1.1 Introduction

The evolution of technology that has started over half a century ago and is still growing rapidly to the extent, that it is hard to keep-up with it without having long term plans, multi-billion dollar projects and inter-global co-operations and co-ordination investments.

Technology is overshadowing all other factors and sectors that were used and affected the life aspects. Almost every single activity, work even entertainment is somehow technology related. Even though this has also many negative impacts in our lives, such as jobs, but certainly technologies' have greater advantages in human life, such as communications and many other benefits.

One of the most important aspects of these advantages is the services that are provided by GNSS. Global Navigational Satellite Systems (GNSS) and their applications have increased in importance, not only for state governments, but also to every single individual with different usages and backgrounds from those working in transportation(all kinds of transportations), scientists and even to farmers.

GNSS plays a significant role in high precision navigation, positioning, timing and scientific questions related to precise positioning.It's also used for scientific studies in different fields such as agriculture, seismic, navigational and climate research.

Global Navigation Satellite Systems (GNSSs) include constellations of Earth-orbiting satellites that broadcast their locations in space and time, to networks of ground control stations and to receivers that calculate ground positions by trilateration. GNSSs are used in all forms of transportation: space stations, aviation, maritime, rail road and mass transit. Positioning, navigation and timing play a critical role in telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, scientific research and so on. They are used to control computer networks, air traffic, power grids and more. Thus the specific objectives of this thesis include the demonstration and understanding of GNSS signals, codes, biases and practical applications, and the implications of prospective modernization (global navigational satellite systems, UN's educational curriculum)

Global Navigation Satellite Systems (GNSS) technology has become vital to many applications that range from city planning engineering and zoning to military applications. It has been widely accepted globally by governments and organizations. That is why we have more than three GNSS systems: the USA GPS, the European Galileo, the Russian GLONASS systems, the Chinese Baidou, and other systems.

There are multibillion dollar investments in this field and intensive worldwide research activities.

The impressive progress in wireless communications and networks has played a great role in increasing interest in GNSS and providing enabling methodologies and mechanisms. All 3G and future generations of cellular phones will be equipped with GNSS chips (global navigational satellite systems, UN's educational curriculum)

GNSS technology dominates the outdoor navigation, which provides accuracy to the range of few meters to 10 m in single point positioning technique or sub-meter to a few meter levels in differential GNSS technique (DGNSS). Different techniques have been developed recently for indoor positioning. They offer either absolute or relative positioning capabilities with acceptable precision. Combining these technologies with GNSS allows us to provide a more reliable and robust location solution. Most common implementation of Hybrid technology for GSM, GPRS and WCDMA is to combine A-GNSS with Cell-ID.

1.2 The Problem

In the Sudan generally, technology and its privileges have not yet been fully implemented apart from some basic usages such as banking, some governmental services and research areas.

One of the most important and most advanced fields of technology is the services of GNSS which Sudan still lacks.

Although GNSS and its applications are of a high importance and a must, Sudan is yet to have that kind of infrastructure which will position the country on the wright path towards development.

Sudan is considered one of the biggest countries in Africa, most promising and one of the richest in terms of natural resources. These resources include the vast agricultural land, water bodies, and the huge amount of livestock. Sudan has a different landscape, ranging from the woods and agricultural lands in the southern and western parts, the desert in some northern and eastern parts to the areas around the river Nile banks.

The size of the country, the resources and the diverse landscape the country has requires observation and scientific research to better understand the effects of the weather changes and the global worming phenomena to the country.

During the last couple of years, the country has started implementing e-government concepts to the services it provides to its citizens. Many GNSS applications fall within the criteria of public services such as aviation, maritime, rail, road and many other services. These services are a must and considered to be the building blocks of a developed country. For such services to be provided with high quality, a GNNS infrastructure is a necessity that every country should invest on.

1.3The Significance of the study:

GNSS, and all the related sub-topics and applications, are considered high technologies. Investing in such projects requires big budgets and long-term plans.Consequently, they require a lot of research and planning. As such, most developing countries, including Sudan, have not yet built or implemented the required infrastructure. But as the whole world grows and is heading towards outer-space technologies to better understand this universe and as precision, position timing and their applications are becoming more and more important, for many reasons, sooner or later the time will come when every country would have to have this infrastructure.

And as there has never been a thesis that covers the possibility and the requirements for implementing such project in Sudan, this thesis will cover, examine and discuss in details if it’s possible to have such technology and apply it in the country and what are the requirements for that.

