Data Transfer of Total Station Traverses

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ABSTRUCT

The major objective of this paper is to transfer field data stored in the total station memory to a computer . Number of stations is established in the study area . The positions of control points are measured by Global Positioning System (GPS) . Electronic Total Station is used to perform horizontal and vertical traversing . The field data are stored in a three dimensional coordinate file. Several serial transportation parameters are tested until the data are downloaded to the computer using T-COM program through an RS-232 interface cable . The total station and the computer operating system must have similar communication parameters . The data must be sent and received simultaneously . Compass rule is used for data balancing . Data are converted into digital plans using Geographic Information System (GIS) and Computer Aided Design (CAD) programs .

Keywords : Total Station , T-COM , Traverse , Data Collect , Data Transfer .

تحويل بيانات مضلعات جهاز المحطة الكاملة

الخلاصة

الهدف الرئيسي من البحث تحويل البيانات الحقلية المخزونة في ذاكرة جهاز المحطة الكاملة (Total Station) الى الحاسوب ، حيث تم تثبيت عدد من المحطات في منطقة الدراسة وقيست مواقع نقاط الضبط باستخدام نظام المواقع العالمي (GPS) وأستخدم جهاز المحطة الكاملة الالكتروني لعمل التضليع الأفقي والرأسي وخزن بيانات العمل الحقلي في ملف احداثيات بالأبعاد الثلاثية ، وتم اختبار عدد من ثوابت نقل البيانات لحين تم تحميل البيانات الى الحاسوب باستخدام برنامج (T-COM) من خلال كبل موصل (RS-232 Interface Cable) ، ويجب ان تكون ثوابت الاتصال متماثلة مابين جهاز المحطة الكاملة ونظام التشغيل لجهاز الحاسوب وان يتم ارسال واستقبال البيانات في نفس الوقت ، واستخدمت قاعدة البوصلة لموازنة البيانات، وتم تحويل البيانات الى مخططات رقمية باستخدام نظام المعلومات الجغرافي (GIS) وبرامج التصميم المساعدة للكمبيوتر (CAD) .

INTRODUCTION

The most commonly used surveying instrument today is the total station. Total station systems contain three components : the distance measuring unit or EDM, the angle measuring device or the odolite, and an onboard microprocessor [2]. Electronic total stations now perform the fastest digital data collection methods. Total stations have drastically increased the amount of topographic data that can be collected during a day. Modern total stations are also

programmed for construction stakeout and highway centerline surveys [6] . Horizontal and vertical traversing are the new important applications using GPS and total station . The linear misclosures of the traverse must be adjusted . There are several methods available for traverse adjustment , but the one most commonly used is the compass rule . It is based on the assumption that the quality of distance and angular measurements is approximately the same . It is particularly applicable to surveys made with total stations [9] . Total stations have made trigonometric levels as accurate as the different differential level techniques in areas possessing large relief landforms . These instruments can quickly transfer three-dimensional coordinates and are capable of storing unique mapping feature codes and other parameters . One of the best features of the total station is the ability to download data directly into a computer without human errors [6] .

Total station provides range , azimuth and elevation from its position to that of   a landmark or a reflecting prism [8] . The development of the no prism total station has made it possible for only one person to carry out field measurements [13] . Total stations calculate coordinates in the field and can continuously store coordinates , either in their internal memory or in a data collector. Modern total stations have an inbuilt data collector. The first step of traversing process is the field survey . Most total stations provide the ability to download data to a personal computer via a cable or Bluetooth connection rather than using a data card [4] . The data are then processed in the computer to produce a coordinate file that contains the point number , point code , NEZ coordinates , and a point descriptor . Data are converted into a graphic file for use in GIS and CAD programs . These programs can transform data into a two-dimensional or three-dimensional design file . There is increasing demand to collect spatially explicit data that can be visualized in GIS and shared in any of a number of common webGIS platforms [12] .

