VISIBILITY STUDY TOWARDS THE IMPLEMENTATION OF GPS REAL TIME KINEMATIC POSITIONING TECHNIQUE (GPS-RTK) IN CADASTRAL MAPS PRODUCTION IN EGYPT

BY

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إن الزيادة المطردة في الأراضي الزراعية وكذلك الحاجة الماسة إلي تلبية الاحتياجات المتزايدة ـاء نظام حديث لمعلومات الأراضي دفع الجهات العلمية والمعنية وعلي رأسها الهيئة المصرية العامة للمساحة إلي استخدام طرق غير تقليدية لإنتاج الخرائـــط الكـ ـــترالية / التفصيلية، وذلك مصاحباً للتطورات التي أدخلت علي الأجهزة المساحية المختلفة وأحدثها محطات الرصد الأرضية المتكـ ـــهزة الرصد علي الأقمار الصناعية . والغرض الرئيسي من هذا البحث تقييم مدي إمكانية استخدام تقنية الـــ RTK- لإنتــاج وتحديث الخرائط التفصيلية في مصر كوسيلة جديدة، ولهذا الغرض تم اختيار قرية زهرة البحرية التابعة لمركز دمنهور- ـحـــيرة كنموذج لمشروع تطبيقي متكامل لإنتاج خريطة كاداسترالية لهذه القرية باستخدام النظام المقترح والتي تم رفعها باســـ أجـــهزة محطات الرصد الأرضية المتكاملة وأيضاً توجد لها خرائط أساسية منتجة من التصوير الجوي ثم تطبيق نظام الـــ GPS-RTK المقترح لرفع جدود الملكيات لتلك القرية ، ومن النتائج التي تم توصلنا إليها في هذا البحث: زيادة معدلات الإنتاج وسهولة الحصـــول علـــي البيانات ونقلها، رفع حوالي ٧٥٠٠٠ فدان من نقطة أساس واحدة، اختصار وقت العمل بنسبة ٧٠% من الوقت اللازم في الطـــرق التقليدية، التغلب نهائياً علي مشكلة تدمير العلامات الأرضية لنقاط حدود الملكية، الوصول بدقة الإحداثيات في حدود ١سم وكذلـــك دقة المساحات إلي ٢سم تقريباً، وعلاوة علي ذلك فإن البيانات مخزنة في صورة رقمية يمكن استدعائها والتعامل معها في إي وقت، ومـــن النتائج السابقة فإن نظام الـــ GPS-RTK المقترح يعتبر الحل الأمثل لجميع المشاكل التي تنشأ من استخدام الطرق التقليدية.

Abstract

Increasing of the cultivated lands and the rapidly escalating need for updated and reliable land information, by both public and private use institutions has forced the Egyptian Survey Authority (ESA) to look for non-traditional procedures for cadastral mapping. This was accomplished by the development of modern instruments e.g.; digital theodolites, electronic distance measuring instruments, total stations and lastly the Global Positioning System (GPS). Recently, many projects for producing or rebuilding cadastral maps have been done, such as: Egyptian-American and Egyptian-German projects. All these new projects accelerate the production rates. Yet, many technical requirements are needed to overcome some major obstacles. Among these obstacles will be: the huge number of traverse stations that must be intervisible; the large number of traverse points, required to cover a limited area (one point per fifty feddans); in addition to the destruction of about 50% of them by the

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people and farming machines. Also, there is no simple kind of quality checks and quality control, because just a ray is observed from the traverse point to the prism in its position. Again, in total station surveys, it is essential to number all boundaries on survey sketches before surveying. Besides, one more team in the office, has to edit and link the separate points to form the polygon, then the resultant form is a closed line not identified area features. Yet, all the defects mentioned above of the total station surveys are still existing.

On the other hand, the Global Positioning System (GPS), which is based on observing artificial earth satellites, and is day and night, all weather, precise and more economical positioning technique, and having several other advantages over alternative traditional techniques, has been recently used in Egypt for every day surveying and mapping works. The GPS has many observing techniques, out of which the real time kinematic technique, known as GPS-RTK which is the technique of concern of this research, is known to be the best one for mapping purposes. Thus, GPS-RTK will speed-up the work considerably and facilitates data acquisition and transfer. The best benefit of this technique is that one can survey more than 75000 feddans from one base station, so the traverse stages including reconnaissance, demarcation, establishment, observations and adjustment are escaped entirely. Consequently, one-get reductions of 70% of the job time, when comparing with traditional surveying techniques. Accordingly, 20 feddans in small areas, and two to three feddans in wet parcels, were surveyed per hour. This number will be raised to 40 feddans/hour, if the areas are larger. The destruction of landmarks problem will be solved completely, because the coordinates of the landmarks will be stored digitally. The quality of positioning and area computation is displayed in the field, with position accuracy of 1cm, and area accuracy of $2cm^2$. Furthermore, all data are stored in digital form, so the boundary disputes, and all setting out problems will diminish. Consequently, the proposed GPS-RTK is the solution for all the above mentioned problems.

