GIS Application in Technical and Environmental Safety of Natural Gas Transmission Pipelines, a Case Study

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Key words: GIS, Natural Gas, Pipeline, Gas leak detection

SUMMARY

The project, which is the subject of this article, is a pilot project of BOTAŞ (Petroleum Pipeline Company) and carried out by GEOGIS inc. in the name of BOTAŞ. BOTAŞ is a related institution of Republic of Turkey Ministry of Energy and Natural Resources operates in crude oil transportation, as well as transportation, distribution, import, storage, marketing, trade and export of natural gas.

BOTAŞ periodically carries out the monitoring of all types of human and natural impacts (landslide, earthquake, buildup, transitions) and gas leaks that may affect pipelines and stations within the scope of operating activities. One of the parameters required for the operation of natural gas pipelines is the location information of the pipelines and the facilities (line valves, compressor stations, pressure drop measurement stations) forming the pipeline system on the route.

BOTAŞ has implemented this pilot project on a defined route, taking advantage of the aerial vehicles to evaluate, query and analyze in GIS format in order to make the inspection and control activities that are physically performed on the pipeline route more effectively. For this purpose, stereoscopic aerial photos were taken along a 1203 km pipeline within the project and on a 200 m wide corridor on both sides of the line. Data were produced in CAD data structure by photogrammetric interpretation, after that CAD data were converted into GIS data structure and BOTAŞ specific attribute information was added. Thus, observations and queries which have to be done in terms of technical safety according to ASME B31.8 standard have been made by GIS analysis. In addition, on the 3D terrain model, video data was recorded by simulating the flight along the route of 1203 km by providing the visualization with the symbols used in the BOTAŞ standards of the vector data.

Another target of the project is to determine the gas leak points which was previously done with conventional (terrestrial) methods, was made from air for the first time. In the scope of the project, which is 1203 km long, potential leaking gas was inspected on lines and stations using helicopter mounted system. ALMA G2 (Airborne Laser Methane Assessment) optical instrument, which is mounted on the Bell 206 Jet Ranger helicopter, was used as a detector in the aerial leak inspection operation.

With the project, BOTAS has made it possible to easily observe and inquire related to technical safety in compliance with GIS in natural gas pipelines and stations on the route, as well as to make gas leak inspection in a short time, thus saving time and labor power.

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1. INTRODUCTION

Natural gas pipelines are used for three purposes: gathering, transmission and distribution (Figure 1). The collection lines are the lines used in the production well area. Transmission lines are used to transfer natural gas from the source to the point where it is transferred to the distribution line and carry natural gas between long distances with high pressures of 50-75 bars through steel pipes of 8-48 inches in diameter. The distribution lines are pipelines of smaller diameter used to deliver natural gas to the end users in residential areas, industrial areas and production facilities after the pressure drop in RMS stations. From the geospatial and GIS perspective, although all three types of pipelines are observed to contain many geographical data and GIS applications, this work is limited to natural gas transmission lines and stations on the line route.

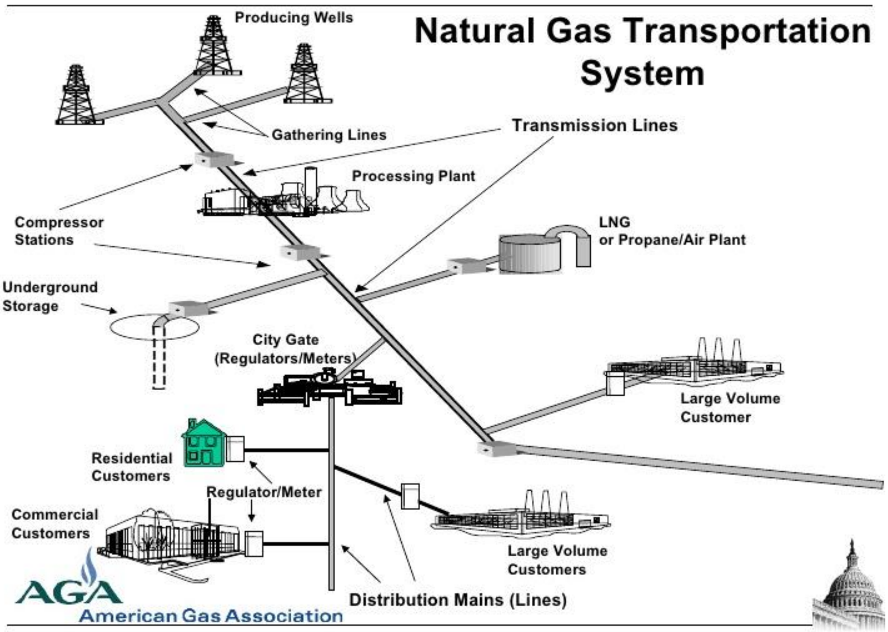

Figure 1

1.1 Natural gas transmission lines in Turkey and BOTAŞ

The construction of natural gas transmission network in Turkey began in the mid-1980s and the first gas transmission was realized in 1987. In the following years natural gas pipeline network in Turkey gradually expanded and today has reached nearly 14,000 kilometers.