TRAVERSES MEASUREMENTS

Traverses are a series of established stations that are tied together by angle and distance [7] . There are two types of traverses , closed traverses and open traverses. Two categories of closed traverses exist , polygon and link . In the polygon traverse the lines return to the starting point . Link traverses finish upon another station that should have a positional accuracy equal to or greater than that of the starting point . The link type must have a closing reference direction [5] . An open traverse neither forms a closed geometric figure nor does it end at a point of known position [10] . The field data are downloaded to a computer . The download computer program is normally supplied by the total station manufacturer , and the actual transfer can be sent through a USB cable . Once the data are in the computer , the data must be translated into a format that is compatible with the computer program that will process the data [7] . Errors made in the field can be adjusted at this stage . Compass rule is used for data balancing . The compass rule equations are :

$$\text{Latitude misclosure} = \text{Field northing} - \text{Fixed northing} \quad \dots \dots (1)$$

$$\text{Departure misclosure} = \text{Field easting} - \text{Fixed easting} \quad \dots \dots (2)$$

$$\text{Latitude correction} = -\frac{\text{Latitude misclosure}}{\text{Traverse perimeter}} \times \text{Line length} \dots \dots (3)$$

$$\text{Departure correction} = -\frac{\text{Departure misclosure}}{\text{Traverse perimeter}} \times \text{Line length} \quad ...(\,4\,)$$

$$\text{Horizontal misclosure} = \sqrt{(Latitude \text{ misclosure})^2 + (\text{Departure misclosure})^2}$$
$$.....\,(\,5\,)$$

$$\text{Relative precision} = \frac{\text{Horizontal misclosure}}{\text{Traverse perimeter}} \quad .....\,(\,6\,)$$

$$\text{Adjusted northing} = \text{Field northing} + \text{Latitude correction} \quad .....\,(\,7\,)$$

$$\text{Adjusted easting} = \text{Field easting} + \text{Departure correction} \quad .....\,(\,8\,)$$

Vertical traversing by trigonometric leveling is the new important application brought into widespread use by the increasing acceptance of the total station [6] . Two-dimensional traverse is extended to three-dimensional traverse if the instrument and reflector heights are entered to the total station . When the level circuit is completed , there is usually some small difference between the given fixed elevation of the benchmark and the observed elevation arrived at in the leveling notes [10] . The relationships for adjusting the elevations may be written as follows :

$$\text{Vertical misclosure} = \text{Field elevation} - \text{Fixed elevation} \quad .....\,(\,9\,)$$

$$\text{Elevation correction} = -\text{Vertical misclosure} \times \frac{\text{Distance from starting benchmark}}{\text{Total length of level run}}$$
$$.....\,(\,10\,)$$

$$\text{Adjusted elevation} = \text{Field elevation} + \text{Elevation correction} \quad ...(\,11\,)$$

INSTRUMENTATION AND DATA DESCRIPTION

Many types of total station equipment are commercially available . The choice between these instruments is based on various factors such as , accuracy , range , type of display , operating software , and the cost benefits . The general principle of all total station instruments is much the same [1] . Electronic Total Station TOPCON GTS-235 N and its accessories (tripod and reflector) are used in this study because they are available in the college laboratory . This total station is equipped with dual-axis compensation in order to correct angles automatically. The total station has automatic point-number increment and point coding . GTS-230 N series is able to store the measured data into the internal memory . The other used equipment are GARMIN GPSMAP 62 , Tape , and Laptop computer with serial port or USB port . The distance measurement accuracy for total station GTS-235 N is $\pm$ (2 mm + 2 ppm $\times$ D) mean sea elevation , where D represents measuring distance (mm) . Minimum angular reading (5" / 1") with accuracy of (5") [11] .

The satellite image of engineering college of Al-Mustansiriya university is obtained from google earth (Figure 1) . The image data are located in Baghdad city of Iraq bounded by geographic latitudes (33° 21' 00" N - 33° 21' 10" N) and geographic longitudes (44° 23' 00" E - 44° 23' 15" E) . Number of control points

is selected at the optimum locations ensures the required distribution and strength of traverse . The horizontal positions of control points are based on GPS measurements whereas the vertical positions represent benchmark elevations obtained from surveying laboratory of engineering college of Al-Mustansiriya university . The fixed elevations of two benchmarks P0 and P6 are (34.127 m) and (33.454 m) respectively .