It will also determine how many ground stations will be required to cover the whole state and specify the best positions around Sudan where these stations will best fit based on geographical criteria that are determined by the specific and particular environmental attributes of these ground stations.

The research will act as one of the pioneers and base studies for the future studies that fall within the same research areas of studies.

1.4Previous Studies and Related Works

To better understand the topic and its concepts, techniques and tools, the researcher had read and discussed a couple of papers and previous studies related to the topic. These previous studies were selected after a hand-full of papers were read and they are all listed in the list of references.

1.5Hypothesis

In the following some hypotheses are formulated to be achieved by this Master’s Theses:

- The implementation of the technology and it’s applications in the Sudan, is as highly possible as it is important.
- If implemented, the infrastructure will help improve and enhance many services that fall within the criteria.
- The number of required ground stations and their approximated locations spread across the country will be analyzed and determined using GIS technologies, tools and techniques.
- The geographical characteristics of these locations will be evaluated and determined.
- The thesis will act as the base and reference if the real project is to actually be built and implemented.

1.6 Project Objectives

- Using GIS technologies to determine how to implement GNSS technologies in the Sudan.
- Approximating the number of ground stations required to cover the whole country.
- Using GIS tools to determine approximated locations for the ground stations.
- determining the geographical features of the above determined locations.
- Raising the awareness of both authorities and publics about the importance of such technologies to the advancement of the country.
- To specify the applications of the technology in basic, daily life cases and issues and how perfectly they are solved using these technologies all over the globe.

1.7The Scope

This thesis and project is implemented for the Sudan. The data for the project, particularly Sudan's political map with states and local areas, will be collected from different sources.

Sudan, like any other state, has a unique land scape with vast differences. It has mountains, green areas, but it also has desert in some parts. So what applies for it may not be the same for other geographical areas. Therefore, the theoretical information in this research could been used for any other research that falls within the same filed, however the factors related to landscape and geographical properties have to be considered.

1.8 The Methodology and Tools

The descriptive research approach will be used for the analysis of this project, because it depends on describing the characteristics of the maps of the whole landscape and other relevant attributes, such as settlements, by using many GIS tools to achieve the pre-determined objectives.

Maps that represent different features, such as mountains, water bodies, settlements and state political boundaries will be used and considered in order to precisely determine the locations of the stations.

1.9 Organization of the thesis:

Chapter1:

This chapter is an introductory part including: An overview, Problem Statement, Research Hypothesis, Reserach Objectives, Research Significance.

Chapter2:

This chapter gives theoretical background, discussessomerelated works, framework, system description and literature review.

Chapter3

This chapter is about methodology and reserach planning: Covers the topics of reserach community, methodoly and research planning

Chapter4

Chapter4 is system Design& analysis that will include: system requirements and system Analysis.

Chapter5

Here the researcher gives the results that the project has achieved and explains his work experiments and their results: tested description, the methods used, algorithms implemented and applied.

Chapter6

In this chapter the researcher gives his recommendations,conclusions, outlook and suggestions to others willing to work in similar topics. A list of all references used to study and implement the project is also given.

2. Literature Review

2.1 An introduction and a historical background:

The race to outer space and navigation has started during the cold war. At the beginning, mainly the competition was between the United States of America and the Soviet Union. Both parties were trying to take the lead in this field. This is the reason why the original motivation for satellite navigation was military applications. Satellite navigation allows the precision in the delivery of weapons to targets, greatly increasing their lethality whilst reducing inadvertent casualties from miss-directed weapons. Satellite navigation also allows forces to be directed and to locate themselves more easily, reducing the fog of war (Wikipedia). The United States managed to be the first to do so. The first satellite navigation system was Transit, which was deployed by the US military in the 1960s.

2.2Global Navigational Satellite Systems (GNSSs)

Global Navigational Satellite Systems, shortly known as GNSS, as a term "is used to describe the collection of satellite positioning systems that are now operating or planned" (Charles Jeffry, 2010).

'GNSS includes constellations of earth-orbiting satellites that broadcast their locations in space and time, of network of ground control stations and of receivers that calculate ground positions by trilateration' (GNSS, UN's Educational curriculum, 2012).

