A comparison study between the manual and Computerized surveying systems in Engineering Surveying

SAMI H. ALI[1]

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Abstract

The present research aims at the comparison of the production time between the manual and computerized surveying systems. The surveying system consists of data acquisition, processing and plotting the engineering plan and contouring .The current computerised system is designed and tested using the pulse Total Station instrument GPT-2006, P.C. computer, traverse network adjustment computer programs, Auto Cad 2005, 2010 and Surfer- 9 contouring program.

The results of the current field experiments showed that the computerized surveying system offers a considerable savings in the data acquisition, processing and plotting times as compared with the manual surveying system, i.e. for traversing , the reduction in the production time is up to (84%), for plan (up to 74%) and for contouring (up to 84%). The practical applications of the current research are in the fields of civil engineering projects (roads, buildings, etc.), irrigation and environmental engineering schemes.

Key Words : Manual and Computerized surveying systems, Pulse Total Station, Production time.

دراسة مقارنة بين نظام المساحة اليدوي والالكتروني في هندسة المساحة

سامي حميد علي

الخلاصة

أهداف هذا البحث هو أعداد دراسة مقارنة وقت الإنتاج بين نظام المساحة اليدوي والالكتروني. إن نظام المساحة يتضمن جمع البيانات ، معالجتها ورسم الخارطة الهندسية والكنتورية. نظام المساحة الالكتروني في هذا البحث تم تصميمه وفحصه باستخدام أجهزة المحطة المتكاملة (PULSE) GPT-2006 والحاسبة الالكترونية P.C ، برامج تعديل المضلعات ، نظام الرسم Auto Cad 2005 , 2010 وبرنامج رسم الخرائط الكنتورية Surfer-9 . تبين من النتائج الحقلية إن نظام المساحة الالكتروني يوفر لنا الوقت الكبير في مرحلة جمع البيانات ، معالجتها ورسمها مقارنة بنظام المساحة اليدوي . حيث أظهرت نتائج هذا البحث بأنه تم الحصول على تقليل وقت الإنتاج للمضلعات بنسبة ٨٤% ، للخارطة الهندسية بنسبة ٧٤% والخارطة الكنتورية بنسبة ٨٤% .

إن التطبيقات العملية لهذه الدراسة في مجالات مشاريع الهندسة المدنية (الطرق ، ألأبنية .. الخ)، مشاريع الري وهندسة البيئة .

1. Introduction

Land surveyors have for centuries been engaged on the task of acquiring original data regarding the shape and the disposition of the ground and supplying this information in the form acceptable to the user. In the past, the visible output has usually been via the medium of drawn topographic plans, which are essentially surface models in graphic form. Such plans have graphically portrayed the ground surface as it exists together with the features and detail upon it.

[1] *Lecturer at the Department of Civil Engineering , College of Engineering , University of TIKRIT.*

The demands of these plans to the user have depended upon their accuracy and reliability in defining the actual ground surface. Large scale engineering plans for engineering projects have provided the basic building blocks in the form most convenient to engineers, designers and other users, who need only specify to the land surveyor either the use to which data will be put or the form of the data and the tolerances that are required. The users had manually investigate these plans for their required purposes. However, the progress made in computers and ancillary technology has altered this situation drastically, computers permit all aspects of a survey can be integrated, from the acquisition of data in the field, processing , storing and the outputting of the final results in the form required by the user; either in digital form, printed listings or as graphic output. The purpose of the present research is to make a comparison of the production time between the manual and computerised surveying systems in order to produce a large scale engineering plan and contour lines at scale 1 / 1000 or larger.

The current manual surveying system consists of data collection, processing and plotting by using the conventional survey equipment and manual methods (see Figure (1)). While, the present computerised surveying system consists of data acquisition, processing and automatic plotting of the engineering plan and contouring. The computerized system was designed and tested using the pulse Total Station instrument GPT-2006, P.C. computer, traverse network adjustment computer programs, Auto Cad 2005, 2010 and Surfer- 9 contouring program. Figure (2) shows the main stages of the automated system. Each system will discussed briefly in the next sections.

2. Manual surveying system

In this system, the survey model was carried out by simple instruments and methods, using theodolite, measuring steel tape and an automatic level. However, these methods may not be used nowadays, but this survey was used The surveying system consists of system specifications and objectives, control traverse network, detail Survey measurements and levelling. Figure (1) shows the main stages of the manual surveying system. The horizontal control network was surveyed by traversing. It consists of one main traverse control networks. A diagram of the traverse network is given in Figure (3). Detail survey points was surveyed by simple surveying method, using tachometric method. Where one can pick up any type of detail, either hard or soft radially from a number of control traverse stations. Levels may be based on an existing bench mark (B.M.) of known height in the survey area or on a local T.B.M. However, levelling of suitable control stations was carried out with reference to a local T.B.M. of assumed height, using an automatic level and staff. Spot heights of carefully selected points, so-called ' random points' were carried out by tachometry. The positions of these points were chosen at changes of slope and direction of the ground surface. The coordinates of the control traverse stations are adjusted by the well known Bowditch and/or Transit methods, using manual processing (using, pocket calculator). Also, the spot heights were computed from tachometric field observations.

Manual plotting begins by first plotting the control traverse stations (survey control stations, grid lines, traverse line, symbols and annotations) , using simple plotting equipment such as, graduated scale, set square, T – square. Once the control stations have been plotted and carefully checked. The control stations are then used, together with the grid, to help with plotting of the detail survey points. Polar plotting technique was used for plotting the detail points that have been fixed from the control stations by tachometric observations with reference to the field sketches. polar plots were accomplished with a protractor and a scale rule (the larger the protractor, the more precise) .Symbols and annotations are added as required. Spot heights that have been collected with polar technique can be efficiently plotted with the polar technique, the contour lines were plotted using linear interpolation technique. However, the estimated production time of the manual surveying system (data acquisition, data processing and plotting) was calculated in order to make a comparison study with the computerized surveying system.

