Usability of GNSS Technique for Cadastral Surveying

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SUMMARY

Cadastral surveys are conducted by General Directorate of Land Registry and Cadastre of Turkey (GDLRC), which dates back to 1847 in Turkey. Over the past several years, 99% of first facility cadastral study has been done. However, the necessity of largely renovation study has showed up owing to new technologies, new requirements and other factors. Regeneration of the portion of the works, especially for the maps made with very old traditional methods, have become essential due to the failures of those in terms of accuracy and technical inadequateness in the present conditions. When it is considered that almost everything is integrated with each other in our global world, measurements made in a seamless datum is not a great option but a necessity. In addition, one of the issues which should be taken into account is that all study should be conducted as fast as possible. When all these issues are considered, the most important concern in determining the position is seemed to be realized by satellite-based positioning systems today. This study focuses on the use of satellite-based positioning systems and issues that should be considered in cadastral surveying.

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1. INTRODUCTION

The population of the world, which increases rapidly at an average rate of % 1.2 annually, has exceeded 7 billion. However, despite the increase in population, 150,000,000 km² terrestrial area, which composes the % 29.2 of the surface of the earth, has not changed significantly. When this is taken into account, it is clear that the leading precious fact is land. Considering that not all of these areas are suitable for the life and use of human being, it is obvious that land and soil should be used with care and managed in accordance with professional policies.

What is undoubtedly essential to do in this regard is to identify the overall aspects of this value and keep records with the use of information systems. In this context, information about the ownership and boundary of a real property is specified with cadastral surveying. When the fact is not only the civilian but also boundary conflicts of many countries, resulting serious legal problems and even wars among countries, the significance of the issue can easily be understood.

In Turkey, Cadastral surveys are conducted by General Directorate of Land Registry and Cadastre of Turkey (GDLRC). When Turkey Republic was established, cadastral studies were enacted in accordance with the 658 numbered Cadastre Law in 1925. Cadastral studies are still conducted with regard to 3402 numbered law in Turkey (İnam et al., 2011). The current status of the Turkey Cadastre is given in Table 1 (URL-1).

Table 1. Status of Turkey Cadastre Realization

Total Units (District&Village)	**Realization**			**problemtic units** (*)
	before 2003	**between 2003-2015**	**on-going**	
52,054	38,803	12,758	193	300

(*) Forest, Border Disputes etc.

Regarding this data, it can be concluded that, 99% of the cadastral studies have been completed. Although the first facility cadastre is about to be completed in Turkey, Cadastre Renovating/Updating studies are in progress because of the following main reasons (Çağla et al., 2011; Meha et al., 2013):

- Cadastral reconstruction,
- Technical inadequateness,

- Loss of application quality,
- Lack of information,
- Showing the boundaries of the ground as its original,
- Land consolidation in urban and rural areas,
- Regular maintenance of cadastre.

Turkish government aims at improving the cadastral system to maintain it in a more appropriate, effective and contemporary manner (Çete, 2010). According to a study carried out by the GDLRC of Turkey in 2008, throughout the country under the Cadastre Law Article 22-a (Renovation Cadastre) that needed to renew approximately 8,100,000 parcels has been determined. A total of 5,642,255 parcels were auctioned by the World Bank and the GDLRC's their own budget between 2009 and 2014, and studies were completed in 3,600,000 parcels (URL-2). This means that about 44% of the parcels have been completed, and it is evident that a lot of studies would be done in this scope. It is generally said that there are plenty of studies in such fields as follows:

- Cadastre renovating/updating studies,
- Setting marks of parcels,
- The works carried out within the scope of land use conversion and amalgamation (measuring the buildings and other details on the parcel),
- Controlling maps and plans registered,
- Forest cadastre,
- Boundary dispute and novation,
- 3D cadastral mapping.

Historical background, current situation and emerging main problems of cadastral studies in Turkey can be found in detail in Çete, (2010); İnam et al., (2011) and URL-2.

