Photogrammetric Survey on the Natural Gas Pipeline Projects of Iran-Turkey-Europe (ITE)

Ferruh Yildiz

Abstract—The ITE Project is a project that has 1800 km length and across the Turkey's land through east to west. The project of pipeline enters geographically from Iran to Doğubayazit (Turkey) in the east, exits to Greece from Ipsala province of Turkey in the west. This project is the one of the international projects in such scale that provides the natural gas of Iran and Caspian Sea through the European continent. In this investigation, some information will be given about the methods used to verify the direction of the pipeline and the technical properties of the results obtained. The cost of project itself entirely depends on the direction of the pipeline which would be as short as possible and the specifications of the land cover. Production standards of 1/2000 scaled digital orthophoto and vectoral maps as a results of the use of map production materials and methods (such as high resolution satellite images, and digital aerial images captured from digital aerial cameras), will also be given in this report.

According to Turkish national map production standards, TM ((Transversal Mercator, 3 degree) projection is used for large scale map and UTM (Universal Transversal Mercator, 6 degree) is used for small scale map production standards. Some information is also given about the projection used in the ITE natural gas pipeline project.

Keywords—Digital Image Processing, Natural Gas Pipe Line, Photogrammetry.

I. INTRODUCTION

UNDER the intergovernmental Agreement, undersigned by the Government of Republic of Turkey and the Government of Republic of Iran on October 25, 2010 for Natural Gas Sales to "Republic of Turkey" and for Transit Transfer of Republic of Iran Natural Gas on Turkish Territories and Exclusive Pipeline for Transmission of Natural Gas over territories of Republic of Turkey (Iran-Turkey-European Natural Gas Pipeline Project-ITE) and based on the intentions of both party states to construct a new exclusive pipeline by following this Agreement, the Memorandum of Understanding undersigned by Ministry of Industry and Energy of Republic of Iran and Ministry of Energy of Republic of Turkey on August 08, 2008 has been

ratified by the TBMM (Grand National Assembly) and the ratification laws has been published in Official Journal number 27764 dated November 23, 2010.

Within the framework of the Memorandum of understanding, it is decided to establish a Project Consortium in order to determine the route of, to construct and, following the construction, to operate ITE Natural Gas Pipeline Project and to carry out other relevant activities by Iran Oil Company (TURAN Transit Company).

Companies appointed to establish a joint consortium specific to this project by two States are Iran Oil Company (TURAN) and Turkish Pipeline Corporation (BOTAS) and Turkish Petroleum Corporation (TPAO).

Within the context of ITE Natural Gas Pipeline Project, out of 35 billion cubic meter gas, 10 billion cubic meters shall be delivered to Turkey and the remaining 25 billion cubic meters shall be delivered to Europe through Greek border.

Services of "Opinion from State Authority, Geodesy, Photogrammetry and Geotechnical Surveys, Land Acquisition, Real Estate Valuation of Immovable Properties" are carried out by the Contractor Company of "Sebat Proje Engineering Company", on behalf of TURAN. Preliminary route corridor of the Project shall start at the Iran-Turkish border and shall pass through provincial borders of Ağrı, Erzurum, Erzincan, Gümüşhane, Sivas, Yozgat, Kırşehir, Kırıkkale, Ankara, Eskişehir, Bilecik, Kütahya, Bursa, Balıkesir, Çanakkale, Tekirdağ, Edirne, respectively (Fig.1).

ITE Natural Gas Pipeline Project shall enter into Turkey at the Iran-Turkish/Dogubayazıt border and shall head down to south towards Horasan-Erzurum area, then, by general terms, shall move towards West and shall pass the Marmara Sea through Çanakkale Straight; on the Anatolian side shall pass through the area between north of Kızıkcaterzi village at Thrace; and shall head to Europe by entering to Greece through Edirne/Ipsala.

Starting from eastern Turkey, Greece, Albania, Italia, to Austria and Swiss and Germany over a natural gas pipeline project extending from the other European cities, respectively (Fig. 2).