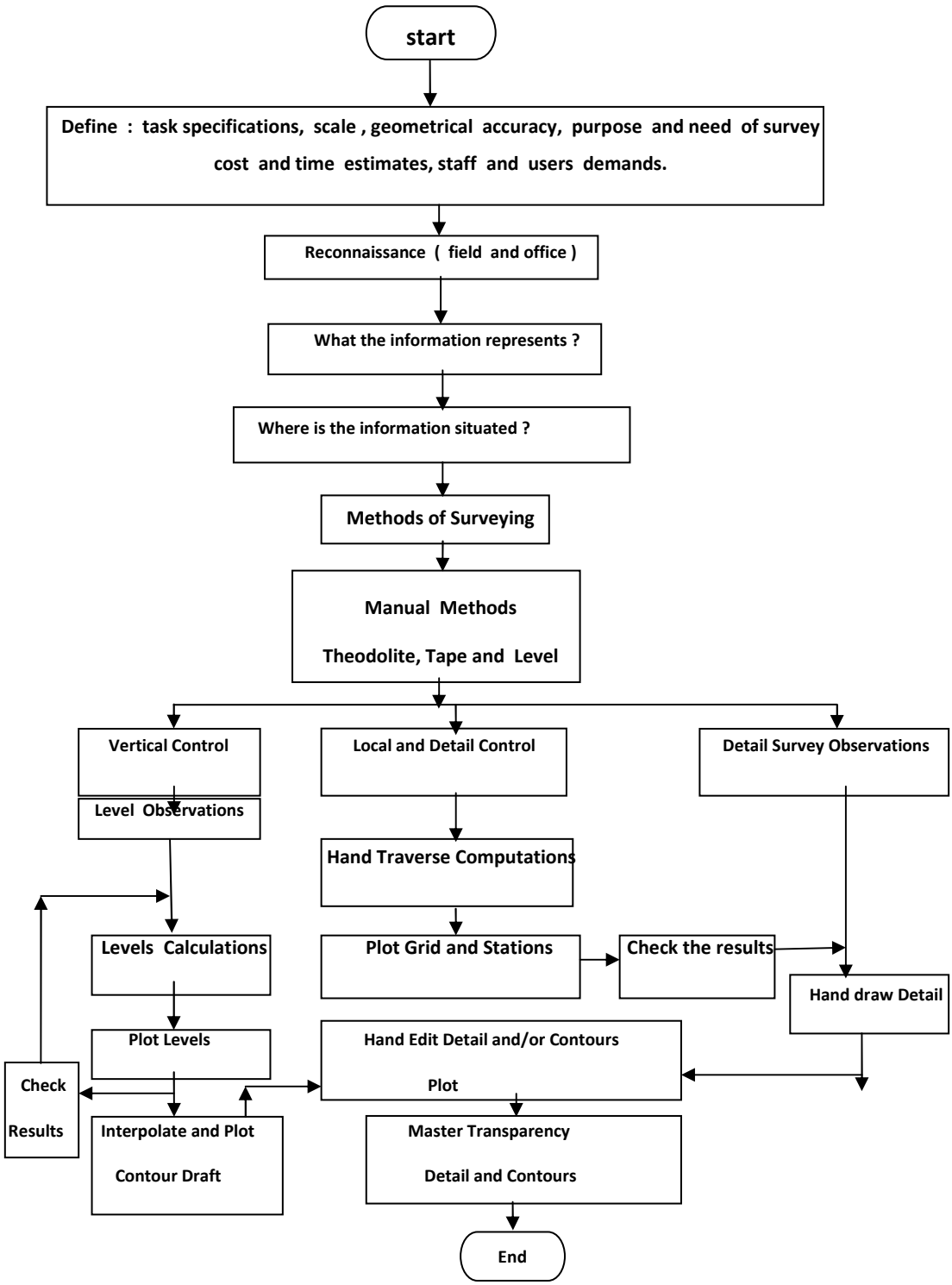


Figure (1) the manual surveying system flow diagram

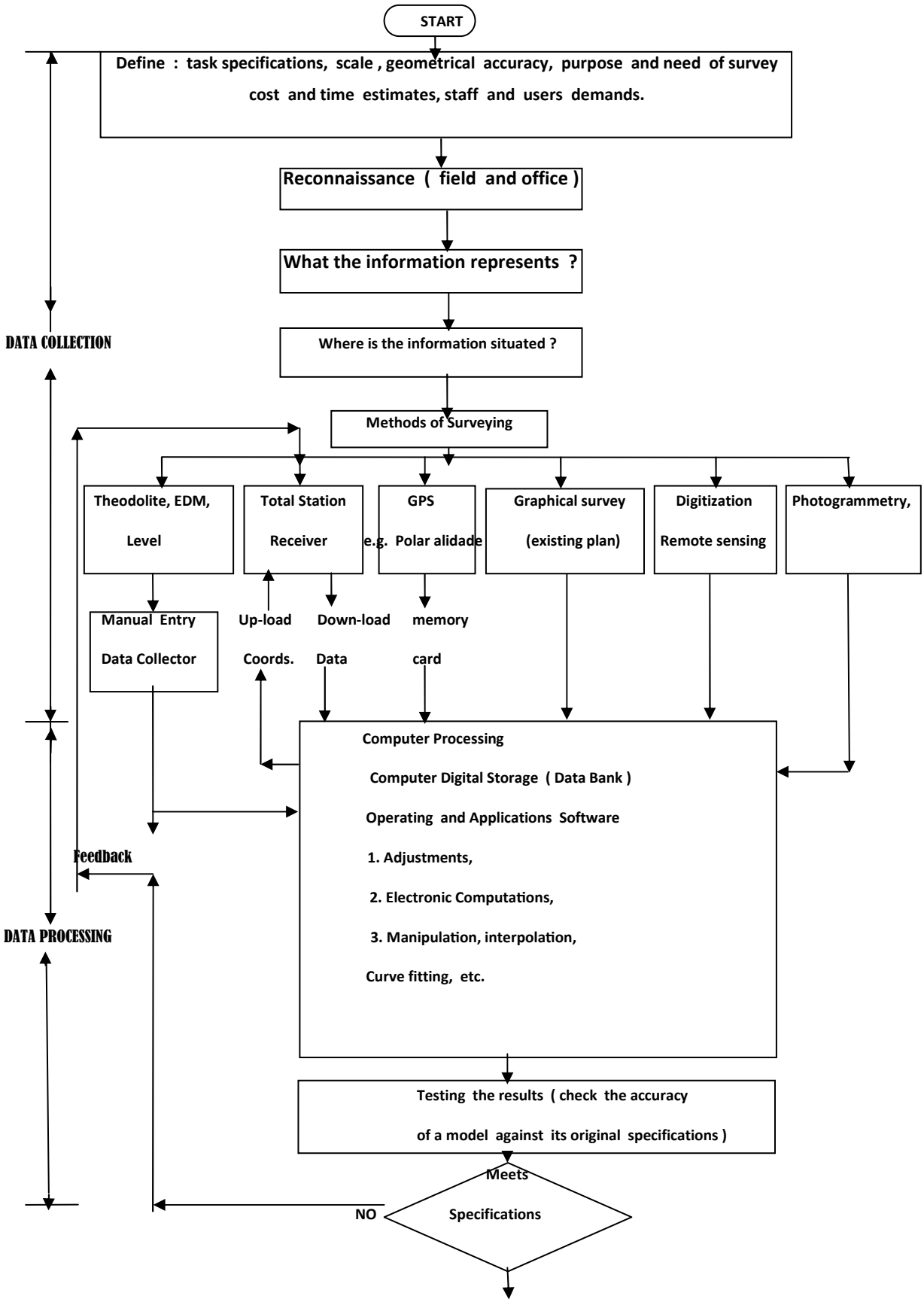


Figure (2) A flow chart of the computerized surveying system

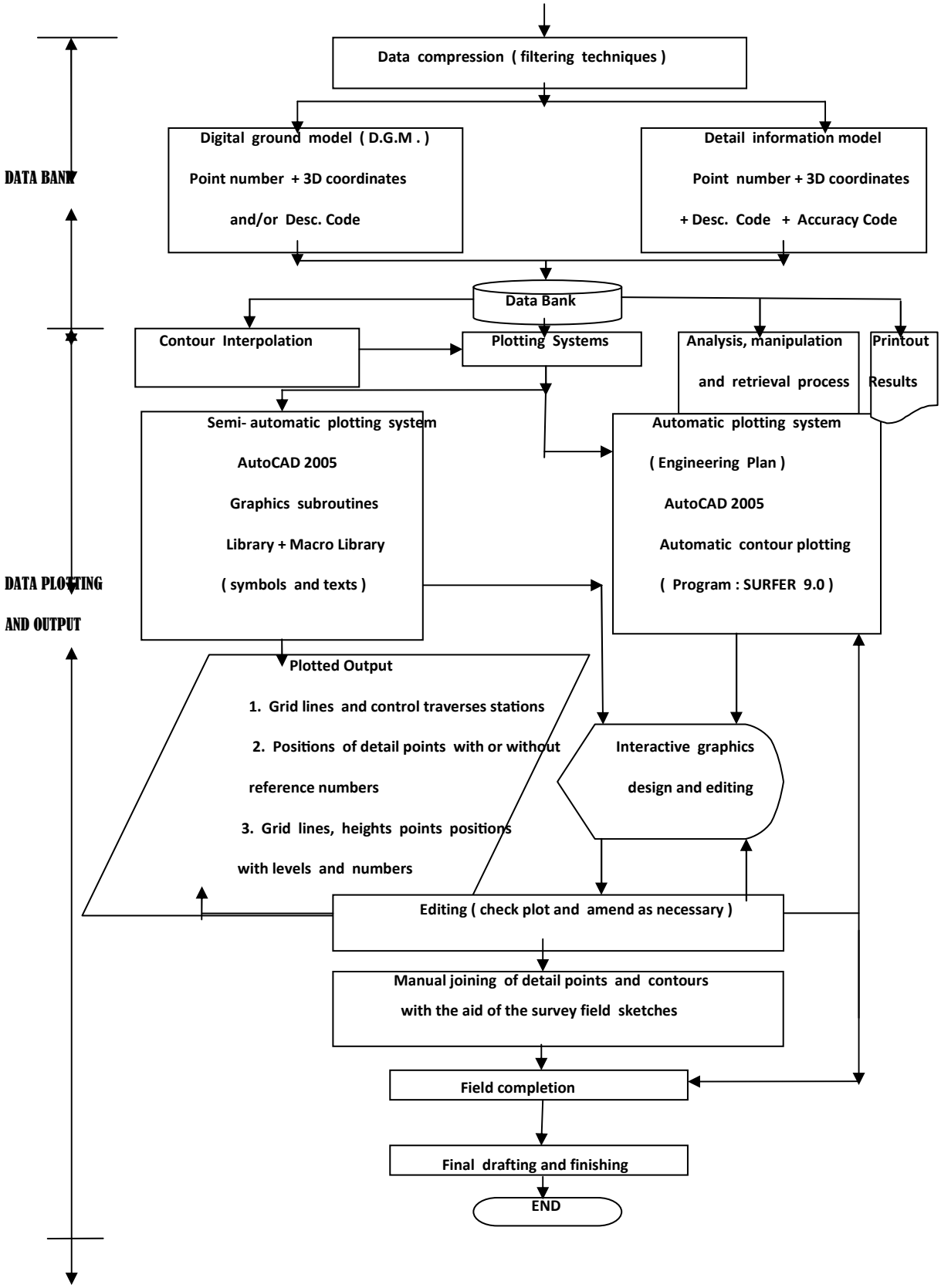


Figure (2) (Cont. 1)

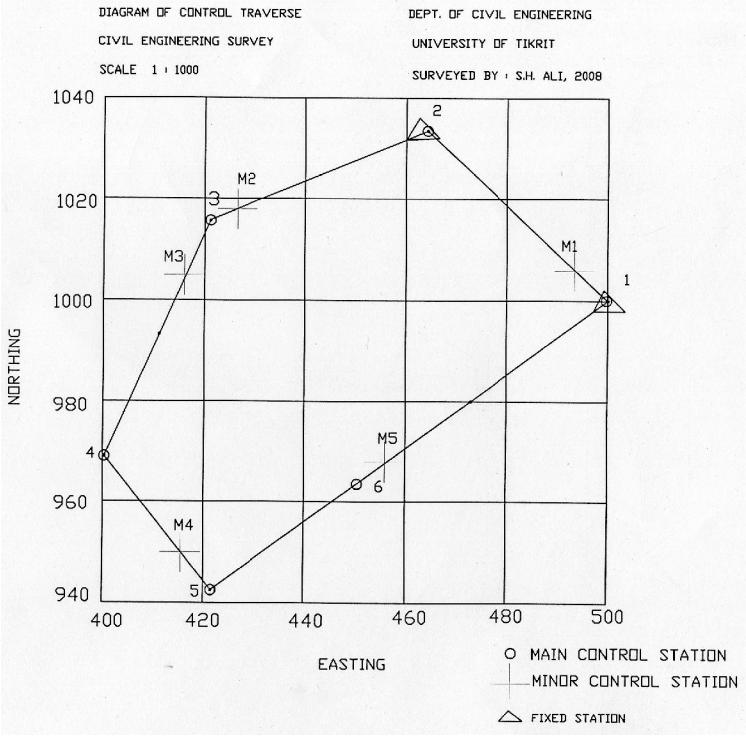


Figure (3) Diagram of the control traverse network

3. The Computerized Surveying System

The main stages of the current computerized surveying system can be divided as follows : (see Figure (2))

(1) Defining the task specifications and preparing cost and time estimates; programming and briefing staff to carry out the work; objectives ;

(2) Data collection (acquiring the survey data in the field);

(3) Data transfer , computer processing and adjustments;

(4) Data bank ;

(5) Data plotting;

(6) Information output, retrieval and analysis;

(7) Field completion , checking, editing and final drawing.

Having looked at all of these stages we found that the most pressing need was for the elimination of errors by checking during all stages of the production process.

4. Data Collection (Capture)

Data collection can be broken into three main elements :

a. Survey instrumentation.
b. Data recording.
c. Field observations and feature (field) coding.

