Current Journal of Applied Science and Technology

Volume 42, Issue 12, Page 32-48, 2023; Article no.CJAST.100156
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Review of Episodic Voyage of Engineering Surveying and Cartography in India

Rabindranath Nanda [a], Siba Prasad Mishra [a*], Kamal Kumar Barik [a] and Kumar Ch. Sethi [a]

[a] *Centurion University of Technology and Management, Bhubaneswar, Odisha-752050, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2023/v42i124109

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/100156

Review Article

Received: 19/03/2023
Accepted: 22/05/2023
Published: 25/05/2023

ABSTRACT

This study presents the Episodic Voyage of Engineering Surveying and Cartography in India to know our past development in mapmaking and cartography, which is as old as Ptolemy's expedition in the 2nd century AD in India. Starting from ropes and sticks to measure, plumb bobs to position, site rule for sighting, and clinometer for height measurement, the Indians and people from other countries, developed the present instruments and methodologies. They have evolved by gathering big data and up to making smart maps by today. The methodology employed is to collect data about the development of innovative technologies in the last 15th to 21st centuries. The journey commenced from Zareb, Kadi, etc. to the development of geo-informatics with the practices of Aerial photography, Geographical Information Systems (GIS), Remote Sensing (RS), Global Positioning Systems (GPS), Image Processing, Photogrammetry by unmanned aerial vehicle (UAV), Light Detecting and Ranging (LiDAR), Web GIS, through large-scale map generation. The innovative practices have given a new direction to the subjects like geography, geology, urban planning,

**Corresponding author: E-mail: 2sibamishra@gmail.com;*

landscaping, and other human application services. The present study includes the search for the advances in surveying and map-making journey to date and the way forward. Eventually, the evolution of technologies will influence greatly the surveying and map-generating Present process. The application handling in the current geospatial ecosystem can be complied with by compiling large-scale maps 1:500, 1:1000, etc. through automation for better smart city planning in India. The change shall paddle the economic growth in different developing countries. However, the survey of marine territories of India is poorly researched.

Keywords: Astronomical survey; GIS/ GNSS applications; GLONASS; largescale maps; mapmaking drone/UAV.

1. INTRODUCTION

Surveying is the process of perceiving the terrestrial notion of a nation, captivating observations for data dissemination of a place (dimensions, elevation, and attributes). Surveying is intended to make small-scale maps and accurate measurements of land mass for human services. They can be geographically small areas, and geodetic (shape of the earth). Classification of surveying processes based on instruments used, purpose intended, the domain surveyed, and the methodologies adopted. A map generation is a graphical tool that organizes the area and the attributes encompassed within to provide geographical knowledge and geodesic information under the cartographic concept [1,2]. The history of surveying and mapmaking in India was datable to 2500-3000 years before the present (YBP) from contemporary Sindh, and Ganga River civilizations [3]. Claudius Ptolemy was the 1st known surveyor who framed the India map (1800YBP), later used by French geographer, *d' Annville. Major James Rennell,* the British surveyor modified the map building scientifically in the 18th Century [4].

The modern map creation is reported in Brahmand Purana, where surveying techniques narrating formulas for areas/volume has placed in the "Sulva Sutra", and "the Artha Shastra" by Chanakya (2300YBP) [8,9]. In the 5th century, Arya Bhat in his "Surya Siddhant" attacked the Geodesy (Shape and Size) of the earth and reported the equatorial circumference of the globe as 40362.35 km. Eratosthenes in Greek (240B.C.) mentioned the same is 40075 km as calculated on the date. The first land records are available as per a land survey by Raja Raja I (Tanjore) from 985-1011 A.D., and later, Sultan Akbar introduced a measurement 'Jerib', in the 16th century [12-14]. Later during the Trigonometric survey, the maps were prepared with scale 1: 63360 scales (1" =1mile) by the Survey of India (SOI), after the Indian revolution of 1857 [15].

The paper scales used for calculation have been replaced by calculators. Shifting from Palm leave inscriptions, the papers and pens were used for storing data but tangible. Now big data platforms or cloud data platforms are doing their job. Similarly, the bamboo yardsticks used for measurements were replaced by chains and compasses in the 20th century and small scaled maps are prepared with large errors and unsuitable for planning and cartography. Later the use of GIS, GPS, and GNSS (UAV-based) are used and have centimeter accuracy, errorless, fast-forward, and multidisciplinary infrastructural expansion became open to all.

The present work involves the chronological development of the map-making process. Modern map-making technology developed and processes changed century-wise from the 17th century till the 21st century. The Survey of India (SoI) kept the artifact within their domain but civilians were ignorant of it till fag end of the 20th century.

1.1 The Astronomy; Ancient India

Late Samanta Chandra Sekhar (Pathani Samant), (1835-1904), an Odia astronomer had shown his excellency, and accuracy, and brought precision in Astronomy, Astrophysics, similar to contemporary coworkers (Table 2).

Table 1. The works of Pathani Samant and results compared with present values

Solar system (Astronomy)	Planet	Siddhant Darpan (1892)	European data (1899)	Modern value
Sidereal of planets (days)	Sun	365.25875	365. 25637	365. 25636
Sidereal of planets (days)	Moon	27.32167	27.32166	27.3216615
Sidereal of planets (days)	Mercury	87.9701	87.9692	87.969256
Ecliptic inclination to planet	Moon	5^0 09'	5^0 08' 48"	7^0 00' 33"
Ecliptic inclination to planet	Mercury	7^0 02'	7^0 00' 08"	5^0 08' 18"
r/R ratio	Mars	1.518	1.52	0.656
r/R ratio	Mercury	0.3875	0.387	0.387

Source: [19-21]

2. REVIEW OF LITERATURE

Map making process became inevitable from the Holocene epoch when owning land by possession and agriculture converted the hunter-gatherers to agrarians under communities and permanent dwellings. The process developed in various ways in different countries that were advanced scientifically are discussed. The present attempt to collect the development of map-making is least found in previous literature and reported chronologically on the art of map-making and its applications.

2.1 Map Making Till the 18th Century

The Babylonian map is exhibited over puddled clay tablet of ≈4300YBP to present digital cartography. The surveying started with the maintenance of land records in Egypt from ≈5000YBP to identify lost farmland boundaries after Nile River floods, and contemporary the Great Pyramid of Khufu in Giza (≈4700 BCE, 230 m long, and 147m high). A painting of 3400YBP found on the walls of Thebes's tomb where chainmen were measuring a grain field in the presence of a land surveyor is shown, https://www.britannica.com/technology/surveying . The surveying instrument, GROMA was used to ascertain straight lines and rectangles in Rome during 1550. Ronnell (1742-1830), was the first officer Surveyor General of Bengal (1767-1777), who conducted the first comprehensive geographical survey of the Indian Territory. W. Mather (1793–96) was the first to conduct a cadastral survey (started by Raja the king of Tanjavoor in1001 A.D. and during the emperor Akbar (Todurmaal) in 1582 [22,23]; of south Indian lands. Surveying plays a pivotal role in geography, geomorphology, land recording, and construction. George Washington (1748), the Mason-Dixon Line (1763-1784), and Captain James Cook (1728 – 1779) were eminent surveyors of their times, https://www.Moore engineering inc.; Com/2020 /03/18/interesting-facts-history-of-surveying/. The episodic journey of land survey in India emerged from the Baramahal, in Tippi, ordered by the Supdt. of Salem, Col. Alexander Read for Socio-Economic and Land Survey from, 1793 to 1796, under Sir Thomas Munro [5].

2.2 Map Making Till the 19th Century

The Great Trigonometry Survey (GTS of India) was on the go in 1802 by British Surveyor Col. William Lambton. St. Thomas Mount was the first point of the GTS, Chennai up to the foothills of the Himalayas took 57 days to measure the 12-km baseline of the Himalayas. A 36" huge ½ ton of Theodolite was deployed in the survey that took almost half a century to finish under the leadership of Lt George Everest, the Survey General in 1852, and the computational part was undertaken by Mr. Radha Nath Sikdar, the Surveyor. It was calculated that the altitude was of elevation of 29002 feet. The modern measurements confirm the height to be 29037 feet. The beginning of systematic topographical mapping in India emerged and the Survey of India (SoI) is considered one of the oldest survey and mapping agencies in the world (Markham 1969, Bartholomew, 1897) (Fig. 1).

