Coordinate Reference Systems Used in Albania to Date

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Key words: Albania, coordinate system, reference system, high system, datum, ellipsoid, map projection, GPS

SUMMARY

In Albania, many organizations have collections of spatial data. Spatial data are created by several agencies as per their needs. Some realities of spatial data are: relevant data is often hard to find, frequently it is not in compatible forms, information describing data is often non-existent, framework data does not exist for broad geographic areas, data sharing across organizations is inconsistent etc. Therefore we need to do: common language, common reference system and common framework. In this paper we give some knowledge about coordinates references systems that are used in Albania to which are related the coordinates of spatial reference. Three common coordinate systems used in GIS in Albania are Geographic coordinate system (Lat-Long), planar (Cartesian) georeferenced coordinate system (easting, northing, elevation) which includes projection from an ellipsoid to a plane with origin and axes tied to the Earth surface, planar non - georeferenced coordinate system, such as image coordinate system with origin and axes defined arbitrarily (e.g. image corner) without defining its position on the Earth and projection.

In order to facilitate the exchange and use of geospatial data by different individuals and organizations, it is important to have a common framework and structure for expressing spatial referencing information. Coordinates are the foundation of GIS, cartography, and surveying, to name just a few fields.

There are thousands of horizontal geodetic datums and Cartesian coordinate systems currently sanctioned by governments around the world to describe our planet electronically and on paper. In Albania we distinguished coordinate reference systems that based on:

- Bessel ellipsoid and Bonn polyconic projection;
- Krasovski ellipsoid and Gauss-Kryger projection;
- WGS 84 ellipsoid and UTM projection.

The Datum of the elevation system in Albania was chosen the MSL of Adriatic Sea, determined from recordings of tide gauge for 1958-1977, which was establish since before second world war from Military Geographic Institute of Florence, Italy. From this tide gauge was establish the Fundamental Bench Mark (FBM) of the First Order Leveling (FOL)

The INSPIRE theme Coordinate reference systems (CRS) provides a harmonized specification for uniquely referencing spatial information. Numerous algorithms and programs are developed to convert coordinates between Albanian System 1987 (ALB87) (Krasovski Ellipsoid and Gauss-Kryger Projection) and UTM, WGS 84. But, till now algorithms and programs are not developed to convert coordinates between coordinate reference system (Bessel ellipsoid and Bonn polyconic projection) and other coordinate reference systems.

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1. INTRODUCTION

The realization of a geoinformation system requires that the geodetic reference system is defined and the measurements are carried out in the chosen system. In every Geographic Information Systems (GIS) project, the user must choose whether to analyze and display data in geographic coordinates or a map projection. There are potentially critical differences between these two ways of measuring the world. In other hand for building up a Spatial Data Infrastructure (SDI), one condition is that all spatial data (geodata) which are used for a specific purpose need to use the same Coordinate Reference Systems (CRS) simultaneously. For that, the definition of each CRS and their relations has to be known. In order to facilitate the exchange and use of geospatial data by different individuals and organizations, it is important to have a common framework and structure for expressing spatial referencing information. To further this goal, the specification of coordinate reference systems and their components conforms to the International Organization for Standardization (ISO) standard 19111:2003 entitled *Spatial Referencing by Coordinates*. The high level abstract model for spatial referencing by coordinates is shown in the diagram below (fig 1).