These elements are clearly becoming more and more inter-related as the degree of instrumental automation increases. The upper portion of Figure (2) shows the various ways that data can be acquired and transferred to the computer. The one element they all have in common is that they are all computer- based. Except plane tabling, survey data acquired in the field has always been in a digital form and is therefore immediately computer acceptable. Each of the above stages will discussed briefly in the following sections.

4.1 Survey Instrumentation

Advances in computer science have had a tremendous impact on all aspects of modern technology. The effects on the data gathering and processing of data in the field surveying. Survey data once laboriously collected with tapes, theodolite, and levels recorded manually in the field books can now be collected quickly, accurately and efficiently in the field by ground survey methods using Total Station. The Pulse Total Station GPT 2006 was selected for the current study which was available at the university laboratory (Ref. (1)). The total station is equipped with dual-axis compensation in order to correct the horizontal and vertical angles automatically. The current total station has automatic point-number incrementation and point coding. Also, it has a zero-set button for the horizontal circle. Other characteristics of the current total station can be found in the manual instruction of the instrument (Ref. (1)).

4.2 Data Recording

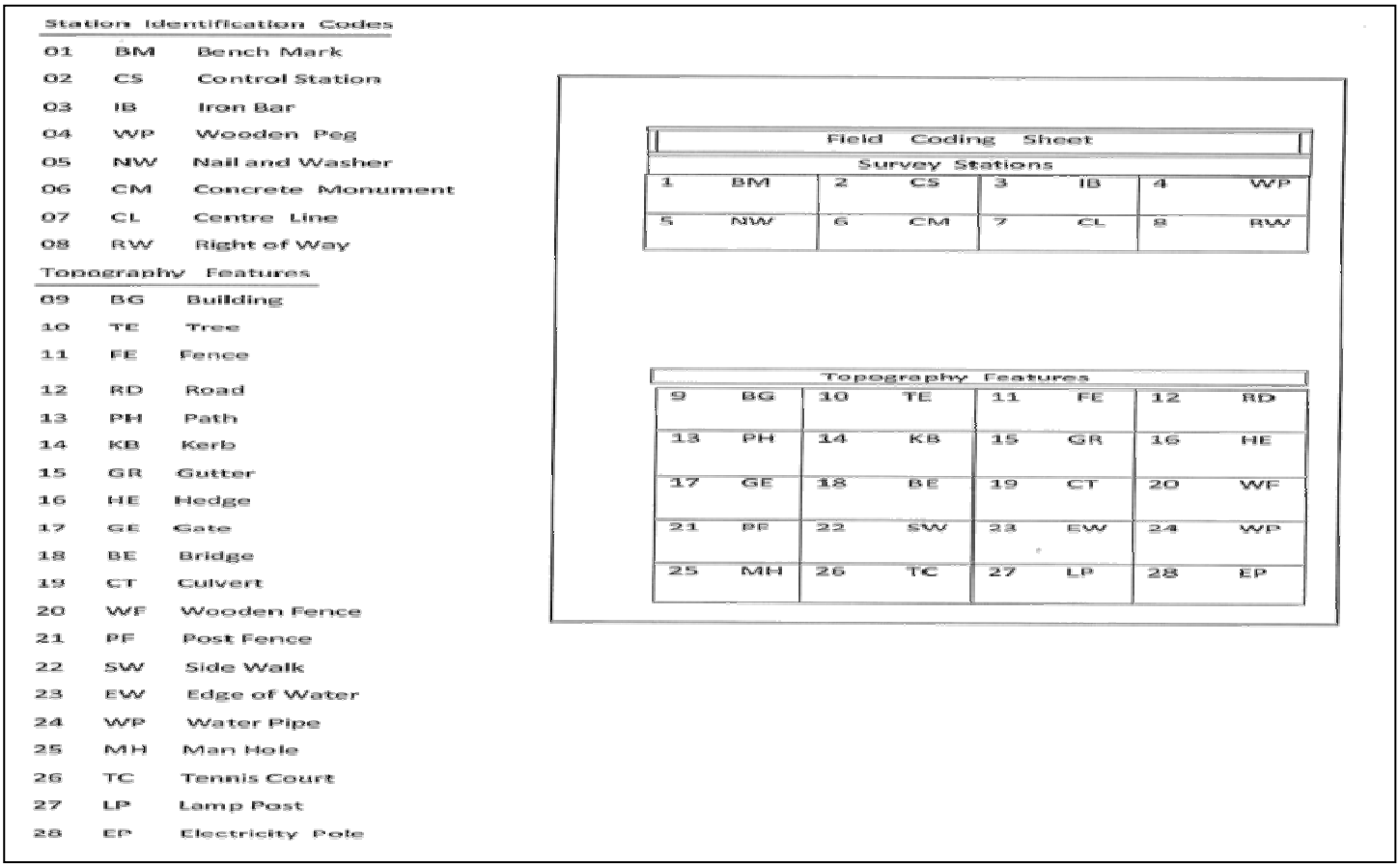
When the computers were first used in surveying, it was only possible to record measurements by hand in field books. This meant that all data captured on site had to be taken to an office and entered manually, into the computer via a keyboard so that the required plan could be compiled and plotted. This is a relatively slow process, prone to error. However, these problems were overcome when using total stations equipment. The captured data by the Total Station can be recorded, processed, edited and stored by data collectors, field computer, on memory cards and on-board in the internal memory (Grant (2)). However, the method of storing and processing information using data collectors and field computers is thought by some engineers to be inconvenient since it involves using an extra piece of equipment . Internal memories and memory cards overcome this problem and offer an alternative approach to data processing and storage. The internal memories are perhaps the most convenient method for storing survey data. For data transfer, it can be connected directly to a computer (see Section 6). In the current study, The pulse Total Station TOPCON GPT- 2006 was used. This Pulse Total Station Instrument is able to store the measured data files and the coordinate data files (Maximum 8,000 points) into the internal memory.

4.3 Field Observations and Field Coding system

As far as field coding is concerned, it is obviously impossible to decide the most suitable form of field coding without first deciding the degree of automation that is required for plotting. Generally, in a digital system , all survey data recorded in the field for subsequent use by computer must be correctly referenced for purposes of identification, processing and plotting. Two coding systems can be used in practice, the first is to employ only numeric codes and the other (alphanumeric or alphabetic) character codes .The choice of a specific coding system depends upon the computer circumstances (i.e. the computer language and the amount of storage space available in the computer to be used) and upon personal preference. The advantage of a numeric coding system is more efficient in computer terms because it requires less data, less storage and faster processing ; these factors will reduce the cost. But, the disadvantage of such system is difficult to remember from the point of view of the user. The (alphanumeric or alphabetic) characters coding system is quick for the layman to understand ' user friendly ' , and has a wide variety of coding possibilities. However, it can be translated into numbers by a suitable computer program, but this conversion process may possibly introduce errors (Day (3)). In the current research, the numeric coding (sequential numbering) was used for coding the traverse network, detail survey points and spot heights, where each point surveying in the field is given a unique number. The criteria for designing such numbering system are, it should be simple, unique, flexible and of uniform format (Johnston (4) , Blachlut et al (5), Johnston (6), Mils et al (7), Sherwood (8),Waugh et al (9),AL-ALI (10), Kavanagh (11), Nathanson et al (12) and Uren et al (13)).

In the present system, the numbering system is kept as simple as possible and the number of digits for each code number is kept as small as possible in order to allow easy handling, checking and avoiding errors; where checking and correcting a large amount of data are relatively costly operations. However, various types of codes are integrated into the current computer system. As far as the feature codes are concerned, in the current system, all physical ground features are grouped into classes for and subclasses for purposes of identification, processing and plotting. For convenience, alphanumeric codes system are assigned to features , which allow the user to divide features into logical groups of his own design. This is so that the computer storage can be arranged to allow a user to find the information relating to a feature code quickly and uses it to build up the plan of the area. Each code consists of a main code and a sub-code. The main code (feature code) is assigned to each detail survey point which indicates the type of detail point being observed (building, tree, fence , road and so on). This feature code is vital to the success of the subsequent processing and output (printing and/or plotting) stages (see Section 8). Moreover, feature codes can be assigned to a particular symbol and/or annotation to a point (e.g. tree symbol) (See Section 8). The main codes are logical abbreviations of words (alphabetic characters) which represent the first and the last letters of different feature names (classes) to be used, permitting the identification of an entire library of feature types. This coding system works admirably , with few exceptions . For example, BG represents building, RD road, etc. Double-barrelled descriptions such as tennis court and lamp post can be represented as TC, and LP respectively. This form of logical abbreviation makes the coding easier to understand, not only from the surveyor , but equally important from the computer operator . Special code sheet was designed for field use which is similar to menu technique used for digitising a plan (AL-ALI (10)) (see Fig. 4).Subclasses within the class are assigned numeric codes (sub-codes) using sequential numbers, starting with one. For example, BG01 represents building number 1, BG02 represents building number 2 etc. This coding facility was incorporated into the computer program (see Section 5.2.2). The sub-codes are sequential numbers , starting with one , which are used for the first feature. Then, the second feature is assigned with numbers , starting with (n+1); where n is the code number of the last station of the previous feature. In this way , the coding of all the features (detail points) in the survey area were performed (see Section 5.2.2). Where, each point of detail surveying in the field is given a unique number. The sequential numbering system was used for each of the detail points.

Accuracy codes can be used to indicate the quality of different detail points (hard or soft detail). In the current computer system, numeric codes are used. For example, code (10) indicates the hard (well-defined) detail points, while code (11) indicates the soft (not well-defined) detail points.