G. M. Someswar et al (2013) state that 'A satellite navigation or SAT NAV system is a system of satellites that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few meters using time signals transmitted along a line-of-sight by radio from satellites. Receivers calculate the precise time as well as position, which can be used as a reference for scientific experiments. A satellite navigation system with global coverage may be termed a global navigation satellite system or GNSS'.

The above three definitions give a precise yet an adequate functionality and definition to the term GNSS however, these are too general. To have a full view and understanding of the topic, more detailed information covering the orbiting, signals, receivers, challenges and many other related sub-topics will be discussed.

There are many GNSS systems today, some fully operational, some partially and some are in different stages of development. All of these systems use the same major concepts with small minor differences in some details.

2.3 GNSS architecture:

2.3.1 Every GNSS is composed of three main segments:

- **The space segment:**
  The space segment consists of a number of satellites, called constellation, which are orbiting about 20,000km above the earth. Each satellite in the constellation broadcasts a signal that identifies it and provides its time, orbit and status (C. Jeffry, 2010). The total number of satellites used differs from one system to another. Usually regional systems require a lesser amount of satellites in contrast to systems that provide global coverage. For instance, Galileo (which provides global coverage) is planned to have 30 satellites, while QZSS (Japan's regional system) is planned to have only 7 satellites (Wikipedia).

- **The control segment:**
  The control segment comprises a ground based network of master control stations, data uploading stations and monitor stations. The master control station (or stations) adjusts the satellites' orbit parameters and the onboard precise clocks whenever necessary to maintain accuracy. The monitor stations on the other hand, usually installed abroad a geographic area, monitor the satellites signals and status and relay this information to the master stations(C. Jeffry, 2010).

- **The user segment:**
  This segment includes a variety of devices and equipment that receive the signals sent by the satellites in the constellation, decodes the signals and uses the data to approximate and estimate the timing and location information.

This equipment ranges from handheld receivers (such as smart phones) to sophisticated, specialized receivers used for high-end survey and mapping applications (C. Jeffry, 2010).

2.3.4 These systems include:

(1) GPS of the United States of America:

Usually people miss concept GPS and GNSS. GPS is only one example of GNSS systems.

The Global Positioning System (GPS) also known as NAVSTAR (**NAV**igation**S**ystem with **T**ime **A**nd **R**anging) was the first fully operational GNSS developed by the United States ‘department of defense (DoD)initially for military purposes before some of its functions were allowed to be used for civilian services. It was launched in 1970’s.

- **The space segment:**

  Its base line consists of constellation of between 24 and 32 satellites that provide global coverage (C. Jeffry, 2010). The satellites are spaced in orbits to ensure that at any point of time there are at minimum 6 satellites in the receiver view. Each satellite transmits radio signals that travel at the speed of light to broadcast the navigation messages. The satellites travel in six different orbits, each is inclined about 57°. The altitude of each orbit is 20,200km.
- **The control segment**:

Consist of a network of monitoring stations that are responsible for satellite’s tracking, monitoring and maintenance. The master control station, located in the state of Colorado, gets data from each of the monitoring stations, which are distributed around the world, and determines both the data to be uploaded and the ground stations that will transmit this control data to the satellites.

- **The user segment**:

  Consist of handset radio receivers that receive signals from GPS satellites available in the view at a given moment. There are millions of receivers in use today. These devices include 300 million receivers in cell phones (S.

Dawoud et al, 2013).This number was since 2013, now it has increased to almost one billion devices.

(2) GLONAS:Global Navigation Satellite System (GLONASS) of Russia

This is the global navigation satellite system provided by the Russian Federation. It was started during 1970's by the Soviet Union in response to the US's GPS.

- **The space segment:**

The nominal baseline constellation of GLONASS comprises 24 GLONASS-M satellites that are uniformly deployed in three roughly circular orbital planes at an inclination of 64.8° to the equator. The altitude of the orbit is 19,100 km. The orbit period of each satellite is 11 hours, 15 minutes, 45 seconds. The orbital planes are separated by 120° right ascension of the ascending node. Eight satellites are equally spaced in each plane with 45° argument of latitude. Moreover, the orbital planes have an argument of latitude displacement of 15° relative to each other (GNSS, UN's Educational curriculum, 2012:27). Among these satellites there are 21 active satellites, while the other three satellites are used as spares. This constellation assures that at least five satellites are available in the view at any point in the earth. A constellation of 21 satellites provides a continuous and simultaneous visibility of at least four satellites over 97% of the earth surface, while a constellation of 24 satellites provides a continuous and simultaneous visibility of at least five satellites over more than 99% of the earth surface (S. Dawoud et al, 2013).