2.3 Objective of the Study

In geography, geodesy is the correct measurement of irregular attributes on earth, whereas, cartography aims at fixing boundaries of landholdings, other attributes like roads, rivers, forests, territory, and water bodies are the survey activities [3]. The identified advanced sectors in surveying are perceptions of big data like machine learning, cloud technology, the Internet of Things (IoT), 5G technology, large-scale maps for smart and green cities, and ledger technology in photogrammetry in the present smart and green city making. The search is for making large-scale maps to provide better smart planning, management, and big data use in the future. The marine sector in the survey is lagging. They reformed the socio-politics with technological advances that have been depicted through legends, mythologies, geography, and history [5-7].

The modern map-making processes used in Smart city development, future transportation, high-rise building infrastructural applications, Building Information Modelling (BIM), high-speed map making, big data accumulation, and large-scale maps shall result. It is possible due to the Internet of Things (IoT), High-speed computers, Automation, software, Artificial intelligence, etc. [16]. So, it is essential to make universal all modern map-making technologies when satellite technology and web technology work on big data, or cloud platforms.

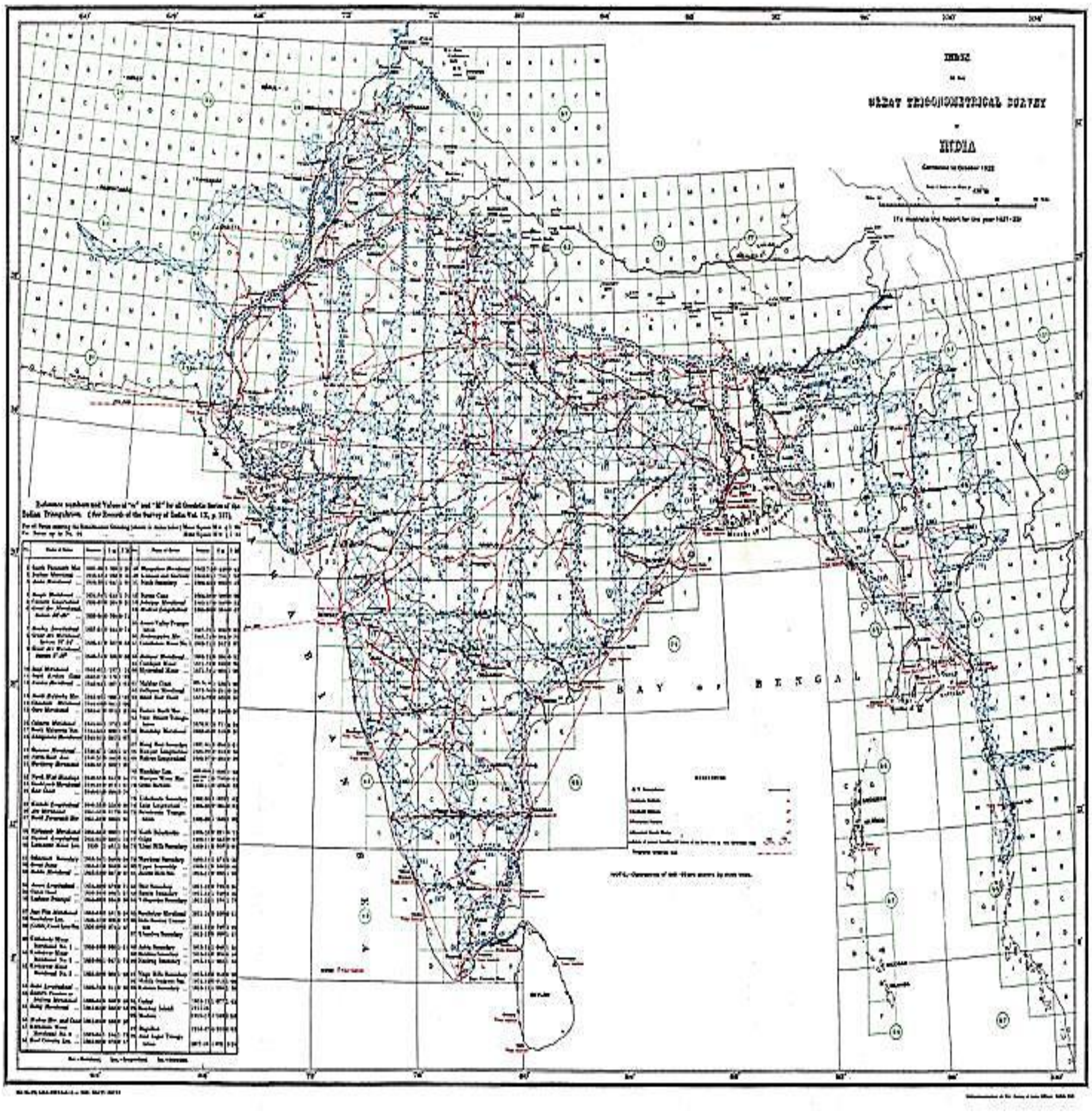

Fig. 1. The Great trigonometrical survey of India
(Source: A Memoir on the Indian Surveys, reprinted 1968, original from 1878)

2.4 Astronomical Survey in India

The glorious ancient survey of the sky (astronomy) Indian astronomy started in the last 05th century A.D., which was commanded by astronomers and mathematicians like Boudhayan (800BC), Aryabhata (Arya Sidhanta; 2476–550CE), Varahamihira (505-587CE); Pancha-siddhantika), Brahma Gupta (598-668CE, the Zero, and solution of quadratic equations), and Bhaskaracharya (1114-1185CE; the decimal system). Pathani Samant (planetary motion), and many others from various regions of India had devoted themselves to astronomy in the past. They have a remarkable contribution to the astronomy domain. Aryabhata was the first noted surveyor of India to report a year consisting of 365 days, 6 hours, and 12mnts, and 30 seconds [10]. Until the 17th century, records reveal that the captains of British and French ships conveyed the positioning of stars, sun, and moon in their voyage diaries of India [11].

3. METHODS AND METHODOLOGIES

Radical modifications occurred in the 20th century in digital, and electronic surveying gadgets such as levels, instruments measuring distance, theodolites, total stations, GPR, etc. used to measure differences in levels, distances, and angles. Innovative and cheaper techniques turned survey works into multidirectional services to the human race with sophisticated satellite technology. The 21st-century technology developments in the survey domain have added to the 20th-century instruments to carry forward their assignment effectively and precisely. They use instruments, and various soft wares like unmanned vehicles (UAV), LiDAR, total stations, GPS receivers, DGPS, GIS and RS, 3D scanners, radio transmitters, Total stations, *etc.* The technique involves the positioning of traits on the surface either direct or indirect extents and finally putting them on a map. Various types of surveying are (Table 2).

3.1 Survey of India

Maj. James Ronnell, (SoI, 1767), the first surveyor general started the precession land survey in India and published the first survey map in 1783. Lord Wellesley (1799) engaged Francis Buchanan for the agricultural survey, and Mackenzie C., and Lambton W. for the topographic and trigonometric survey of British territory. The geographer and geodesist, Lambton, planned the great trigonometric survey of India in 1818. The 18th and 19th-century methods of map-making were tapestries and plain surveys. Walker (1870) placed the India map in a global framework with lat. & long (Roy R. D., 1986[16]).