Station Identification Codes

01	BM	Bench Mark
02	CS	Control Station
03	IB	Iron Bar
04	WP	Wooden Peg
05	NW	Nail and Washer
06	CM	Concrete Monument
07	CL	Centre Line
08	RW	Right of Way

Topography Features

09	BG	Building
10	TE	Tree
11	FE	Fence
12	RD	Road
13	PH	Path
14	KB	Kerb
15	GR	Gutter
16	HE	Hedge
17	GE	Gate
18	BE	Bridge
19	CT	Culvert
20	WF	Wooden Fence
21	PF	Post Fence
22	SW	Side Walk
23	EW	Edge of Water
24	WP	Water Pipe
25	MH	Man Hole
26	TC	Tennis Court
27	LP	Lamp Post
28	EP	Electricity Pole

Field Coding Sheet

Survey Stations

1	BM	2	CS	3	IB	4	WP
5	NW	6	CM	7	CL	8	RW

Topography Features

9	BG	10	TE	11	FE	12	RD
13	PH	14	KB	15	GR	16	HE
17	GE	18	BE	19	CT	20	WF
21	PF	22	SW	23	EW	24	WP
25	MH	26	TC	27	LP	28	EP

Figure (4) field coding sheet

5. Data Collection Surveying System

The current data collection system consists of system specifications and objectives, astronomical azimuth observations, a control traverse network, detail surveying observations and levelling. The surveying system was carried out by the author at the college of engineering survey test area in 2009/2010. The survey model measurements was carried out by using the pulse total station instrument TOPCON GPT – 2006. It is common practice in surveying to prepare a digital planimetric model separately from the digital height model , because the planimetric positions are not related to the shape of the ground surface. Also the accuracy requirements of heights may be higher than for planimetric detail . Although, in a survey there are common points for plan and height. However, when using the total station equipment for data acquisition, the positional coordinates and height can be calculated simultaneously. Each stage of the computerized surveying system will be described briefly as follows : (see Figure (2)).

5 .1 Data collection operation (Field techniques and procedures) using the Total Station

The system was tested using the data from a survey test area at the university carried out by the author in 2009/2010. The survey model measurements was carried out by using the pulse total station instrument TOPCON GPT – 2006. However, the following practical applications of the Total Station GPT -2006 will be considered briefly:

1. Traversing with total station .
2. Detail surveying using total station .
3. Measuring heights (reduced levels) with total station .

5.2 Executing Data Collection

5.2.1Traversing with Total Station

A horizontal control network was established around the survey area in order to pick up the detail survey points. The surveying of these control stations were done by traversing. A total station loop traverse has been used for the current test area (see Figures (3) and (5)). However, the two–dimensional traverse can be measured if the instrument and reflector heights are not given. This can be extended to three-dimensional traverse if the instrument and reflector heights are entered into the total station as individual observations are taken. Otherwise , the three –dimensional traverse is performed. All of the measured coordinates for traverse are stored by the total station using its internal memory. The collected data must be downloaded to a computer for subsequent processing and adjustment. The observed values northings and eastings of the intermediate traverse stations are adjusted by approximate and/or least squares methods (see Section 6).The adjusted coordinates values are stored on a control file for later printing or automatic plotting (see Section 6.1).Additional control points can be observed using other methods such as, side shot and resection (free stationing) methods (Milne (14) and Ref. 1). Additional minor control points (1, M2, M3,M4 and M5) have been measured using the side shot and resection methods (see Figure 3). In the resection method avoid the "danger" resection circle. It is also possible to observe three dimensional traverses with a total station. In our case, the heights of the first control station 1 and those of the closing station 2 are entered into the total station via its keyboard . Also, the instrument and reflector height for each individual observations are entered. Heights are then computed for each station in the traverse. The misclosure for height is calculated and compared with the standard specifications, if the misclosure in the heights is accepted, they are adjusted by approximate and/or least squares methods (AL-ALI (15)) and then stored on the control file (see Tables 1 and 2). Generally, in control surveys, (forced-centring equipment) speeds up the field work, as the tribrach mounted on the tripod is centred and levelled only one time. However, prisms must be tribrach -mounted if a higher level of accuracy is required, when three-tripod (or more) traversing is used. Care is still needed to avoid centring errors especially for short leg traverse.

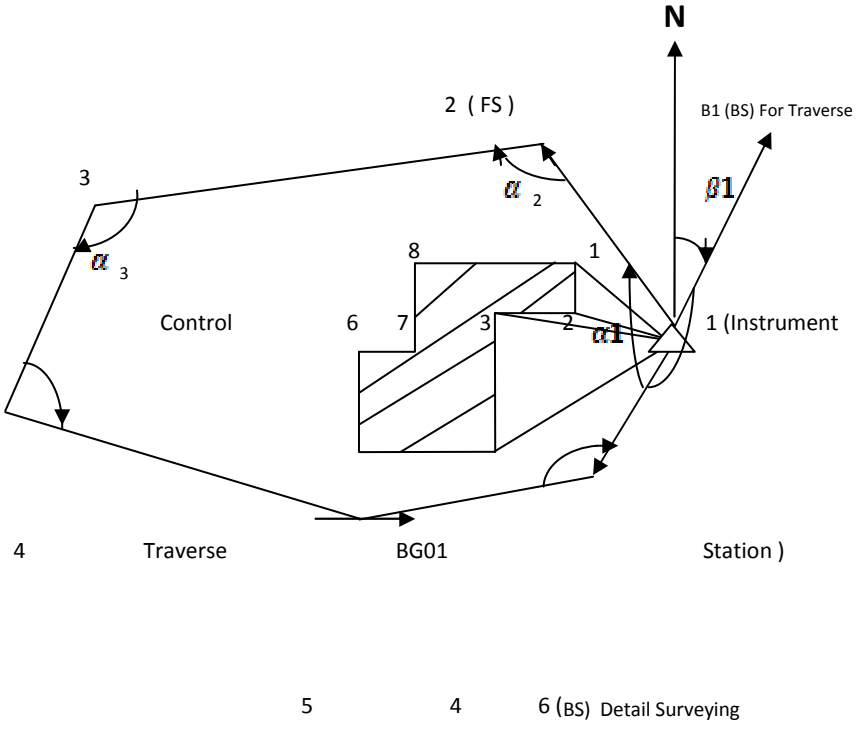


Figure (5) sketch showing detail survey points tie to a control traverse

5.2.2 Detail Points Survey System

The aim of the detail survey observations is to produce a two dimensional or three dimensional Model of the ground details. Where, the final production is an engineering plan at scale 1 : 1000 or larger. The detail surveying system was designed to create a detail model which defines the relative positions of the geometrical features on the ground surface (e.g. buildings, paths, trees, etc.). Detail can be subdivided into hard (well-defined) (e.g., corners of a building) and soft (not well-defined) (e.g., trees). In a detail survey system, the amount and type of detail that is located or picked up) for any particular survey varies with the scale and the intended use of the plan. These factors must be carefully considered in advance of any field survey work. The inter-relation between the instrumentation , data recording and feature coding is increased as the degree of instrumental automation increases. Before surveying of the detail points, consideration must be given to the geometrical nature of the detail features and the density of the points required to represent the feature within the desired level of the accuracy. Generally, as with all surveys, realistic technical specifications have to be made for a particular task. The first step is to select a geometrical model of the survey area. Then, the specifications of this model are specified in terms of the plottable accuracy (e.g., ± 0.2 mm) at the scale of the plan and the definition of a physical feature. The definition of the detail points (hard or soft details) is an important consideration in specifying the accuracy of the field work. It is impossible to measure detail points with an accuracy higher than their natural definitions (e.g. hedges).For rounded features ,sufficient number of points along the string needed to be recorded in order to produce a satisfactory curve if these points are joined up by a straight line. The density of these points depends upon the curvature of a string line. However, a curve fitting facility can be used to obtain a reasonable curve line through the measured points describing a feature (See Section 8.3.1). In practice, the surveyor observes more points in order to over-define the feature for safety rather than to under-define it. However, an optimization procedure has to be used in order to reduce the number of the measured points (Douglas et al (16) and Page (17)) and use the curve fitting facility to fit the observed points .

During the field work, the total station is set up at each point in the control network in sequence and used to pick up detail points from them as required, using the radial method . A survey by the radial method can progress rather rapidly since all measurement readings are done on the radial station only. In the current study, the survey detail points are picked up at random (i.e., not in string order). Figure (5) shows a detail surveying measurement being taken from a control station 1 to the detail points. Moreover, it is normal practice to observe the horizontal and vertical angle on one face only , where the total station should be in good adjustment and calibration .The total station is set up over the occupied station mark at control station 1, sight to the back sight station 6 (see Figure 5) . The prism mounted on the detail pole is held on the detail point being fixed (BG01) and observed by the total station at point 1 .Any number of intermediate sights (ISs) can be taken to define the topographic features being surveyed (e.g., Building BG01, detail point 1, 2, 3, 4) which are visible from the control station(1)(see Figure (5)) . The point number (most total stations have automatic point-number incrementation) and point description (feature code) for that point can then be entered and recorded using the designed field coding sheet (see Figure 4) and (see also Sections 2.3). The current total station GPT - 2006 has the options of speeding up the field work by employing " automatic point number incrementation" mode (see Ref. 1). However, This automatic point number incermentation mode has been used successfully for numbering the road detail, some of the building detail points and other detail survey points of the test survey area. However, in this case, where automatic booking and plotting is used (see Sections 2.2 and 8), a unique point number must be assigned to the detail point and a feature code must be assigned to it so that it will be recognized by the software to process and the survey data and plot the final plan (see Sections 2.3, 6 and 8). Also, the height of the prism/reflector

is measured and entered into the instrument in order to produce a three-dimensional detail model . The facility of the OFFSET can also be used to locate points when it is difficult to set up the prism directly over the detail point, for example the centre of a tree (Ref. 1). Some of the detail points (e.g., tree, lamp post) are picked up using this facility. In addition, the surveyor prepares field notes showing the overall detail, individual point Locations unique point number, feature code and joining feature code (on-and-off) (see Section 2.3). The field sketches and notes should be neat, clear and comprehensive. These field notes help the surveyor to keep track the completeness of the work and will be invaluable later during data editing and preparation of the plot file (see Section 8.2). Also, this field sketch will help the surveyor for joining the points which define the desired feature on the graphics display and/or at the automatic plotting stage (see Section 8.2). Although, the sequence of observing the survey detail points are picked up at random (i.e. not in string order) ,but the sequential numbering system of each feature was used for connecting the detail points at the subsequent automatic plotting stage (see Section 8.2). This method will give more flexibility to the surveyor in the field and later at the digital plotting stage.