All these study have been carried out either by related Official Cadastral Units or Licensed Surveyors. In those studies, cadastral surveys have been conducted with the use of conventional terrestrial methods/equipment; i.e. steel band, EDM, theodolite and for a couple of decades total stations and etc. Nevertheless, Global Navigation Satellite System (GNSS) (especially GPS and GLONASS), which have many advantages over conventional methods, have begun to be widely used all around the world. GNSS systems are competing with conventional methods in almost all fields of surveying applications including cadastral surveying. Although the GNSS systems have considerably facilitated the measurements, there are still some limitations in their usability in some cases like in densely urban areas, mountains, heavy tree cover, ravines and similar places. Even though the combination of GPS and secondary satellite system like GLONASS observations can overcome the abovementioned problems, conventional surveying techniques are still required in some instances.

2. A REVIEW of GLOBAL NAVIGATION SATELLITE SYSTEM

The term GNSS is now used to describe a many different satellite positioning systems operated by different countries. Among them, GPS (Global Positioning System) is the very well-known and widely used one while the others, i.e. GLONASS, Galileo etc. have started to be used or about to be used in the near future. 20 years ago, the usage of the GNSS by civilian was mainly limited to merchant ship crews and surveyors, but today there are millions of receivers which are used to achieve different tasks. Moreover, GNSS technology is becoming the most effective positioning methods for all types of engineering projects (Bonnor, 2012). GNSS is competing with traditional surveying techniques and has widely used for marine, air and land applications for achieving navigation, surveying and scientific purposes because of the advantages such as being almost independent of weather conditions, not requiring surveying points seeing each other, being able to manage surveying during the day&night, and etc. The systems that constitute the GNSS are briefly given in the following sections.

2.1 GPS

GPS is a satellite-based radio navigation system which was maintained by the United States Department of Defense. Although it was originally designed as a military system, it has become a global utility primarily used as a navigation system and its civil applications have grown much faster. The system provides position, velocity and time anywhere in the world. Since the launch of the first operational GPS satellite in 1978, as of today, the GPS has been widely used in marine, air and land applications. Positioning with GPS can be realized in two main ways: *i*-absolute positioning, *ii*- relative positioning. A general classification of the GPS positioning methods are shown in Fig. 1 (Kahveci and Yıldız, 2012).

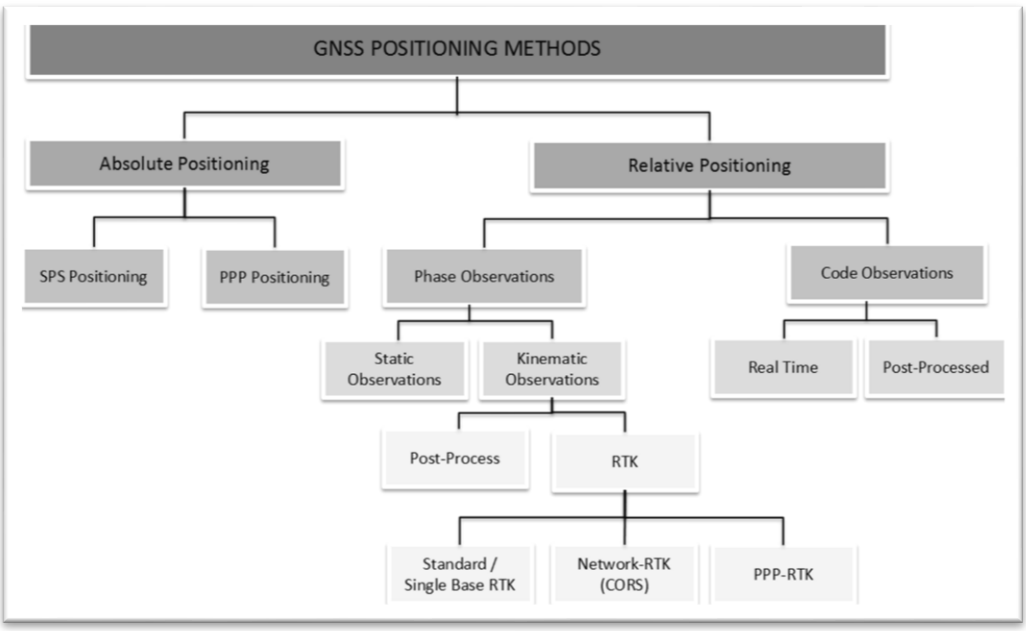

Fig. 1. General Classification of GNSS Positioning Methods

The GPS was declared as Fully Operationally Capable (FOC) in July 1995 with 24 satellites. At present, there are 31 satellites 30 of which are operational (Table 2).