The main objective of the present research is to assess the capability of GPS-RTK technique for the production and/or updating the cadastre system in Egypt as a new tool. An applied practical field test has been carried out in Beheira Governorate, to assess the system performance. Also, the results obtained from both GPS-RTK and the total station techniques, as applied to the above-mentioned experimental site, are compared and analyzed.

1. Introduction

A land record for tax purpose is known as a "cadastre". The word brought from France and means a public register of the quantity, value and ownership of the immovable property in a country, compiled to serve as a basis of taxation [GTZ, 1997]. The expression "cadastral survey" is used to denote a survey of the boundaries of land units of a country whether or not the survey has connection with taxation. Its function is to define the parcels or pieces of land, which constitute the units of record, whatever the purpose of the record. It gives each parcel a distinctive appellation. The outline or boundaries of the properties, parcels, and the parcel identifiers are normally shown on large-scale maps which, together with registers, may show for each property/parcel rights, restrictions, nature, size and value. Cadastral survey is a term usually used to designate a large-scale survey of land in which the boundaries are accurately located and the areas of properties are determined, topographical and cadastral details such as, roads, roadways, canals, railways, properties and buildings are drawn. Registers of areas, landowners, the saleable land of Government, the land of public utility, village site, and threshing floor of the village usually accompany such maps.

Proper cadastral mapping in Egypt began in 1897, at the time when ESA was established. By the end of the year 1907, all the cultivated area in Egypt (about 6 million feddans) was covered with cadastral maps of scale 1:2500. At that time, the cadastral survey was executed by using the system of theodeolite traversing controlled by triangulation points, the plotting of holdings in the field, the calculation of the area of each holding for map sheets, and compilation of the land-registers on certain forms. The increase in the total area of the cultivated land, to about 9 million feddans and the rapidly escalating need for updated and reliable land information, by both public and private use institutions, has forced ESA to look for non-traditional procedures for cadastral mapping. This was accomplished by the development of modern instruments e.g.; digital theodeolite, electronic distance measuring equipment, total stations and lastly GPS.

It is an accepted fact that a planned and well-organized development of a country depends on reliable and ready available information on the land. All plans and schemes for improvement and reform measurements have to be based on an effective administration, which has fast and ready access to all pertinent data of a country. Consequently, the survey organizations of a country have a duty for providing the required up to date information to decision-makers. A modern property cadastre can be used for fiscal purposes, for legal applications and as planning tools. Concerning statistical data and topography it forms a multi-purpose cadastre or so called Land Information System (LIS). ESA has, as one of its essential basic responsibilities, the duty to provide accurate cadastral maps and plans to enable the processes execution achieved with security and efficiency. In common with many of the world today, the research Institutes and Universities have to examine up-to-date methods in order to reduce to a minimum the time required to revise the out-of-date maps and support ESA's decision makers to provide new mapping of areas where a lot of development has taken place. To produce the desired results fast and economically the most modern surveying techniques and data processing have to be applied. In order to find the most suitable technique, instruments and organization required, a pilot project of reasonable size was carried out.

1.1 The Purposes and Procedures of the Cadastral Survey in Egypt

Cadastral survey deals with one or more of the following purposes:

- To secure the necessary data for writing the legal description and for finding the area of designated plots of land, the boundaries of the property being defined by visible objects, which is known as **Original Surveys**.
- To re-establish the boundaries of a tract for which a survey has previously been made and which the description may be in the form of the original survey notes, an old deed, or a map or plot on which are recorded the measured lengths and bearings of sides and other pertinent data, which is known as **Re-Surveys**.
- To subdivide lands into small units in accordance with a definite plan which predetermines the size, shape and location of units, which is known as **Subdivision Surveys**

The traditional cadastral survey in Egypt is still performed with the same field methods as those adopted in the year of 1900. The total process of producing maps and registers is divided into seven stages, namely

- Demarcation and Traversing.
- Detail Surveys.
- Traverse Computations.
- Plotting the Map-Sheets.
- Plotting Details-Survey.
- Area Determination.
- Land-Registers.