- **Control Segment:**

The system's control center is located in Kranznamensk Space Center about 70 km southwest Moscow. The center is connected with 8 tracking stations distributed across Russia. These stations are responsible for tracking and monitoring the satellites status in the orbits, determining the ephemerides and satellite clock offsets with respect to GLONASS time, and transmitting this information to the system control center via radio link once per hour.

- **User segment:**

The user segment, like all user segments, consists of hand-held devices used to take advantage over the navigational services that are provided by the system. This includes hundreds of millions, even billions of smart devices, phones, tablets and other special GNSS devices.

(3) Galileo of the European Union

Looking for participation in the existing GNSS systems, Europe tried to take part in GPS's control and development. However, this was not acceptable by US. Therefore, Europe tried starting co-operation with Russia to further develop the GLONASS system, but there was no interest from the Russian side. Finally, the European countries took the decision to develop their own GNSS system. In 2002 the European Union (EU) and European Space Agency (ESA) agreed to introduce their own GNSS called Galileo as an autonomous, alternative, and competitive GNSS to GPS and GLONASS. The Galileo system is scheduled to be fully operational in 2020. The European commission in 2000 estimated the cost of Galileo system to reach 3.4 billion Euros including an operation phase until 2020. Nevertheless, they estimated that the cost of two days of GPS service interruption in 2015 would cost Europe's transport and financial sectors about one billion Euros. In 2002 a complete definition of the Galileo project for the main characteristics and performance were summarized in high level document. First experimental Galileo satellites, GIOVE-A and GIOVE-B, were launched in 2005 and 2008. While the first two Galileo satellites were launched on October 2011 (S. Dawoud et al, 2013).

- **The space segment:**

The space segment of Galileo will include a constellation of a total of 30satellites, 27 are operational and 3 spare satellites. These satellites are spaced around the plane in three circular medium earth orbits (MEO) with 23.600 km Altitude. Galileo constellation guarantees that at any point on the earth, there will be at least 6 satellites in the view (S. Dawoud et al, 2013).

- **Ground (control) segments:**

The ground segment consists of two ground control centers responsible for Central Processing Facility; they are located in Oberpfaffenhofen, Germany and Fucino, Italy. Moreover, the control centers are connected with five tracking and control stations, 9 C-band uplink stations, and about 40 Galileo sensor stations (S. Dawoud et al, 2013).

- **The user segment:**
  The user segment of Galileo must be developed in parallel with the core system to ensure that the receivers and users will be available in time when the Galileo reaches its full operational capabilities. Galileo provides test user segment specifications and implementations to develop receivers to experiment and validate the Galileo services and provide a proof of the system performance. There are several running projects and there are several receivers' product lines that introduce Galileo receivers (e.g., GARDA receiver) (S. Dawoud et al, 2013).

(4) Compass of thePeople's Republic of China

This is the GNSS that is developed and run by the People's Republic of China (PRC). It is still in the construction phase. The Chinese government decided to build their own global navigation system in 1980. They developed a navigation system called Beidou (English: Compass), it consists of 3 satellites. Since 2000, it provides its service only to the China and the neighboring regions covering an area of about 120 degrees longitude in the Northern Hemisphere. Compass comes in place as the second generation of Beidou satellite navigation system, which is providing navigating services for Asia-Pacific region since 2012. The system will provide global navigation services by 2020. Compass will provide a civilian service with accuracy of 10 meters, and 50 nanoseconds in time accuracy, and a military and authorized user's service, providing higher accuracies.

The Compass constellation will consist of 35 satellites including 5 geostationary orbit (GEO) satellites, 3 in highly inclined geosynchronous orbits (IGSO) and 27 medium Earth orbit (MEO) satellites that will offer complete coverage of the globe. The fifth geostationary orbit satellite was launched in December 2011. Compass official governmental website announced, that this fifth satellite completes the construction of the basic regional navigation system for servicing China (S. Dawoud et al, 2013).