Table 2. GPS Constellation Status (as of March 13, 2015) (URL-3)

	GPS
Total Satellites in Constellation	31 SC
Operational	30 SC
In Commissioning Phase	-
In Maintenance	1 SC

2.1.1 Network RTK / TUSAGA-Aktif (CORS-TR)

In recent years, Network-RTK (or commonly known as Continuously Operating Reference Station-CORS) has been used extensively while producing economical and rapid solutions with only single GNSS receiver. CORS networks have been established in many countries and regions all over the world. For instance, Germany has approximately 270 reference stations with an average spacing of about 40 km, Switzerland has 31 stations with an average spacing of 35-50 km, Sweden has 170 stations with an average spacing of 60-70 km, and Indonesia has more than 230 CORS stations (Reddy, 2010).

Similar to the world samples, a network called as TUSAGA-Aktif has been established in Turkey by *Istanbul Kultur University* in association with the *General Directorate of Land Registry and Cadastre of Turkey (GDLRC)* and *the General Command of Mapping of Turkey* and sponsored by *the Turkish Scientific and Technical Research Agency (TUBITAK)* in 2009 (Bakıcı and Mekik, 2014). TUSAGA-Aktif system has 146 reference stations with an average spacing of 70-100 km covering entire Turkey and Turkish Republic of Northern Cyprus (Figure 2).

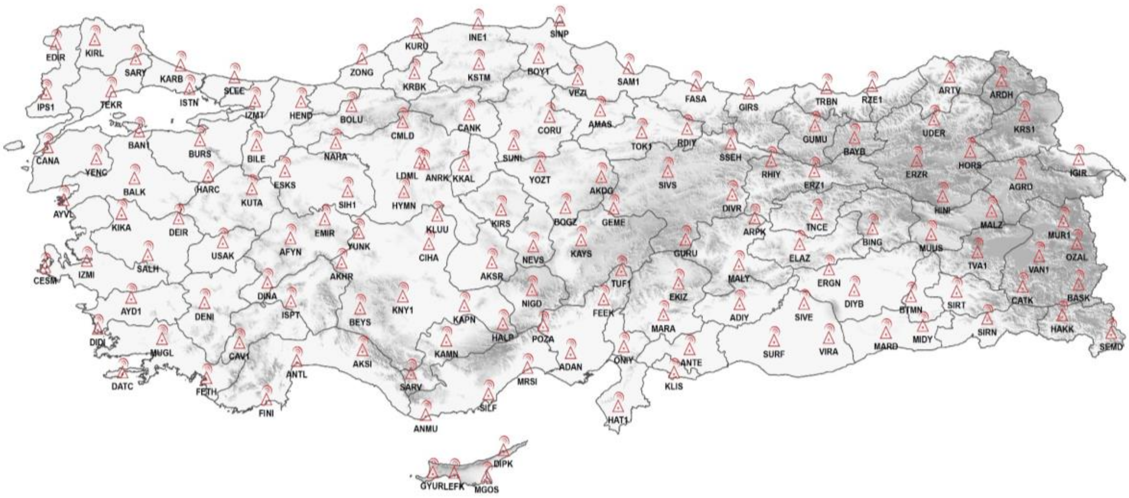

Fig. 2. Location of TUSAGA-Aktif Reference Stations (Bakıcı, 2015)

The system aims;

- to determine positions fast, economically and reliably with cm accuracy within minutes, even seconds, 24/7 in real-time,
- to model the atmosphere (troposphere and ionosphere),
- to predict weather,
- to monitor plate tectonics,
- to determine datum transformation parameters between the old system and ITRF*yy* (Bakıcı and Mekik, 2014).

