

# GEODETIC INFRASTRUCTURE OF TURKEY FOR GIS, GPS AND REMOTE SENSING APPLICATIONS

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### ABSTRACT:

What scale is the GIS basic scale? The answer of this question is very important. Since when GIS applications are investigated in the world today, it is seen that GIS developers' concepts mainly intersect on small scale applications. However digital maps scale is starting from 1 over 1 which represents real dimension. Therefore the resolution and positioning quality of data defines the scale of applications. If so, GIS scale starting from 1 over 1. In that case GIS concept might be expressed as a pyramid and from bottom to top, and it might be ordered as Land Information System, Urban Information System and finally Special Purpose GISs. Certainly there are two main indispensable information structures at the very bottom of this pyramid. They are a precise, reliable and robust geodetic infrastructure and basic maps respectively. Remote Sensing and Photogrammetry are mainly used as geo-data collection technologies. Therefore they take place to produce basic maps and related data collections in that definition. So both technologies need to stand on geodetic infrastructure. Hence this paper has been prepared for transferring information about geodetic infrastructure of Turkey to the people who would like to carry out GIS, Remote Sensing and Photogrammetric applications in Turkey. From that point further in this paper reader will obtain detail information about existing coordinate systems and their responsible institutions in Turkey. More over, way of working with these coordinate systems will be expressed. Thereafter sufficiency of geodetic infrastructure of Turkey will be discussed for GIS applications and data collection techniques, like Remote Sensing, Photogrammetry and GPS. Finally close future strategies on national geodetic infrastructure that are going to be applied in Turkey will be pointed out and interpreted.

## 1. INTRODUCTION

Today, use of Geographical Information System (GIS), Global Positioning System (GPS) and Remote Sensing are taking very important role for most of the governmental institutions, municipalities, private companies and etc. Since, they would like to monitor changes, illegal constructing activities, pollution, agricultural activities and etc. in their responsible region. More over they would like to rapidly update information on their systems with reliable and accurate data. In other words, they would like to establish a GIS for meeting their requirements and would like to use remote sensing and GPS for rapid data collection. In other way, day by day the resolution of remote sensing images is extremely increasing. Therefore the accuracy of coordinates of control points on images is getting much more important than the past. Since much reliable and accurate positioning are demanded to shift, rotate and scale the image coordinate system to national coordinate system. More over, in most cases there is not only single coordinate system validity for most countries. Especially when urban area is concerned, this is much more dramatic in Turkey. Since there are several existing coordinate systems such as national (ED50) current, national (ITRF) coming, city-wide local, zone-wide local and etc. However GIS should have a fundamental coordinate system that should be transformable to the other existing coordinate systems to eliminate the coordinate inconsistency. In effect, this is an easy mathematical manipulation if the transformation parameters are valid and if they reflect the character of working area regarding expected requirements.

## 2. EXISTING COORDINATE SYSTEMS

As is very well known Turkey is a very old country its history also past through Ottoman Empire. Therefore several different types of coordinate systems for regional and country-wide mapping purposes exist. Moreover information collected from past to today based on these existing coordinate system. Today in global level people talk about Geographical Information Systems (GIS). In general GIS means all geo-based information collected are gathered within a computer supported environment and using software all information are queried regarding relations with each other. Hence the results of query are used to make decision. However in order to integrate all these geo-based information they must all be identified on a common coordinate system and datum. This means that if several different coordinate system and datum exist, these must be convertible each other. Otherwise geo-based information gathered within a system cannot be integrated with each other. They might demonstrate messy results that might not be beneficial.

Therefore if a GIS is concerned whatever data or data collection technique or system is used the coordinate system and datum information that data are based on is very important. In that case everyone who will set up a GIS must have geodetic background of the data. Moreover one should have excellent knowledge of existence geodetic infrastructures that data in the based can correctly be interpreted and integrated with each other.

Following lines and sections provide detail information about the geodetic infrastructure of Turkey for the people who would

like to set up a GIS or collect data using any geo-based data collection technology.