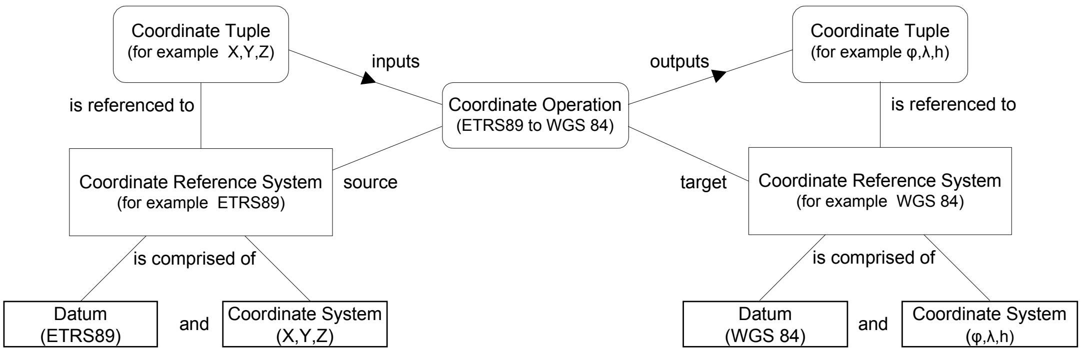

Fig. 1. The abstract model for spatial referencing by coordinates

New methods of acquiring spatial data and the advent of geographic information systems (GIS) for handling and manipulating data mean that we no longer must rely on paper maps from a single source, but can acquire, combine, and customize spatial data as needed. To ensure quality results, however, one must fully understand the diverse coordinate frameworks upon which the data are based. Datums and Map Projections provides clear, accessible explanations of the terminology, relationships, transformations, and computations involved in combining data from different sources. The paper focuses on different coordinate systems and datums that are used in Albania.

2. COORDINATE REFERENCE SYSTEMS (CRS)

Geographic locations in a geospatial object are specified in terms of the object's coordinate reference system (CRS). A CRS associates a coordinate system with an object by means of a datum (fig 2). Therefore, a CRS definition must encompass a definition of a coordinate system and a datum. In the context of ISO 19111 a CRS is defined by its datum. Three types are important in the context of this paper:

- Geodetic CRS – a CRS based on a geodetic datum (e.g. WGS 84 or ETRS 89 - note that both these names are also names of geodetic datums)
- Projected CRS – a CRS derived from a geodetic CRS by means of a map projection. The datum is expressed by the geodetic datum of the base geodetic CRS from which the projected CRS is derived (e.g. Albanian National Grid)
- Vertical CRS – a one dimensional CRS based on a vertical datum (e.g. MSL Depth). It is the definition of the CRS that must be supplied with a spatial dataset in order that a full understanding of the meaning of the coordinates in the data can be gained. By extension the CRS should also be expressed in full on any map products that are produced.

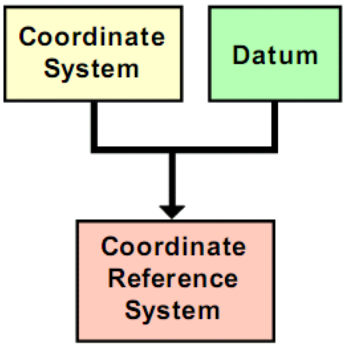

Fig. 2. A coordinate reference system combines a coordinate system with a datum, which gives the relationship of the coordinate system to the surface and shape of the Earth

A coordinate system (CS) is a sequence of coordinate axes with specified units of measure. A coordinate system is an abstract mathematical concept without any defined relationship to the earth. Coordinate systems generally have not been explicitly described in geodetic literature, and they rarely have well-known names by which they are identified. The historic colloquial use of 'coordinate system' usually meant coordinate reference system. A datum specifies the relationship of a coordinate system to the earth, thus ensuring that the abstract mathematical concept can be applied to the practical problem of describing positions of features on or near the earth's surface by means of coordinates (fig.3).
Coordinate reference systems, coordinate systems and datums are each classified into several subtypes. Each coordinate system type can be associated with only specific types of coordinate reference system. Similarly each datum type can be associated with only specific types of coordinate reference system. Thus, indirectly through their association with CRS types, each coordinate system type can only be associated with specific types of datum.
In Europe there exist a very lot of different Coordinate Reference Systems (CRS), and new CRS are defined (table 1). This collection of European Coordinate Reference Systems collects

a lot of paneuropean, regional and national CRS information.