More details about these technical procedures can be found in Nassif, 2001.

1.2 Preliminary Investigation Towards Modern Cadastre in Egypt

Since the beginning of the eighties, ESA has found itself confronted with a rapidly escalating need for up-dated and reliable land information, by both public and private user institutions. These requirements can not be fulfilled using traditional procedures. On the other hand, the survey techniques show a tremendous modernization due to the development in computer, photogrammetry, and modern instruments. Digital theodeolite, electronic distance measurements, total station and lastly the GPS technology change the methodology of surveying. In this context, a leading Egyptian-American project that started in 1989 produced cadastral maps for four Egyptian Governorates using GPS and Photogrammetry. Yet, the project had to use terrestrial total stations and traditional methods, for demarcation of land boundaries, and recommended using Photogrammetry for planning of large new areas. The Photogrammetric department in ESA produces 1:2500 base maps and conveys them, to the Survey Bureaus in the Governorates, to accomplish the cadastral work. The maps are produced from aerial photography with scale 1:10000. The main irrigation system, bridges, roads, tracks and urban blocks are well identified in these maps [ESA, 1992].

When significance of the cadastre was recognized, ESA applied to the German government for support in the frame of the Egyptian-German technical corporation, for the purpose of modernizing the methods and procedures for establishing and up-dating the cadastre. A pilot project was started in 1995 with co-operation, with the German Government, to rebuild the cadastre system in Egypt. The project selected the GPS accompanied with Digital Plane Table (DPT) system to be the applied tool for this purpose. The previous system is designed to give a few centimeters accuracy, with quality assurance, instantaneously. Accuracy of the system was tested relatively and absolutely, the project includes a geodetic network over 100 km^2, representing a parcel boundary. A deviation of eleven cm was arisen when the GPS rover was occupied and compared with previous results obtained by the total station. In 1997, the project was claimed in Aswan symposium, in which the relative accuracy of the positions is approximately 30 cm. Areas were computed using the total station data, which were surveyed with care, and also were computed using the GPS data. Area of 37 parcels were compared in different combination, the measured area was 8544 m^2 the difference in area was 18 m^2, which gives a relative accuracy is 1/475 [Zulsdorf, 1996].

2. Implementation of GPS-RTK in Cadastral Surveying

GPS can be considered as the most advanced real time positioning technique, based on transmitting a coded satellite massage, which would be received by a ground portable-receiving unit. Using GPS data, both point and relative positioning are possible. However, because of the uncertainties in the satellite positions, clock behavior, and propagation delays, absolute point positioning will likely be obtained with accuracies of only a few meters. For most positioning requirements for geodetic and geodynamic applications, it will be necessary to use GPS in a relative mode. Using the code or carrier phase measurements for relative positioning consists of taking differences between measurements. In this way, the effect of the various errors such as, the GPS signals, satellite orbit, satellite clock, receiver clock, and atmospheric propagation errors, common to the measurements being differenced, are removed or greatly reduced [Wells, et. al., 1987].

Generally, GPS can be used to position static objects or moving (kinematic) objects. Although the observations (ranges) are the same, the fact that the antenna is either stationary or moving introduces significant differences. If the antenna is stationary, one can observe many repeated ranges to each of several satellites. This gives redundant observations, over-determined solutions and consequently a higher accuracy of the determined position. When the antenna moves, one can only get instantaneous (fixes) with no redundancy [Nassar, 1994a]. In the kinematic mode, the key word is "motion". The roving unit actually captures the data according to a pre-specified epochs, say every five seconds, ten seconds, etc., along the route to be surveyed. However, if the roving receiver is allowed to stop a few minutes on each desired point to be positioned, and move again to the next point. the system of collecting GPS observations will be termed as GPS semi-kinematic or Stop and Go technique. This latter technique was found to give comparable position accuracy as the conventional GPS static technique [Nassar, et. al., 1998].

As a check for cycle slips and measurement errors, it is good kinematic survey practice to re-visit several previously surveyed points, perhaps return to the home station, or repeat an antenna swap at the end of the survey [Kleusberg, 1990]. Some redundancy time should be planned in the survey schedule [Ashkenazi, et. al., 1990]. Most kinematic surveyors use a prism pole or a range pole to hold the antenna. If the antenna is properly plumbed, 1: 100,000 and higher accuracy kinematic baseline are possible, [Remondi, 1985].