These are the major GNSS systems that exist around the globetoday. However, they are not the only ones. There are many regional GNSSs that provide regional services that are bound to specific geographical locations, such as:

- **QZSS of Japan**
  The Quasi Zenith Satellite System (QZSS) is a regional navigation satellite system that is in the development phase by the Advanced Space Business Corporation (ASBC) team, which was authorized by the Japanese government in2002. QZSS covers regions in East Asia and Oceania centering on Japan, and is designed to ensure that users are able to receive positioning signals from a high elevation at all times. The plan is to place the satellites in High Elliptical Orbit (HEO), which helps to overcome the objects (building) interception for the satellites signals. The system also improves positioning accuracy by transmitting signals L1C/A, L1C, L2C and L5 that are equivalent to modernized GPS signals. QZSS uses the time base of GPS. They use the Japanese satellite navigation Geodetic System (JGS) to represent the calculated Cartesian coordinates. The difference between JGS and WGS84 used by GPS is 0.2m. The navigation message is also the same as the navigation message broadcasted by the GPS system (S. Dawoud et al, 2013).

- **IRNSS of India**
  The Indian Regional Navigational Satellite System, abbreviated as (IRNSS), is the regional GNSS that provides navigational services for India. It was established in 2012. The system consists of seven satellites three of which are in geo-synchronous orbits and the rest in geo-stationary orbits. The system provides position accuracy of better than 20 meters throughout India(C. Jeffry, 2010).

Table 1 compares (based on eleven factors) all internationally known GNSSs (both regional and global systems). The table was extracted from Wikipedia encyclopedia:

Table 1: Key parameters of known GNSSs (Wikipedia)

System	***BeiDou***	***Galileo***	***GLONASS***	***GPS***	***NAVIC***	***QZSS***
Owner	China	European Union	Russia	USA	India (IRNSS)	Japan
Coverage	Regional (Global by 2020)	Global	Global	Global	Regional	Regional
Coding	CDMA	CDMA	FDMA	CDMA	CDMA	CDMA
Orbital altitude	21,150 km (13,140 mi)	23,222 km (14,429 mi)	19,130 km (11,890 mi)	20,180 km (12,540 mi)	20,180 km (12,540 mi)	32,000 km (20,000 mi)
Period	12.63 h (12 h 38 min)	14.08 h (14 h 5 min)	11.26 h (11 h 16 min)	11.97 h (11 h 58 min)	1436.0m (IRNSS-1A) 1436.1m (IRNSS-1B) 1436.1m (IRNSS-1C) 1436.1m (IRNSS-1D) 1436.1m (IRNSS-1E) 1436.0m (IRNSS-1F) 1436.1m (IRNSS-1G)	
Revolutions per sidereal day	17/9	17/10	17/8	2		
Number of satellites	5 geostationary orbit	18 satellites in orbit,	**28** (at least 24 by	**31** (at least 24 by	3 geostationary orbit	in 2011 the Governme

	(GEO) satellites, 30 medium Earth orbit (MEO) satellites	15 fully operation capable, 11 currently healthy, 30 operational satellites budgeted	design) including:[15] 24 operational 2 under check by the satellite prime contractor 2 in flight tests phase	design)[16]	(GEO) satellites, 5 geosynchronous (GSO) medium Earth orbit (MEO) satellites	nt of Japan has decided to accelerate the QZSS deployment in order to reach a 4-satellite constellation by the late 2010s, while aiming at a final 7-satellite constellation in the future
Frequency	1.561098 GHz (B1) 1.589742 GHz (B1-2) 1.20714 GHz (B2) 1.26852 GHz (B3)	1.164–1.215 GHz (E5a and E5b) 1.260–1.300 GHz (E6) 1.559–1.592 GHz (E2-L1-E11)	Around 1.602 GHz (SP) Around 1.246 GHz (SP)	1.57542 GHz (L1 signal) 1.2276 GHz (L2 signal)	1176.45 MHz(L5 Band) 2492.028 MHz (S Band)	
Status	22 satellites operational, 40 additional satellites 2016-2020	18 satellites operational 12 additional satellites 2017-	Operational	Operational	6 satellites fully operational, IRNSS-1A partially operational	

		2020				
Precision	10m (Public) 0.1m (Encrypted)	1m (Public) 0.01m (Encrypted	4.5m – 7.4m	15m (Without DGPS or WAAS)	10m (Public) 0.1m (Encrypted)	1m (Public) 0.1m (Encrypted)

2.4GNSS Applications

The main and original motivation for satellite navigation was military applications. Satellite navigation allows the precision in the delivery of weapons to targets, greatly increasing their lethality whilst reducing inadvertent casualties from miss-directed weapons. Satellite navigation also allows forces to be directed and to locate themselves more easily, reducing the fog of war.