2. when all detail points have been located from the occupied station (1), the total station can be moved to the next traverse (set up) station (e.g., station 2 in this example) (see Figure 5).

The data acquisition can proceed in the same manner as that already described, that is, BS at STA. 1, FS at STA. 3, and you can take all the detail points (ISs) which are visible from the set up station (2) .In this way, all measurements of the detail points have been completed.

The coordinates(NEZ) of each detail points with its reference number and feature codes are recorded and stored into the internal memory of the instrument for subsequent data transfer and data processing (see Section 6) . Since all the observations and feature codes have been logged, they are downloaded into the computer ready for processing , storing and plotting (see Sections 6, 7 and 8).However, in order to speed up the field work, other modern instruments (e.g., prismless total station and/or mortorised total stations and/or real -time detail surveying system and/or terrestrial laser scanner instrument) can be used (Kavanagh (11), Uren et al (13), Refs. 18, 19, Eiteljorg (20), Refs. 21, 22 and Uff et al (23)). In general, surveys involving a high proportions of measurements at each set-up of the total station can be fully justified and effective.Output results are not given in present article , because of the lack of the space .

5.2.3 Measuring heights (reduced levels) with total stations

This method of measuring the height is known as trigonometrical heighting and is the basis for all height measurement with total station. The advantage of measuring heights with a Total Station is that sightings can be taken over longer distances that are not possible with levelling (Uren et al (13)).For height (engineering) work, The Total Station should be equipped with dual-axis compensation to ensure that the (horizontal and vertical) angles errors remain minimum(tolerable). The following errors should be taken into considerations during the field work i.e., the errors in zenith angle, telescope collimation, curvature , refraction and other natural errors effects and the errors related with the use of handheld prism pole (Kavanagh (11), Uren et al (13), Refs. 1 , 24 and Hodges et al (25) and Burnside (26)). The most important error is in measuring the zenith (vertical angle). It is also used in other applications programs by a total station when heights are required for three-dimensional traverses and plan (see Sections 2.1 and 5.2.2), when performing a resection with elevations, and for remote height measurements (Ref. 1).However, this method can be used very effectively for contouring, particularly in open areas where a large number of sighted spot heights can be located from a specific set up (instrument) station . In the current project, a temporary bench mark of known (assumed) coordinates (E, N, Z) was chosen in the survey area. Spot heights of carefully selected points, so-called ' random points ' were carried out by using the Total Station GPT -2006. The field surveyor will select sufficient points at changes of slope, and a long the physical features (e.g., ridges, valleys, tops and bottoms of

embankment etc.), in order to create a good representation of the ground surface. The density of these points will depend on how complex the ground is, and how accurate a result is required. However, This field method is a more efficient process than the grid method, which requires more skill from the surveyor. The general considerations of selecting various coding systems in practice for coding the field survey observations have been discussed in section (2.3). Simple sequential numbering system was used. However, the same procedure for locating the three dimensional detail points was used to fix the so -called ' random points ' (carefully selected points). The coordinates (N, E, Z) of each height point are displayed on the instrument and stored in the internal memory of the Total Station for subsequent processing and creation the digital elevation model, contouring and design programs (e.g., highway design software) (see Sections 6 and 8.3)(Allan (27) and Davies (28)). Output results are not given in the current technical paper , because of the lack of the space. However, Functions in the internal memory manager that greatly aid the editing of the field data observations are the ability to scan (search) forwards and backwards or using point number through the internal memory (see Ref. 1). This editing of the field survey data was executed before the actual transfer of the data to the P.C computer was performed.

6. Data Transfer and Data Processing

In the current example shown in Figure (4) (see also Figure 6), the captured data must be downloaded into the computer. The download computer program is normally supplied by the total station manufacture, and the actual transfer can be cabled through an RS232 interface cable. However, in the current research , the TOPCON download program (T-COM) has been used. Where, the captured data can be downloaded to the P.C. computer via an RS232 interface cable. The measured data or coordinate data can be transferred from the internal memory of the instrument to the P.C computer using the memory manager mode (Ref. 1). survey data have been stored in coordinate files for later editing and plotting on an interactive graphics terminal or by automatic plotters, using computer-aided design (CAD) programs (e.g., Auto Cad 2005) and SURFER -9 (Finkelstein (29) and Ref. 30)).The collected survey data in the internal memory should be transferred to another source at frequent intervals – at least once a day. Never erase the original data from any source until a backup copy has been created and read successfully. Having processed the data in this way, it is now possible to view the coordinates (NEZ) of the traverse, detail points and contouring data on the computer screen either in textual form, for example a list of point numbers, N, E, Z and feature codes or graphical form as a plot. Both can be displayed on the screen and edited as required (see Section 9)(Finkelstein (29)). The following optional adjustment computer programs by (1) Bowditch, (2) Transit, (3) least squares (variation of coordinates) method are used to adjust the horizontal control network (closed and link traverses) from the field observations by the Total Station instrument. Also, The least squares program computes the absolute error ellipse parameters of each station and the relative error ellipse parameters between the adjacent control stations .The absolute and relative error ellipses parameters are derived from the variance-covariance matrix of the vector of unknowns (Moffitt et al (31), Ref. 32, Allan (33), Mikhail et al (34), Allan(35) and Al-ALI (10)). Each program will print out the degree of precision of the calculation and error messages will show if the results are outside of the accepted tolerances. However, the computed relative accuracy of the traverse is within the specified accuracy of this survey traverse network. A typical output results are shown in Tables 1, 2 and 3. The final adjusted coordinates may be stored, on a control file, for subsequent automatic access during further control and detail survey computations. Also at this stage, additional data points (e.g., inaccessible ground points) can be computed and added to the data control file. Additionally, missing data positions can be computed by using various intersection, resection (free stationing), and interpolation techniques, with the resultant coordinates (N, E, and Z) being added to the

control data file(see Figure 3). The diagram of control traverse network and error ellipses are plotted on a graphics terminal and an automatic digital plotter (see Figure 5 and Section 8).

7. Digital Data Bank

In order to create a digital data bank, the form and the contents of the digital data bank depend on the objective. The main objective of the digital data bank is to allow easy access, retrieval and updating of the information, in order to satisfy the user requirements. The data bank can be created from the processing of the original field survey observations which are captured by the Pulse Total Station .The vector technique for the storage the referenced data was used Strings of coordinates (two or three dimensional coordinates).Detail information can be stored as two and/or three dimensional coordinates with their reference numbers and feature code. Ground height information in the form of three dimensional coordinates and their reference numbers and/or feature code as a model in the data bank. This model is known as digital ground model (D.G.M) or digital terrain model (D.T.M.). These models refer to a three dimensional geometrical model , i.e. plan and height. Originally, the word D.E.M. refers to a height model only. However, these models are stored on a disc file for subsequent computer plotting and manipulation(see Sections 8 and 9).A compression techniques has been used to save the computer storage capacity. Some compromise must be made between accuracy, processing time, and the cost of using a particular compression technique .In this study, two files have been created from the data collection stage by the total station i.e. measured data file and coordinate data file (see Ref. 1). The measured data file are stored on a sequential disc file (archive file) and accessed if desired using the archive facility for restoring the file. However, the measured data may be printed out as an aid to clarity and produce a comprehensive document. In the current research, sequential file system was used.

The following information are stored in the current digital data bank :

1. Traverse control points coordinates with their reference numbers (see Table (1).
2. Detail survey points data (Point number, The coordinates (N, E, Z) , Feature codes and Accuracy Codes) .
3. D.G.M Levelling data (Point number, The coordinates (N, E, Z).

Table 1. Output results of the programs "ADJBOW", "ADJTRN" and "ADJLST"

Station No.	Bowditch's Method		Transit Method		Least Squares Method		
	Easting (M)	Northing (M)	Easting (M)	Northing (M)	Easting (M)	Northing (M)	Height (M)
1	500.000	1000.000	500.000	1000.000	500.000	1000.000	100.000
2	464.166	1033.394	464.166	1033.394	464.173	1033.397	99.770
3	421.205	1015.783	421.204	1015.783	421.208	1015.786	99.901
4	400.243	969.616	400.244	969.615	400.245	969.622	99.778
5	421.462	942.425	421.464	942.424	421.457	942.438	99.801
6	451.998	964.659	452.000	964.658	451.994	964.666	99.972
RELATIVE ACCURACY = 1 / 1,2397							

Table 2. Absolute error ellipses parameters – output results of the least squares adjustment program " ADJLST"

STATION No.	SEMI-MAJOR AXIS (m)	SEMI-MINOR AXIS (m)	BEARING OF SEMI-MAJOR AXIS (Degrees)
1	FIXED POINT	--	--
2	FIXED POINT	--	--
3	0.031	0.005	67.187
4	0.036	0.019	46.785
5	0.036	0.010	54.589
6	0.032	0.006	53.834

Table 3. Relative error ellipses parameters – output results of the least squares adjustment program "ADJLST"

LINE		SEMI-MAJOR AXIS (m)	SEMI-MINOR AXIS (m)	BEARING OF SEMI-MAJOR AXIS (Degrees)
FROM	TO			
2	3	0.031	0.005	67.187
3	4	0.036	0.006	24.462
4	5	0.019	0.005	322.101
5	6	0.032	0.005	54.228
6	1	0.032	0.006	53.834