Figure (1) Satellite image of study area

FIELD WORK : DATA COLLECTION

The geodetic coordinates latitudes and longitudes of stations P0 , P1 , and P6 are measured using GPS . The default map datum and ellipsoid for GPS is World Geodetic System (WGS 1984) . The measured geodetic coordinates are transformed to Iraqi map projection of Universal Transverse Mercator (UTM) Zone 38 North based on ellipsoid defined of Clarke 1880 using ArcGIS 9.3 (Table 1) .

Table (1) Coordinates of control points

Point ID	Measured coordinates by GPS		Transformed Coordinates by GIS	
	Latitude (φ)	Longitude (λ)	Northing , N (m)	Easting , E (m)
P0	33º 21' 08.0''	44º 23' 04.0''	3690225.840	442725.041
P1	33º 21' 07.4''	44º 23' 04.7''	3690208.795	442743.034
P6	33º 21' 03.0''	44º 23' 08.8''	3690075.122	442850.031

The total station is set up and leveled at station P1 and the reflector prism is held at benchmark P0 . The height of instrument (INSHT) and reflector height (R.HT) are measured by tape . The vertical distance (VD) is measured by total station . The elevation of station P1 (Z_{P1}) is obtained from the equation (12) , where (Z_{P0}) represents the elevation of station P0 (Figure 2) .

$$Z_{P1} = Z_{P0} + R.HT - VD - INSHT \qquad\qquad ..... (12)$$

The program menu is set to the type of survey (Data Collect) being performed and to the required instrument settings. The type of field data is selected to be stored N , E , and Z. The instrument station is identified from the menu. The date , station number , coordinates , elevation , the INSHT , and the R.HT are inserted . A backsight is carefully taken at station P0 . The coordinates and elevation of instrument station P1 and benchmark station P0 are entered in memory. A foresight is made on the third station P2 . Then the line's departure and latitude are computed and added to the coordinates of instrument station to yield the coordinates of foresight station P2 . The total station is set up and leveled at a second instrument station P2 . A backsight is taken at station P1 . The coordinates and elevation of instrument station P2 and station P1 are obtained from memory. A foresight is made on the station P3 . The coordinates of foresight station P3 are measured . The total station is moved , set up and leveled at third instrument station P3 . A backsight is taken at station P2 . The coordinates and elevation of instrument station P3 and station P2 are obtained from memory. A foresight is made on the station P4 . The coordinates of foresight station P4 are measured . The total station is moved , set up and leveled at fourth instrument station P4 . A backsight is taken at station P3 . The coordinates and elevation of instrument station P4 and station P3 are obtained from memory. A foresight is made on the station P5 . The coordinates of foresight station P5 are measured . Finally , the total station is set up and leveled at instrument station P5 . A backsight is taken at station P4 . The coordinates and elevation of instrument station P5 and station P4 are obtained from memory. A foresight is made on the station P6 . The coordinates of foresight station P6 are measured . The measured data of traverse are illustrated in Table (2) . The used total station is able to store the measured data into its internal memory . The procedure of total station data transfer from field to finish is illustrated in Figure 3.
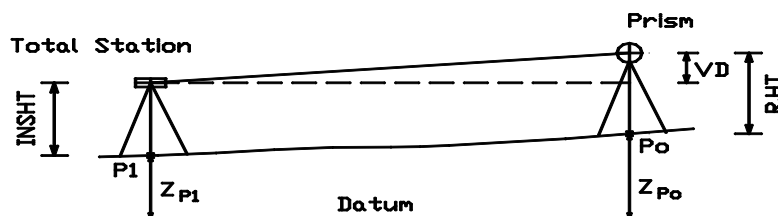