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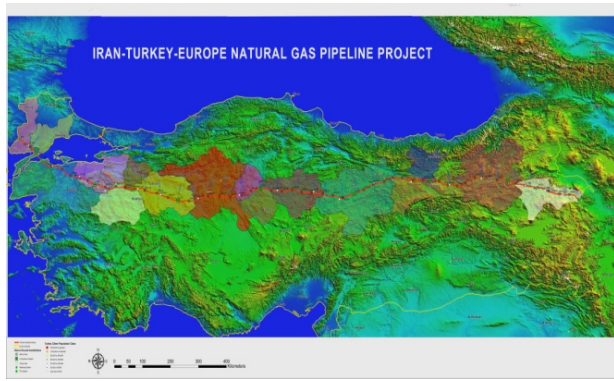
Fig. 1 ITE Pipeline map

Fig. 2 ITE Pipeline Europe-Turkey-Iran route

The length of the ITE pipeline in Turkish territory is approximately 1790 km up to Türkgözü/Ipsala-Greek border. Pile diameter of ITE is planned to be 56 inches on land and 36 inches of two pipes for sea crossing at Canakkale Straight. Length of the pipeline crossing the sea shall be approximately 17km. ITE Project Planning Time;

- Starting in 2011 the map production and engineering study of the pipeline,
- Starting in 2013 the construction of the pipeline,
- Passed the first phase operational in 2016,
- Planned to reach full capacity in 2020.

II. ITE PROJECT PHOTOGRAMMETRIC STUDIES

This section provides the methodology of the photogrammetric aerial survey activities of the technically confirmed 500 m wide ITE Project Route Corridor of the section between Iran-Turkey Border / Greece-Turkey Border. The survey activities of the stage include the following main activities:

Establishment of Photogrammetric Ground Control Points and Survey

Flight Permission, Flight Planning

Aerial survey (image capturing) of the pipeline corridor

Photogrammetric triangulation and adjustment

Produce of orthophotos maps (1/2000)

Produce of photogrammetric vector maps (1/2000)

Orthophoto maps of 1/2000 scale with a width of 1200 m shall be produced taking the center line of preliminary route corridor (500 m) given under the contract by ITE.

In addition, utilizing the same stereo aerial pictures, photogrammetric digital vector maps of 1/2000 scale with a width of 500 m shall be produced.

Due to that the route corridor is extremely broken, flights are generally planned to be in 2 or more columns. Photogrammetric ground control points necessary for photogrammetric landmarks shall be installed on ground before flight and ground markings shall be applied. Necessary flight permits shall be obtained from concerned institution.

The aerial survey will be of the purpose to capture the topography and features along this defined pipeline route corridor. In the scope of aerial survey and aerial photogrammetry are used.

DTM and DEM, to be produced by photogrammetric stereo model, are used to produce orthophotos and digital vector maps [1].

a) Photogrammetric aerial survey using Vexcel UltraCam-X large format digital camera with 15 cm resolution (GSD: Ground Sampling Distance), covering the width of 1.3 km along the pipeline route,

b) Digital orthophoto and DEM from orthophoto generation,

c) Production of DTM from Stereo Model,

d) Photogrametric digital vector map production for a minimum 500m wide mapping corridor by combining the planimetric data from stereo plotting and contour data derived from Stereo Model observations.

e) Extension of planned time shall be considered in taking the permits for flights at border areas (at an area of 10 km at Greek-Iran borders) and works shall be carried out to obtain stereo satellite images.

Photogrammetric ground control points shall be installed corresponding to block corners column edges formed by flight columns for photogrammetric triangulation survey and adjustment calculation works.

Block stones and/or triangulation stones shall be used as ground installations [2].

In order to obtain sensitivity stipulated by regulations at the end of photogrammetric triangulation block adjustment calculation works, care should be given to have a geometric distribution of 4-6 for these points in the column.

A. Coordinate Systems, Flight Corridor and Photogrammetric Blocks

The Greece-Turkey Border – Turkey-Iran Border section of the ITE Natural Gas Pipeline falls into 4 UTM Zones (35-36-37-38) with different coordinate systems (Fig. 3). For the flight planning the coordinate systems of the 1/25.000 scaled topographic databases System ED50 (6th degree) has been used.

The coordinates in ED50 system have then been transformed into WGS-84, because the Flight Management System (FMS) defines WGS-84 [3].
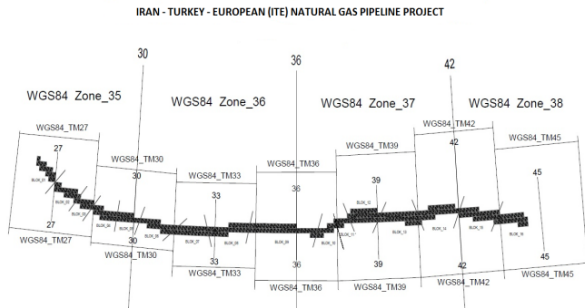
Fig. 3 ITE project photogrammetric blocks

The flight planning foresees that the application of aerial photos will be done along the pipeline route with a width of 1,300 m on either side of the planned flight axis covering a total corridor of 2,600 m. Generally, two parallel column flights are planned along the pipeline corridor with a rate of 30% sidelap, %70 Endlap. The Ground Sampling Distance (GSD) is determined 15 cm due to the required 1:2,000 scale of the map which will be produced.

