the same 19 points surveyed by kinematic technique.

2) The second set will be the discrepancies between 3-d Cartesian coordinates of the 19 points surveyed by both stop and go technique and kinematic on the fly technique.

3) The field test was done in a region between MAKKAH-JEDDAH old road as shown in figure (4 a and b). The field procedure of the test was started by setting up a dual frequency GPS receiver of GX1230 [20] at a fixed point near the road, which was defined as a reference point.

4) A second GPS receiver of the same Leica type was set up at another point about 50m from the reference receiver.

5) The initial point, which is needed for Stop & Go technique, and Kinematic technique.

6) The observational operating parameters were the same for both receivers which are MASK angle 15° and 3 seconds rate of observations.

7) The initialization was occupied about 15 minutes, then the rover receiver began collecting stop and go data every 3 seconds. A number of 19 points were surveyed along Jeddah - Makkah old road. Each point took 15 seconds of recording data (5 epochs).

8) The surveyed route was about 6.9 km from the reference receiver.

9) The number of satellites ranged from 5 to 10, and the GDOP (Geometric Dilution of Precision) ranged from 2 to 4.8. The time elapsed to complete the route by stop and go route was nearly 70 minutes.

After the stop and go survey was done, the rover receiver was turned off, but the reference receiver must be worked on. After that the rover will be working again at the initial point, for kinematic mode. The same procedure was done in the initialization process as mentioned before on Stop & Go process. Also, the same 19 points will be occupied again along the surveyed path. Each point took a one-epoch of recording data (3 seconds). The number of satellites and GDOP nearly were the same mentioned before in case of stop and go mode. In this case the time elapsed to complete the route by kinematic path was nearly 60 minutes. In this context, the same beginning steps in cinematic mode will be repeated. Then, the rover receiver will be turned on again near the initial point, but in the kinematic on the fly mode. The observational operating parameters were the same as done before. The rover receiver started to visit the 19 points without any initialization process. Each point took one-epoch (3 seconds) of recording data. The number of satellites and GDOP were also as described before. The time elapsed to complete the route, by kinematic on the fly technique was nearly 50 minutes. After completing the field work, the data processing by LEICA Geo Office (LGO) Software were done [21]. The 19 points were run three times which are: stop and go; kinematic; and kinematic on the fly. In each run, all the baselines from the reference point to the 19 points were processed giving the 3-d Cartesian coordinates of the 19 points. Finally, the three sets of coordinates belonging would be obtained from the 19 points. The first set is the 3-d coordinates of the 19 points processed by stop and go technique.

The second set is the 3-d coordinates for the same 19 points, but processed by kinematic technique.

The third and last set is the 3-d coordinates processed by the kinematic on the fly technique.

Figure 4a: MAKKAH-JEDDAH old road with the 19 surveyed points about 7 km route.

Figure 4b: Reference Base Station GPS receiver of GX1230

V. ANALYSIS AND RESULTS

The analysis will be depending on a comparison of the coordinate's differences (discrepancies) ΔX, ΔY, ΔZ, and the positional discrepancies ΔP the difference between stop-go and kinematic techniques, also, the difference between stop-go and kinematic on the fly technique will be done as follows:-

A. STOP & GO VS KINEMATIC RESULTS

The differences between stop &go and kinematic techniques are:

$$\Delta X_{K-S\&G} = \Delta X_K - \Delta X_{S\&G}$$
$$\Delta Y_{K-S\&G} = \Delta Y_K - \Delta Y_{S\&G}$$
$$\Delta Z_{K-S\&G} = \Delta Z_K - \Delta Z_{S\&G} \qquad (4)$$

Where:

X_k, Y_k, and Z_k = The cartesian coordinates from kinematic technique.

$X_{S\&G}$, $Y_{S\&G}$, and $Z_{S\&G}$ = The cartesian coordinates from stop and go technique.

Also, the positional discrepancy and the standard deviation can be calculated from:

$$\Delta P_{K-S\&G} = \sqrt{(\Delta X_{K-S\&G})^2 + (\Delta Y_{K-S\&G})^2 + (\Delta Z_{K-S\&G})^2} \quad (5)$$

$$\sigma^2_{\Delta P_{K-S\&G}} = \sigma^2_{\Delta X_{K-S\&G}} + \sigma^2_{\Delta Y_{K-S\&G}} + \sigma^2_{\Delta Z_{K-S\&G}} \qquad (6)$$

The discrepancies in 3-d Cartesian coordinates, calculated using equations (4), along with the positional discrepancies between the stop-go,

and kinematic results for the 19 points under consideration calculated using equation (5) will be shown in the Table (1) W.R.T the distance from each point from the reference base station and rover receiver. Also, figure (5) shows these Cartesian discrepancies graphically, while the figure (6) shows the positional discrepancies. On the other hand, the descriptive statistics of positional discrepancies will be shown in the table (2).