2.1 Aspects of GPS-RTK

Transmitting the pseudorange and/or the carrier phase observations from the reference station to the moving receiver makes it possible to compute the location of the moving receiver in real time. This includes ambiguity resolution on the fly. On-site computations allow for real-time quality assurance of kinematic and rapid static applications, and allow precise navigation to a known location. An operational system for surveying application provides centimeter-positioning accuracy in real time. Instead of transmitting the observation, it is preferable to transmit corrections, which are added to the observations of the moving receiver. If the position of the moving receiver is determined on the basis of the transmitted observation or observational corrections, and if the position is determined in real time, one speaks of differential GPS (DGPS). If the data is transmitted in real-time.

the DGPS technique will be termed as GPS-RTK, however with certain characteristics as given in Table (1). One of the major difficulties for real-time applications is implementation of a reliable communication link between master and rover. In RTK mode (cm level accuracy) all the observed data must be transmitted from the reference to the rover. For low to medium accuracy applications, this has been overcome by reducing the amount of data that must be transmitted and the frequency of these transmissions, by transmitting the corrections to the observations only.

RTK is a GPS technology where the carrier phase is used to determine the position. It is not a low noise or heavily filtered code phase position solution. GPS-RTK makes use of the carrier phase rather than code phase (DGPS), as given in Table (1). In GPS-RTK technique, a base station has to be located at a known station. This station transmits corrections every second to any number of rovers. As such the Integer Ambiguity (N) has to be solved, i.e. the number of wavelengths from satellite to GPS antenna. The basic output from the RTK receivers is precise 3D coordinates usually in Lat/Long/Height on the GPS datum, the World Geodetic System 1984 (WGS84). Some receivers are able to directly output local Transverse Mercator coordinates in the order of 1-2 cm in horizontal positions and 3-5 cm in vertical according to the GPS-RTK accuracy specifications [Ken, et. at., 1994].

GPS-RTK surveying requires an important step called initialization. This procedure must occur before the system can provide baselines accuracy at the centimeter level. The recent dual frequency versions of the GPS survey system are capable of fully automatic initialization, irrespective of whether the roving unit is stationary or moving. There are two essential items in real time surveying: the initialization reliability and time to initialize. It should come as no surprise that there is a direct correlation between these parameters and the quality of the satellite measurements made by the GPS receivers. In turn, this quality is dictated by a source of measurement error, external to the receiver, known as multipath. Multipath is a dominant error source on satellite measurements, for more details about multipath rejection technology, see [Langley, 1992]

2.2 GPS-RTK Practical Considerations for Cadastral Surveying

GPS is competing with traditional surveying techniques in almost fields of geodesy and surveying. Cadastre surveying includes detailed measurements and setting out. However for real time kinematic positioning, GPS-RTK system, to be successful in cadastral surveying there are some remaining factors to be taken into consideration. The survey area is usually small; within, say, 10x10 km. The detailed measurement can be performed in rapid static or stop-and-go kinematic mode, and the data processing can usually be handled separately after data collection. However setting out requires that a roving receiver have an on-line connection to a reference receiver placed on a known point. This task implies real-time surveying, where instantaneous position data are transferred from the reference station to the roving receiver in order to provide the coordinates of the roving receiver with respect to those of the stationary receiver with, say, cm accuracy level in both horizontal and vertical coordinates. The GPS-RTK base station must output corrections once per second to the rover, through the radio link. Initialization is required at the start of day and this is usually a matter of turning the base station on, turning the mobile receiver on, then waiting a short while for initialization. Initialization is also needed anytime after which the continuous tracking of all available satellite signals is hindered such as after power failure, or going under a bridge. One minute of times is an acceptable industry benchmark for On the Fly (OTF) re-initialization to occur [Erwin, et. al., 1996].

3. Map Projection Systems and Coordinates Transformation In Egypt

The function of the map projection is to establish a one-to-one correspondence between points on the datum surface and points on the projection surface, and to establish a representation of one on the other. All survey maps of Egypt in ESA are produced based on the Egyptian Transverse Mercator Projection (ETM). The some properties of this projection. which make it the suitable projection for Egypt, are: it is truly conformal (Orthomorphic); and the central meridian is undistorted. A new trend in ESA is to divide the country to five zones, all of them have the same origin, each zone extend in the east west direction three degrees. The used projection is also Transverse Mercator. The reference geodetic datum is the WGS84 instead of the Helmert 1906 local ellipsoid, which were used in the old system (ETM). The proposed system is called the Modified Transverse Mercator (MTM).