B. Aerial Flight Equipment

The following Equipments are available for the Aerial Survey flights:

Plane Brand and Model   : CESSNA T206
Tale Number (Sign)   : TC-KFZ
GPS-IMU   : APPLANIX 410
Digital Camera   : Vexcel UltraCam-X
Lens   : 100.5 mm
Image Output   : 14430 x 9420 pixels
Image Sensor Size   : 7.2 micron x 7.2 micron (as pixel size)
Ground Sampling Distance (GSD)   : 15 cm
Endlap (Forward Overlap)   : 65%
Sidelap   : 30%
Flight Height : 2100 m (Above Mean Ground Level)

GPS measurements are made, using the differential mode so as to know precisely where frame centres are located. For this purpose, a second computer and an accurate dual-frequency GPS receiver will be placed in the aircraft. This computer, connected to the on board GPS receiver enables the necessary data to be stored.

Fixed GPS ground stations will be set up on the relevant ground control points in a suitable location to make observations in differential mode. The distribution of the ground stations which are used for differential GPS observations during the flights will be selected so that the distance to the airborne GPS receiver will not exceed 80 km.

The processing of digital images from raw images until final digital images will be performed during and immediately after the aerial flights. Also the DGPS and IMU/INS data will be processed immediately on daily basis, in order to enables immediate feedback to the aerial crew in case any data acquisition may be insufficient, and would have to be repeated.

C. Aerial Triangulation

Purpose of the aerial triangulation is to provide necessary control points for absolute orientation of photogrammetric models, or in other words, to provide exterior orientation parameters (ΔX, ΔY, ΔZ, Ω, Φ, K) for each photograph [4].

TABLE I
PHOTOGRAMMETRIC BLOCK ADJUSTMENT A-PRIORI DATA

Photogrammetric Block Name	Photos Used in Adjustment (Number)	Ground Control Point (Number)	Image Point Used in Adjustment (n)	RMS (σ_0) (micron)
BLOCK-01_TM27	404	67	50668	1.7
BLOCK-02_TM27	464	94	44263	1.7
BLOCK-03_TM27	348	46	45216	1.7
BLOCK-04_TM30	540	83	92522	2.2
BLOCK-05_TM30	590	96	96938	2.5
BLOCK-06_TM30	743	99	100856	1.6
BLOCK-07_TM33	686	100	96468	1.5
BLOCK-08_TM33	387	123	43995	1.4
BLOCK-09_TM36	559	157	72881	1.4
BLOCK-10_TM36	418	59	53231	1.7
BLOCK-11_TM39	413	62	54223	1.6
BLOCK-12_TM39	657	81	94415	1.7
BLOCK-13_TM39	610	94	86499	2.6
BLOCK-14_TM42	775	97	130681	1.8
BLOCK-15_TM42	832	109	121138	1.1
BLOCK-16_TM45	544	72	71061	0.9

Generally the process of measuring the photogrammetric triangulation points is performed automatically by the MATCH AT program. The measured aerial photograph coordinates are adjusted by the MATCH AT program which works according to the principles of the bundle adjustment method and additional parameters.

By the method of the bundle adjustment; before the least square adjustment, it is cleaned out from its gross errors by using the robust estimation algorithm to all images. In the adjustment procedure; additional parameters, which will eliminate the atmospheric refraction and earth curvature errors, are included. Beside the physical parameters above; the parameters below are also included to the adjustment model.

- Self-Calibration
- GPS-Mode
- Drift-Mode
- GPS-Antenna eccentricity
- INS-Mode
- INS-Rotational angle limit

Aerial images are prepared as photogrammetric block basis; and these blocks consisting of a number of air photographs and are adjustment. The Photogrammetric adjustment results are shown on the Table-I, Table-II.