In this system, the corrections are computed and transmitted by different methods such as Virtual Reference Station (VRS), Flachen-Korrektur Parameter (FKP), Master Auxiliary Concept (MAC), and Differential GPS (DGPS) techniques. RTCM 3.0 and higher protocols are used for communication between users and the control center and thus GSM, NTRIP over GPRS/Edge and radio links are utilized (Mekik et al., 2011). The coordinates can be realized in ITRF96 datum and 2005.0 measurement epoch. In addition to the RTK correction, all the reference stations can also log the GNSS data for later use. Therefore, users can download 1 second-interval data with a limited fee and 30 seconds-interval data freely via web-site of the service. The user of the TUSAGA-Aktif has been increasing day by day and the number has reached to 6,128 as of March 15, 2015 (Bakıcı, 2015).

The usage of the TUSAGA-Aktif is permitted by Large Scale Map and Map Information Production Regulation (LSMMIPR) in cadastral surveying. Usability of the TUSAGA-Aktif for cadastral surveying not only provides greater speed but also requires less time, less money and fewer personnel.

2.2 GLONASS

The Russian Federation operates their own satellite-based system called as GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (GLONASS) and it was developed primarily for the use of the Soviet military. Development of the system began in 1976, but the first satellite was launched in October 1982 and 10 more satellites were launched between 1982 and 1985 (Bonnor, 2012). Due to the financial recession in Russian Federation, GLONASS system continued to work with too few satellites in 1980s and 1990s. In 2000, after the economic recession period, Russian government made a considerable investment to reconstruct the GLONASS satellite system. The system was made fully available for civilian in 2007. In 2010, GLONASS achieved 100% coverage of Russia's territory. Full Operational Capability (FOC) and thus full global coverage for GLONASS were attained with 24 satellites in 2011. As of today, GLONASS system has 28 satellites 24 of which are operational (Table 3).

Table 3. GLONASS Constellation Status (as of March 13, 2015) (URL-4)

	GLONASS
Total Satellites in Constellation	28 SC
Operational	24 SC
In Commissioning Phase	-
In Maintenance	-

2.3 Galileo

European Commission decided to develop the Europe’s own global navigation satellite system named as Galileo. Unlike GPS and GLONASS, construction and operation of Galileo will be under the control of civilians. Galileo was designed to cooperate with GPS and GLONASS. The full operational capability constellation of Galileo will consist of 30 satellites (27 operational + 3 active spares). These 30 satellites will revolve around the world in three circular Medium Earth Orbit (MEO) planes and at an inclination of the orbital planes of 56 degrees to the equator. On 21 October 2011 a Soyuz rocket from French Guiana launched two satellites, with two more following on 12 October 2012. The Galileo In-Orbit Validation (IOV) test campaign was conducted in 2013. The test shown that deployed four Galileo satellites and ground infrastructure work very well. They will be followed by several launches with Ariane-5 or Soyuz from the Europe’s Space Port in French Guiana (URL-5; URL-6).

2.4 BeiDou (BDS)

BeiDou Navigation Satellite System (BDS) is the global navigation satellite system which has been established and operated independently by China. The system was planned to establish as three steps: demonstrational system, regional system and global system. The regional system is in full operation comprising 5 Geostationary Earth Orbit (GEO) satellites, 5 Inclined Geosynchronous Earth Orbit (IGSO) satellites and 4 Medium Earth Orbit (MEO) satellites. The system gives two types of service to their users as standard positioning service which is free for all civilian users and precise positioning service & system-embedded wide area differential positioning are only for authorized users (Xu et al., 2014).

In 2020, the BeiDou will provide high accuracy and high reliability positioning to GNSS users in any time and all-weather conditions in global coverage (Li et al., 2014).

2.5 Japan Quasi-Zenith Satellite System (QZSS)

Japan is planning a Quasi-Zenith Satellite System (QZSS) using three satellites. In March 2013, Japan’s Cabinet Office announced the expansion of the QZSS from three satellites to four. The plan was to have four satellites constellation in 2018. The system will include three satellites in the Inclined Geosynchronous Earth Orbit (IGSO) and one satellite in the Geostationary Earth Orbit (GEO) (Montenbruck et al., 2014). The first satellite (named as Michibiki) was launched in September 2010. At present, only one QZSS satellite is in operation. High elliptical orbits (more than 70 degree) increase the reliability of the satellites in service area more than 12 hours a day (Bonnor, 2012). Therefore, users can receive the signals with high elevation angle from at least one of the satellites of QZSS. Moreover, Japan and USA have agreed that GPS and QZSS have complete compatibility and interoperability of the systems. With small modifications of the GPS receiver, users can receive QZSS signal and calculate their position combining the GPS signals (Kogure et al., 2006).