BOTAŞ is a related institution of Republic of Turkey Ministry of Energy and Natural Resources operates in crude oil transportation, as well as transportation, distribution, import, storage, marketing, trade and export of natural gas. BOTAŞ, which was founded in 1974, currently provides natural gas to 77 out of 81 provinces in Turkey.

1.2 Technical and environmental safety in natural gas transmission pipelines

The provision of technical safety in the operation of natural gas transmission lines is of primary importance in terms of ensuring the protection of human life, the environment, natural gas stations and the settlements in the vicinity. Stations that are completed and opened to operation and transmission pipelines connecting them must be provided with technical and environmental safety throughout their working life (BOTAŞ, 2014). The elements that create risks to the pipelines in terms of technical and environmental safety can always occur, so risk assessment and control activities must be provided regularly and systematically. Pipeline anomalies, or risks, are natural or man-made geographical features. If necessary precautions are not taken in time, they can cause serious danger.

The human structure or geographically dangerous anomalies defined in the relevant regulation of BOTAŞ are given below (BOTAŞ, 2014);

- All kinds of buildings,
- Sand or gravel pit, mine,
- Landslide and erosion zones,
- Fault lines,
- Natural gas pipeline crossing points;
    - Road,
    - Highway
    - Rail systems,
    - Power transmission line,
    - Stream, river,
    - Channel, flume,
    - Other pipelines.

1.3 Gas leakage causes in natural gas transmission lines and stations

Most important risk factor in the lines and stations on the route is gas leaks that can occur for various reasons. Generally the reasons for gas leaks are;

- Due to the pipeline; for instance, gas components that may cause internal corrosion and coating material defects that may cause external corrosion.
- Due to third parties; for instance, the use of any kind of drilling machine near the pipeline or excavation with heavy work machines can cause damage to the pipe.
- Due to natural disasters; for instance, severe earthquakes and landslides can cause serious damage to the pipe.
- Due to isolation problems in the stations.

For whatever reason, the occurrence of gas leaks in various sizes from time to time in natural gas transmission lines is an inevitable result. The important point is to make regular repairs on the pipelines and stations on the route and to make necessary repairs at the leak points that are detected. It is possible to carry out the gas leakage inspection by terrestrial methods or by using aerial vehicles.

1.4 Supervision of anomaly control and gas leak inspection works in BOTAŞ

The risks that may be caused by the anomalies in pipelines and stations and the inspection for the gas leakage are regularly carried out by BOTAŞ's operational units. The controls are made using terrestrial methods by land vehicles or by walking along the pipeline route and reporting.

1.5 The pilot project to conduct the controls with aerial vehicles and to generate and report the results in the GIS environment

A pilot project aimed at achieving control tasks in a shorter time, with less workload and with more precise results, by utilizing the developing technology has been tendered by BOTAŞ in 2016. The results of the pilot project realized on the 1203 km natural gas transmission line are evaluated by BOTAŞ.

2. PROJECT OF PIPELINE ROUTE CONTROL AND NATURAL GAS LEAK INSPECTION OF NATURAL GAS TRANSMISION PIPELINE AND STATIONS ALONG 1203 KM PIPELINE ROUTE BY AIR VEHICLES

2.1 Scope and purpose

The scope of Project in general consists of two stages. First is route control for anomalies by air vehicles along 1203 km long pipeline in 400 m wide, including stations settled on the route (Figure 2). The second is natural gas leak inspection by air vehicles inside at least 7 m wide corridor (3.5 m wide at left and right side of center line of pipeline).

Figure 2

The types of stations on the route are listed below;

- Line Vanes Stations,
- Pig Stations (Figure 3),
- Regulator / Meter Stations (RMS),
- Compressor Stations,
- Take-off Vane Stations.