Table 2. The surveying methodologies, adaptability, and purpose of their uses

Methods	Methodology	Survey Purpose	When needed	When done
Geodetic	DGPS, triangulation, HP leveling, Gravity Observation	Precision control of earth curvature	Helps other networks of surveying	Finding height and coordinate
Cadastral	Traverse, Triangulation; Trilateration, Aerial photo	land holdings, and boundaries	Tehsil land attributes	Demarcation landholdings
Topographic	Leveling, Triangulation Traverse, Trilateration, photogrammetry.	Land, structure, soil, water body (height/depth)	Attributes on earth-surface	For all-purpose
As-Built	Tapestry, leveling, total station	Construction projects	construction projects	Physical site measurement
Photogrammetry, (design/structures	Terrestrial and Aerial surveys, drones, and LiDAR	photographs from the air, and ground trotting	When attributes are not accessible	Remote/ inaccessible areas
Drone & LiDAR (Light detection or radiation)	An aerial survey using satellites, GIS, GPS, or DGPS	Real photos (Airplanes), UAVs, Drones)	High precision 2D & 3D survey)	remote sensing, and lasers

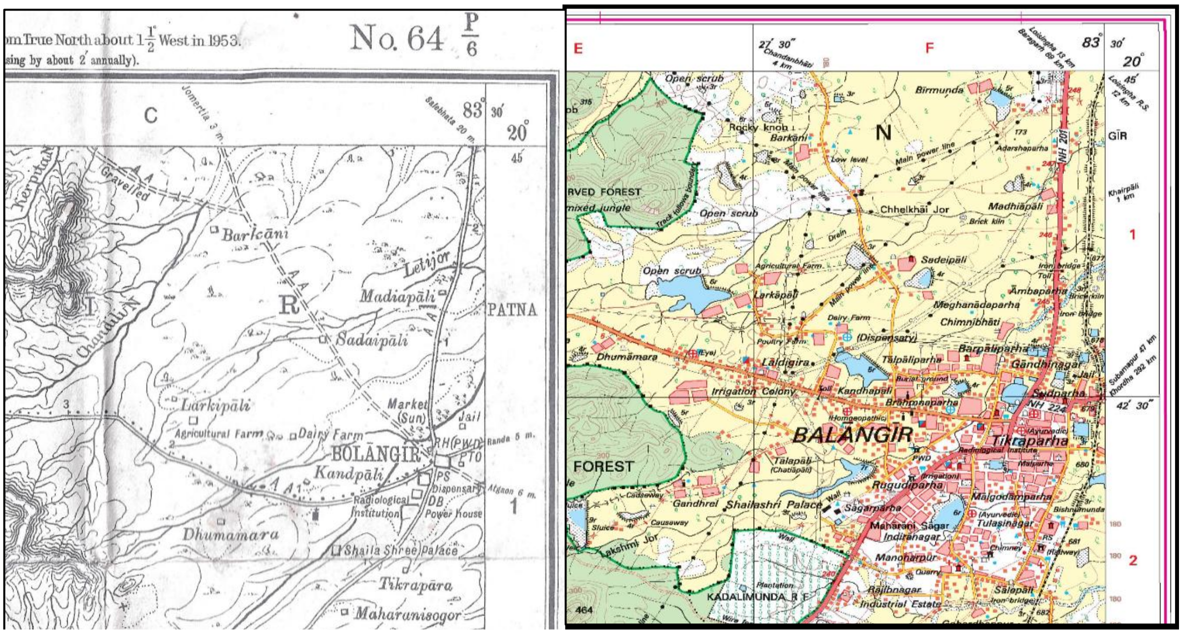

Fig. 2(a). Old Map (64P6) of Balangir Odisha, Surveyed Season 1854-55 & 1858-63, Pub: 1959 (In 1" to 1-mile scale), Fig. 2(b) compared with present map in 1:50000scale (Source: SoI)

Montgomerie after Col. Walker (1867) started the trigonometric survey of India and calculated the height of Karakorum, and many hills of the Himalayas. Mount Everest was named after Sir George Everest, 1865 having an altitude of 8850m in 1852. Later in 2005, the Chinese expedition team calculated the height of Mount Everest as 8844.43m (without any ice cap and snow depth of 3.5 m), and the Karakorum Range of Hills (K-2). The noted surveyors from 1843 to 1904 in India were Andrew Scott Waugh, Radhanath Sikhdar, and Montgomerie who completed the balance works of George Everest [13]. Some Indian surveyors contributed much to the survey of Tibet, Mongolia, and central Asia in the 19th century. They were Pundits of Kashmir (Nain Singh, Pundit Kishan Singh, Hariram, and Nem Singh), etc. [14-17]. The South India territorial maps were generated by Colin Mackenzie in 1799 [18] Fig. 2(a) and Fig. 2(b).

3.2 Survey Gadgets; Present and Past

The indigenous instruments used were Mana Yantra, (tangent staff measuring height and distance of mounts), Chapa Yantra, (calibrated wheel, to measure time on a sunny day), Golardha Yantra, (hemispherical dial), and Swayambaha Yantra (water clock), (Fig. 2), [22,23]. Adding to the compass survey, the spirit levels, plumb line, and pendulum, the theory of Isostasy was introduced in the surveying.

The Trigonometrical Survey of the Indian subcontinent was started by George Everest (SOI in 1823). The current cadastral records were started by Waugh in 1861 as revenue and topographical surveys, to fix the boundaries of estates/provinces, villages, and their boundaries whereas topographical surveys were for the dimensions and delineation of natural attributes. The scale used in the topographical surveys was 1 inch: 1 mile. The survey departments were Madras, Bombay, and Bengal presidencies with free power for their revenue and military purposes, [13]. The survey instruments used during the 19th, 20th, and 21st century is in (Fig. 3).

3.3 20th Century Surveying and Map Making

Indian surveyors had reached the epitome of map-making with high precision and maintained national security. Maximum maps are on a small scale (1: 2500000, 1: 50000, and 1:25000). Two series of maps were generated. They were open series maps (OSM) for civilians and defense series maps (DSM) with contours for national security until 2005. They prepared small-scale maps considering the datum on the peak of Everest (WGS-1984), and Universal Transverse Mercator (UTM) projection. The printed map-making started during World War II.

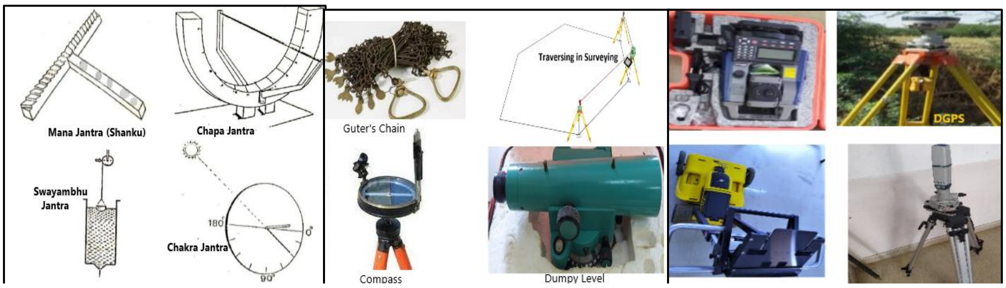

Fig. 3. 19th-century astronomical, 20th-century cadastral, and 21st-century ground-survey gadgets

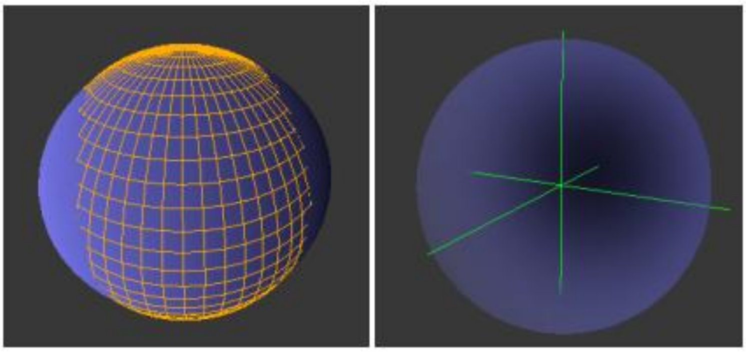

Fig. 4. The Horizontal datum as WGS 84, NAD27, NAD83, and NAV88 (Example of a Vertical Datum)

A datum outlines an ellipsoid and is acknowledged as appropriate for the complete profile of the Globe. An ellipsoid is at specific coordinates, and its location on the Earth is called a Geodetic Datum.

Modern map printing machines are available in SOI since 1964. After independence (1947) the geodetic, photogrammetry, cartography, novel map printing, and geophysical surveys gave a new direction to Indian map-making replacing the prior explorative past surveys. The new instruments and gadgets like the La-Caste Romberg gravimeter, Berlin's chronograph, Danjon Astrolabe, the Q.H. M., crystal clocks, B.M.Z. Quartz Horizontal magnetometer; Zero Balance Magnetometer was an instrument incorporated to settle gravity anomalies. These contemporary instruments introduced exemplary corrections to the field magnetic observations, high procession electronic measuring instruments, cadastral maps, and positional astronomy, (Fig. 5), [3].