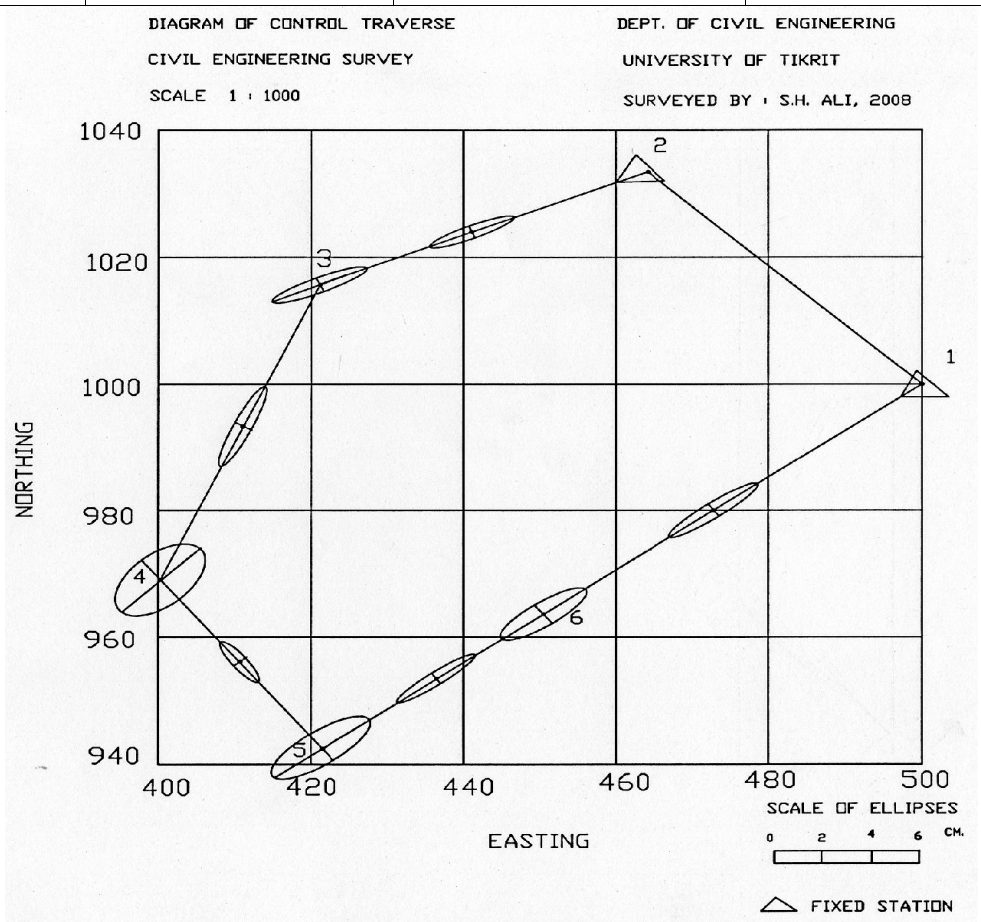


Figure (6) Absolute and relative error ellipses of the traverse network

The current method of storage is not efficient for searching data items, because the computer file has to be searched sequentially. Alternatively, the use of random access file will improve the efficiency of editing and the retrieval of data items and remove the requirement of strict sequential searches. As a result the access time will be decreased and hence speed up the retrieval process. However, this technique was not used in the current system and further investigations will be required. Various manipulation and retrieval facilities from the current digital data bank were executed (see Section 9).

8. Data Plotting

There are many commercially and in-house produced computer software packages available for the production of engineering surveying drawings. The main factors for choosing the desired software are that its capabilities, costs and to satisfy the needs of the user (i.e. the surveyor and design engineer and not vice-versa (Kavanagh (11), Johnston (4,6), Mils et al (7), AL-ALI (10), Fort (36), Refs. (37) and (38)).In the current study, Auto Cad 2005 has been used for plotting the Total Station survey. Auto Cad 2005 is a powerful 2D and 3D design and drafting platform that automates the design tasks and provides a digital tools. The designer can create, view, manage, plot and share his design (Finkelstein (29)), where the dialogue between the surveyor and the computer is interactive. The operators sees on the screen what is being doing and what has been done. Although, the software system provide a high level of automation, the operator is always in complete command. He can make decisions based on his knowledge and interpret the results presented to him. The plot created on the computer screen is checked for completeness and edited as required, prior to the automatic plotting on the digital plotter. The Auto Cad 2005 graphics software has a wide range of facilities. It is supplied with libraries of symbols, line types, line weights, colours, curves, texts, shading, control commands and so on. These can themselves be amended and extended to allow users to create their own macro(symbols) libraries and feature codes. These symbols can be placed in any position on the drawing, to any scale and at any orientation (see Section 8.2). Also, The technique of layering is one very important facility which was available in the software. This facility was used in the current study.

The plotting of a survey can be divided into the following stages :

(a) Computer –aided plotting the traverse control network;
(b) Computer –aided plotting the detail survey points;
(c) Computer –aided potting the contour lines.

Each of the plotting stage will be discussed briefly .

8.1 Computer -aided plotting the traverse control network

When the adjusted coordinates of the traverse control network stations have been computed (see Section 6 and Table (1)). These coordinates are stored on a disc control file in the computer for subsequent use and automatic plotting . A line printer print-out is automatically produced showing all the coordinates and/or level of all control stations of the network. Such coordinates have many uses in engineering surveying operations, one being to provide a framework for the production of survey drawings, either by computer – aided plotting or by hand. The plotting facilities for plotting the diagram of the control traverse network operate into two stages, namely :

(1) Plotting the grid model , title and other annotations;
(2) Plotting the positions of the traverse stations with station number and/or connecting lines and/or symbols (see Figure 6).
(3) Plotting the absolute (position) error ellipse for each traverse station and the relative error ellipses between the traverse stations (see Figure 6).
(4) Plotting the whole plot of the survey network at any desired scale (plotter format imited), grid interval and orientation.

The above stages of the plotting are plotted into layers using the important layering facility in the graphics software. The software allows layers to be turned on and off as required. This enables users to set up layers of detail and allows them to select and plot only those of particular interest (

Finkelstein (29)). Editing of the check plot was performed using the off-line and /or the interactive editing techniques. The technique of interactive editing provides a very rapid method of detecting errors, and allow their speedy corrections and no plotting material is wasted. This is normally done prior to the running of the plot on a line printer or an automatic plotter in order to save time and cost. However, this technique of editing will eliminate the obvious errors of the plotted points, but a check plot is still required to be produced on a line printer and/or an automatic plotter for final checking of the completeness and positional accuracy of the plotted stations. Few errors have been detected and corrected. With both editing techniques, a line printer output is simultaneously produced listing the coordinates (ENZ) of the control stations with their reference numbers (see Table (1)), which can be used an aid to identification (e.g. incorrect code of a point).

8.2 Computer –aided plotting the detail points

It is obviously impossible to decide what is the most suitable form of field coding without deciding the degree of automation that is required for plotting. For plotting the plan, there are many possible solutions (options) , but, in the present research two plotting systems will be examined,(a) semi-automated system and (b) automated system. These systems will be discussed in the following sections :

8.2.1 Semi – Automated Plotting System

After the field survey data are downloaded into the computer (see Section 6), the resulting coordinates and height of detail points from the observations by the Total Station may be stored on a Survey File for subsequent computer plotting and/or digital ground modelling. The coordinates , point number and feature codes are then stored in the data bank which can be accessed as required (see Section 7). Having processed the data in this way, it is now possible to view the detail points on the computer screen either in textual form, for example as a list of point numbers, N,E, Z and feature codes or in graphical form as a plot. Both can be displayed on the screen and edited as required with any selected section of the data bank being viewed (Finkelstein (29)). The positions of the survey control stations and the detail points and/or point numbers and/or feature codes are plotted on the computer screen and/or line printer or an automatic (drum or flatbed) plotter (see Sections 5 and 6) . The grid model , text and other annotations are plotted and stored in layers, as described in Section 8.1. Then, the positions of the detail points, reference number and field codes are plotted in a specific layer. Moreover, the positions of the control survey stations with reference numbers and special symbols (markers) (i.e. centered triangle and cross symbols) are plotted on the computer point plot. The points plot is produced on the computer screen by simply using the desired plot commands of the Auto Cad software and edited as required, then the plot is plotted on the line printer and/or automatic plotter. Off-line and on-line editing techniques of the check computer plot has already described in Section 8.1 .By reference to the field sketch appropriate points are joined up manually using pencil, scale and French curve and edited where necessary to form the engineering plan. The resultant pencil plot can be can be traced manually to produce the fair drawing (AL-ALI (10) and Mils et al (7)). If a digital survey model is required for subsequent engineering design, then the final tracing plot can be digitised .The advantage of such system is that the computer can produce the final fair drawing at any required scale or grid interval and orientation. As a result, a considerable savings in tracing time are obvious, if the final survey has to be plotted at more than one scale. However, this system output is not shown in the current article , because of the lack of the space . The computer points plot should be produced on dimensionally stable plastic (film) in order to reduce any effect of shrinkage or distortion in the plotting material and to form the basis for the final plot, which can be plotted manually or by computer. This system offers a considerable savings in the processing and plotting time over purely manual methods. By producing an accurate computer plot showing the positions of all instrumentally observed points (within the original field survey observations and automatic plotter accuracy), the surveyor can easily and quickly complete any part of the plot which may be required in advance of the full survey. Moreover, The surveyor can detect any positional errors which might escape notice on a computer completed survey, because the surveyor has a clear mage of the survey that was carried out by him. Also, the satisfaction most surveyors obtain from

completing the plotting stage manually. However, in an ideal world, the field surveyor would process his own observations in the office and create or supervise the final survey drawings.

8.2.2 Automated (fully automatic join) Plotting System

This system comprises of the following stages :

1. The automatic recording of the survey points by the Total Station with the field coding or (trans-coding) and a field sketch were used for joining the detail points on the interactive computer graphics prior to automatic plotting by using the Auto Cad graphics software2005. In the current study, field coding system has been used (see Section 2.3).
2. The detail points of a desired feature are joined by the specific type lines ,weight and colours in sequence. The sequential numbering system of the detail points with the aid of a field sketch will help the surveyor for connecting the specific detail points of a ground feature (e.g., building) . The technique of layering is one very important facility. In this, either at the coding stage or during the subsequent editing, particular features can be placed in their unique layer; for example all trees could be placed in a tree layer, all buildings in a building layer and so on. However, the software allows layers to be turned on or off as required. This allows users to set up layers of detail and enables them to select and plot only the desired type of details (Finkelstein (38)) or any combination of details – roads, fences and houses, or roads, footpaths and sewers. Moreover, another advantage is that should it be necessary to alter any of the details, say substitution of house types, only the affected layer (s) need be modified. However, in the current research, layers have been created in order to plot each ground feature in a specific layer, and every layer must have a colour, a line type, and a line weights (see Figure (8)).
3. Spline curve fitting techniques was used to join the detail points which define the curved lines feature (Bolton (39) and Finkelstein (29)).
4. When all detail survey was plotted to form the finished engineering plan, then the cross symbols, reference number and feature code of the detail points are cleared up from the computer check plot in the interactive mode.
5. The placement of symbols, texts and shading was performed . However, various types of symbols have been digitized and stored in the data bank for subsequent automatic selection by symbol feature number and/or type (AL-ALI (10)).
6. Editing the check plot was executed using off-line and interactive editing techniques (see Section 8.1).