Plane transformation can be performed for conversion between two map projection systems, using for instance the 2D-similarity transformation model, which is a four-parameter model. Sharp, well-distributed, and well-identified control points, with known plane coordinates in the two systems under transformation, are required to do the transformation. Two control points are quite enough, theoretically, however one must have more than two controls to check the transformation process. On other hand, there is another alternative way for carrying out the required transformation, however, based on the concept of 3D coordinate transformation between different geodetic datums, which are Helmert ellipsoid system and WGS84 ellipsoid system in our case here. Recall that, such 3D transformation is usually performed using one of the seven parameters model, such as the simple model of Bursa [Nassar, 1994b]. The latter approach will be used in this research, using seven available control points to transform the digital ETM map for El-Zahra El-Baharia village to the proposed system MTM projection. However, the first approach is implemented here, for simplicity.

4. Cadastral Surveying Project in Beheira, As A Study Case

The selected pilot project area for the practical application located in Beheira Governorate was implemented to develop new procedures always with regard to existing procedures and regulations. The selection of Beheira was based on some considerations. It has original cadastre survey 1937, modern base map produced from aerial photogrammetry 1992, through the American project cadastre maps using total stations 1992, and because it is full of many tall crops rice and corn which were a challenge to use the GPS-RTK technique. The significant goals of the project are: development and implementation of a modern cadastre system (multi-purpose cadastre) suitable for Egypt rural and urban areas; review and adaptation of the technical organizational and legal regulations according to the modern procedures and techniques; and consideration of the needs of relevant organizations and users.

4.1 Features of the Selected Project Site

El-Zahra El-Baharia village in Beheira Governorate was chosen to investigate the possibility of using the proposed GPS-RTK system for modern cadastral survey in Egypt This village has the following characteristics:

- The total area was about 712 feddans divided into 5 hods. The area of each was 100-150 feddans; each hod was divided into 40-60 parcels.
- It has a great number of topographical features such as roads, canals, drains, etc.
- The parcels contained a great number of palm trees, which formed a great obstacle to the traditional survey work but was easily overcome by a good planning and using the GPS-RTK system capability.
- The village has maps for all the stages of old and modern cadastre systems, and also the base maps, which were produced from aerial photography in 1992.
- The total station survey including the traverse observations, computations, boundary survey, editing and plotting were done. This traditional total station survey final product has been used as the basic standard, against which the corresponding GPS-RTK results will be compared.

Consequently, the choice of this village with all these features was supposed to give a good example of what a surveyor faces in rural areas of Egypt.

4.2 Available Digital Base Maps for the Project Site

In the beginning of the project, many candidate sites were chosen to be the area of this research. However, choice was Beheira Governorate due to the availability of digital maps that were produced from several techniques. The different sources of the available digital base maps for the project site are explained as follows:

a. Digital maps were produced by ESA, photogrammetry department. These maps were prepared during the Egyptian American project as base maps for cadastre purposes. The scale of these maps is 1: 2500 generated from aerial photography (1990). The reference ellipsoid is Helmert 1906 and the projection is the Egyptian Transverse Mercator (ETM), related to the red-belt zone. Irrigation system, roads, bridges and urban blocks are clearly identified in these maps. The sheet with lower left corner

(920N, 562.5 E) was selected to be the area of interest. The sheet dimension is 1.5 km in east-west direction and 1km in north-south direction. it is almost one/third of El-Zahra El-Baharia village area The digital form of these maps is available in the DXF-CAD formats.

b. Digital maps produced by SRI for ESA's American project from 1990 to 1992 using the terrestrial total stations. Traverse observations and computations, survey of parcel corners, survey of all public and private areas, and plotting the features were performed on the computer using the attached mapping program to the first time in Egypt. The result of this survey is a digital map in CAD format including the parcel boundaries. The legal boundaries of district, villages, and blocks were also included sixteen traverse and control points were plotted in the maps and physically recognized in the field were used to survey EL-Zahra village. Seven of these controls were in the selected sheet and were used in the coordinate transformation process. The coordinate of the parcel corners, lengths, and areas of these maps, in digital form, were considered to be the reference features to compare the accuracy of the proposed GPS-RTK technique.

5. The Used Instruments and Software

The selection of candidate instruments and software was based on the technical specifications and the facilities that fit the demands of the project. The target was to establish a system has the following requirements. suitable for Egypt's cadastral conditions; the quality control (QC) of the output tested and approved, hard worker, capable to collect GIS data, and easy to re-survey To achieve the mention requirements a brief discussion of the used instruments and software in this project, will be given below

5.1 The Used Instruments

- **TC-2000 Total Station** with 0.5 sec standard deviation in angle measurements, 0.1sec reading on the screen and ±(0.1mm ± 1ppm) in length measurement
- An intelligent **GRE-4 data collector** is attached to the total station for data storage, data retrieval, data revising and data editing. The traverse closing error can be checked as well as inverse check.