First technical national regulation based on geodetic reference systems was approved on 10<sup>th</sup> April in 1974. It was regulating of map and plan making in 1:2500 scales or larger. Before that regulation large scale maps and plans were making regarding the technical contracts of individual intuitions. Moreover, 1974 regulation was allowing land surveyors to produce maps and plans on plane geometry. Therefore maps and plans produced based on that regulation created problem by time. Since while edging those maps for large areas inconsistency occurred due to ground curvature ignorance. However at that time that was fitting the requirements. Thereafter two technical regulations were approved in 1976 and in 1988. The regulation in 1976 was Standard Topographic Photogrammetric Mapping in 1:5000 Scales and the regulation approved in 1988 that is also the current regulation in Turkey was Large Scale Map Production. After 1998 regulation maps produced in Turkey connected to the national coordinate system, moreover maps previously produced have been began to be converted to the national coordinate system. Therefore today the maps based on most GIS application have been produced regarding this regulation. The 1988 regulation does not allow land surveyors to use plain geometry all maps regarding this regulation produced based on ellipsoidal geometry and Transversal Mercator projection. However use of this regulation is must for only cadastral map production, nevertheless it does not regulate all type of map production in the country. Hence maps and data collection are still be made out of standards. In order to prevent this and standardizing the data collection and map production for all purposes a new regulation has been prepared and it is currently on the stage of approval by the cabinet.

## 2.1 Turkish National Geodetic Network

National geodetic network establishment was begun at the beginning of 1900 in Turkey (Ulsoy 1982, Şerbetçi 1999). National geodetic network constitutes 27 large triangulation chain rings (~250 km x ~250 km), see Figure 1.

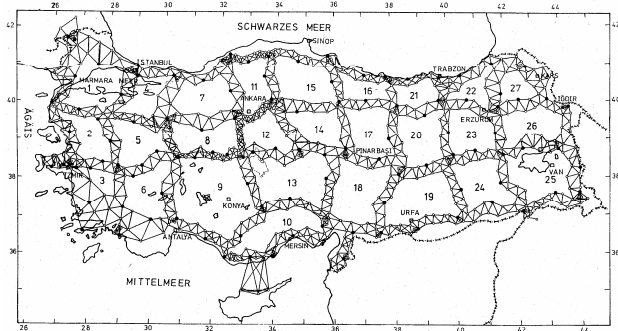


Figure 1: National Geodetic Network

As is clearly seen on Figure 1 that the establishment of the network was began from north-west of Turkey and moved down to south and then again to north and south. If this order analysed with the development process of the country it can be seen that the geodetic networks and mapping process is very important for national developments (Ayan et. al. 2003)

The datum of National Geodetic Network is ED50 (European Datum 1950). This datum was realised connecting to 8 geodetic control stations of European network from Greece and Bulgaria. More technical details of National Geodetic Network

can be obtained on Table 1 (Aksoy et al. 1999, Çelik et al, 2003)

Table 1: Technical Specs of National Geodetic Network

Datum	ED50
Ellipsoid	International Hayford
Adjustment	1954
European Network Connection	8
I <sup>st</sup> Order Chain Rings	27
Astronomic Station	99
I <sup>st</sup> & II <sup>nd</sup> Order Stations	904+3320
Density of I <sup>st</sup> & II <sup>nd</sup> Ord. Stn.	185 km <sup>2</sup> ≈(13 km/stn)
III <sup>rd</sup> Order Stations	≈55000
Density of I <sup>st</sup> , II <sup>nd</sup> & III <sup>rd</sup> Ord. Stn.	13 km <sup>2</sup> ≈(3-4 km/stn)

National Network of Turkey is a hierarchical geodetic network. Upper order control stations always provide coordinates to lower order control stations. While designing of the National Geodetic Network tectonic characteristic of the country was ignored. Scientific researches show that positions are almost 2 cm changes every year because of crustal movements. Due to the fact National Geodetic Network deforms and distorts (Altner et al, 1999). In that case, result of a basic calculation might show that from 1954 to 2004 almost 50 years past the separation of the stations from each other achieve almost 1 metre. This figure comes out without earthquake effect. If this is concerned the case is more dramatic. Especially after earthquake local displacements randomly differ from the global movements (Aliosmanoğlu 2002, Ayan et al. 2002, Aliosmanoğlu and Çelik 2002, Çelik et al. 2002). As a summary it might be said that National Geodetic Network is not sufficient to fit GIS, GPS, Photogrammetric and Remote Sensing application requirements. Nevertheless it cannot be put it away since much information has already been collected based on this network and hence legal rights of people remain based on this network.

There are several governmental institutions that are responsible to take care of it and to condense it. However General Directorate of Land Registry and Cadastre, General Commander of Mapping are the main institutions. The others are specifically Provincial Bank, Municipalities.