Figure (2) Data Collection by Total Station

Table (2) Measured data by Total Station

| Point ID	Northing N (m)	Easting E (m)	Elevation Z (m)	Line	Distance (m)	Azimuth (α)
P0	3690225.840	442725.041	34.127			
				P0-P1	24.785	133º 27' 00''
P1	3690208.795	442743.034	33.282			
				P1-P2	145.525	72º 51' 00''
P2	3690251.706	442882.089	33.153			
				P2-P3	39.587	154º 48' 40''
P3	3690215.883	442898.937	33.135			
				P3-P4	56.640	168º 29' 10''
P4	3690160.383	442910.242	33.139			
				P4-P5	129.443	212º 57' 45''
P5	3690051.777	442839.813	32.954			
				P5-P6	25.511	23º 29' 00''
P6	3690075.175	442849.979	33.459			
Traverse Perimeter（P）=					421.491	
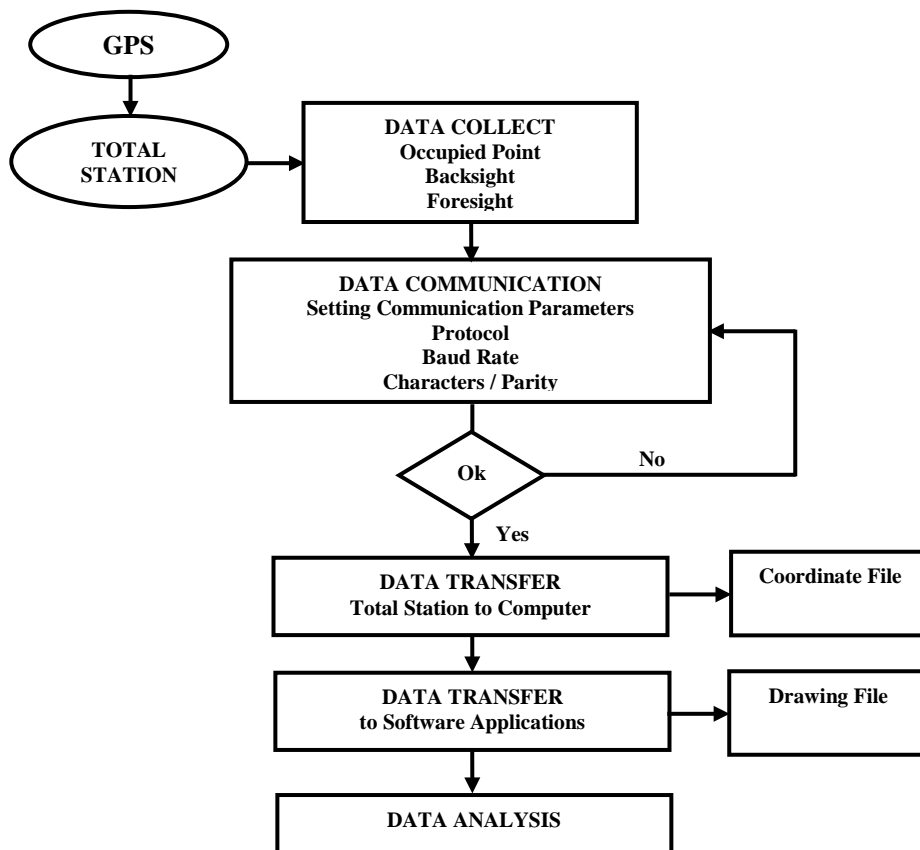
Figure (3) Total station data transfer from field to finish