Figure 3

The geospatial data intended to be produced beside gas leakage inspection in the lines and stations within the scope of the project are listed below;

- Orthophoto mosaic image with 10 cm GSD,
- DSM and DTM,
- Vector data and coordinate list of pipelines and stations,
- Anomalies in vector data structure, natural or human formed;
  - Landslide zones and their natural gas pipeline catch points. If the landslide zones do not cut the pipeline, the distance and location information (coordinates) on the pipeline.
  - The erosion zones and their natural gas pipeline catch points. If the erosion zones do not cut the pipeline, the distance and location information (coordinates) on the pipeline.
  - Active fault lines (The data obtained from General Directorate of Mineral Research and Exploration- MTA was used)
  - Highway, main road, village road and pipeline crossings,
  - Railway system (railway, subway etc.) roads and pipeline crossings,
  - Power transmission lines and pipeline crossings
  - Rivers, streams, irrigation canals and pipeline crossings,
  - Mines, stone and sand quarries,
  - Housing (all kinds of buildings, facilities and human structure objects),
- Video recording of flight animation along pipeline route in 3D environment,
- Location classification along the route according to Section 840 of ASME B31.8 pipeline standard (ASME, 2016).

2.2 Pipeline route control – work steps

2.2.1 Aerial photo acquisition, pre and post operations

The KML file provided by BOTAŞ, which contains the location information of the pipeline and the stations, was the starting point of the project. Based on this data, flight and ground control point plans have been prepared.

Flight planning was done with 80% forward and 60% side overlap so that high resolution DEM production could be achieved. 699 ground control points were planned, kinematic or static GPS measurement method was applied according to the location of the point.

For aerial photo acquisition, Cessna T207A model aircraft and Intergraph DMC camera of GEOGIS were used (Figure 4). After the photogrammetric triangulation and adjustment process, the photographs were made ready for photogrammetric interpretation.

Figure 4

2.2.2 Photogrammetric interpretation

By using LPS (Leica Photogrammetric Suite) for photogrammetric interpretation, the following geographical features were digitized in 3D;

- All kind of roads,
- Rivers, channels and canals,
- Buildings (classified as houses, factories, public buildings, greenhouses, stables, etc.)
- Sand, stone, gravel quarries,
- Wire fences, walls,
- Power transmission lines,
- Landslide areas

In addition, the fault lines, erosion zones and landslide regions data from MTA database are also added to the data set.

The pipeline route was visually controlled via aerial photographs and corrected by using evident traces and line markers that are on the pipeline (Figure 5).

Figure 5

Technical support was obtained from BOTAŞ experts during this process. The amount of correction is in the range of 1,5-2,5 m and it is observed during the verification tests made on the field, the attitude accuracy of pipeline is in the range of 5-20 cm after correction.

2.2.3 Obtaining anomaly datasets using geospatial analysis

After the location-accurate pipeline data was obtained, location analysis was performed using this data and other geographical data so that anomaly data sets for the crossing points were obtained. Furthermore, after buffer analysis, buildings close to the pipeline route were added to the anomaly data set (Figure 6).

Figure 6

Points where the landslide and erosion areas cut into the pipe line or the points on the pipeline that are close to those zones are also part of the data set as geological anomalies. The fault lines and the points at which fault lines cut into the pipeline are also elements of the data set (Figure 7).

Figure 7

2.2.4 Video recording of flight animation on the pipeline route

Flight animation was performed along the pipeline route in the 3D environment created by vector data, anomaly data set (using symbology determined by BOTAŞ), DTM and orthophoto, and recorded as video (Figure 8). The symbols used for anomalies in 3D animation video recordings are standard symbols used by BOTAŞ and have been converted into symbol sets that can be used in GIS environment.