## 2.2 Turkish National Fundamental GPS Network

Turkish National Fundamental GPS Network (TUTGA) has been established to remove the problem mentioned above of National Geodetic Network, to provide reliable and robust geodetic network infrastructure for current and future geo-based data collection technologies, see Figure 2. TUTGA were established between 1997 and 1999 (Anonym, 2002) and it has been realised based on an agreement among General Directorate of Land Registry and Cadastre and General Commander of Mapping. It has been designed as four dimensional (4D). Designing concept is sufficient for all type of small scale, low resolution digital mapping and data collection applications.

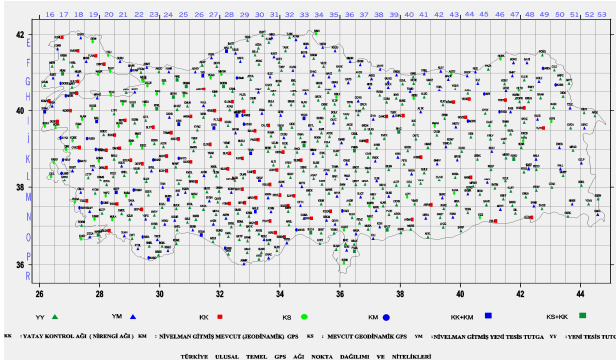


Figure 2: Turkish Fundamental GPS Network – TUTGA

Datum of TUTGA is International Terrestrial Reference Frame 1996 (ITRF96) at epoch 1998.0. Therefore it is the part of global network. Which means any data collected or map produced based on TUTGA has a global meaning and is globally identified and valid. However TUTGA needs to be condensed for large scale mapping applications and high resolution digital data collection. The new regulation that is on approval stage defines the standard rules of condensing strategies of TUTGA. However these condensing processes have been made since mid 1990 by municipalities for forming geodetic infrastructure for Urban Information Systems. The technical specifications of TUTGA can be obtained on Table 2 (Çelik et al, 2003).

Table 2: Technical Specs of TUTGA

Datum	ITRF96
Ellipsoid	GRS80
Number of Control Stations	594
Common with National Geo. Net.	91
Common with Geodynamic Net.	53
Common with Levelling Net.	181
Common with SLR Stations.	5
Density of Control Stations	25-70 km
Density of Control Stations	1315 km <sup>2</sup> /stn

TUTGA has also been designed as a hierarchical control network due to largeness of the country. However, as it is mentioned it is 4D control network and the 4<sup>th</sup> dimension is time. Using 4<sup>th</sup> dimension of TUTGA tectonic characteristic of the country has been taken into account. Therefore velocity model of TUTGA has been determined by using the control stations of TUTGA that are also the member of Geodynamic Networks. Moreover the second phase of TUTGA GPS observations have been completed in late 2003, therefore the latest velocity model generated will be much precise to present the tectonic characteristic of the country.

However there are two main weakness of TUTGA. One of them is the dense of the control stations; therefore it needs to be condensed. The other one, may be the most important one is to have less number of common stations with the National Geodetic Network. Therefore geo-based information transfer cannot precisely and reliably be possible without determining regional transformation parameters with additional works from National Geodetic Network to TUTGA.

General Directorate of Land Registry and Cadastre, General Commander of Mapping are the main institutions that are responsible to take care of TUTGA. However beside these institutions primarily Provincial Bank and municipalities and

then all other governmental institutions are responsible to condense the TUTGA regarding the Large Scale Map and Map Information Production Regulation that is on approval stage.

### 2.3 Local Geodetic Networks

As is mentioned previously Turkey is a very old country. Therefore geo-based information transfer is always necessary from very past to today and future. As is also mentioned the first technical regulation of Turkey that was forcing land surveyors to connect National Geodetic Network for large scale applications was approved in 1988. Therefore the mapping and cadastral works made before hand had local vision rather than country-wide vision. However people have legal rights on all information collected based on those maps and plans. Hence all those must be taken care of and related with current geodetic infrastructure. As an example Figure 3 shows local network developments of İstanbul by time (Güneş et al, 1985 and (Yalın and Maktav, 1995). The latest and the current GPS network of İstanbul is not shown on the figure however it has been established in 1999 based on TUTGA and named as İstanbul GPS Control Network (IGNA) (Ayan et al, 1999).