Table 1: Cartesian and positional discrepancies between Stop& go and kinematic GPS techniques

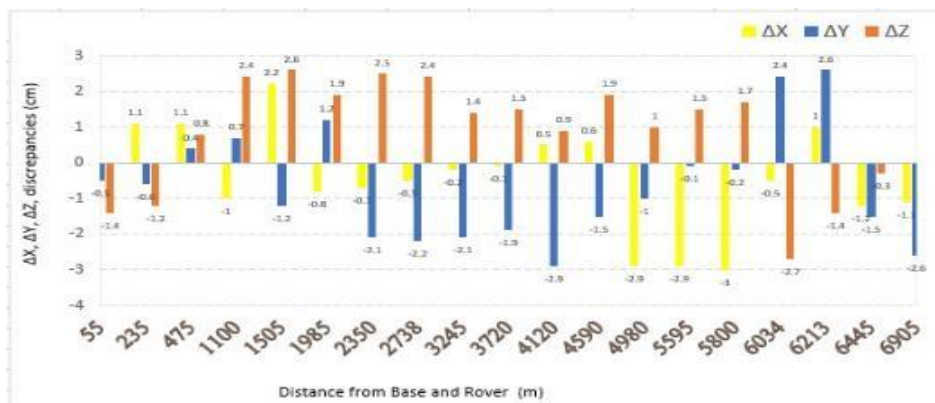| Point	Dist. from Ref to Rover. (m)	ΔX (cm)	ΔY(cm)	ΔZ(cm)	ΔP (cm)
1	55	1.2	-0.5	-1.4	1.9
2	235	1.1	-0.6	-1.2	1.7
3	475	1.1	0.4	0.8	1.4
4	1100	-1	0.7	2.4	2.7
5	1505	2.2	-1.2	2.6	3.6
6	1985	-0.8	1.2	1.9	2.4
7	2350	-0.7	-2.1	2.5	3.3
8	2738	-0.5	-2.2	2.4	3.3
9	3245	-0.2	-2.1	1.4	2.5
10	3720	-0.1	-1.9	1.5	2.4
11	4120	0.5	-2.9	0.9	3.1
12	4590	0.6	-1.5	1.9	2.5
13	4980	-2.9	-1.0	1.0	3.2
14	5595	-2.9	-0.1	1.5	3.3
15	5800	-3	-0.2	1.7	3.5
16	6034	-0.5	2.4	-2.5	3.6
17	6213	1.0	2.6	-1.4	3.1
18	6445	-1.2	-1.5	-0.3	1.9
19	6905	-1.1	-2.6	-0.8	2.9

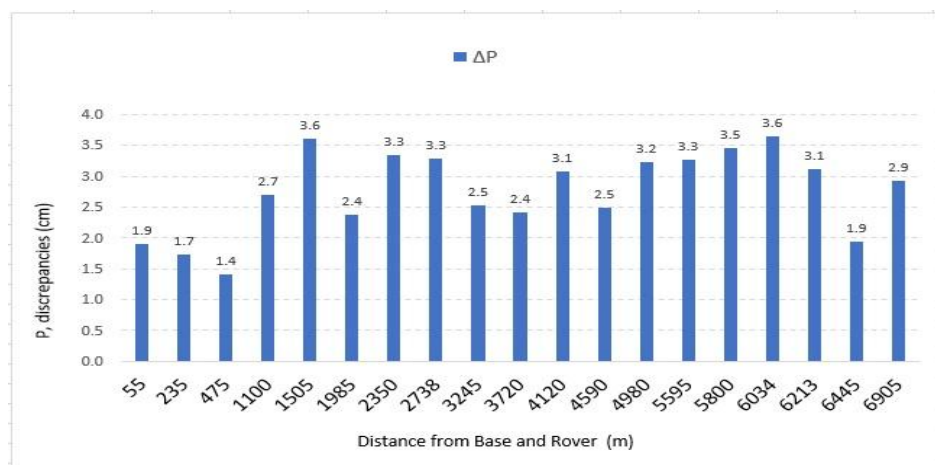**Figure 5: Variation of cartesian discrepancies between stop-go and kinematic techniques**

Figure 6: Variation of positional discrepancies between stop-go and kinematic techniques

In the following the advanced statistical tests will be applied. The table (2) will be illustrated maximum, minimum, mean, and the stander division for both single observation and stander division for the mean respectively (σ_X and $\sigma_{\bar{x}}$). This random sample will be assumed according to the normal distribution curve [22] and [23].