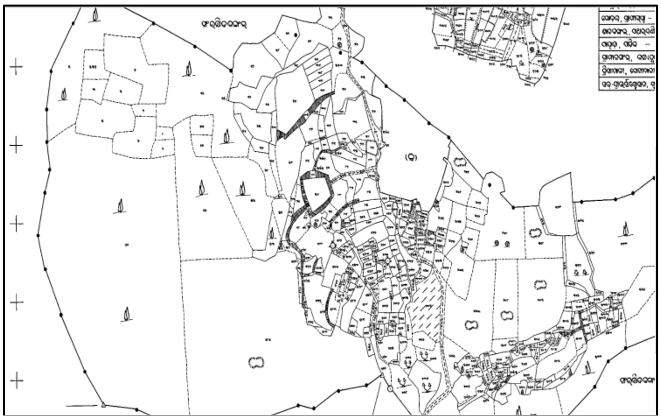

Fig. 5. Cadastral map of the twentieth century for land-owning

3.4 Large-scale Maps Necessities

The geographic one-sheet (maximum scale) maps in India were available in the 1:250000 scale for use by professionals, geologists, educationists, geographers, political, town planning, forestry, and engineers. The making and correction of cadastral maps were handed over to the state revenue departments in 1905, for better land planning and scheduling of records. The marine survey, remote areas, and underwater mining survey domains were neglected.

The geodetic and topographic survey has contributed to the geographic and topographic map of the globe. The map of the land mass of India needs 385 numbers topo-sheets (degree sheets) on a 1:250,000 scale. Sixteen topo sheets of 1:50000 scales are needed to prepare a degree sheet. An Indian map requires about 5000maps in 1:50,000 scale representing India. The map in the 1:50000 scales contains four 1:25000 scaled sheets. Moreover the errors, precision, and presentation of attributes in large maps are more. It is because a polygon in a 1:25000 map can present as a line in a 1:50000 scale map and a discontinuous point in a 1:250000 map, [24]. The cadastral maps, town-planning maps, tourist maps, drainage maps, military, security, and forest territorial maps, *etc.* need large-scale maps. The country is lagging that requires high-precision large-scale maps of 1:500, 1:1000, 1:2000, and 1:10000 scale for better planning. Less modern equipment and technologies existed in the 20th century to make large-scale maps.

3.5 The 21st-century Map Making

The mapmaking, and digital cartography in India by SoI, there exist numerous web portals, and big data (cloud) sharing podiums are accessible for the informal right of entry, networking, allocation of geospatial data, and fact sheets. The National Data Sharing Accessibility Policy (NDSAP-2012) of the Government of India (GOI)) warrants the generation of the database generation, and sharing for innovative activities by both analog and digital platforms (SoI, AR-2016-2017). The use of satellites for various big data collection and rainfall measurements by Global Precipitation Measurement (GPM) is allowed at various levels (Fig. 6).

The available major Indian platforms and web services sources for geospatial data in the 21st century are BHUVAN: (Indian Space Research Organization; ISRO), India-WRIS: (Water Resources related data), and NICES: (National Inf. System for Climate & Env.). The digital database generation, by Indian satellite GAGAN (GPS Aided GEO Augmented Navigation System), and IRNSS (Indian Regional Navigation Satellite System) is the Indian indigenous platform initiated by ISRO. Many similar systems in operation, globally are GNSS (Global Navigation Satellite System), NavIC (India), QZSS (Japan), Galileo (Europe), GLONASS (Russia), Beidou, (China), and GPS (USA) are offering navigation signals, [25-27].

4. GPS; THE GLOBAL POSITIONING SYSTEM

The NAVSTAR (Navigation System with Time, and Ranging), and GPS are the radio positioning and time-transfer system (satellite-based) from 1970, designed, erected the model, tested, and operated by the US Dept. of Defense. GPS caters to high positional accuracy, better precession positioning, and level, in determining time, direction, and speed without any inter-station discernibility as a single, global datum [28]. Three-dimensional signals are freely available to the users, 24 hours, irrespective of weather, and anywhere on land, sea, and air on Earth, [29].

On June 17, 2021, Seventy-Seven GPS navigation satellites were launched, of which 30 numbers of satellites are operational, 3 numbers are in reserve, one is under test, 41 numbers have been retired and 2 were missed during launch. At a minimum, the requirement of the GPS constellation involves 24 satellites to be in operation, and 31 to be active (List of GPS satellites – Wikipedia). Each satellite is assigned a space vehicle number (SVN) and pseudo-random code number (PRN) and .has an orbital period at a position of roughly 12 hours in the open sky settings. A GPS receiver receives quality information at a setting of at least 24hrs operational six satellites with an orbital inclination of 55^0 and an orbital radius of 20200 km- 26560 km on earth, and incessant identification broadcast, telemetry information, the status of the satellite, and high-resolution rectified orbit parameters (ephemerides) to one and all (Fig. 6).

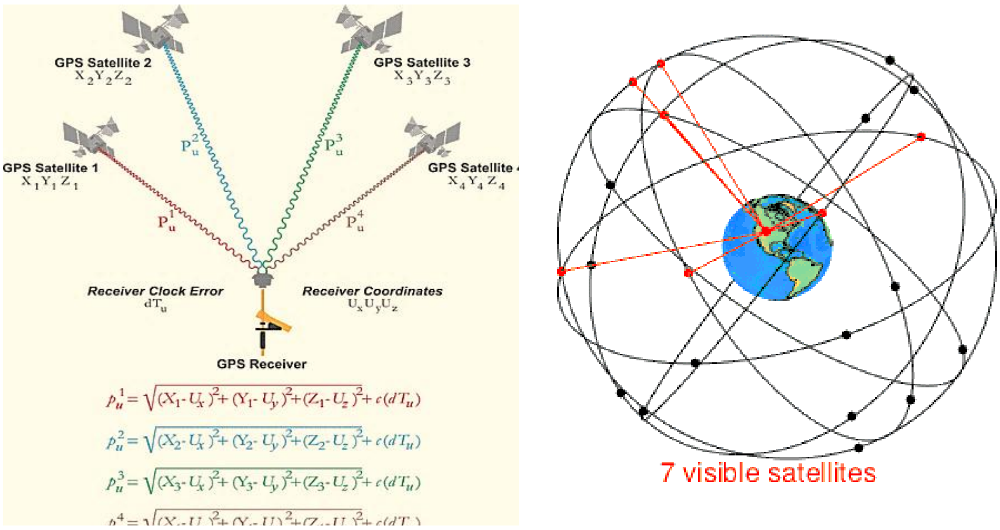

Fig. 6. GPS satellite positioning and 7 visible satellites at a point (c) (Source: Dr. Lohani's PPT)

4.1 GNSS Applications

Insignificant abnormalities in time in receipt of data inculcate huge locational errors. An error of 1µsec can introduce an error of 300m and one nanosecond creates an error of 30 cm. The civilian services of the consumers are the application of GNSS are GIS submissions, transference, ground mapping, time judgment, machine control, maritime, land surveying, defense, and port automation. Other usages of it are rainfall recording, timing/synchronization, structural destruction plotting, surveying/mapping, entertaining, tracking of an object, communication, remote sensing, etc. [33].

4.1.1 Global Navigation Satellite System (GLONASS)

The GLONASS, a non-civilian constellation of the system of satellites was technologically advanced by the Soviet Union in the 1970s, and later have civilian applications after 1993. GLONASS was operational but later declined. Russia was dedicated to bringing the system operational by 2011. The GLONASS system comprises 24 satellites at 12 frequencies moving 25510 km high and in three orbital planes. The period of revolution is 8 days. The visibility is reliant upon the positioning of the receiver's location. The control segment of it comprises units of system control, and network tracking stations in the USSR [41].

Each satellite of the constellation is very popular in India that can transmit slightly different L1 and L2 frequencies but with different frequencies of the same code by adopting a method called FDMA (Frequency Division Multiple Access). The constellation has 24 antipodal satellites that transmit signals at equal frequencies, spinning at identical orbital planes at the 180^0 phase. The satellites in pairs can communicate at the same frequency because they never perform at a similar interval when viewed by a receiver on the Earth, https://www.gps.gov/systems/gnss/, [42].