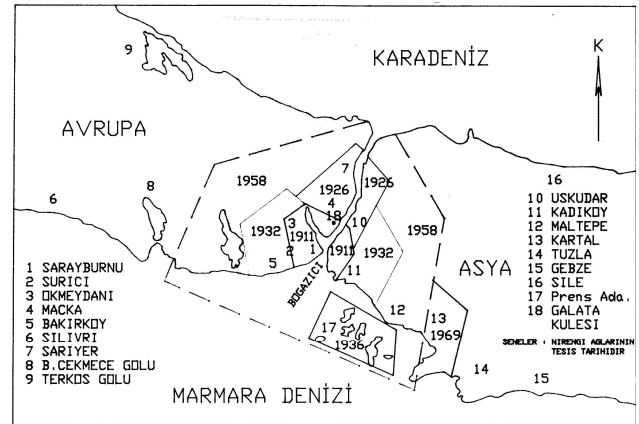


Figure 3: Cadastral Network Development of İstanbul by Time

As is seen from Figure 3 that first modern cadastral network was established in 1911 using plane geometry. Thereafter it had been partially extended. Most cities of Turkey have similar scenarios. Therefore existence of all these networks should be known and the new design of data collection should be made with respect to the existence of these networks.

Information about these networks can be obtained from local institutions like regional directory of cadastre, municipality, local government and etc.

### 3. HOW TO USE THESE GEODETIC NETWORKS?

As is mentioned there are several type of geodetic networks in Turkey. Even though national one is the most accepted one for many type of mapping applications, local networks are also still used. Therefore any new applications or technologies are concerned the existence of all network should be investigated and most precise transformation parameters has to be produced for the region. However the latest network is TUTGA. Therefore any kind of mapping work or data collection that will be carried out should be designed based on TUTGA and then if transformation parameters do not exist with other existing networks they have to be determined, surely transformation parameter determination aspect should be considered while

designing process of TUTGA densification. Thereafter only the new collected information might be integrated with the existing information.

The new datum and coordinate system of Turkey is the datum and coordinates system of TUTGA. Especially in remote sensing applications in order to orient and scale images remote sensing people use hand held GPS or small scale maps such as 1:25000 scales in Turkey. As is very well known that achievement of most accurate coordinate of using hand held GPS is about 10 to 15 meters and of using small scale is about 10 to 20 meters.

More over using hand held GPS provide the coordinates on WGS84 datum which is not used in Turkey and small scale maps based on ED50 datum which has deformation and distortion problems. Therefore in that case whichever accurate images are used orientation and scaling of an image can only be successful within 10s of meters range. However surveying profession discusses on using high resolution remote sensing images for large scale and even for cadastral applications, today. Therefore geodetic infrastructure of Turkey should be well understood and whichever type of work carried out is primarily designed based on TUTGA.

#### **4. RESULTS AND RECOMMENDATIONS FOR SUFFICIENCY OF GEODETIC INFRASTRUCTURE FOR GIS, GPS, PHOTOGRAMMETRY AND REMOTE SENSING**

Remote Sensing, Photogrammetry and GPS might be counted as latest and fastest data collection technologies for GIS today. However both Remote Sensing and Photogrammetry need support of GPS or similar or conventional geodetic positioning technology for locating, orienting and scaling the images. Therefore they might be mentioned as indirect geo-data collection technologies. In that case their integration with geodetic infrastructure can be realised using GPS or terrestrial positioning techniques.

There are recently two types of geodetic infrastructure called as TUTGA and National Geodetic Network in Turkey. So, both Remote Sensing and Photogrammetric works should be connected one of them or both. These two geodetic infrastructures are transformable each other in several meter level precession. However their transformability is better (5 to 15 cm level) in some region such as İstanbul, İzmir, Zonguldak, Sakarya and etc. because of densification networks of TUTGA. These precise transformation parameters can be obtained from local governmental organisations and municipalities. Especially for these regions there might be no problem using geodetic infrastructure for any kind of Remote Sensing and Photogrammetric applications. In other words geodetic infrastructure for these regions will fit all the requirements of Remote Sensing and Photogrammetry technology.

However for small scale applications of Remote Sensing and Photogrammetry TUTGA will compensate all most all expectations from a geodetic infrastructure. As is previously mentioned TUTGA is a modern geodetic network in 4D. The only short of TUTGA is its dense. However, today all most all remote sensing images and technologies are used for small scale applications. In that case it might be correct to mention that TUTGA is sufficient for small scale remote sensing and photogrammetric applications. However for large scale applications it needs to be condensed and its precisely

transformable connections with all existing geodetic networks must be formed.

As a result the geodetic infrastructure of Turkey is sufficient for all type of small scale Remote Sensing and GIS applications today and it needs to be condensed for large scale Photogrammetric, Remote Sensing and GPS and GIS applications.

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