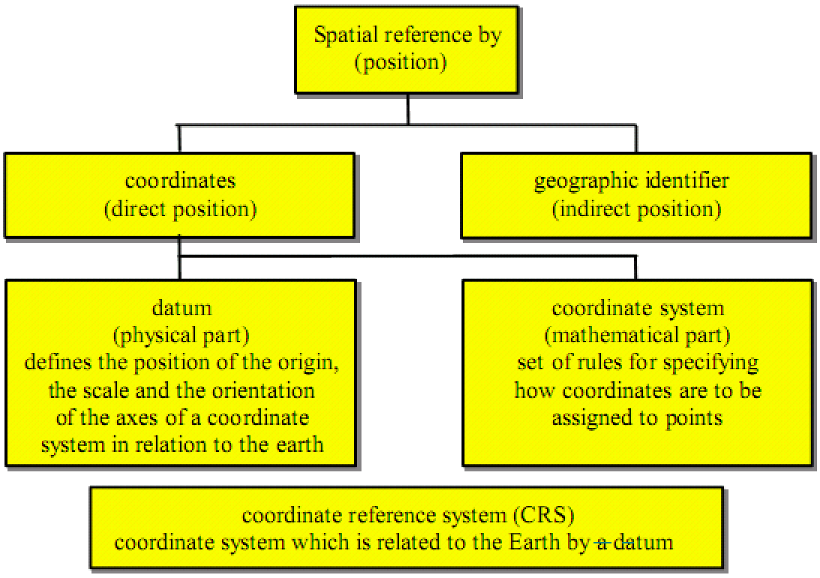

Fig. 3. The definitions of CRS, datum and coordinate system

Tab. 1. Different Coordinate Reference Systems (CRS) in Europe

CRS-EU **Information and Service System for Coordinate Reference Systems in Europe**	***EVRS*** **Information System for the European Vertical Reference System**
It contains: • description of national Coordinate Reference Systems • description of pan-European Coordinate Reference Systems • description of transformation parameters from national Coordinate Reference Systems to pan-European Coordinate Reference Systems including o quality of transformation o verification data of transformation o possibility for online conversion and transformation of single points for test and verification purposes (position) links to the National Mapping Agencies of the European Countries	It contains: • definition of EVRS • description of realizations of EVRS - EVRF2000 and EVRF2007 • projects and products for EVRS (UELN, EUVN, EUVN-DA) references for EVRS (resolution, papers, bibliography)

2.1. Coordinate Reference System subtypes.

Geodetic survey practice usually divides coordinate reference systems into a number of sub-types. The common classification criterion for sub-typing of coordinate reference systems can be described as the way in which they deal with earth curvature. This has a direct effect on the portion of the earth's surface that can be covered by that type of CRS with an acceptable degree of error. The following types of coordinate reference system are distinguished: Geographic (Geographic 2D, Geographic 3D), Geocentric (ISO 19111 classifies both geographic and geocentric coordinate reference systems as geodetic CRSs), Vertical, Projected, Engineering and Compound (in historic geodetic practice, horizontal and vertical positions were determined independently). It is established practice to combine the horizontal coordinates of a point with a height or depth from a different coordinate reference system. This has resulted in coordinate reference systems that are horizontal (2D) and vertical (1D) in nature, as opposed to truly 3-dimensional. The coordinate reference system to which these 2D+1D coordinates are referenced combines the separate horizontal and vertical coordinate reference systems of the horizontal and vertical coordinates. Such a system is called a compound coordinate reference system (CCRS). It consists of a non-repeating sequence of two or more single coordinate reference systems).
For spatial coordinates, a number of constraints exist for the construction of compound CRSs. Coordinate reference systems that are combined shall not contain any duplicate or redundant axes. Valid combinations include: Geographic 2D + Vertical, Geographic 2D + Engineering 1D (near vertical), Projected + Vertical, Projected + Engineering 1D (near vertical), Engineering (horizontal 2D) + Vertical, Engineering (1D linear) + Vertical.

2.2. Coordinate System subtypes. Datum subtypes

The coordinates of points are recorded in a coordinate system (CS). Each CS type may be associated with only specific types of CRS. The following types of coordinate system are distinguished: ellipsoidal, Cartesian, affine, gravity-related, linear, spherical, polar, and cylindrical.
A "Datum" is a standard representation of shape and offset for coordinates, which includes an ellipsoid and an origin. A datum implies a choice regarding the origin and orientation of the coordinate system. It is the datum that makes the coordinate system and its coordinates unambiguous. We recognize three types of datum – geodetic, vertical and engineering (fig. 4).