TRANSFER THE FIELD DATA INTO COMPUTER

The collected data by total station are transferred to computer using T-COM program. A serial port RS-232 interface cable is used to connect the total station to computer . The serial port from other drivers such as the modem , the printer, and the scanner is released . The communication setup in the total station and in the termination application is used . Several parameters of serial data transportation are tested until the data are successfully downloaded to the computer . The used parameters are Ack/Nak protocol , COM5 , 9600-baud rate , 7 bits , odd parity and 1 stop bit (Figure 4) . Both ends of the connection should be set similarly for communication. The computer application is made ready for receiving data and save the log , input and send command to the total station. The received character strings will be scrolled in the log window. When the ID of the last point is shown and scrolling stops , the log as a text file is saved . Using Microsoft Excel point ID numbers , the measured parameters and coordinates are to be cut out. Spending a few minutes with Microsoft Excel will solve the problem [6] . The measured coordinates of points appear in T-COM window after data transfer (Figure 5) .
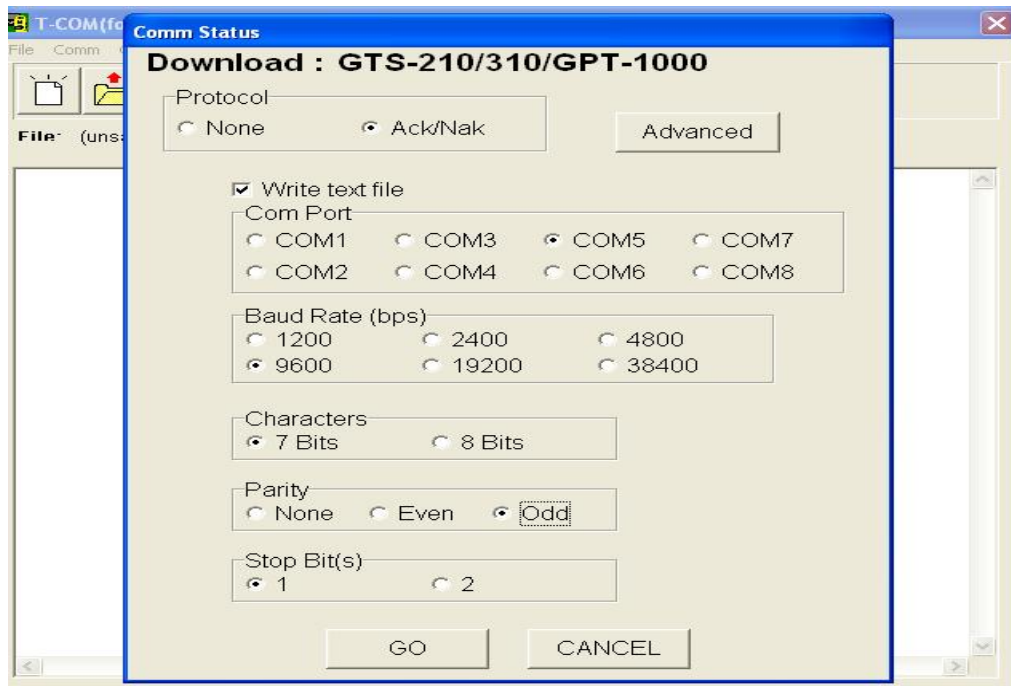

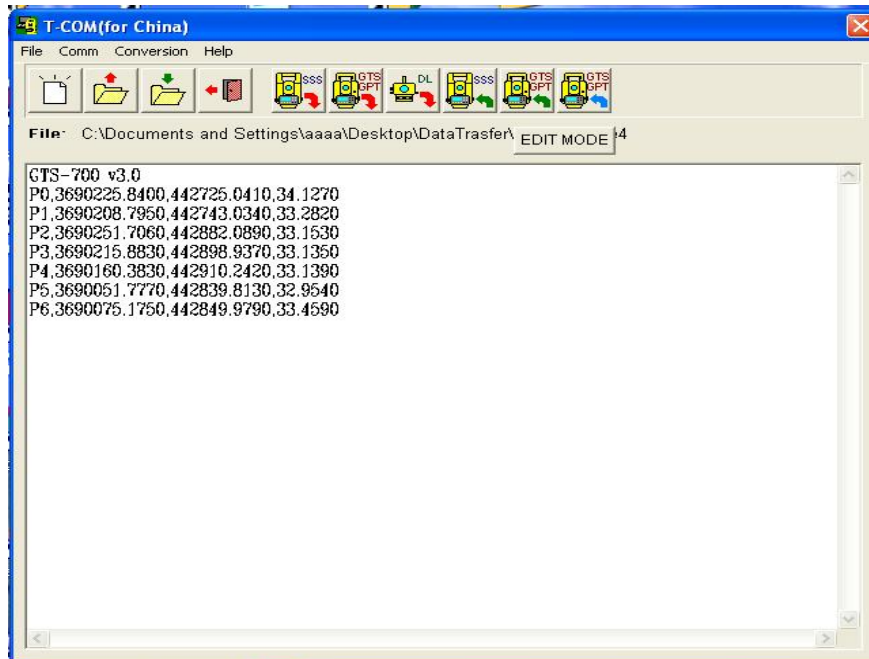**Figure (4) Used Parameters in Data Communication**