Table 2: Max, Min, mean and S. between Stop& go and kinematic GPS techniques (cm)

Disc.	ΔX	ΔY	ΔZ	ΔP
max	2.2	2.6	2.6	3.6
min.	-3	-2.9	-2.5	1.4
range	5.2	5.5	5.3	2.2
mean	-0.4	-0.7	0.8	2.8
σ_X	1.5	1.6	1.6	2.9
$\sigma_{\bar{x}}$	0.3	0.4	0.4	0.7

The first test is based on constructing a confidence interval for the population mean μ which equal to zero, in order to test the sample mean *m* of each discrepancy. The following confidence interval is used [22] and [23]:

$$\mu - T.\sigma_{\bar{x}} \prec m \prec \mu + T.\sigma_{\bar{x}} \qquad (7)$$

Where:-
μ = The population mean value (μ=0),
T = The student distribution value corresponding to a certain probability level, usually taken as 95%, and degree of freedom (n-1),
$\sigma_{\bar{x}}$ = The sample standard deviation for mean.
From the data which is illustrated in table (2), and using the equation (7) the above confidence interval for the mean values of the discrepancies between stop-go and kinematic techniques can be computed. Table (3) will be summarized the results of the previous test. Because of, the mean of each discrepancy is located within the confidence interval, so, it means that systematic errors in both solutions.

Table 3: First statistical testing results of the mean of the discrepancies between Stop & go and kinematic techniques (cm).

Disc.	ΔX	ΔY	ΔZ
df	18	18	18
T	2.09	2.09	2.09

	ΔX	ΔY	ΔZ
$\sigma_{\bar{x}}$	0.3	0.4	0.4
mean	-0.4	-0.7	0.8
Lower limit	-0.6	-0.8	-0.8
Upper limit	0.6	0.8	0.8
Test result	pass	pass	pass

The second statistical test is used to discover any existing offbeat in each individual discrepancy, on the basis that the discrepancies are a small sample taken from a population of mean μ=0 and variance ($\sigma_{\bar{x}}^2$). In this case, each individual discrepancy Δ_i (i=1 : n), should satisfy the following probability statement or confidence interval [22] and [23]:

$$m - T.\sigma_X \prec \Delta_i \prec m + T.\sigma_X \qquad (8)$$

Where:-
T = The normal or student distribution value as indicated before, (The student distribution value corresponding to a certain probability level, usually taken as 95%, and degree of freedom (n-1).
μ = The population mean value (μ=0),
σ_X = The standard deviation of the population for single observation and is not known in the above probability statement, it can be usually estimated from the standard deviation SD of the sample of discrepancies on hand, using the following probability statement:

$$\frac{(n-1)SD^2_{single}}{\chi_1^2} \prec \sigma^2_{single=x} \prec \frac{(n-1)SD^2_{single}}{\chi_2^2} \qquad (9)$$

in which, $\chi_1{}^2$, $\chi_2{}^2$ are the tabulated probability values in Chi square distribution tables, interpolated at (n -1) degree of freedom and probability levels of (1-α)/2 and (1+α)/2 respectively, that is α_1=2.5%, and α_2=97.5% [22] and [23].

After establishing the upper and lower limits of the above confidence interval of $\sigma_{\bar{x}}^2$ any reasonable value for $\sigma_{\bar{x}}^2$ can be taken, just to satisfy these limits, from which its square root σ will be substituted into the confidence interval of equation (8). Table (4) shows the results of this test. These values are satisfying the limits of the chi square test. The second part of table (4 a & b) shows the results of applying the confidence interval of equation (9). For instance, 100% of the examined points are passing the test for the X, Y, and Z discrepancies. These results indicate that such discrepancies are of random nature, and hence, can be practically and statistically insignificant.

Table 4: Results of statistical testing of the individual discrepancies between Stop& go and kinematic GPS techniques (cm).