2.6 GAGAN and IRNSS

India's satellite system is named GPS Aided GEO Augmented Navigation (GAGAN). The first GAGAN communication satellite was launched on 21 May 2011. The aim of the system is not only navigation but also communication and some other purposes. The Indian Regional Navigational Satellite System (IRNSS), which is an autonomous regional satellite navigation system, was approved by the Indian government in May 2006 to provide accurate position information in Indian region.

The first IRNSS satellite was launched in July 2013. Four Inclined Geosynchronous Earth Orbit (IGSO) and three Geostationary Earth Orbit (GEO) satellites were planned to be launched so that all satellites were visible in Indian Region (Majithiya et al., 2011). The entire IRNSS constellation of seven satellites is planned to be completed by 2015. IRNSS will provide two types of services; one is the Standard Positioning Services (SPS) available for all users and the other is Restricted Services (RS), available for authorized users.

Deployment status of global and regional satellite positioning systems is summarized in Table 4 (Montenbruck et al., 2014).

Table 4. Current Status of Space-based Positioning Systems

System	Blocks	Sats
GPS	IIA	8
	IIR-A/B	12
	IIR-M	7
	IIF	4
GLONASS	M	24
	K	1 *
Galileo	IOV	4 *
BeiDou	GEO	5
	IGSO	5
	MEO	4
QZSS	N/A	1
IRNSS	N/A	1 *

** have not been declared as operational.*

2.7 Combined Services Performances

A total of 6 satellite-based positioning systems that operated by different countries, i.e. GPS, GLONASS, Galileo, BeiDou (BDS), QZSS, and GAGAN&IRNSS, have become available for different type of users all over the world. The abovementioned systems will work together and will be compatible, interoperable and interchangeable among each other. This obviously increases the availability and the coverage while providing more robust and reliable services. The combined system provides more accurate positioning in some locations that have marginal sky visibility like urban canyons, mountains, heavy tree cover, ravines, open-pit mines and extreme marine environments where satellite signals may either be blocked or strongly degraded by obstacles (Tamrakar, 2013).

By combining the multi-GNSS systems, improved performance in the following domains can be expected as:

- ***Availability:*** Using GLONASS in combination with GPS as an example, the number of available satellites will increase twice or more when compare the GPS alone. With the addition of more GNSS system integration, more satellites will be available all around the earth. This is especially important in partially obstructed areas like urban canyon environments, heavy tree cover, ravines, mountains, open-pit mines.
- ***Position Accuracy:*** Increasing availability of more satellites generally leads to better satellite geometry and enhanced better positioning performance.
- ***Integrity:*** Combined satellite systems will enhance the provision of integrity information.
- ***Redundancy:*** The combination of independent systems will lead to the required level of redundancy (Awange, 2012).

The most important constraint that restricts the use of the systems can be the environments without clear view of the sky. Although the use of the combined systems provides a solution, even this cannot be sufficient in some cases. In that case, at least two or three control points should be established in the closest clear location of the study area. After determining the coordinates of those points with GNSS, measurements with conventional optical methods will be better than feasible.

2.8 Advantages of GNSS Usability

GNSS measurements, widely used in many areas, are prevalently used in cadastral measurements as well. The reason is the system provides important advantages to the users. Some of the advantages of GNSS surveying with respect to conventional methods in cadastral survey is given below (Tamrakar, 2013).

- Inter-visibility between consequent stations are not required,
- Traverse stages in the field for providing control points for classic surveys are not needed,
- Establishment of the control points is more accurate, easier with less cost,
- The measurements can be made in day time and at night, under almost all weather conditions,
- Simple field operation,
- Continuous 3D positioning,
- All coordinates can be estimated in a global datum, i.e. ITRF*yy* or so on.