Figure (5) Data transfer using T-COM program

DATA TRANSFER TO SOFTWARE APPLICATIONS

Two types of digital data transfer have to be distinguished , numeric files and graphic files. The first is simpler from the surveyor's point of view . It begins with a text file . Text file needs software programs to produce digital plans . Usually , the data are transformed to Microsoft Office Excel table . These data are arranged in the worksheet columns . Information in a Microsoft Excel spreadsheet are transformed to AutoCAD drawing . Figure 6 shows the resulted data view of traverse in AutoCAD program . Microsoft Office Excel tables are opened directly in ArcGIS . Excel files are added to ArcMap like other data , through the Add Data dialog box . The added table is opened from the source tab of the table of contents. Excel tables behave like other tables that do not have an ObjectID field. Numeric fields are converted to the Double data type in ArcGIS [3] . Excel tables are then transformed to shapefiles . Two shapefiles are created : point shapefile and polyline shapefile . Data view and attribute table of traverse are illustrated in Figure 7 .
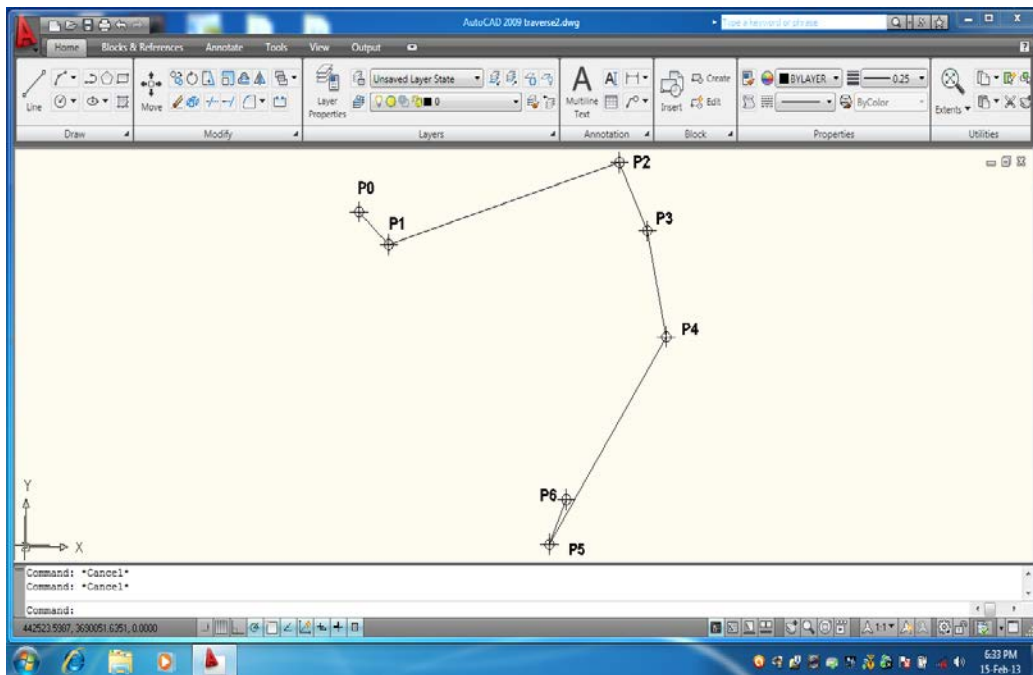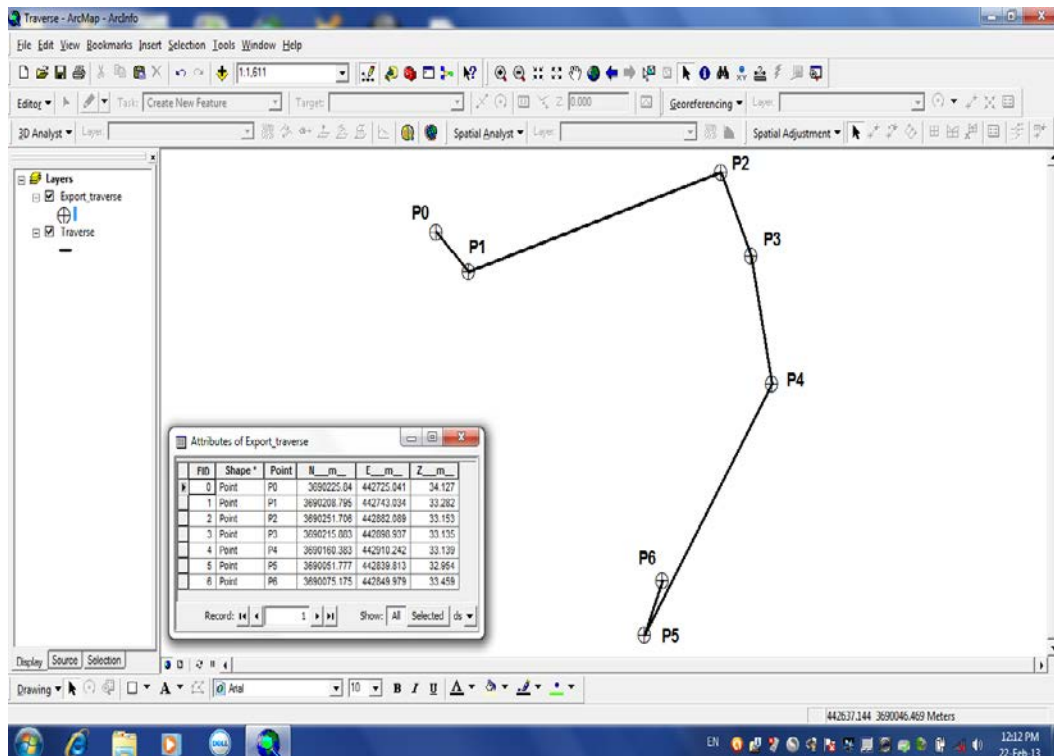
Figure (6) Data view in AutoCAD