7. At this stage , a hard copy of the screen display can be printed on a simple printer or on an ink-jet colour printer. Plot files can be plotted directly on a digital plotter (see Figure (7)). The resulting plan can be plotted to any desired scale, limited only the paper size. Example of the computer plots are shown in Figure (7).

The advantages of the automated plan system are as follows :

(1) It offers a considerable savings in the processing and plotting time over the semi-automated and manual methods .

(2) The final automated plot of the survey can be produced at any required scale, contents and orientation as compared with the semi-automated system (see Section 8.2.1) or manual methods.

(3) It eliminates the requirement of the photographic reduction as compared with the semi-automated or manual plotting methods.

8.3 Contouring by Computer

This section is concerned semi-automated and automated contouring plan plotting systems using the Total Station heights observations (see Section 4.2.3). Once the field observations have been processed and stored in the data bank by the software (see Section 6). A D.E.M can normally formed from the spot heights collected at existing Points of detail or in a grid mesh will have heights values that do not coincide with exact contour values. In the present paper only the interpolation in a net of triangles method will be considered briefly .In the current research , ground survey method (carefully selected points so-called ' random points') using the pulse total station will be considered. Heights points are carefully chosen at changes of slope and changes in the direction

of a contour. Also, break lines (e.g., ridge lines, ditch lines, etc.) should be surveyed in the field. This careful selections of spot height locations on the site will produce an accurate contours (see Section 5.2.3). For contour plan generation, there are two possible solutions as follows :

(a) Semi-automated plotting system.
(b) Automated plotting system .

(a) Semi-automated System

The aim of this system is plot the contour lines by using the current approach i.e. part-computer part manual. The computer is used to produce a dot plots with the spot heights and/or reference numbers as a series of dots in their correct plan position. The contours are then finished manually. This procedure also gives the surveyor an opportunity to inspect the work for any mistakes, as part of a quality control scheme. Moreover, in order to produce a digital data bank, the contour lines can be digitised (AL-AlI (10)). However, this system was not considered in the current study.

(b) Automated plotting system

In the current system, the software package (SURFER - 9) was used in order to interpolate and plot the contour plan automatically from the total station spot heights data (Ref. 30)(see Section 4.2.3). The contour interval for the terrain, scale and the intended use of the contour plan must be selected. This software uses the triangulated irregular network (TIN) technique . The sides of the triangles are analysed so that contour crossings can be interpolated linearly along all sides to give a series of points on the required contours. This method becomes popular nowadays for generating the contour lines automatically from carefully selected points (so-called ' random points '). This approach is similar to the conventional-manual approach for plotting the contour lines. The triangles are treated as planes and surface is smoothed. The triangular contouring system can provide both greater speed and more accurate representation of the surface when compared with other contouring systems, providing the positions of the spot heights have been carefully selected in the field (or in photogrammetry); where the surveyor should select points at changes of slope and direction. First, the TIN network is created from the observed ' random points ' by the Total Station and other defined break lines (in the study area , there are no break lines). Then, the raw contours are computer generated from the observed spot heights of the chosen points. To make the contour pleasing to the eye, as well as representative of the ground surface, Smoothing technique was used to soften the sharp angles occurring when contours are generated from TINs (as opposed to the less angular lines resulting in contours derived from a uniform grid approach)(Ref. 30, Schut (40), McCullagh et al (41), Pucker et al (42) and Christensen (43)). An important test of computer software is the contours must preserve the integrity of the original of the original spot heights from which they have been derived. In other words, a spot height must be on the correct side of a contour line. This process, from field to finished plan, is fully automated where electronic data capture and transfer was used (see Sections 2.2 and 5). The use of layering technique is one very important facility. The contour plan can be plotted in a specific layer. This contours layer can also be added and placed on the plan. Moreover, another facility was incorporated into the SURFER-9 program in order to stop the contour lines at the positions of buildings or similar features, where the user must define the areas(boundaries) over which contours should not be drawn (Ref. 30).Then, the resulting computer contours plot can be accepted. The SURFER-9 can create a perspective view 3D surface and 3D wireframe plots of a particular survey area in order to view a specific survey area at different angles .Surface area and volumes computations of the desired survey area can also be executed using this software which are very useful facility in civil engineering projects (e.g., roads and highways design). some computer contour programs produce a meaningless contours, where there are insufficient spot heights data, but the surfer-9 software generates an acceptable contour lines .However, this program can produce meaning less contours at places where there are insufficient number of spot heights which describe the actual ground surface. A typical output of the SURFER-9 software is shown in Figure 9 .The automated contouring plotting system offers a considerable saving in the field time, processing and plotting time as compared with the manual methods .

9. Manipulation and Retrieval Facilities

Various manipulation and retrieval facilities can be performed from the digital data bank (Digital survey model) and digital elevation model DEM (see Section 6).
The options available are :

Selection of survey points by point number, their feature code, the accuracy code, E, N and/or Z coordinates; plot the required area of the interest at any desired scale and orientation and update any part of the stored information of a survey area.