Table 4a : Calculation for σ

Calculation for σ			
Disc.	ΔX	ΔY	ΔZ
df	18	18	18
T	2.09	2.09	2.09
SD^2_{single}	2.3	2.6	2.6
X^2_1	32.9	32.9	32.9
X^2_2	8.9	8.9	8.9
lower limit	1.3	1.5	1.5
Upper limit	4.5	5.2	5.2
σ_X	2.3	2.6	2.6

Table 4b: Test for individual discrepancy

Test for individual discrepancy			
Disc.	ΔX	ΔY	ΔZ
df	18	18	18
T	2.09	2.09	2.09
σ_X	2.25	2.56	2.56
lower limit	-3.5	-4.0	-2.5
upper limit	2.7	2.6	4.1
% pass points	100%	100%	100%

B. STOP & GO VS KINEMATIC ON THE FLY RESULTS

The discrepancies between stop-go and kinematic on the fly techniques are:

$$\Delta X_{OTF-S\&G} = \Delta X_{OTF} - \Delta X_{S\&G}$$

$$\Delta Y_{OTF-S\&G} = \Delta Y_{OTF} - \Delta Y_{S\&G}$$

$$\Delta Z_{OTF-S\&G} = \Delta Z_{OTF} - \Delta Z_{S\&G} \qquad (10)$$

Where:

X_{OTF}, Y_{OTF}, and Z_{OTF} = The cartesian coordinates from kinematic on the fly technique.

XS&G, YS&G, and ZS&G = The cartesian coordinates from stop and go technique as mentioned before. Also, the positional discrepancy and the standard deviation can be calculated from:

$$\Delta P_{OTF-S\&G} = \sqrt{(\Delta X_{OTF-S\&G})^2 + (\Delta Y_{OTF-S\&G})^2 + (\Delta Z_{OTF-S\&G})^2} \qquad (11)$$

$$\sigma^2_{\Delta P_{OTF-S\&G}} = \sigma^2_{\Delta X_{OTF-S\&G}} + \sigma^2_{\Delta Y_{OTF-S\&G}} + \sigma^2_{\Delta Z_{OTF-S\&G}} \qquad (12)$$

The discrepancies in 3-d Cartesian coordinates, calculated using equations (10), along with the positional discrepancies between the stop-go, and kinematic on the fly technique results for the 19 points under consideration calculated using equation (5) will be shown in the Table (5) W.R.T the distance from each point from the reference base station and rover receiver. Also, figure (7) shows these Cartesian discrepancies graphically, while the figure (8) shows the positional discrepancies. On the other hand, the descriptive statistics of positional discrepancies will be shown in the table (6).

Table 5: Cartesian and positional discrepancies between Stop& go and kinematic on the fly GPS techniques

Point	Dist. from Ref. Receiver. (m)	ΔX(cm)	ΔY(cm)	ΔZ(cm)	ΔP(cm)
1	55	-0.3	0.3	0.7	0.8
2	235	0.6	-0.3	0.9	1.1
3	475	2	-0.5	1.5	2.5
4	1100	0.3	-1	2.4	2.6
5	1505	0.3	-0.6	2.3	2.4
6	1985	-1.8	1.5	1.7	2.9
7	2350	-0.7	-0.8	1.6	1.9
8	2738	-0.4	-1.1	1.4	1.8
9	3245	-0.1	-1.7	0.9	1.9
10	3720	0.1	-1.6	0.7	1.7
11	4120	0.1	-1	0.2	1.0
12	4590	0.3	0.2	0.5	0.6
13	4980	-1.1	-1.5	0.4	1.9
14	5595	-1.5	-0.9	1.3	2.2
15	5800	-3	-0.2	1.7	3.5
16	6034	0.4	2.3	-3	3.8
17	6213	1	2.6	-1.4	3.1
18	6445	-0.4	-1.1	-0.4	1.2
19	6905	-2	-1.1	-2.3	3.2

Table 6: Descriptive statistics of the discrepancies between Stop& go and kinematic on the fly GPS techniques (cm).