Figure (7) Data view and attribute table in ArcGIS

DATA ANALYSIS AND RESULTS

Total station traverses consist of field data collection , data communication , and sending data to a computer program for processing . These procedures offer great flexibility and ensure the data are visualized in an optimal form. The traverse misclosure errors are effected mainly by the number of points , the distribution of points , and the observation method . The resulted traverse survey is fallen at the third order class specification accuracy . The horizontal positions of control points are based on GPS measurements whereas the vertical positions represent benchmark elevations . Hence , the misclosure in vertical positions is less than misclosure in horizontal positions . The compass rule is used to balance the horizontal data (Table3) . For trigonometric leveling , the total station should be equipped with dual-axis compensation to ensure that the angular errors remain minimum . The data resulted from total station trigonometric leveling are balanced in Table 4 . For the purposes of location , design , and construction it is necessary to extract profile along the traverse line . However , this can not be done until an adjustment has been made to distribute any misclosure . The profile drawing is a graph of elevations , plotted on the vertical axis , as a function of distances plotted on the horizontal axis . Profile is extracted from the three dimensional data file using AutoCAD software (Figure 8) .

Table (3) Balancing the data of horizontal traversing

Point	Measured Coordinates		Correction m		Adjusted Coordinates (m)	
ID	N (m)	E (m)	ΔN	Δ E	N'=N+ΔN	E'=E+ΔE
P0	3690225.840	442725.041	0.000	0.000	3690225.840	442725.041
			- 0.003	0.003		
P1	3690208.795	442743.034	- 0.003	0.003	3690208.792	442743.037
			- 0.018	0.018		
P2	3690251.706	442882.089	- 0.021	0.021	3690251.685	442882.110
			- 0.005	0.005		
P3	3690215.883	442898.937	- 0.026	0.026	3690215.857	442898.963
			- 0.007	0.007		
P4	3690160.383	442910.242	- 0.033	0.033	3690160.350	442910.275
			- 0.016	0.016		
P5	3690051.777	442839.813	- 0.049	0.049	3690051.728	442839.862
			- 0.004	0.003		
P6	3690075.175	442849.979	- 0.053	0.052	3690075.122	442850.031
P6 (Fixed) N = 3690075.122 m , E = 442850.031 m						

Latitude misclosure = 3690075.175 – 3690075.122 = + 0.053 m
Departure misclosure = 442849.979 – 442850.031 = – 0.052 m
Horizontal misclosure = 0.074 m