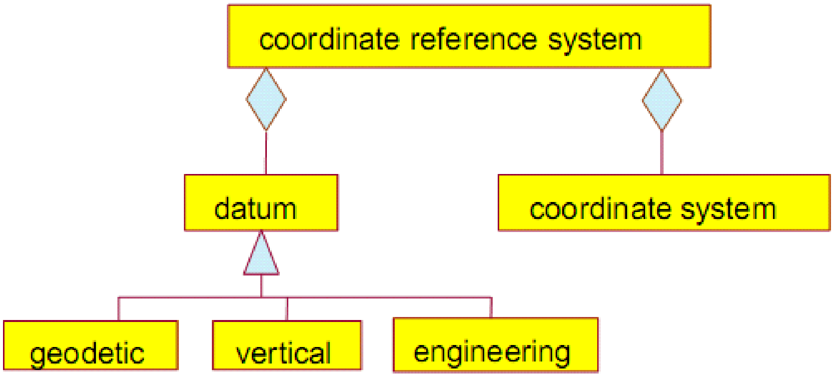

Fig. 4. The coordinate reference system (CRS) is an aggregate class with the component classes datum and coordinate system, geodetic datum, vertical datum and engineering datum are subclasses to the datum

There are a vast amount of datums, some used for measurements all over the world, and other local datums defined so they fit very well with a local area. Some common ones are: World Geodetic Datum 1984 (WGS84), European Datum 1950 (ED50) and North American Datum 1983 (NAD83) etc. The most well-known is WGS84 used by the GPS systems today. It is a good approximation of the entire world and with fix-points defined almost all over the world. When it was defined they forgot to include points in Europe though, so the Europeans now have their own ETRS89, which is usually referred to as the "realization of WGS84 in Europe". The problem here was solely because of continental drift, so they defined some points relative to WGS84 in 1989, and keeps track of the changes. In most use-cases it is of no real importance and we can use one or the other. People often refer to having their data in WGS84, and we see now why this doesn't make sense. All we know from that is that the data is defined using the WGS84 datum, but we don't know which coordinate system it uses.
A vertical datum defines the relationship of a gravity-related coordinate system to the earth. An engineering datum defines the relationship of a coordinate system used for engineering purposes to the earth. For both vertical and engineering types the most important attribute is the datum name, which implies the relationship.
A geodetic datum defines the relationship of a geographic or geocentric coordinate system to the earth. In addition to the datum name (which again implies the relationship), essential attributes of a geodetic datum are the chosen model of the earth – the ellipsoid – including details of name and defining parameter values, together with the details of the zero or prime meridian from which longitudes are reckoned.

3. COORDINATE REFERENCE SYSTEMS (CRS) USED IN ALBANIA

The ability to successfully change from one datum to another requires knowledge of:

a. Geoids
b. Ellipsoids
c. Coordinate Systems
d. Geodetic Height
e. Geodetic Datums
f. Coordinate Systems
g. Methodology to shift from one datum to another

From second half of XIX century, in Albanian territory are made some coordinate reference systems especially to support mapping of Albanian ground territory. Thus, we distinguish coordinate references following:

- The Triangulation Network that was established by Military Geographic Institute of Vienna (MGIW) during 1860-1873, in the framework of the construction of the geodetic basis is done for mapping of Balkan at 1:75000 scale. We have not any detailed information about, but we know that in the 1918 the geodetic coordinates of the points of triangulation were calculated on Bessel ellipsoid (dimensions determined by Friedrich Wilhelm Bessel, based on several meridian arcs and other data of continental geodetic networks of Europe, Russia and the British Survey of India), Gauss-Krüger cylindrical projection, with origin the intersection of the Equator by the meridian of Ferro.
  Reference parameters of the Coordinative Reference established by Military Geographic Institute of Vienna (MGIW) in the 1860-1873 period are:
  Ellipsoid: Bessel 1841, non geocentric
  Ellipsoid origin of north: Earthy equator,
  Ellipsoid origin of east: Ferro Meridian (-17.5^0 in west of Greenwich)
  Projection: Polyconic of Bonn
- The geodetic coordinates of the points of triangulation that carried out by Military Geographic Institute of Italy (IGM), in the 1927-1943 period, were calculated on Bessel ellipsoid, Bonn projection with central meridian Lo=20', as origin was determined the astronomical point of Lapraka, Tirana. At the same time, IGM carried out the Leveling Net (about 150-170 km). The origin for Heights System was chosen the MSI, of Adriatic Sea, determined with a temporary tide gauge very short recording time (one month).
  Reference parameters of the Coordinative Reference established by Military Geographic Institute of Italy (IGM), in the 1927-1943 period are:
  Ellipsoid: Bessel 1841, non geocentric
  Ellipsoid origin of North: Earthy Equator ($\varphi = 0^0$),
  Ellipsoid origin of East: Meridian $\lambda_0 = 20^0$
  Projection: Bonn
  False origin of North: 0.000 m
  False origin of East: 0.000 m
  Scale of deformation in central meridian ($\lambda_0 = 20^0$): $k_0=1$
- In the 1955, the specialists of Military Topographic Group of Albania carried out the reconstruction and the densification of the IGM Net in order to grant the request for mapping at 1: 25 000 scale. At the same time, the first- order network was transformed