- **Trimble 4000SSI GPS receiver** with standard deviation ± (0.5cm+1ppm) for base line computation. The instrument is designed for high precision survey applications. The receiver automatically acquires and simultaneously tracks up to16 satellites, it precisely measures carrier and code phases and stores them in an internal battery backed-up memory. In addition, the antenna is provided with Everest multipath rejection software [Trimble, 1996].
- **TRIMMARK IIE Radio**, Base, Repeater and Rover attached to the GPS receivers to form the GPS total station set. Its range is 12Km and has power of 25watt.
- **TSC1 Trimble GIS data logger** is a powerful hand-held field computer with a full alphanumeric keyboard.

5.2 The Used Software

- The **GPSURVEY** GPS processing software consists of many modules, such as: planning module; project manager module; wave (processing) module; coordinate system module (**GPTRANS** program); and adjusting module (**TRIMNET PLUS** software is a least squares adjustment module for networks), accompanied with full statistic assessment. The program applies many tests to assess the existence of systematic errors in RTK data.
- **ASSET Surveyor** is a software system produced by Trimble Navigation Limited, for wide range of Geographic Information System (GIS) data collection applications. Together with a GPS receiver, the asset surveyor software can quickly and accurately collect the attributes and GPS position of geographic points, lines and areas. This information is stored in one or more data files, which can be loaded into pathfinder office software. After editing data can then be output in a wide range of, GIS-compatible formats [Trimble, 1998].
- **Pathfinder office** is a GPS data management program. Design of dictionaries, setup of coordinate systems and data quality control is a powerful module in the software. Editing attributes, layers, codes and offsets can be achieved. The software can export the data to different GIS formats (ARC-INFO, ARC-VIEW, and MAP-INFO).
- **Trimmap:** is a powerful mapping software from Trimble Navigation Limited. The program contains many modules, fulfilled all branches of survey computations and

mapping requirements. The software can deal with data from GPS data logger as well as many total stations models. The software was used in traverse and detail surveying computations of the total station observations. The observations were managed from transfer stage to cartography and final map production, including editing of raw data, layers creation, symbolization, legend, grid and data quality control.

6. Mission Planning and Methodology of Data Acquisition

There are four critical phases in mission planning of this project:

- Organize feature and attribute information using a data dictionary editor in **Pathfinder Office** software. A data dictionary is a description of the objects to be collected for a particular project or job. It is used in the field to control the collection of these objects and information about them. The element of data dictionary can include point, line, and area features.
- Feeding the **TSC1 data logger** with boundary corners coordinates, lengths and areas from the digital maps, this were surveyed by the electronic total stations (the reference system).
- Configure the data logger in the office; datum, coordinate system, zones, height reference, geoid model, measurement tolerances and data collection criteria. This defines the method of data acquisition and saves time in the field.
- Determine when the best satellite coverage will occur using the quick plan utility in the **GPSURVEY** software. This prevents wasting time in the field waiting for a satisfactory satellite constellation.

In the following, a brief discussion of the two main stages, which are known as field and office stages, are given

a. The Field Stage

This stage included preparing sketches, observing and measuring the existing control points and picking up all detail points. The work was arranged as follows:

- Reconnaissance the area under consideration

- Preparing a neat sketch, this shows the properties and topographical features using the available maps
- Reconnaissance of the traverse control points that were used in traditional survey technique in 1992.
- A three hours static session was performed using five GPS receivers. Two GPS receivers occupied two stations of the Egyptian national geodetic network (HARN). ESA published this national network in the Modified Transverse Mercator projection that based on the WGS84 ellipsoid. Then, the survey of the parcels boundary were performed on this projection. The occupation of the control stations was to connect the project to the national net. First station was 0Y12 in Hosh-Eisa City, 20 kilometers from the project's site and the second one was 0Z93 at Kallwat village 30 km from the project. Three points were chosen at EL-Zahra village to use them as a GPS-RTK base station and checking controls.
- Three of the traverse stations that established during the implementation of American-Egyptian project in 1992 were found and checked using the GPS-RTK system.
- The seven-transformation parameters of Bursa model using the established HARN control points common with the old Helmert system, as well as ETM and MTM projection parameters were uploaded to the data-logger. Average of twenty centimeters errors were detected in each checkpoint after transformation in north and east direction.
- WGS84 coordinates of the clearly identified features were observed using the GPS-RTK technique. This step was to convert the projection from the old Egyptian Transverse Mercator (ETM) based on local Helmert1906 reference ellipsoid to the Modified Transverse Mercator (MTM) based on WGS84.
- The GPS-RTK position values obtained under the following observation criteria: the position dilution of precision PDOP not more than 5, the signal-to-noise ratio fixed to be 4; the elevation mask set to be 15 degree; the logging intervals was 5 seconds, and the tolerance in position recording set to be 3cm in horizontal and 5cm in vertical.
- Picking up detail points: initially for this technique, it is required to have one control point to cover a circular area of radius 10 km. The extra control points in the area of interest these will be used as checkpoints. Old maps were used as a guide sketches to simplify the surveying process. Coordinates of the boundary corners were loaded-up