4.1.2 Galileo and Copernicus (Europe)

Under European Union's global navigation system and space program equipped with Satellite Laser Ranging (SLR), low Earth orbiters (LEOs) have to guarantee global positioning service under civilian control, launched in 2016. The program aimed at enhancing the navigation accuracy and better use of Copernicus data services by 2024, for free open service, and high reliability. The GNSS is suitable for applications where safety land cover through CLC (*CORINE* Land Cover), transportation through the ground, and air [43-46]. The GIOVEs (A and B) are the test satellites. At present 27 satellites are operational in three planes at an inclination of 56 degrees and a radius of 23616km and three are in spare. Once the assembly is functioning, Galileo signals are delivered. They shield all latitudes. Only two satellites of Galileo Control Centers (GCC) are located in Europe. The data recovery is conveyed by the assemblage of 20 number Galileo Sensor Stations (GSS) through a global network and later sent to the GCC. The satellite delivers worldwide Search and Rescue (SAR) functions [47-48].

4.1.3 BeiDou (China)

The global navigation system in Beidou, China (previously called COMPASs), was initially providing regional coverage. BDS-3 was commissioned (Aug 2020, formally) as a part of GNSS with GEO and MEO satellites for global exposure (http://en.beidou.gov.cn/). The GPS is a constellation of 35 satellites (5 GEO and 30 MEO) revolving in six orbital planes, with an orbital inclination of 55^0, and revolving at 27528km orbital radius above the earth's surface. Beidou provides dual levels of services, *i.e.* for civilian use and licensed military services. They deliver free of charge to users with more accurate data in China [49].

4.1.4 IRNSS (India Regional Navigation Satellite System, India)

The IRNSS system is a regional GNSS owned by India that covers all regions of the country. It is orbiting at a height of 1500 km over the mainland of India. The constellation system aimed to install seven satellites and was operational by 2018 and renamed NavIC, i.e. "the sailor" or " the navigator" in 2016. The first out of seven IRNSS-1 A launched in July 2013. The other six satellites IRNSS-1B to IRNSS-1G was launched were launched in April 2016. The eighth satellite, IRNSS-1H, (replace IRNSS-1A, failed on 31 Aug. 2017, [50]. The constellation comprises eight satellites, three of them in geostationary orbit (GEO), and at about 36,000 km altitude. The rest 5 are inclined geosynchronous orbit (GSO). The satellites aim to maintain absolute position accuracy (< 10 m over the Indian mainland, and < 20 m over the NIO (North Indian Ocean) [51].

4.1.5 QZSS (Quasi-Zenith Satellite System, Japan)

The QZSS (Japan), a regional GNSS constellation of satellites, is functioned by QZS System Service Inc. (QSS). The system supplements GPS to increase its reportage in East Asia and Oceania. QZSS (Michibiki) launched as a constellation of four-satellite in Nov. 2018. In addition, three satellites are constantly visible from the Asia-Oceania region. Japan plans to have an operational seven satellites by 2023, [52], https://qzss.go.jp/en/ overview/services/ sv01_what.html.

4.2 Smart Mapmaking Processes

Various GNSS units use a static receiver titled as the base station. The base stations can transmit rectifications to the rover station (survey tool for receiving signals from satellites) for improved exact positioning. The stations fix the various satellites by the modus of Operandi called the code-based positioning technique. The setting of the base stations has appropriate tenacity employing the ephemerides of the orbit and interval of action of the constellation. The base station calculates the GNSS errors due to measuring differential ranges. The error information is transmitted for rectifications to the rovers, to incorporate in the position reckoning. The data link warrants the base and the rover for position accuracy. A minimum of four satellites is essential (six numbers for better absolute accuracy). The performance of the differential GPS is excellent when the length of the baseline is up to tens of kilometers which can be used in smart map processes [53].

4.2.1 Satellite-Based Augmentation System (SBAS)

The geosynchronous satellite system delivers services to improve the GNSS accuracy, wide-area corrections (range errors), and boost the reliable monitoring of the data (Fig 7).

SBAS provides dual-level services *i.e.* free or commercial. SBAS increases signal transmission during multi-range of signal transmission from satellites. SBAS services are free-to-open services supplied via GAGAN (GPS-Aided GEO Augmented Navigation system) to the civilians at the GPS frequency by the Government (except CDGPS) and paid commercial at a different frequency in India (Fig. 7).

WAAS (Wide Area Augmentation System) from North America, MTSAT Satellite Based Augmentation System (MSAS from Japan), CDGPS (Canada and the continental United States), EGNOS (European Geostationary Navigation Overlay Service), and Satellite Navigation Augmentation System (SNAS – China). The SBAS system used for commercial purposes includes Omni STAR or Omni STAR GPS which transmits differential rectifications at L-band frequencies near GPS frequencies with 3 levels of services. This GNSS system delivers consistent, meticulous GNSS locations that contribute to the users decreasing costs and improving productivity. The VBS provides sub-meter-level horizontal accuracy at the foundation level. The XP can provide decimeter accuracy at dual L_1 /L_2 solutions. The further improvement is HP to Omni STAR XP which delivers developed sub-decimeter accuracy, very useful for land surveying.

4.2.2 Real-Time Kinematic (RTK)

The RTK is employed to diminish or disregard errors from the satellite data for the base and the rover. RTK modification performed by the base station is conveyed to the rover to precise errors caused by the ionospheric, ephemerides, tropospheric, and satellite clock. The uncertainty that transpires in the resolution practice is useful to manage the complete cycles. Identical to the differential GNSS, the position accuracy of the rover is governed by the precision of the base station, the extent of the baseline, and the excellence of the satellite observations at the base station. The VRS (Virtual Reference Stations) is the RTK network which is an extensive network of base stations, [54] (Fig. 8 (a)). It is used when the corrected coordinates are required for instance on the ground itself.

4.2.3 Conjugate GNSS/Inertial Navigation Systems (INS)

Grouping of GNSS with INS can provide uninterrupted information on the time, position, and velocity of the celestial constellation. The INS practices revolution and speeding up of data from an Inertial Measurement Unit (IMU) that computes the location of the satellites from time to time. The INS can deliver all data like roll, pitch, and heading data. In the absence of an external orientation like a GNSS solution that acts as an external reference, the INS clarification shall drift gradually (Fig. 8(a), and Fig. 8(b)).

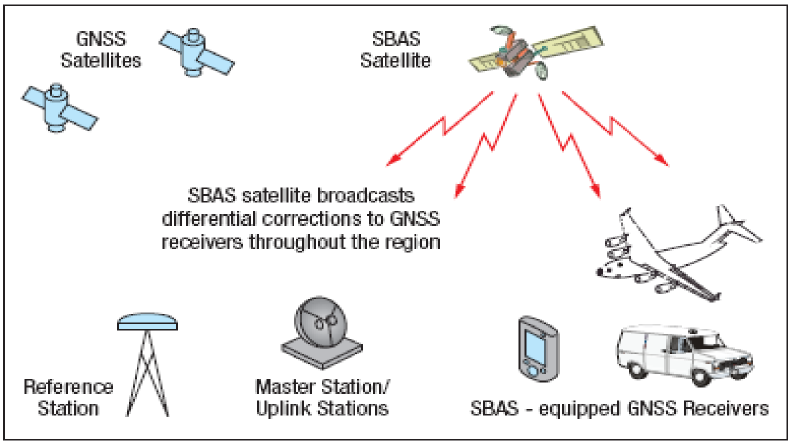

Fig. 7. Satellite-Based Augmentation System
http://www.omnistar.com/chart.html

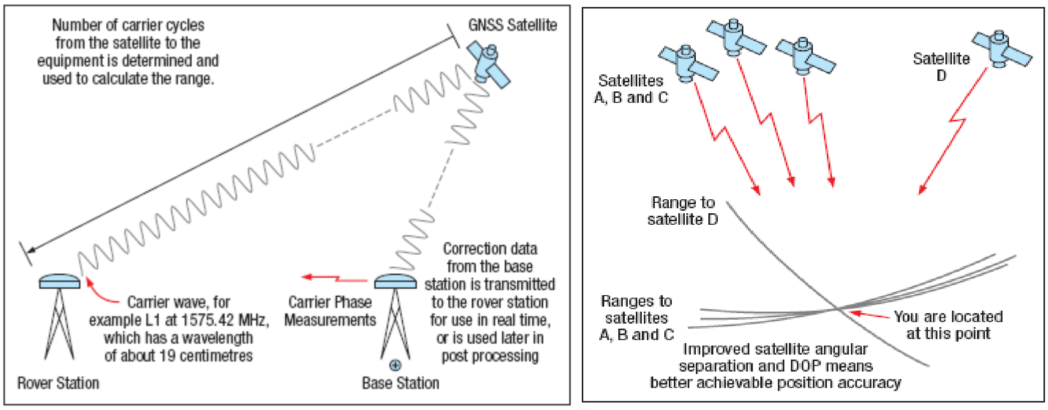

Fig. 8(a). GNSS system in (a) Real-Time Kinematic (RTK) (source MARXACT) (b) Dilution of Precision (DOP)

The conjoint GNSS with INS offers precise and dependable navigation information. The attached systems permit the INS to utilize the GNSS data to encompass its implication. So that the INS results get as input feeds back to the GNSS results to develop the data reacquisition, and convergence stage (Fig. 8 (a), (b)).