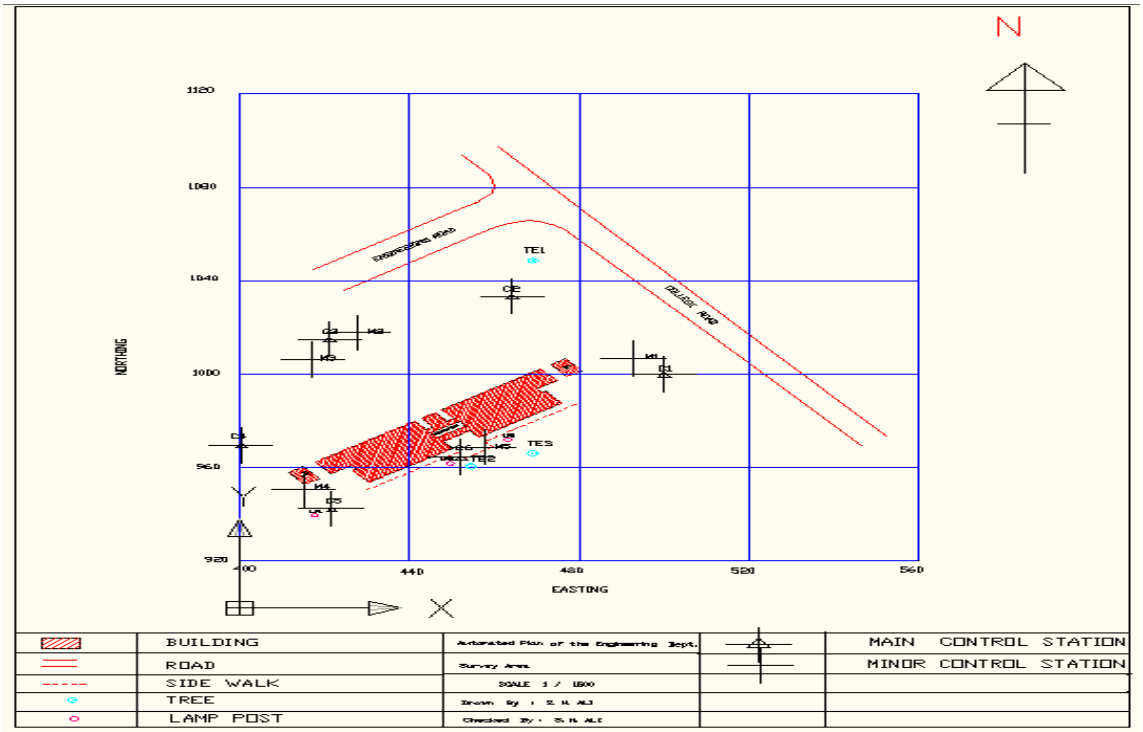


Figure (7) Automated Plan of the Survey Area. Scale 1/1400

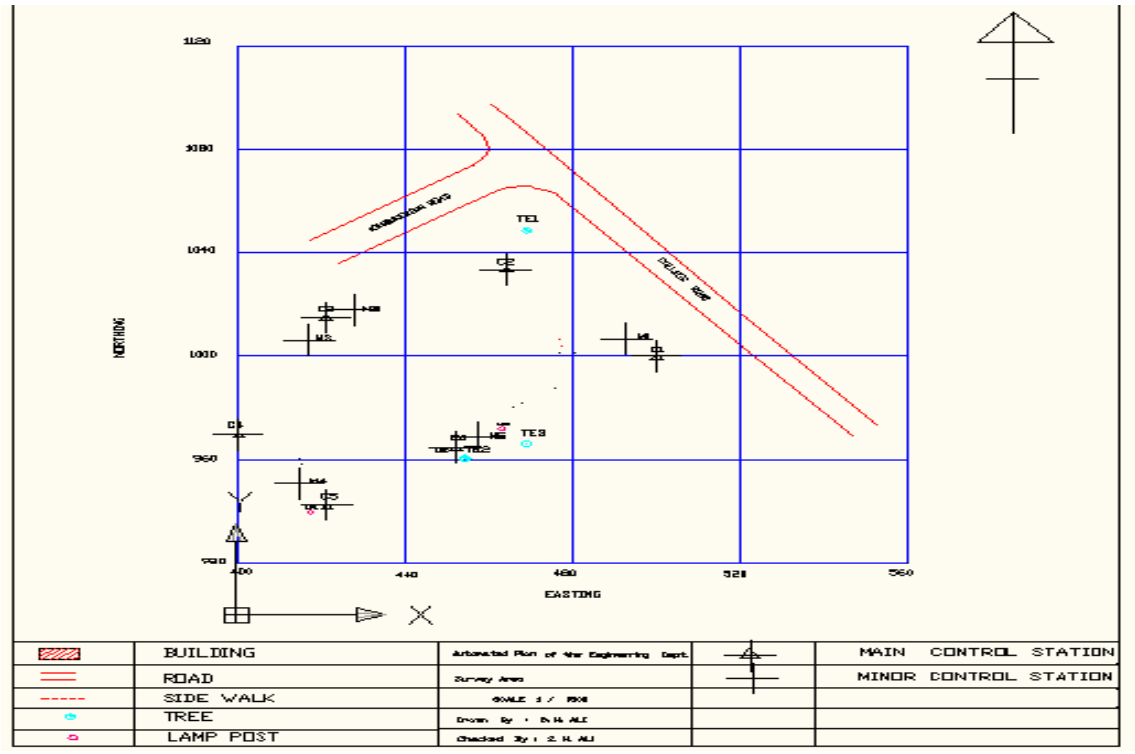
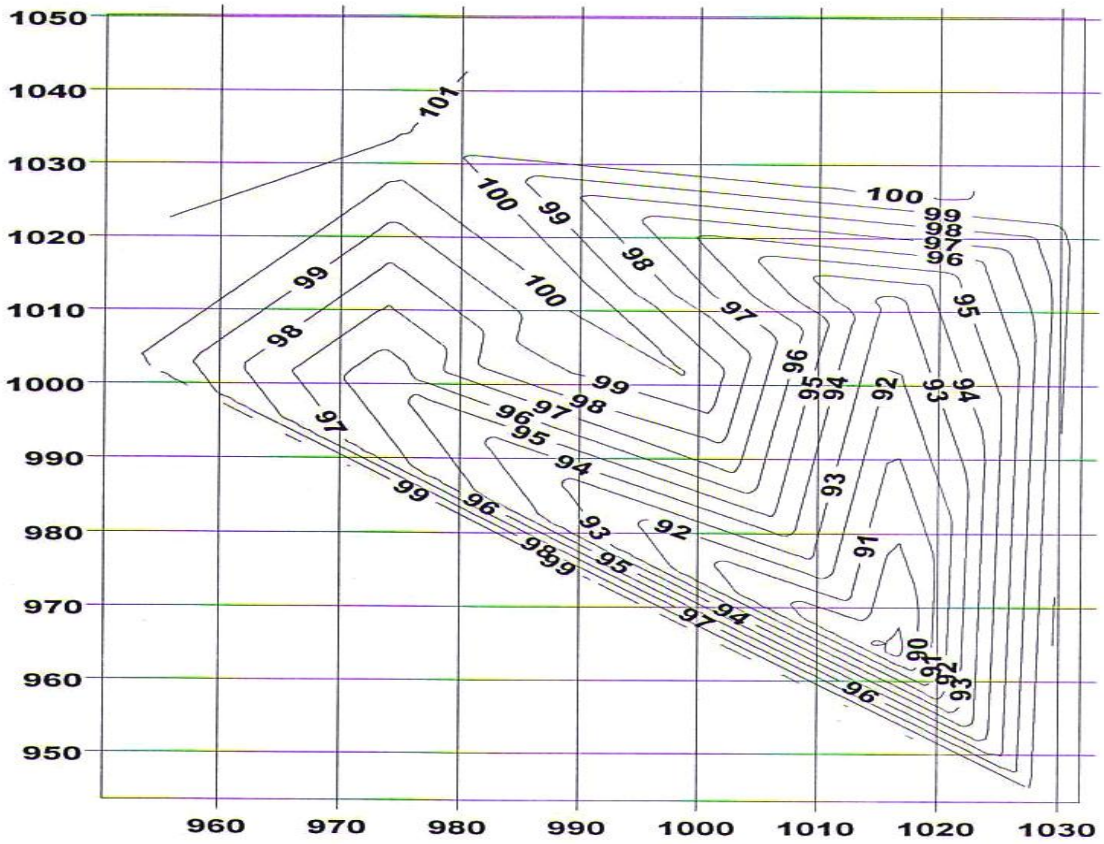


Figure (8) Example of the road layer turned on.



Figure(9) Automatic contour plan (contour interval=1.0m scale 1/1000)

10. Field completion, editing and final output information

No matter how much care is taken to avoid mistakes and omissions in plan making, some do escape the checking systems used by the surveyor. It is important that a plan should be given a final field check. In the current plotting system, very few errors have been detected. Then, these errors were located and corrected ,using the editing techniques (see Sections 8.1). However, some additional field survey measurements may be required. Once the survey plot has been completed on the graphics screen and all the point coordinates have been stored in the computer memory, the survey plot can be transferred to a digital (automatic) plotter for final presentation. The resulting plan can be plotted to any desired scale, limited only by the paper size. In the current research, A3 digital plotter has been used and the papers used are not very stable. However, the final plan should be plotted on stable plastic material.

11.Evaluation of the results of the surveying systems

A summary of the test results of the surveying systems is tabulated in Table (4). For each test, the combined production time of various stages (Traverse, Plan and contouring) from the data acquisition stage, processing and /or transfer time and plotting is given in Table (4). The transfer data speed was used for downloading the survey data from the instrument to the computer at 600 baud. However, the processing time for the coordinates (NEZ) was included within the actual data collection time. The actual measurement time from sighting the prism until measurement completed was estimated as (2-10 Secs.). The assessments of both surveying systems will be based on the above parameters. From the preliminary results, the following points can be concluded :

(a) Both semi-automated and automated systems offer a considerable saving in collecting , processing and plotting time as compared with the manual system. The next remarks will be related to the automated system as compared with the manual system only.

(b) The total data collecting time required for field observations of the traverse is reduced (up to 60%) by using the Pulse Total Station as compared with the traditional (manual) field survey method.
(c) The total processing time required to process the traverse field measurements is reduced (up to 97%) as compared with the manual processing method.
(d) The total plotting time for plotting the traverse network is reduced (up to 97.6%) by using the automatic plotter as compared with manual plotting method.
(e) The total data acquisition time required for field measurements of the engineering plan is Reduced (up to 57.5%) by using the Pulse Total Station as compared with the traditional field survey method.
(g) The total processing time required to process the plan field survey measurements is reduced (up to 95.5%) as compared with manual processing time.
(h) The total computer plotting time for plotting the plan is reduced (up to 97%) by using the digital plotter as compared with manual plotting method.
(i) The total data gathering time required for field observations of the contour plan is reduced (up to 57%) by using the Pulse Total Station as compared with the traditional field survey method.
(j) The total processing time needed to process the contouring field survey measurements is reduced (up to 93%) compared with the manual processing time.
(k) The total plotting time for plotting the contour lines is reduced (up to 97%) by using the automatic plotter as compared with the manual plotting system. When the combined production time of various stages from the data collection ,processing and plotting was estimated.

Then, the results are summarized as follows :
(1) The total production time for traversing can be reduced by (up to 84%).
(2) The total production time for plan can be reduced by (up to 74%).
(3) The total production time for contouring can be reduced by (up to 84%).
However, further investigations of the cost and accuracy of the surveying systems are required.

Table 4. Production time (data acquisition, data processing and data plotting)

No	ITEM	DATA ACQUISITION TIME		DATA PROCESSING AND/OR TRANSFER TIME			DATA PLOTTING TIME		
		TRADITIONAL METHOD	TOTAL STATION METHOD	MANUAL METHOD	SEMI-AUTOMATED METHOD	AUTOMATED METHOD	MANUAL METHOD	SEMI-AUTOMATED METHOD	AUTOMATED METHOD
		HR. MIN. SEC.	HR. MIN. SEC.	HR. MIN. SEC.	MIN. SEC.	MIN. SEC.	HR. MIN. SEC.	MIN. SEC.	MIN. SEC.
1	TRAVERSE	01 30 00	00 36 00	01 05 00 (APPROXIMATEMETHODS)	NA	00 42	01 38 00	1 05	2 20
2	PLAN	05 20 00	02 16 00	01 28 00	00 20	00 39	02 36 00	2 15	4 35
3	CONTOUR	01 05 00	00 28 00	00 30 00	NA	01 23	01 55 00	NA	3 45

NOTE :

1. Manual Joining The Traverse Points Plus The Tracing Time = 15 min.
2. Manual Joining The Detail Points (Plan) Plus The Tracing Time = 45 min.
3. CPU = Central Processing Unit time.
4. TR.T = Transfer time from the instrument to the computer (downloading).
5. NA = Data are not available.

12. Conclusions and Recommendations

The present work covers various levels of the design process in engineering surveying. The work carried out so far shows how a manual and general purpose computer aided design can be used in a variety of applications in the engineering surveying. The automation of engineering

surveys has now reached the stage where all aspects of a survey can be integrated, from the data acquisition of data in the field, the reduction and calculation of the data and outputting of the final results in the form required by the user, either in digital form, printed listings or as graphic output.

The computerized surveying system, as designed and tested by using the total station instrument , P.C computer, traverse adjustment computer programs, Auto Cad 2005 graphics software and SURFER-9 contouring program, accomplishes all of our initial objectives of the current study. Whether the configuration of hardware and software described is the most expedient (suitable) available will be the subject of continuing debate and discussion . For engineering plan and contouring production, two systems were designed , semi-automated and automated systems; it was proved that both systems offer a considerable saving in capturing, processing and plotting time over purely manual methods. Moreover, the acquisition time, processing time and plotting time for traversing, plan and contouring was reduced considerably from the analysis of the field results of the present field experiment, by using the current computerized system as compared with the manual system. The results were showed that a reduction in the production time for traversing was reduced by (up to 84%), for plan (up to 74%) and for contouring (up to 84%).It is important to realize that in computer supported design system, the human user is still providing the function of taking decisions, based on the facts presented to him by the computer, his previous experience and judgment. Moreover, the full potential of total station instruments cannot be realized unless they are used in conjunction with automated (computerized) systems of data recording, processing and plotting. It is this total survey integrated system rather than the total station that will become the focal point of technological advance. Further investigations are required to estimate the cost and the accuracy of the present computerized system.

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