into the data logger, from digital file of total station survey, this process is greatly recommended in the re-survey work and parcel transactions.

- Roads, bridges, trees, railways and block boundaries were surveyed and added to the observations.

b. The Office Stage

- Data transfer: Data was transferred from the data logger into **Pathfinder Office** software.
- Revising the collected data; GPS data acquisition criteria, precision, and attributes were accurately executed.
- The program provides data editing tools, often used to clean data before exporting it to specific software, e.g. AutoCAD or GIS.
- During data revising and quality control phase; deleting individual positions or blocks of positions, modifying attributes, and adds offset values were performed in many data files.
- The digital maps of the total station survey were displayed as a background file to measure the difference in positions, lengths, and areas between the two techniques.
- Data files were exported in the shape files format. This format deals with the graphic and attribute data as well and it's a common format suitable for importing into the Geo-Media professional software.
- Hence, we have all the cadastre system in digital form, the updated maps will be conveyed to the interested authorities through a computer net.
- The owner will have a deed certificate indicate the exact location of the parcel and his neighbors, accompanied with a complete information of the ownership and history of the parcel transactions.

7. Discussion and Analysis of the Obtained Results

Using the GPS-RTK system for survey of boundary marks gave a high accuracy. At each mark the surveyor can check the accuracy before recording the position. Applying the standard specifications for GPS-RTK observations [Trimble, 1997] and set the tolerance in horizontal and vertical direction. Since the data are processed instantaneously using the phase and code data of the base receiver, a complete statistic analysis can be obtained. Firstly, as a main check, the GPS-RTK rover occupied the three control points which, were established in the village. These occupations were performed to check the set up of the base in terms of proper feeding of the base coordinate, projection parameters, and antenna height and radio setup in each working session. The coordinate differences of the stations number two and three that obtained after the post processing of the static session and the coordinates which obtained in real time on the data–logger screen using point number one as a base. The coordinates of the points are in Modified Transverse Mercator, zone number three, MTM3, and the datum is WGS84. The coordinate differences were obtained for these well-known stations, as follows:

$$\Delta N = N_{STATIC} - N_{RTK} \tag{1}$$

$$\Delta E = E_{STATIC} - E_{RTK} \tag{2}$$

Table (2) illustrate the obtained coordinate differences at two well-known stations at the project site. From Table (2), it can be seen that, the resulted differences range from 0.16 cm to 0.54 cm in the Northings and from 0.91 cm to 1.40 cm in the Eastings. These results can be accepted and verifying the expected GPS-RTK accuracy specifications.

Table (3) illustrate the obtained average error values at each boundary corner based on two different confidence levels. The first one at 68% confidence level, the obtained maximum average error values are 5 mm in the Northings and 4 mm in the Eastings, 9 mm for the error ellipses major axis, and 3 mm for the error ellipses minor axis. The second one at 95% confidence level, the obtained maximum average error values are 10 mm in the Northings and 8 mm in the Eastings, 15 mm for the error ellipses major axis, and 3 mm for the error ellipses minor axis.

Table (4) and Figure (1) show the statistic of the horizontal positions discrepancies between traditional total station and GPS-RTK that obtained at boundary corners of the parcels. From this table, it can be seen that the resulted horizontal precision ranges from 0.5 cm to 6.3 cm, with a mean value of 1.56 cm, and RMS of 0.88 cm. Also, from the graph depicted in Figure (1), it can be seen that the maximum horizontal precision up to 6.3 cm occurred at very few parcel positions. These results specified as high accuracy and satisfy the practical applications.