Relative precision = $\dfrac{1}{5696}$

Table (4) Balancing the data of vertical traversing

Point	Elevation (m)	Distance (m)	Cumulative Distance (m)	Correction (m)	Adjusted Elevation (m)
P0	34.127	0.000	0.000	0.000	34.127
P1	33.282	24.785	24.785	0.000	33.282
P2	33.153	145.525	170.310	- 0.002	33.151
P3	33.135	39.587	209.897	- 0.002	33.133
P4	33.139	56.640	266.537	- 0.003	33.136
P5	32.954	129.443	395.980	- 0.005	32.949
P6	33.459	25.511	421.491	- 0.005	33.454
P6 (Fixed) = 33.454 m					

Vertical misclosure = 0.005 m

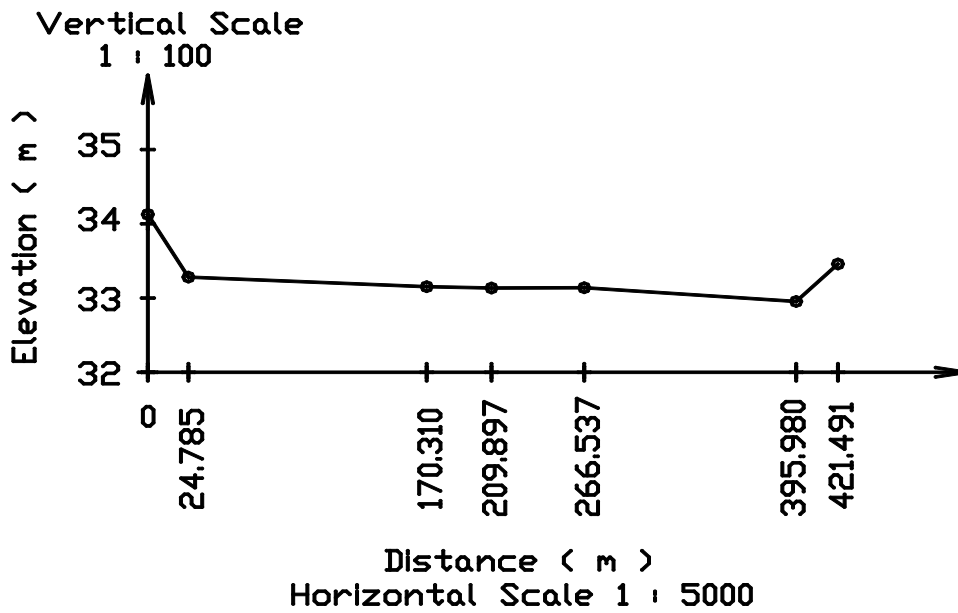Allowable error = $12 \sqrt{k}$ =$12 \sqrt{0.421491}$ = 7.791 mm = 0.008 m

Figure (8) Extraction of profile along traverse line

CONCLUSIONS

From the concepts of analysis of the results , the following conclusions can be drawn:

1. The advantages of data collection are lost if the data are not transferred to a computer system . Several parameters of serial data transportation must be tested until the data are successfully downloaded to a computer . The total station and the computer operating system must have the same communication parameters . Also , the data must be sent and received at the same time , otherwise , the data can not be downloaded .

2. Some total stations have developed data collectors that can perform traverse computations ; others require programs to perform these operations. The procedure of storing and processing information using data collectors and field computers seems to be inconvenient since it involves addition field equipment . Internal memory overcomes this problem and offers an alternative approach. If the internal storage device is fixed , then downloading is done through a cable connection . Bluetooth wireless is a new technology designed to replace cables for connecting total station by computer .

3. Data transfers record quickly and confidently measurements taken by a total station for mapping . The downloaded data can be converted automatically to a text format . Recently software programs such as CAD and GIS enable the user to produce complete plans . Data collector software is now capable of exporting files in **.**dxf format for AutoCAD or shapefiles for GIS programs .

4. The central processing unit of total station calculates the rectangular coordinates. These coordinates are referenced to the instrument station coordinates and the backsight direction . Total station trigonometric leveling can achieve accuracies similar to a level instrument . The advantage of elevation measurements by a total station is that the line of sight can reach longer distances than a level instrument . GPS is useful to fix both orientation and location of the total station measurement. Third order accuracy is obtained in this study for both horizontal and vertical traversing . This accuracy is compatible for most engineering works .

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