The abovementioned features make GNSS quite attractive for survey works.

2.9 Some Recommendation for GNSS Usability

Some recommendation as a minimum standard for the surveyors using GNSS is given below (Tamrakar, 2013; URL-7; URL-8);

- GNSS surveyors should be trained before using this technique in cadastral surveys,
- As GNSS signals and fixed solutions can be affected from cell tower, radio station, and high-voltage transmission line, to establish geodetic control points must not be selected in the areas where they degrade GNSS signal quality,
- Reflecting surface like metal roofing, big vehicles and large water surface in surveying area may cause multipath error. Thus, it is suggested not to choose these kind of places,
- The location of the points must be well located in terms of ground stability, accessibility, clear sky views, protection from vandalism and disturbance,
- Although it is not necessary for the control points, the points should be intervisible for ease of subsequent use by conventional techniques,
- A proper observation log must be filled up,
- GNSS station obstruction diagram should be drawn carefully (obstructions and their elevation angle is shown),
- GNSS results can be affected by meteorological changes notably due to longer distance, thus instantly changing weather conditions must be written down in observation logs,
- GNSS receiver and antenna used in the survey should be of geodetic or survey grade equipment,
- GNSS measurement equipment should be calibrated and standardized periodically before used in the field,
- The measurements should be carried out by considering the accuracy criteria accepted/recommended by the official authority/related regulation(s),
- The appropriate equipment and methods should be the choice to be able to meet the required accuracy,
- Zero baseline test should be conducted for a pair of GNSS receivers to verify the precision of the receiver, to prove that the receiver is operating correctly and to validate the data processing software,
- GNSS antenna height must be measured once before and after each survey,
- If possible, the GNSS surveys are conducted during the periods when the maximum number of satellites is in view, and the value of PDOP is at its minimum,
- The GNSS surveys should be observed with enough time to remove large outliers and to fix the reliable solutions,
- At least two independent observations (two baselines) should be carried out,
- Independent observations should be carried out after 30 minutes elapses (this allows the satellite constellation to change) by changing the height of the antenna (with cold start),
- Minimum 2 minutes observation is recommended for RTK and CORS RTK users,
- CORS RTK surveyors should use the nearest CORS base station for single-base users.
-

Whether conventional or GNSS system is used to get the required accuracy of the survey, the surveyor should understand and be aware of the following issues (URL-9);

- The limitation of the equipment to be used,
- The observation procedures,
- Processing techniques,
- Statistical analysis.

3. USABILITY of GNSS TECHNIQUE for CADASTRAL SURVEYING in TURKEY

Cadastral surveys have been carried out with different methods using various type of instruments with a compass and steel tape and then prism, tachometer, reduction tachometer, electromagnetic measurement instruments and more recently total station (Çağla, et al., 2011). The rapid change in the world of science and technology has closely affected our profession and has started to use satellite-based positioning systems, especially GPS and GLONASS.

All the standards must be adapted to the government agency in Turkey with regard to map and map information production. Those standards were enacted in Large Scale Map and Map Information Production Regulation (LSMMIPR) accepted in 2005. According to these regulations, cadastral measurements can be conducted with GNSS systems (in some situation conjunction with conventional terrestrial methods). In case of using the GNSS methods, the measurements should be conducted by considering the criteria given in the Regulation.
Some measurement and accuracy criteria recommended by the LSMMIPR is given in Table 5 (URL-10).

Table 5. Some Accuracy Criteria for Control and Detail Points Measurements in Turkey