Furthermore, the statistics of discrepancies between the areas of parcels obtained from traditional total station and GPS-RTK surveying techniques are given in Table (5) and shown in Figure (2), based on the following formula:

$$\Delta_{AREA} = AREA_{TOTAL\ STATION} - AREA_{GPS\text{-}RTK} \quad (3)$$

The discrepancies ranges from $-0.79\ m^2$ to $+0.95\ m^2$ with a mean value of $0.04\ m^2$, and RMS of $0.44\ m^2$. From these obtained results, it can be concluded that, the area determined by GPS-RTK more accurate than the traditional techniques, saving time, efforts and costs. In this context, for estimating the rate of work using the GPS-RTK system, an area of 350 feddans was considered. Finally, from the practical point of view and the gained experience from the applied project, a comparison between the traditional total station and GPS-RTK techniques including; used instruments, work stages, rate of work, man power, and the final output, is shown in Table (6). The produced digital cadastral map for the studied project area as produced from the GPS-RTK technique directly is shown in Figure (3).

In short statements, a two years plan to finish the cadastre mapping in Egypt is outlined in Table (7). The proposed plan needs to be executed in perfect scientific management of the field and office work in each Governorate. In order to achieve this task by the previous cost the two rovers unit should be use the same base. This operation system will reduce the cost of equipment by twenty five percent. Each base station will be located and connected to the national 2nd order geodetic net. The ESA established this net especially for cadastre work with base lines about 25 kilometers. To intensify the control points, a static session will be performed for 90 minutes including the new base station and two points of the net. About five hundred control points are required, to cover the whole country.

8. Concluding Remarks

It becomes so clear now that a planned and well-organized development of a country is impossible without reliable and well-established land information system. The role of the ESA is to provide the required up-to-date information to government and public. A modern property cadastre can be used for fiscal purposes, for legal registration as a planning tool. In connection with statistical data and topography, it forms a multi- purpose cadastre or so-called Land Information System (LIS). To produce desired results fast and economically, the most modern surveying techniques and data processing have to be applied. The swiftness of implementation is the most important factor in cadastre system production. In this research, the adopted GPS-RTK technique could solve most of the negative problems in the traditional total station technique. The following concluding remarks introduce the privilege of the GPS-RTK technique:

- GPS-RTK will speed-up the work considerably and facilitates data acquisition and transfer.
- The best benefit of the GPS-RTK system is that surveying more than 75,000 feddans from one base, so the traverse stages including reconnaissance, demarcation, establishment, observations and adjustment are escaped entirely.
- The job time reduced by about 70% of the job time when comparing with traditional technique.
- The quality of positioning and area computation is displayed in the field with position accuracy of 1cm, which is quite equivalent to control point's accuracy.
- The orientation and numbering of all boundary marks are no longer a delay production in the field.
- The destruction of landmarks problem will be solved completely, because the coordinates of the landmarks will be stored digitally. Accordingly, it will be easy to stake out these points, then the transactions will be performed very accurate and so easy.
- As parcel surveyed with high accuracy in area computations and all data are stored in digital forms problems of boundary disputes and all setting out problems will diminish.
- After the analysis of results, study the accuracy of the gained production and from the researchers point of view, the GPS-RTK system can solve the problems of rural

cadastre in Egypt in few years plan. Starting from the new reclaimed lands, which represent sixteen percent of the total rural area. These new lands are relatively large in. It is possible to establish a cadastre for these lands in three months if we have two crews in each Governorate, as we can survey over 200 feddans/day in large areas.

- As a kind of quality control and checks it is required to log raw data on the base and rover receivers to do processing and compare the results for random data samples. This process is utilized during the interference of the radio and at the areas out of the radio coverage range.
- For the areas, which have old cadastre and represent seventy percent (70 %) of total rural area, it is possible to establish cadastre for these categories of lands in thirty months, considering that the rate of work will be twenty feddans/hour. Establishment of the cadastre needs (800) working days if we have (60) crews all over the country.

Finally, for the rapid and the lowest cost, step by step improve and complete the cadastre work all over the country, the modern technology in surveying and registry, can be used. Using the GPS-RTK system accompanied with GIS data-logger reduces the time and cost and cancels many stages in traditional cadastre production. The GPS-RTK system will be so helpful in future planning of the national projects. Spatial and attribute queries can be executed to give accurate geometrical and attribute information. A prime motivation for revised cadastral mapping is to support an efficient information management system, by means of which the massive volume of registered property maps, and precise survey data in highway, public works, and other departments can be integrated.

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