from the IGM. System (1934) into the 1942 coordinate system, which based on Krassovsky ellipsoid, Gauss-Krüger projection with central meridian Lo=21'.

Reference parameters of the Coordinative Reference established by of Military Topographic Group of Albania with Russian help in 1955 year are:

Ellipsoid: Krasovski 1945, non geocentric
Ellipsoid origin of North: Earthy Equator ($\varphi = 0^0$),
Ellipsoid origin of East: Central Meridian $\lambda = 21^0$
Projection: Gauss-Kryger (Mercator Transversal)
False origin of North: 0.000 m
False origin of East: 500 000.000 m, in west of meridian $\lambda = 21^0$
Scale of deformation in central meridian ($\lambda_0 = 21^0$): $k_0=1$

- The New Albanian Net, which constituted from Triangulation and Leveling was designed, rebuilt, measured and calculated from Military Topographic Institute of Albania (MTI) during 1970-1985 (fig. 6). Leveling Networks, were designed, measured and calculated at the same time as the triangulation, during 1970-1985, from Military Topographic Institute (MTI).

  Reference parameters of the Coordinative Reference established by of Military Topographic Institute of Albania in the 1970- 1985 period are:

  Ellipsoid: Krasovski 1945, non geocentric
  Ellipsoid origin of North: Earthy Equator ($\varphi = 0^0$),
  Ellipsoid origin of East: Central Meridian $\lambda = 21^0$
  Projection: Gauss-Kryger (Mercator Transversal)
  False origin of North: 0.000 m
  False origin of East: 500 000.000 m, in west of meridian $\lambda = 21^0$
  Scale of deformation in central meridian ($\lambda_0 = 21^0$): $k_0=1$