Point Order		C1 (1st Order)	C2 (2nd Order)	C3 (3rd Order)	C4 (4rd Order)	Detail
Properties		The points that are based on the high degree of networks and have 15-20 km distance length between them.	The points that are based on the high degree of networks and have 5 km average distance length between them.	The points that are based on the high degree of networks and have 3 km average distance length between them.	The points that are based on the high degree of closed traverse networks and photog. points.	Surveying point (parcel corner points, parcel border points, etc.)
Observation Mode *S*: *Static* *RS*: *Rapid Static* *K*: *Kinematic* *RTK*: *Real-Time Kinematic*		S	S	S/RS	S/RS/K/RTK	RTK (TUSAGA-Aktif /CORS)
Receiver Frequency		Dual	Dual	Dual	Dual	Dual
Satellite Number (min.)		4	4	4	5	5
Elevation Cut-Off Angle (min.)		15^0	15^0	10^0	10^0	10^0
Measurement Interval (max.)		15 sec.	15 sec.	15 sec.	10 sec. (S) 5 sec. (RTK)	5 sec.
Occupation Time		2 hour	45 min.	20 min. (per km +3 min. if > 5 km)	7 min. (S/RS) 5 epoch (RTK)	3 epoch (RTK)
Allowed Accuracy Values (in cm)	**Horizontal** (σ_φ; σ_λ)	± 3	± 3	± 5	± 8	± 7
	Vertical (σ_h)	± 5	± 5	± 5	± 8	± 7
LSMMIPR Article Numbers		14-15	19-20	22	26 (43 for RTK)	45-46

More information about the survey criteria can be accessed in URL-10.

4. CONCLUSIONS

In this study after explaining cadastre's current situation in Turkey briefly, it has been explained that areas of study and issues of study should be carried out in Turkey. As explained in the study, although 99 % of cadastral surveys were completed in Turkey, there are still a lot of studies that will be carried out (like especially renovation, regular maintenance of cadastre, and etc.). Even if optical methods can be still used, GNSS systems have become essential tools for cadastral surveyors thanks to their many advantages. Thus, indeed, it is widely used by providing flexibility and offering cost effective solutions around the world. By utilizing the type of CORS networks, positioning with high accuracy and in short time routinely is conducted in Turkey and across the world.

In summary if to say;

- The cadastral maps which constitute the basis for property right as one of the most fundamental human rights should be meticulously conducted by expert surveyors. Surveys carried out by unqualified technical staff will cause difficult and even irremediable problems,

- Training the users of this technology is extremely important. Those who carry out such measurements should be aware that they also produce important information. Thus, cadastral practitioners should be well trained and educated in the use of GNSS systems,

- Some control mechanism should be established and conducted in the field in addition to the ones that are already carried out in conventional methods,

- It is mostly possible to get a result even under the quite large DOP values, in poor satellite configuration and in multipath environment. Coordinate information by looking at the results cannot solve a problem without taking these factors into account. Furthermore, it could bring about new problems.

REFERENCES

Awange, J. (2012), Environmental Monitoring Using GNSS: Global Navigation Satellite Systems, Springer, Berlin Heidelberg.

Bakıcı, S. (2015), Geoinformatik Teknolojilerinin Tapu ve Kadastro Genel Müdürlüğünde Kullanımı, 1. Konum Belirleme ve Uydu Navigasyonu Zirvesi-2015, 20 Mart, İstanbul (In Turkish).

Bakıcı, S. and Mekik, Ç. (2014), TUSAGA-Aktif: Delivering Benefits to Turkey, Coordinates, X (02), pp.19-26.

Bonnor, N. (2012), A Brief History of Global Navigation Satellite Systems, The Journal of Navigation, 65 (1), pp.1-14.

Çağla, H., Akkus, S., Civcik, E., and Ozugur, İ. (2011), Konya Example of Cadastre Renovation Work in Turkey, FIG Working Week 2011, 18-22 May 2011, Marrakech-Morocco.

Çete, M. (2010), The Recent Reforms in the Turkish Cadastre, FIG Congress 2010, 11-16 April, Sydney, Australia.

İnam, Ş., Ertaş, M., Yalpır, Ş., Başarır, A., and Akca, M. (2011), Renovation Studies in Turkey Cadastre: Reasons and Project Results, FIG Working Week 2011, 18-22 May 2011, Marrakech-Morocco.

Kahveci, M. ve Yıldız, F. (2012), GPS/GNSS Uydularla Konum Belirleme Sistemleri Teori ve Uygulama. (Güncellenmiş 5. Basım), Ankara: Nobel Yayınevi (In Turkish).

Kogure, S., Sawabe, M., and Kishimoto, M. (2006), Status of QZSS Navigation System in Japan, Proceedings of the 19th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS 2006), Fort Worth, TX, September 2006, pp. 2092-2102.