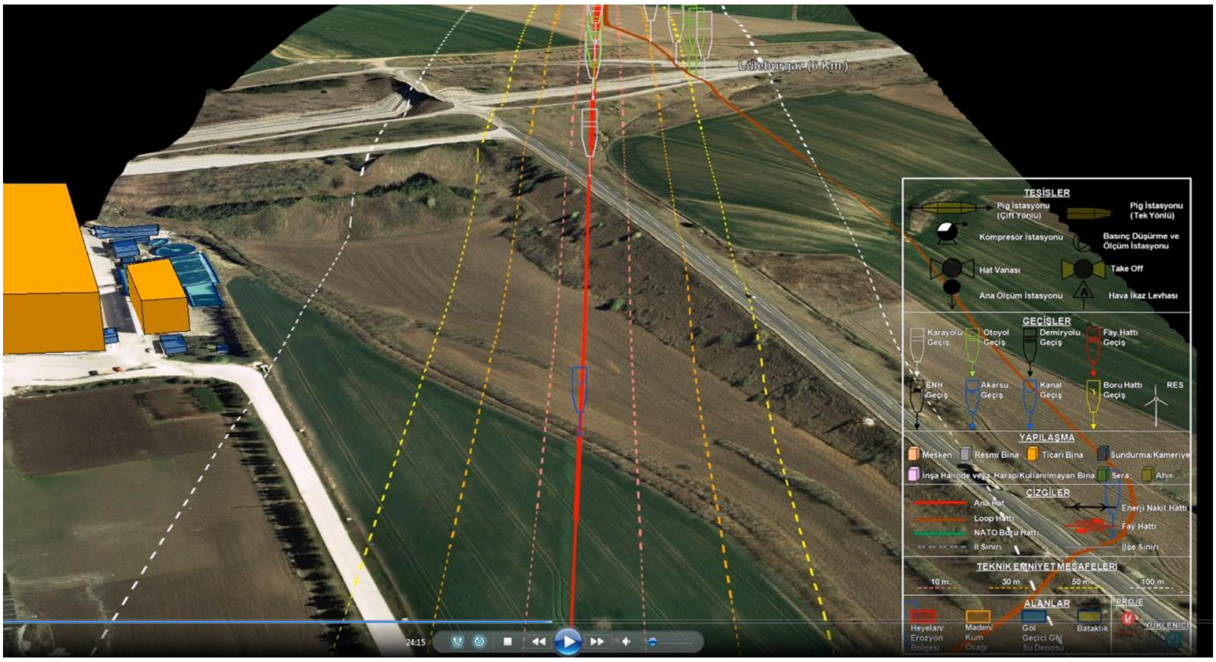

Figure 8

2.3 Gas leak inspection

Gas leak inspection of natural gas pipelines and stations by aerial vehicles was made on the right and left side of the pipeline in a 3.5 meter wide corridor within a minimum of 7 meters (Figure 9) according to reference information of G501 standard (DVGW G 501, 2012).

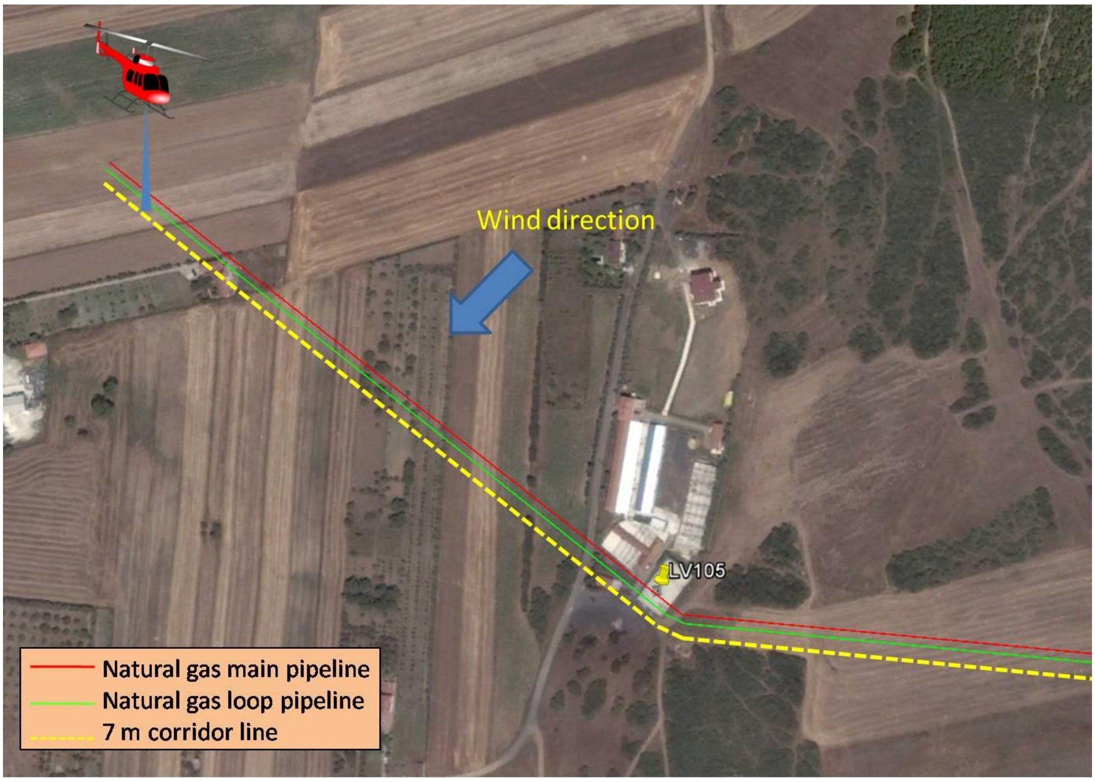

Figure 9

As the detector, ALMA G2 (Airborne Laser Methane Assessment) optical device mounted on a Bell 206 Jet Ranger helicopter was used (Figure 10).