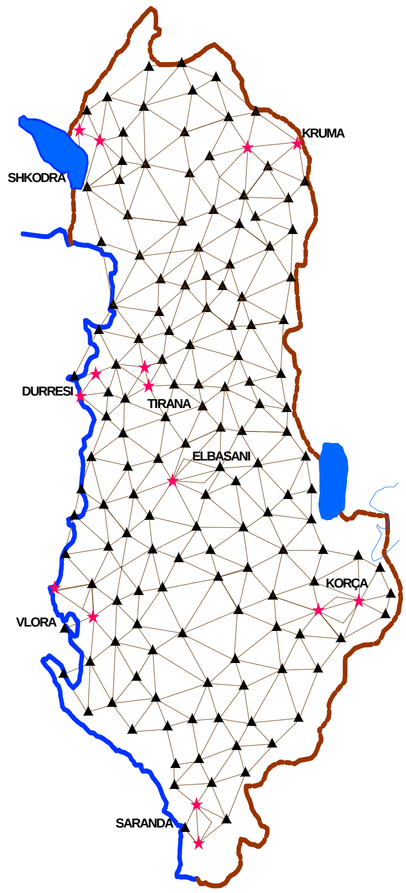

Fig. 6. First class of Albanian Triangulation Network

The Datum of the elevation system was chosen the MSL of Adriatic Sea, determined from recordings of tide gauge for 1958-1977, which was establish since before second world war from Military Geographic Institute of Florence, Italy. From this tide gauge was establish the Fundamental Bench Mark (FBM) of the First Order Leveling (FOL).
The cadastral maps that were done for about 40 years by using the classical methods (tachymetry) are a scale of 1:2500 and 1:5000. The maps were used not only for cadastral purposes but also for different considerations such as land irrigation systems, land management, and so forth. Two co-ordinate systems for cadastral maps production are applied: (1) one system based on the Bessel ellipsoid is used to produce maps at a scale of 1:2500; (2) and the other system based on the Krasowski ellipsoid is used to generate maps at a scale of 1:5000. The Gauss-Kruger projection is used for both systems; for the first system the central meridian is 20°, and for the second it is 21°. The maps at the scale of 1:2500 in the Bessel co-ordinate system are based on a map sheet layout system unique to Albania. Map sheets produced in the Krasowski system are referenced by geographic coordinates.
Immovable Property Registration Office (IPRO), Ministry of Justice: IPRO, as part of its property registration scope, has produced a cadastral layer that includes coverage for all the eight cities. The cadastral borders are in AutoCAD DWG/DXF format, while the

attribute data resides partly in a relational database, and partly in hard-copy format. The spatial data is acceptably accurate at scales of 1:500-1:1,000 in urban areas, and at 1:2,500 scale in rural areas. The data is spatially referenced in the Albanian National Coordinate System (Gauss-Kruger, Krasovski/Pulkovo 1942). IPRO is at present in the midst of a large-scale modernization project, which will produce a highly automated property registration updating procedure, as well as a GIS-compatible cadastral database. This database will be of vital importance for any regulatory planning initiative, and so the solving of the coordinate conversion issues is of utmost importance.

- A Global Positioning System (GPS) geodetic control network survey was performed in Albania during October 1994 in collaboration with United States Defense Mapping Agency Aerospace Center (DMAAC). The purpose of the survey was to establish World Geodetic System 1984 (WGS 84) positions on 35 existing stations within the Albanian geodetic control network. The selection of the stations to be included in the survey was made by M.T.I. personnel. The objective of GPS measurements campaign of February 98 in collaboration with University of Wisconsin, Florida, USA was: Connect the Albanian Geodetic Network to the International Terrestrial Reference System (ITRF) and define the inter-relationship between the local and international reference frameworks. It was proposed to occupy stations included in US National Imagery and Mapping Agency (NIMA) GPS network of 1994, thus it would be possible to re-adjust the NIMA network data. The fiducially network included the IGS stations GRAZ, MATERA, SOFIA and PENC and stations KAMZA, KORCA, SHKODRA. The final coordinates are referenced to ITRF 96, Epoch 1998.0, also the final WGS 84 geodetic coordinates. The final co-ordinates for the new EUREF stations were performed by fixing the co-ordinates of four ITRF stations (Wettzell1202) and are given in the International Terrestrial The Military Institute of Albania is responsible for producing a variety of cartographic products, including hard-copy topographic maps at the following scales: 1:10,000, 1:25,000, 1:50,000, and 1:100,000. All of these products are spatially referenced in the Albanian National Coordinate System. In addition, the Institute distributes 1:50,000 scale hard-copy maps produced in collaboration with the USA agency NIMA (National Image and Mapping Agency – now called NGA: National Geospatial-Intelligence Agency). These products are spatially referenced in the UTM (WGS84) coordinate system. The Institute’s 1:25,000 and 1:50,000 scale series may be suitable background cartographic material for city-based GIS projects, since they exhibit a standard graphic “language”, as well as indicate the regional context of the city.