Li, M., Qu, L., Zhao, Q., Guo, J., Su, X., and Li, X. (2014), Precise Point Positioning with the BeiDou Navigation Satellite System, Sensors, 14(1), pp.927-943.

Majithiya, P., Khatri, K., and Hota, J.K. (2011), Indian Regional Navigation Satellite System - Correction Parameters for Timing Group Delays, InsideGNSS, 6(1), pp.40-46.

Meha, M., Kadiri, Q., Çaka, M., Murati, R., Ahmeti, A., Shaqiri, B., Kelmendi, F., Sinani, Q., Xani, E., and Ahmetaj, K. (2013), Catalogue for Measuring and Creating Cadastral Units, Kosovo Cadastral Agency.

Mekik, Ç., Yıldırım, O., and Bakıcı, S. (2011), The Turkish Real Time Kinematic GPS Network (TUSAGA-Aktif) Infrastructure, Scientific Research and Essays, 6(19), pp. 3986-3999.

Montenbruck, O., Steigenberger, P., Khachikyan, R., Weber, G., Langley, R.B., Mervart, L., and Hugentobler, U. (2014), IGS-MGEX: Preparing the Ground for Multi-Constellation GNSS Science, InsideGNSS, No. 1/2, pp.42-49.

Reddy, J. (2010), The Integration of CORS Networks and the Cadastre and its Application in NSW, Australia, FIG Congress 2010, 11-16 April, Sydney, Australia.

Tamrakar, R.M. (2013), Potential Use of GPS Technology for Cadastral Surveys in Nepal, Nepalese Journal of Geoinformatics, Vol 12, pp.33-40.

Xu, A., Xu, Z., Xu, X., Zhu, H., Sui, X., and Sun, H. (2014), Precise Point Positioning Using the Regional BeiDou Navigation Satellite Constellation, Journal of Navigation, 67(3), pp. 523-537.

URL-1: The Current Status of the Turkey Cadastral Studies (In Turkish).
Available from: http://www.e-tkbm.gov.tr/publisher/projeizleme.htm [accessed 13/03/2015].

URL-2: TKGM 2014 Yılı Performans Programı (In Turkish).
Available from: http://www.tkgm.gov.tr/sites/default/files/icerik/ekleri/tkgm-performans_programi_tasari-2014.pdf [accessed 13/03/2015].

URL-3: GPS Constellation Status.
Available from: http://www.glonass-center.ru/en/GPS/ [accessed 13/03/2015].

URL-4: GLONASS Constellation Status.
Available from: http://www.glonass-center.ru/en/GLONASS [accessed 13/03/2015].

URL-5: Galileo.
Available from: http://www.gsa.europa.eu/galileo/why-galileo [accessed 13/03/2015].

URL-6: Galileo.
Available from: http://www.esa.int/Our_Activities/Navigation/The_future_-_Galileo/What_is_Galileo [accessed 13/03/2015].

URL-7: Singapore Land Authority - Guidelines and Specifications for GPS Surveys of ISN Markers (Version 2.4), Mar 2011.
Available from:
http://www.sla.gov.sg/Portals/0/Circulars/att/LS/csdsgsd/Guidelines_and_Specifications_for_GPS_Surveys_of_ISN__Markers_v4.PDF [accessed 13/03/2015].

URL-8: New South Wales Government - Surveyor General's Directions No. 9, GNSS for Cadastral Surveys, May 2014.
Available from:
http://www.lpi.nsw.gov.au/__data/assets/pdf_file/0006/25944/sgddir9_Ver2.5_May_2014.pdf [accessed 13/03/2015].

URL-9: Guidelines for Cadastral Surveying using Global Navigation Satellite Systems (GNSS), NIMA (National Imagery and Mapping Agency), 2003.
Available from: http://www.sssi.org.au/userfiles/docs/QLD Region/documents_1342665635458677117.pdf [accessed 13/03/2015].

URL-10: Large Scale Map and Map Information Production Regulation (In Turkish).
Available from: http://www.resmigazete.gov.tr/eskiler/2005/07/20050715-5.htm [accessed 13/03/2015].

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