4.2.4 Differential Global Positioning Systems (DGPS)

DGPS works on a GPS receiver placed setting, called reference station (RS) with improved accuracy and veracity. The RS, due to its fixed location, can compute the differential position between the true and derived positions of GPS. The RS computes the errors incorporated in the GPS signals by matching the known station to the satellite signals. The differences between the measured and Insitu range for the visible satellites are premeditated, named the differential correction. After the rectification of signals, the DGPS is broadcast from the RS. It is used directly by the roving GPS to gather the modified position data. There are two main sources of real-time DGPS that the USDA uses, Maryland NRCS (2007).

4.2.5 Drones

Indian cities and their urban are growing at a faster rate through disorganized and unplanned growth. The emergence of new urban is non-conforming to land use plans, encroachments, unauthorized colonies, and land conversion from swamps, fallow lands, and agriculture to towns resulting in environmental degradation, and poor quality of life and stressing the urban local bodies for proper land management. The geospatial knowledge like Drone/ UAVs functioning on GIS/RS methodologies can deliver input data for the base maps groundwork. This helps as a pre-requisite for making Master, Zonal, and Local Areas. Plans of both small scale especially applied for small and medium towns become easy in this method. Thus, Drone/ UAVs can cater to one of the cheapest alternatives to gather data by flight, and empower uses that were difficult earlier. India is planning to prepare large maps of its smart cities for better planning.

4.3 Light Detection and Ranging (LiDAR)

LiDAR works by way of remote sensing (RS) methodologies that use light coming as a pulsed laser of variable range. The instrument has a laser, scanner, and specialized GPS receiver device mounted over platforms over airplanes, drones, and helicopters. Digital photogrammetry locates about > 1K points/minute at cm-precision whereas LiDAR pulls together 10K to 40K points/sec so very fast. LiDAR can have versatile uses like the military system of finding local patch areas, geo-hazard determination, estimating the canopy volume of trees by 3D mapping (alternative to Photogrammetry), and aerial applications. The LiDAR deploys water-penetrating green light to quantity the positioning of the seafloor and riverbed elevations with precision and accuracy [57,58].

5. SPATIAL DATA INFRASTRUCTURE

The spatial data infrastructures (SDI) are the framework, or elementary physical and organizational structures that desire to enable competent and effective usage of spatial information, and in India, it is framed as NSDI. The NSDI takes a leading role in India in framing policies, Maintaining Geoportals, creating Data Register (NDR), setting up a cloud platform, etc. The awareness about the spatial or GIS data accumulation of this information required to be available free for all which commanded the growth of concepts and practices of SDI at national and global levels [30-32]. SDI should have the potential to deal with spatial data generated by others and used for the data models and different technological dimensions when addressing issues of data dissemination. SDI handles multiple data sets or databases and hosts geographic data, attributes, documentation (metadata), and a means to discover, visualize, and evaluate the data (cataloging and Web mapping). In addition, the software serves to support applications of the data to make SDI functional [34,35,40]. The organization must include the organizational agreements and needs to coordinate/administer them locally, regionally, nationally, and/or on a transnational scale. The infrastructure provides the ideal environment to connect applications to data – influencing both data collection and applications construction through minimal appropriate standards and policies, (Sarada et al. 2018; Gil et al. 2019, Izdebski et al. 2021, Nunez-Andres et al. 2022).

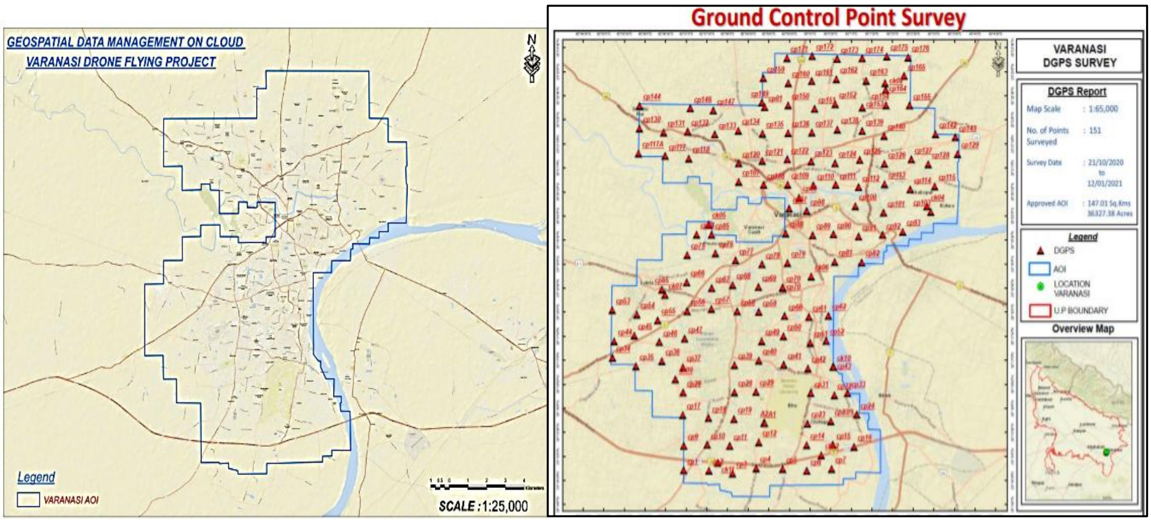

Fig. 9. (a) Geospatial data management by GNSS system and Fig. 9 (b) its Ground control point survey of a location in Varanasi Township

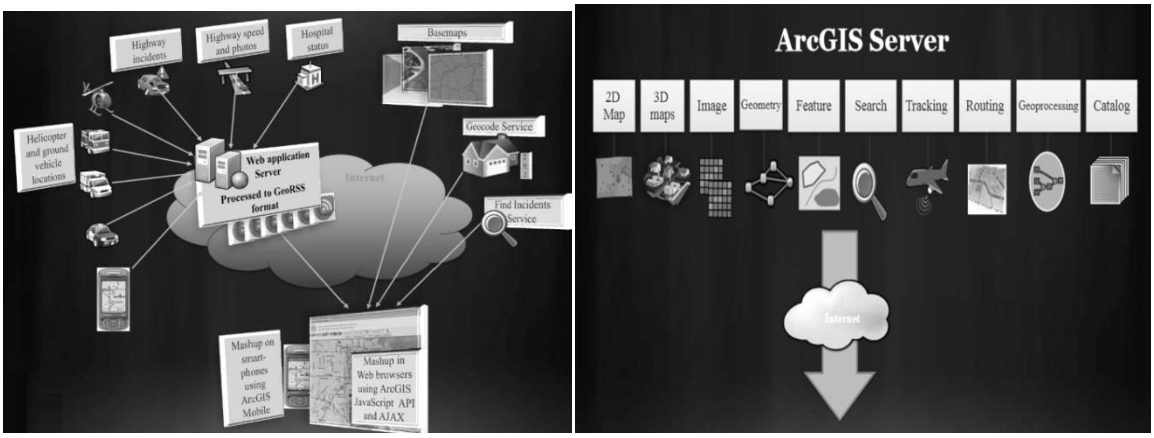

Fig. 10 (a). Web GIS uses for data conception: Fig. 10 (b) Applications of Arc GIS servers

The Govt of India has constituted Nation's spatial data infrastructure at the national level to frame rules and norms for special data dissemination. The function is also to accrue large-scale spatial data of various scales 1:500; 1:1000 and 1:2000 for the use of line departments for effective land planning and coordination (64, (Fig. 9(a) and Fig. 9(b)).