Figure 10

The ALMA system uses a technology based on the measurement of the amount of infrared laser light having a radioactive wavelength of 1650 nm absorbed by methane gas. The laser beam is emitted from the Optical Unit of the system and strikes objects such as soil, grass, wood, concrete, and asphalt on the ground surface (Figure 11). The system analyzes the reflected laser beam and calculates how much is absorbed by the possible methane. The special detection algorithm allows instantaneous measurement of the methane present on the laser beam path between the optical unit and the ground surface.

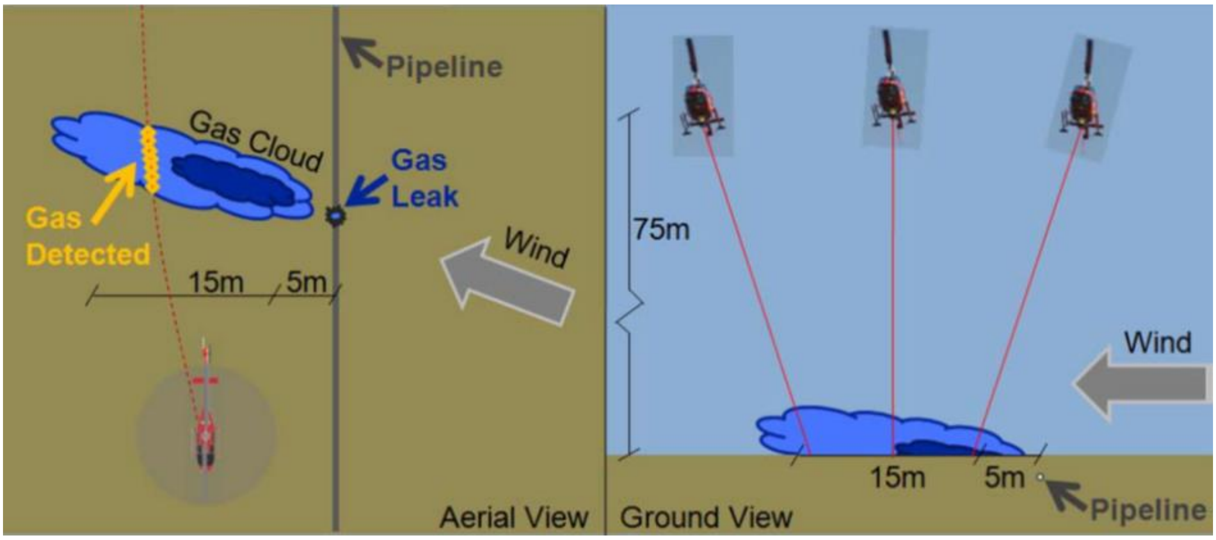

Figure 11

Flight at low speed and minimum height has a positive effect on the detection of the system, so even small gas clouds can be detected. During the helicopter inspection, the ideal flight speed is 65 knots (120 km/h) and maximum 100 knots (185 km/h). The ideal environment for flight is the absence of ice, snow and water on the ground, and the wind speed on the ground is less than 5 m / s.

Along the 1203 km long project route, helicopter flights for gas leak inspection were completed in 5 days. The data sets and video records related to the inspection have been examined and necessary studies have been carried out by BOTAŞ.

3. CONCLUSION

The data sets produced in this pilot project have enabled the identification and reporting of anomalies that have big importance in terms of the safety of natural gas transmission lines, by geographical analysis. In addition, video recordings in 3D environment prepared using actual aerial photographs facilitated analyzes and evaluations made by BOTAŞ managers and engineers within the scope of control / maintenance / repair works for pipelines.

Airborne inspection of gas leaks has enabled effective control, reporting and evaluation in a large area and has allowed the pipeline operating units to repair gas leaks as soon as possible.

In summary, it has been determined that the actual data obtained by photogrammetric studies in the project area and the laser control of the gas leak inspection by air are suitable control methods that provide uninterrupted operation of the natural gas transmission pipelines. These methods also contributed to the strengthening of natural gas transmission pipelines in terms of technical and environmental safety.

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BIOGRAPHICAL NOTES

Mr.Tuncer Ozerbil is a geospatial engineer specializing in GIS and 3D city modeling. He worked at Turkish Military Service as engineer officer for 25 years and after retirement he has been working at GEOGIS inc. as GIS Manager since 2012. He has master's degree on GIS and Cartography from Yıldız Technical University.

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