Each of the 16 photogrammetric blocks in the ITE project is adjusted freely by the MATCH AT software. Number of images, number of ground control and check points, number of redundancy of adjustment, root mean square errors (RMS;rms) of the results obtained from adjustment and root mean square errors of the each coordinates of the ground control points (GCP) and check points are summarized in the Table-I, Table-II.

Measurements and maps produced as a result of this project satisfies all the criteria as predicted by national and international map production standards [5].

D. Orthophoto Maps

Orthorectified images will be mosaiced and color balanced creating a seamless orthophoto mosaic where disturbing tonal differences or visible seemliness between adjacent photos are not allowed.

An index file, describing the map sheet division shall be delivered as well. Exterior orientation parameters (ΔX, ΔY, ΔZ, Ω, Φ, K) for each photograph shall be delivered for creating stereo models of the photographs obtained. Suggested format for orientation parameters is MATCH-AT format well recognized as a world standard which most of the systems are able to import.

Digital Terrain Model data shall be obtained automatically or manually depending on the morphological structure of the terrain.

Morphological data which will be acquired on three dimensional evaluation basis (Dry/flowing rivers, ridges, slopes, roads, bridges, viaducts, pits, etc.) shall be appended to the digital terrain models and the created model shall be ensured to reflect the topography identically.

Digital terrain model shall be created in grid format and necessary smoothing parameters shall be applied depending on terrain structure.

Point space of digital terrain model in grid format shall be 15-20m. Digital altitude models calculated separately and edges of contour line curves obtained from these shall be matched. Digital altitude models shall be produced in stages based on route.

Contour lines with a width of 2 m shall be produced by applying triangulation with suitable software on Digital Terrain Models. Such automatically obtained curves shall be cross checked from stereo models. In addition, these drawn contour lines shall be edited by checking their cartographic standards [6].

III. RESULTS AND DISCUSSION

As it is described above, the works at the project areas are examined with its aspects in relating with the principles and technical basics stated in the relevant articles of the Turkish Map Production Rules (BOHHBUY);

- Flight planning and image capturing,
- Photogrammetric triangulation survey and adjustment,
- Photogrammetric evaluation,
- Digital terrain model, contour line production
- Visualization,
- Comparison of the results obtained by the geodetic surveys at the terrain with the values obtained by photogrammetric studies,
- Orthophoto map productions,

TABLE II
PHOTOGRAMMETRIC BLOCK ADJUSTMENT A-POSTERIE DATA

Block Number	RMS GCP σ_X (meter)	RMS GCP σ_Y (meter)	RMS GCP σ_Z (meter)	RMS Check σ_X (meter)	RMS Check σ_Y (meter)	RMS Check σ_Z (meter)	GCP Used	Check Point Used
BL-01	0.010	0.007	0.003	0.048	0.081	0.104	59	8
BL-02	0.006	0.005	0.005	0.061	0.074	0.085	84	10
BL-03	0.005	0.005	0.003	0.056	0.092	0.104	41	5
BL-04	0.007	0.005	0.003	0.045	0.029	0.096	75	8
BL-05	0.020	0.011	0.006	0.072	0.037	0.103	86	10
BL-06	0.007	0.006	0.004	0.064	0.071	0.099	89	10
BL-07	0.014	0.013	0.008	0.088	0.042	0.070	90	10
BL-08	0.007	0.007	0.003	0.050	0.076	0.096	111	12
BL-09	0.005	0.005	0.008	0.093	0.045	0.094	142	15
BL-10	0.004	0.004	0.003	0.061	0.055	0.138	50	5
BL-11	0.005	0.005	0.002	0.053	0.088	0.110	41	4
BL-12	0.005	0.007	0.002	0.049	0.094	0.070	68	8
BL-13	0.007	0.006	0.006	0.073	0.066	0.099	152	14
BL-14	0.004	0.004	0.003	0.085	0.077	0.105	107	8
BL-15	0.004	0.003	0.001	0.042	0.046	0.118	99	10
BL-16	0.005	0.003	0.003	0.059	0.049	0.068	65	7

The results of the performed examination;

whether the results obtained by the method described above comply with the conditions of the BOHHBUY or not; and whether the expected error criteria are within the limits (estimated values) stated in the BOHHBUY are controlled.

Digital photogrammetry has been an essential tool to apply to the most engineering projects in the recent 5 years.

Digital photogrammetry has also many advantages presenting as high precision, establishment cost, providing economical solutions and time duration.

These results could put forward digital photogrammetry to most advantegous position together with the technological development in the future.

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