The ability to supply satellite navigation signals is also the ability to deny their availability. The operator of a satellite navigation system potentially has the ability to degrade or eliminate satellite navigation services over any territory it desires (Wikipedia). For example, GPS signals were always affected by the department of defense's policies. It used the "selective availability (SA)" as a means of controlling the system's signals. This had hugely affected the accuracy of the system. In 2000 the US congress decided to take actions to make GPS services more unlimited and enhanced by removing selective availability (S. Dawoud, 2013). This decision had a huge positive impact to GNSS future, services, studies, navigation accuracy and applications. Today, almost every smart phone has a GPS receiver installed on it. Navigation has become more easy, fun and accurate.

GNSS applications and usages are many. Though the initial purpose was military, these applications range from sophisticated, specialized receivers used for high-end survey and mapping applications to simple position and timing determination receivers. There are countless number of such applications in different fields such as transportation, machine control, surveying, port automation, timing, marine and many others (C. Jeffry, 2010).

2.5GNSS Challenges and Sources of Errors

GNSS's accuracy and quality of services depend on the accuracy of the pseudo-ranges (the distance between the receiver and the satellite). These pseudo-ranges are determined by calculating the differences in time readings (time difference of arrival known as (TDOA)) between the satellite clocks and receiver clocks.

These pseudo-ranges, hence the GNSS services' quality, are affected by many sources of errors. Table 2 explains the sources of GNSS errors and their ranges (in terms of position accuracy).

Table 2: GNSS error ranges(C. Jeffry, 2010).

Contributing source	**Error range**
Satellite clocks	+_ 2 m
Orbit errors	+_ 2.5 m
Ionospheric delays	+_ 5 m
Tropospheric delays	+_ 0.5 m
Receiver noise	+_ 0.3 m
Multipath	+_ 1 m

Since the services' quality and accuracy depend on the correctness of the pseudo-ranges, reducing the above mentioned errors and their effects is a huge area of research and development. There are many techniques that are used to enhance the accuracy of GNSS services such as real time kinematic (RTK), satellite based augmentation systems (SBAS) and differential GNSS (DGNSS) which is the topic of this thesis.

2.6Differential Global Navigational Satellite System (DGNSS)

DGNSS is one of many techniques that are used to enhance the accuracy of the pseudo-ranges, which are the most significant factor that affects the GNSS services' quality and accuracy.

2.7 The concept and technique of DGNSS

The DGNSS uses two receivers. The first, called reference (base) station is at a fixed position with known coordinates determined by conventional surveying techniques. The second, known as rover or remote, is a mobile receiver with unknown coordinates or location.

Observations are made at the fixed reference station (changes of the pseudo ranges and resulting changes of station coordinates with 1 Hz repetition rate). These changes are transmitted (wireless) as corrections to the rover (mobile receiver). This enhances accuracy level to $\leq$1m (GUC, lecture notes). The base station compares the ranges, determines the errors and calculates the corrections. Differences between the ranges (errors) are usually attributed to satellites ephemeris and clock errors, but mostly to errors associated with atmospheric delay. The corrections are then sent to rover receivers which incorporate them to their position calculations (C. Jeffry, 2010). To achieve this, a data-link between the reference station and the rover is needed if the corrections are required in real-time and at least four satellites in the view at both reference station and the rover. The absolute accuracy of the rover's computed position depends on the absolute accuracy of the base station's position.

Since the satellites orbit high above the earth, the propagation paths from the satellites to the base stations and the rovers pass through the similar atmospheric conditions, as long as the two are not too far apart. DGNSS works very well with base-stations to rovers' separation with up to tens of kilometers (C. Jeffry, 2010).

Among all GNSS augmentation and enhancement techniques, differential GNSS was the first to be developed and applied. Now, it is widely used by navigation users all over the world. Nowadays, almost all commercial GPS units, even handheld ones, offer DGPS data inputs. To some degree, a form of DGPS is now a natural part of most GPS operations (Wikipedia). But it isn't just with GPS; all GNSSs can use this technique.