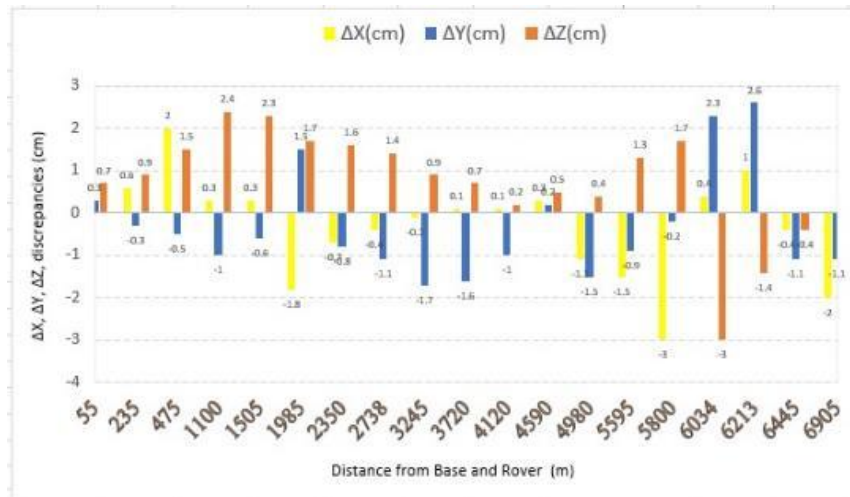| discrepancy	ΔX	ΔY	ΔZ	ΔP
max	1.0	2.6	2.3	3.8
min.	-3.0	-1.7	-3.0	0.6
mean	-0.6	-0.2	0.3	2.2
Range	4.0	4.3	5.3	3.2
σ_X	1.6	1.8	2.0	1.0
$\sigma_{\bar{x}}$	0.4	0.4	0.5	0.2

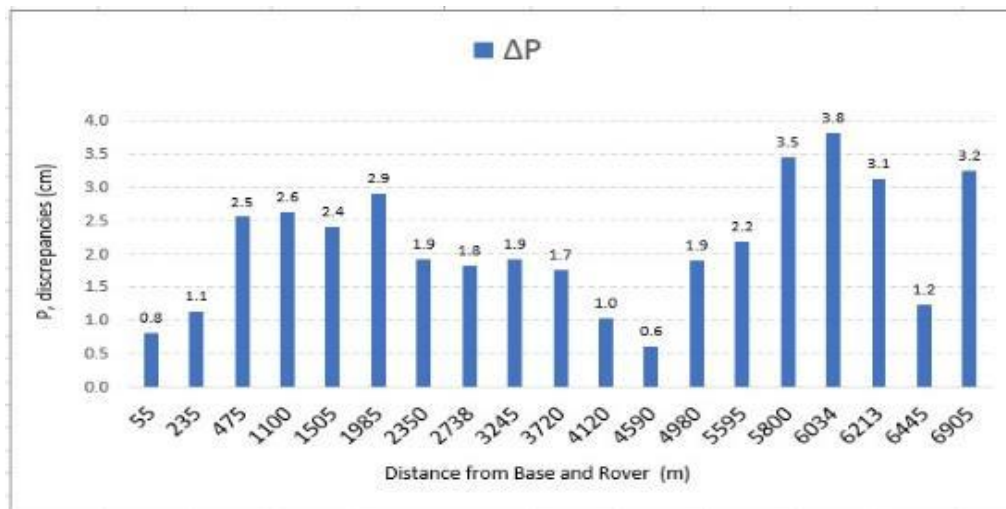**Figure 7: Variation of cartesian discrepancies between stop-go and kinematic on the fly techniques**

Figure 8: Variation of positional discrepancies between stop-go and kinematic on the fly techniques

As mentioned before, in order to check the presence of any systematic errors in the sample of the resulted discrepancies, two advanced statistical tests are applied. The results of the first statistical test are summarized in table (7). Looking at the table (7), will be illustrated the mean of each discrepancy is located within the confidence interval. This means that no significant or systematic errors in both solutions. The second statistical test is used to discover any existing offbeat in each individual discrepancy, the results of this test are shown in table (8). The inspection of this table reveals that all points have no systematic errors, and the two solutions are statistically compatible with each other.

Table 7:Second statistical testing results of the mean of the discrepancies between Stop & go and kinematic on the fly techniques (cm).