5.1 Data Visualization (WEB GIS)

The wide use of WEB GIS can be created software and run a web browser when connected to the internet. It has better applications of the GIS software based on a local area network (LAN) [36-39]. The use of cloud platforms on the internet has become fast. The information acquisition and transfer are astounding. Their applications are real-time map browsing, map generation, special data catalog, and geographical search engines [59,60]. The WEB services originated from WEB sites, from Soap to REST. Later web services were extended by browser-side APIs. SOAP is a simple XML-based protocol to let applications exchange information over HTTP. The REST (representational state transfer) is the style of software architecture, used in the World Wide Web arena, Fig. 10(a) and Fig. 10(b).

6. DISCUSSION

The surveying technology traversed in its journey from cadastral maps to the present. Past surveying was focussing on exploration, conquest, and expansion through the Great Trigonometric Survey for the army forerunners until the 19th century. GPS in the late 20th century helped in gathering big data for survey works but became a handy tool to boost physical activity like locating positions, and talking about environmental changes, smart city planning, and health sectors The ancient surveying gadgets were chains, compasses, plane tables, slide rules, Vernier scales, orthogonal coordinates, telescope, micro-meters, triangulation, dumpy levels, Mercator's projection, and theodolites. The methodologies developed were knowledge in arithmetic, algebra, calculus, physics, analytical geometry, trigonometry, and astronomical sciences [55,56]. They were rural-oriented, agriculture-based, maps generation through scientific surveying, as per Dr. Bill Hazelton, SCSU Land Surveying and Mapping Science Program. The upsurge of a nation's development is done by urbanization, political uproar for national and state boundaries, and economic expansion. The survey has given some specialized direction to smart planning through large scaled maps. Mountains and glaciers shall be visible to the cartographers in the under-ocean fabrics [61-65]. As technology continues to change the world in the 21st century, land surveying developments are moving into an entirely new realm of near-complete automation, big data preparation, and smart map generation.

7. CONCLUSION

- Apart from current methodologies, the data source for the generation of high-resolution National Topographic Data Base (HR-NTDB) is in the process of acquiring through High-Resolution Satellite Imagery (HRSI), UAV/Drones, LiDAR, and many smart map-making processes like Robotics.
- Drones, or UAVs, can collect data quickly over large areas and rough terrain, and easily.
- Robots outfitted with 3D laser scanners can cover rough terrain that would be too dangerous or difficult for humans to traverse.
- Light Detection and Ranging (LIDAR) technology - a type of remote sensing surveying that uses pulsated light from a laser to measure ranges in preparation of plans and maps.
- In addition to the latest technologies, it has become essential to prepare large-scale maps (1:500; 1:1000, 1:2000, and 1:5000), so that it will help the town planners, travelers, and policymakers to have proper management of the land schedule in the future.
- The wide use of Web GIS is gradually gaining importance in various fields and various apps that are handy and popular.

Land surveying has become such a dynamic field; it is up to the professional to continue his research and stay updated with the latest land surveying technologies. The future of land surveying shall come up for various services common in large-scale maps, the use of Robots, and the digital future of smart cities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Novak JD, Cañas AJ. The theory underlying concept maps and how to construct them. Florida Institute for Human and Machine Cognition. 2006;1(1);1-31.
2. de Ries KE, Schaap H, van Loon AMM, Kral MM, Meijer PC. A literature review of open-ended concept maps as a research instrument to study knowledge and learning. Qual Quant. 2021:1-35.
3. Mondal TK. Mapping India since 1767: transformation from colonial to postcolonial image. Misc Geogr. 2019;23(4):210-4. DOI: 10.2478/mgrsd-2019-0023.
4. Agrawal GC. Glorious years of the survey of India. Reproduced from northern flash – special annual 1987,1-9, ex-surveyor general of India. 220;1987.
5. Bradshaw J, Hunter WW. Sir Thomas Munro and the British settlement of the Madras presidency; 1894.
6. Markham CR. A memoir on the Indian surveys. 2nd ed. Meridian; 1969.
7. Bartholomew JG. Thacker's, 1897. Reduced survey map of India. 2nd ed, Extended and rev. To date, with Inset produce maps, tea District maps, Sketch maps of Calcutta, Bombay, and Madras, and General index. Thacker: Spink & Co., W. Thacker & Co.
8. MacLeod MN. Historical records of the survey of India. Nature. 1947;159(4033): 213-4. DOI: 10.1038/159213a0.
9. Morrison KD. Harappa excavations 1986-1990, *A multidisciplinary approach to third millennium urbanism*. Monographs in world Archaeology No. 1993;3:260-263.

10. Pant M, Funo S. The grid and modular measures in the town planning of MohenjoDaro and Kathmandu valley A study on modular measures in block and plot divisions in the planning of MohenjoDaro and Sirkap (Pakistan), and Thimi (Kathmandu valley). J Asian Archit Build Eng. 2005;4(1):51-9.
DOI: 10.3130/jaabe.4.51
11. Pati DC. Unknown tales of Orissa's maritime past, (Source British Library); 2004.
12. Takao H. Aryabhata. Encyclopaedia Britannica; 2021.
13. Macleod MN. Historical records of the survey of India. Nature. 1947;159(4033): 213-4.
DOI: 10.1038/159213a0.
14. Chadha SM. Survey of India through the ages. Himalayan J. 1991;47.
15. Sharp T, 2021. how big is Earth? NASA's Goddard Space Flight Center; Greenbelt, Maryland.
16. Petrie CA, Orengo HA, Green AS, Walker JR, Garcia A, Conesa F et al. Mapping archaeology while mapping an empire: using historical maps to reconstruct ancient settlement landscapes in modern India and Pakistan. Geosciences. 2019;9(1):1-26.
DOI: 10.3390/geosciences9010011.
17. D'souza VG, 2019. Impact of technology on modern land surveying techniques. Geo-spatial world.
18. Roy Chowdhury A. Survey of India turns 250: remembering a British past when mapping was for the sake of conquering. The Indian Express; 2017.
19. Roy RD. The Great Trigonometric Survey of India from a historical perspective. Indian J Hist Sci. 1986;21(1):22-32.
20. Naik PC, Satpathy L. S.C.S. the great nacked-eye astronomer. Bull Astronomical Society India, SAO/NASA Astrophysics Data System (ADS). 1998;33-49.
21. Rama Subramanian K, Srinivas MD, Sriram MS. Modification of the earlier Indian planetary theory by the Kerala astronomers (*c.* 1500 AD) and the implied heliocentric picture of planetary motion. Current Science, historically commentary and Notes. 1994;66(10):784-90.
22. Mohapatra PK. Pathani Samanta: the great Hindu astrologer. Orissa Rev. 2007:1-3.
23. Mohanty S. 100 years of Siddhanta-Darpana. Mon Newsl Vigyan Prasar News. 1999;1(11):6-8.
24. Sahu NK. The legacy of Samanta Chandrasekhara. Odisha review. Jan: GOO; 2012.
25. Srikant SV. Restriction on maps in India. Geospatial world; 2010.
26. Dwolatzky B, Trengove E, Struthers H, McIntyre JA, Martinson NA. Linking the global positioning system (GPS) to a personal digital assistant (PDA) to support tuberculosis control in South Africa: a pilot study. Int J Health Geogr. 2006;5(34): 34.
DOI: 10.1186/1476-072X-5-34
PMID 16911806.
27. No DS. SATNAV policy- 2021, department of space. Indian Satell Navig Policy. 2021:1-22_3P-16013/58/2021-DIR(PJ)-D0S, GoI.
28. Chama SNK, Katukojwala S, Ammana SR, Agarwal S, Reddy KVK, Achanta DS. Design and development of NavIC and GPS-based geolocation system for CO 2 monitoring. In 2021, Int. Conf. on Innovative Practices in Tech and Management (ICIPTM). 2021;50-4.
29. Beekhuizen J, Kromhout H, Huss A, Vermeulen R. Performance of GPS devices for environmental exposure assessment. J Expo Sci Environ Epidemiol. 2013;23(5):498-505.
DOI: 10.1038/jes.2012.81, PMID 22829049.
30. Maddison R, Mhurchu CN. Global positioning system: a new opportunity in physical activity measurement. Int J Behav Nutr Phys Act. 2009;6(1):1-8.
31. Raju PLN. Fundamentals of GPS, satellite remote sensing, and GIS applications in agricultural meteorology. In: Proceedings of the a Training workshop. 2003;7-11.
32. Sheridan I. Drones and global navigation satellite systems: current evidence from polar scientists. R Soc Open Sci. 2020;7(3):191494.
DOI: 10.1098/rsos.191494, PMID 32269789.
33. Singal P, Chhillar RS. A review on GPS and its applications in computer science. Int J Comput Sci Mob Comput. 2014;3(5):1295-302.
34. Kerle N, Nex F, Gerke M, Duarte D, Vetrivel A. UAV-based structural damage mapping: a review. ISPRS Int J Geo Inf. 2020;9(1):14.
DOI: 10.3390/ijgi9010014.
35. Tegedor J, Øvstedal O, Vigen E. Precise orbit determination and point positioning