  Reference parameters of the Coordinative Reference established by of Military Topographic Institute of Albania after 1994 year are:
  Ellipsoid name: WGS 84
  Ellipsoid origin of North: Earthy Equator ($\varphi = 0^0$),
  Ellipsoid origin of East: Central Meridian $\lambda = 21^0$ E
  Map Projection name: UTM zone 34 N
  False northing, in grid units: 0.000 m
  False easting, in grid units: 500 000.000 m, in west of meridian $\lambda = 21^0$
  Scale factor at natural origin in central meridian ($\lambda_0 = 21^0$): k_0=0.9996
  Magnitude of projection zone: 6^0,
  Projection Zone: 34

Projected CRS axes units name: meter

- Albanian National Grid (ANG) is the national standard CRS for land mapping in Albania. The components of the CRS are as follows:
  1. Base Geodetic CRS – WGS 84
  2. Geodetic Datum – WGS 84
  3. Ellipsoid – WGS 84
  4. Prime Meridian – Greenwich
  5. Coordinate System - Ellipsoidal
  6. Projection Parameters – ANG
  7. Projection Method – Transverse Mercator
  8. Coordinate System – Cartesian

ANG was originally created using classical techniques. The geodetic datum was realized by triangulation using physical monuments (Trig Points). However, the realization of the datum is now performed through the use of the coordinate transformation.

Numerous mathematical techniques have been developed to convert coordinates between Albanian System 1987 (ALB87) (Krasovski Ellipsoid and Gauss-Kryger Projection) and UTM, WGS 84. These techniques include a variety of multiple-parameter and multiple-regression transformation equations.

4. CONCLUSIONS

In order to facilitate the exchange and use of geospatial data by different individuals and organizations, it is important to have a common framework and structure for expressing spatial referencing information. Coordinates are the foundation of GIS, cartography, and surveying, to name just a few fields. Coordinate systems, covering ellipsoids, datums, and plane coordinates are used in GIS and GPS.

There are thousands of horizontal geodetic datums and Cartesian coordinate systems currently sanctioned by governments around the world to describe our planet electronically and on paper. In Albania we distinguished coordinate reference systems that based on:

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6. BIOGRAPHICAL NOTES OF THE AUTHORS

Asoc.Prof.Dr.Eng. Pal Nikolli. Graduated at the Geodesy branch of Engineering Faculty, Tirana University. In 1987 has been nominated lecturer in the Geodesy Department of Tirana University. In 1994 has been graduated Doctor of Sciences in cartography field. During this period, have taught the following subjects: "Cartography" (for Geodesy and Geography students) and "Geodesy" (for Civil engineering & Geology students). Actually he is lecturer and tutor of the following subjects: "Elements of Cartography" (for Geography students), GIS (for Geography students, diploma of first and second degree) "Interpretation of Arial Photographs" (for Geography students, diploma of first degree), "Satellite Images" (for geography students, diploma of second degree) "Thematic Cartography" (for Geography students, diploma of second degree) and "Topography-GIS (for the Geophysics students, diploma of second degree). Mr. Nikolli is the author and co-author 8 textbooks (Elements of Cartography and Topography, Elements of Cartography, Geographic Information Systems, Processing of satellite images, Cartography, etc), 3 monographs (History of Albanian Cartography, Mirdita on Geo-Cartographic view, etc), more than 50 scientific papers inside and outside of the country, more 40 scientific & popular papers, etc. Has participated in several post graduation courses of cartography and GIS outside of the country (1994, 2000 - Italy), etc.

Bashkim IDRIZI, was born on 14.07.1974 in Skopje, Macedonia. He graduated in geodesy department of the Polytechnic University of Tirana-Albania in 1999year. In 2004, hot the degree of master of sciences (MSc) in Ss.Cyril and Methodius University-Skopje. In 2005 he had a specialization for Global Mapping in Geographical-Survey Institute (GSI) of Japan in Tsukuba-Japan. On year 2007, he held the degree of Doctor of sciences (PhD) in Geodesy department of Ss.Cyril and Methodius University–Skopje. He worked in Agency for Real Estate Cadastrefrom May 1999 until January 2008. During those period, in 2004 he appointed for head of cartography department, i.e. geodetic works. From October 2003 up to January 2008, he worked as a outsourcing lecturer in State University of Tetova. From February 2008, he works as a cartography and GIS Professor at the State University of Tetova–Tetova. He continuo with working as outsourcing lecturer in geodesy department of the University of Prishtina-Kosova. He is the author of three cartography university books, and more than 60 papers published and presented in national and international scientific conferences related to geodesy, cartography, GIS and remote sensing. From March 2010, he is elected as president of Geo-SEE (South-European Research Association on Geo Sciences).

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