Disc.	ΔX	ΔY	ΔZ
df	18	18	18
T	2.09	2.09	2.09
$\sigma_{\bar{x}}$	0.4	0.4	0.5
mean	-0.6	-0.2	0.3
Lower limit	-0.8	-0.8	-1.0
Upper limit	0.8	0.8	1
Test result	pass	pass	pass

Table 8: Results of statistical testing of the individual discrepancies between Stop& go and kinematic on the fly techniques

Table 8a: Calculation for σ

Calculation for σ (cm).			
Disc.	ΔX	ΔY	ΔZ
df	18	18	18
T	2.09	2.09	2.09
SD^2_{single}	2.6	3.2	4.0

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X^2_1	32.9	32.9	32.9
X^2_2	8.9	8.9	8.9
lower limit	1.4	1.8	2.2
Upper limit	5.3	6.5	8.1
σ_X	1.6	1.8	2.2

Table 8b: Test for individual discrepancy

Test for individual discrepancy (cm).			
Disc.	ΔX	ΔY	ΔZ
df	18	18	18
T	2.09	2.09	2.09
	1.6	1.8	2
lower limit	-3.7	-3.5	-3.0
upper limit	2.5	3.1	3.6
% pass points	100%	100%	100%

VI. CONCLUSIONS

This current research is studying an alternative, techniques in case there are issues found to use the RTK or VRS techniques especially in mountain areas like MAKKAH region. So, this research is concentrated on making comparative study between GPS stop-go, kinematic, and kinematic on the fly techniques from points of view of accuracy, time elapsed for the initialization process, observation time for each surveyed point and surveying productivity. The field test is done in MAKKAH-JEDDAH old road between the mountains of MAKKAH about 7 km of the road were surveyed three times in the same conditions using two dual frequency GPS receivers of GX1230. As mentioned before in section 4 the total elapsed time of the stop-go surveying was nearly 70 minutes, the total elapsed time for the kinematic surveying was approximately 60 minutes and The total elapsed time of kinematic on the fly technique was approximately 50 minutes (no initialization process was needed in this technique). The methodology of investigation is based on the statistical analysis of the behavior of the discrepancies in the 3-d Cartesian coordinates of the 19 points. According to mention of all the above for the analysis and results the next conclusions can be Listed:

1. In both stop-go and kinematic techniques, the coordinate discrepancies between the two techniques have mean values of -4 mm in X-coordinate, -7 mm in Y-coordinate, and 8 mm in Z-coordinate, with a standard deviation of 0.3 cm, 0.4 cm, and 0.4 cm for X, Y and Z coordinates respectively.

2. The 3-d Cartesian discrepancies between the stop-go and kinematic techniques are statically and practically insignificant, where the results showed that the positional discrepancy between the two techniques has a mean value of 28 mm with a standard deviation of 7 mm.

3. Using one-epoch only (3 seconds) in case of Kinematic technique does not affect the accuracy of the resulted coordinates, comparing with 5-epocks (15 seconds) in case of stop-go technique. This will save about 10-15% per hour for any Kinematic survey without any reduction in the obtained accuracy.

4. In both Stop & Go and kinematic techniques are needed for the initialization process which takes a time period about 15 minutes, especially in case of satellite-signal blockages, which happen when the GPS surveying is conducted near overhead obstacles such as road sign, adverting frames, trees….etc.

5. In both stop-go and kinematic on the fly techniques, the coordinate discrepancies between the two techniques have mean values of -6 mm in X-coordinate, -2 mm in Y-coordinate, and 3 mm in Z-coordinate, with a standard deviation of 4 mm, 4 mm, and 5 mm for X, Y and Z coordinates respectively.

6. The 3-d Cartesian discrepancies between the stop-go and on the fly Kinematic techniques are statically and practically insignificant, where the results showed that the positional discrepancy between the two techniques has a mean value of 22 mm with a standard deviation of 2 mm.

7. Using one-epoch only (3 seconds) in case of Kinematic on the fly technique does not affect the accuracy of the resulted coordinates, comparing with 5-epocks (15 seconds) in case of stop-go technique. This will save about 10-15% per hour for any Kinematic survey without any reduction in the obtained accuracy.

8. In the on the fly technique the surveying work can be saved at least about 15 minutes from every re-initialization process. In this context, the surveying work by using kinematic on the fly will be saved the time more than another post processing Kinematic techniques which be needed for initialization or re-initialization process so, the surveying productivity will increase when using this technique.

Finally, in case the issues to use RTK or VRS due to communication problems specially the regions within mountains areas such as MAKKAH in this situation the GPS kinematic on the fly technique is highly recommended to replace the stop-go and kinematic techniques, in all the surveying works of medium scale. Also, the distance between the surveyed point and the reference receiver does not affect the resulted coordinates for about 7 km.

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