using GPS, GLONASS, Galileo and BeiDou. J Geod Sci. 2014;4(1): 65-73.
DOI: 10.2478/jogs-2014-0008.

36. Håkansson M, Jensen ABO, Horemuz M, Hedling G. Review of code and phase biases in multi-GNSS positioning. GPS Solut. 2017;21(3):849-60.
DOI: 10.1007/s10291-016-0572-7.

37. Hofmann-Wellenhof B, Lichtenegger H, Collins J. Global positioning system: theory and practice. Springer Science+Business Media; 2012.

38. Rama Rao PVS, Gopi Krishna S, Vara Prasad J, Prasad SNVS, Prasad DSVVD, Niranjan K. Geomagnetic storm effects on GPS-based navigation. Ann Geophys. 2009;27(5):2101-10.
DOI: 10.5194/angeo-27-2101-2009.

39. Yasyukevich YV, Vesnin AM, Kurkin VI. Global navigation satellite systems for ionospheric error correction in radio-engineering systems: challenges and prospects. Radiophys Quantum El. 2020;63(3):177-90.
DOI: 10.1007/s11141-021-10044-4.

40. Jamal H. Sources of errors in GPS and their correction. Urban Plan. 2017;2017.

41. Bidikar B, Chapa BP, Kumar MV, Rao GS. GPS signal multipath error mitigation technique. In: Satellites missions and technologies for geosciences. Intech open; 2020.

42. Brack A, Männel B, Schuh H. GLONASS FDMA data for RTK positioning: a five-system analysis. GPS Solut. 2021;25(1): 1-13.

43. Sarkar S, Banerjee P, Bose A. A review of 36 years of GLONASS service from India. Gyroscopy Navig. 2018;9(4): 301-13.
DOI: 10.1134/S2075108718040065.

44. Brumfiel G. Galileo gets ready for takeoff. Nature; 2011.

45. Strugarek D, Sośnica K, Arnold D, Jäggi A, Zajdel R, Bury G. Determination of SLR station coordinates based on LEO, LARES, LAGEOS, and Galileo satellites. Earth Planets Space. 2021;73(1):87.
DOI: 10.1186/s40623-021-01397-1.

46. EU space program. Galileo and Copernicus: services launched, but the uptake needs a further boost, Special report No 7(2021). 2021;1-69.

47. Bury G, Sośnica K, Zajdel R, Strugarek D, Hugentobler U. Determination of precise Galileo orbits using combined GNSS and SLR observations. GPS Solut. 2021; 25(1):11.
DOI: 10.1007/s10291-020-01045-3.

48. Hein GW. Status, perspectives, and trends of satellite navigation. Satell Navig. 2020;1(1):22.
DOI: 10.1186/s43020-020-00023-x, PMID 34723195.

49. Nina KW. Shifting articulations of space and security: boundary work in European space policy-making, European Security, Taylor and F. Doi; 2021.
DOI: 10.1080/09662839.2021.1890039.

50. Xie J, Zhang J, Wang G. The construction method of BeiDou, a Satellite Navigation Measurement error system. Wirel Commun Mob Comput. 2019;2019:1-15.
DOI: 10.1155/2019/1438739.

51. Goswami D, Sanjiv K. NavIC. Int J Eng Res Technol, (IJERT). 2018;06(17).

52. Guddad K, Sudha KL, Reddy KN, Chandana S, K, Reddy N et al. IRNSS data processing. IJERT NCCDS. 2021; 2021:09(12).

53. Wu F, Kubo N, Yasuda A. Performance analysis of GPS augmentation using Japanese quasi-Zenith Publishing Satellite System. Earth Planet SP. 2004;56(1): 25-37.
DOI: 10.1186/BF03352488.

54. Li W, Batty M, Goodchild MF. Real-time GIS for smart cities. Int J Geogr Inf Sci. 2020;34(2):311-24.
DOI: 10.1080/13658816.2019.1673397.

55. Gil J, Díaz L, Granell C, Huerta J. Open source based deployment of environmental data into geospatial information infrastructures. Int J Appl Geospatial Res. 2012;3(2):6-23.
DOI: 10.4018/jagr.2012040102.

56. Izdebski W, Zwirowicz-Rutkowska A, Nowak da Costa JN. Open data in spatial data infrastructure: the practices and experiences of Poland. Int J Digit Earth. 2021;14(11):1547-60.
DOI: 10.1080/17538947.2021.1952323.

57. Núñez-Andrés MA, Lantada Zarzosa N, Martínez-Llario J. Spatial data infrastructure (SDI) for inventory rockfalls with fragmentation information. Nat Hazards. 2022;112(3):2649-72.
DOI: 10.1007/s11069-022-05282-2.

58. Ekaso D, Nex F, Kerle N. Accuracy assessment of real-time kinematics (RTK)

measurements on unmanned aerial vehicles (UAV) for direct geo-referencing. Geo Spat Inf. Sci. 2020;23(2):165-81.
DOI: 10.1080/10095020.2019.1710437.

59. Pırtı A. Evaluating the accuracy of post-processed kinematic (PPK) positioning technique. Geod Cartogr. 2021;47(2): 66-70.
DOI: 10.3846/gac.2021.12269.

60. Famiglietti NA, Cecere G, Grasso C, Memmolo A, Vicari A. A test on the potential of a low-cost unmanned aerial vehicle RTK/PPK solution for precision positioning. Sensors (Basel). 2021; 21(11):3882.
DOI: 10.3390/s21113882, PMID 34199821.

61. Guo C, Xu Q, Dong X, Li W, Zhao K, Lu H et al. Geohazard recognition and inventory mapping using airborne LiDAR data in complex mountainous areas. J Earth Sci. 2021;32(5): 1079-91.
DOI: 10.1007/s12583-021-1467-2.

62. Wei W, Shirinzadeh B, Nowell R, Ghafarian M, Ammar MMA, Shen T. Enhancing solid-state LiDAR mapping with a 2D spinning, LiDAR in urban scenario SLAM on Ground Vehicles. Sensors (Basel, Switzerland). 2021;21(5):1773.
DOI: 10.3390/s21051773
PMID 33806421.

63. Sarda NL, editor. Geospatial infrastructure, applications and technologies: India case studies Acharya PS, editor Sen S, editor. Springer. 2018;1-255.

64. Mishra SP, Nayak SP, Mishra S, Siddique M, Sethi KC. GIS and auto desk modelling for satellite cities around Bhubaneswar. IJITEE. 2019;8(11): 297-306.
DOI: 10.35940/ijitee.K1328.0981119

65. Das A, Mishra SP, Pattanayak GD, Sethi KC. Geo-bio chemistry of wetlands in laterite mines, the Chilika catchment, Odisha: GIS study and XRF spectroscopy appraisal. Int J Adv Res. 2019;7(1): 688-714.
DOI: 10.21474/IJAR 01/837

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/100156