2.8 Nationwide DGNSS Systems

There are many operational DGNSSs in use throughout the world; according to the US Coast Guard, 47 countries operate systems similar to the US NDGPS (Nationwide Differential Global Positioning System). There are some significant examples of DGNSS systems by country/countries:

- **The United States**

The first DGNSS system was developed by the United States Coast Guard, called firstly DGPS and that has evolved to the US NDGPS (Nationwide Differential Global Positioning System). The United States Department of Transportation, in conjunction with the Federal Highway Administration, the Federal Railroad Administration and the U.S. National Geodetic Survey appointed the U.S. Coast Guard as the maintaining agency for the U.S. Nationwide DGPS network. The system is an expansion of the previous Maritime Differential GPS (DGPS) which the Coast Guard began in the late 1980s and completed in March 1999. DGPS only covered coastal waters, the Great Lakes, and the Mississippi River inland waterways, while NDGPS expands this to include complete coverage of the continental United States. The centralized Command and Control unit is USCG Navigation Center, based in Alexandria, VA.The USCG has carried over its NDGPS duties after the transition from the Department of Transportation to the U.S. Department of Homeland Security. There are 82 currently broadcasting NDGPS sites in the US network (Wikipedia)

- **Canada**

The Canadian system is similar to the US system and is primarily for maritime usage covering the Atlantic and Pacific coast as well as the Great Lakes and Saint Lawrence Seaway. It has been developed by the Canadian Coast Guard and it also overlaps US DGPS coverage of contiguous waters (Wikipedia)

- **Australia**

Australia runs two DGPS systems: one is mainly for marine navigation, run by the Australian Maritime Safety Authority, broadcasting its signal on the longwave band; the other is used for land surveys and land navigation, and has corrections broadcast on the Commercial FM radio band (Wikipedia)

- **European DGPS Network**

The European DGPS network has been mainly developed by the Finnish and Swedish maritime administrations in order to improve safety in the archipelago between the two countries. In the UK and Ireland, the system was implemented as a maritime navigational to fill the gap left by the demise of the Decca Navigator System in 2000. With a network of 12 transmitters sited around the coastline and three control stations, it was set up in 1998 by the countries' respective General Lighthouse Authorities (GLA) - Trinity House covering England, Wales and the Channel Islands, the Northern Lighthouse Board covering Scotland and the Isle of Man and the Commissioners of Irish Lights covering the whole of Ireland. Transmitting on the 300 kHz band, the system underwent testing and two additional transmitters were added before the system was declared operational in 2002. In Germany SAPOS is the DGPS service operating more than 120 stations nationwide. Similar services exist in Austria, Switzerland, France, Spain and other European countries (Wikipedia)

3.1 Methodology & Research Planning

To achieve the goals of the thesis, the researcher used the descriptive research methodology. For this reason Sudan's political map was used. The researcher tried to sub-divide the map to determine points with pre-determined set of characteristics and certain criteria. However, there is no tool within the software that has such capabilities. The points that could be inserted to the map through the software could only be random points.

To have a set of points with certain criteria, such as distance and radius, we have to use GPS devices. The researcher had no access to such hardware, so another solution had to be found through the use of shape files for the Nile River, Sudan map and northern state boundary.

3.2 The Study Area

Northern (Arabic: الشمالية Aš Šamāliya) is one of the 18 wilayat or states of Sudan. It has an approximated area of 348,765 km², the biggest state, and an estimated population of 833,743 (2008). Dongola is the capital of the state. The town of Wadi Halfa, the headquarters of the British colonialist in the late nineteenth century, is located in the north of the province. The state has a total of seven localities. Theother towns(localities) include Merowe, Karima, Al-Dabbah and Dongola (Wikipedia).

Northern Sudan was in ancient times Nubia which goes back in history to thousands of years. It was famous for its many different civilizations and kingdoms.

Jebel Uweinat is a mountain range in the area of the Egyptian-Libyan-Sudanese border. The state has international boundaries with Egypt from the northern side and Libya from the north-west side. It also has local boundaries with the River Nile state from the eastern side, Northern Darfur state from the north-west side and from the southern side with Khartoum and Northern Kordufan state.

The River Nile runs through the whole state starting from the boundary with Khartoum state. It's 650km long journey to Egypt to the north. The majority of the population lives at the river banks because they are mostly farmers.

Figure 3.1: The Testbed

3.3 Methodology

In order to achieve the goals of this thesis we are using geographical planning and analyzing tools. The all-in-one solution is a Geographical Information System, in short GIS. In the following the main features of a GIS are outlined.

3.3.1 Geographical Information Systems - What is GIS?

- Definition 1: A GIS is a toolbox

"a powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes" (P. Burrough, 1986).

" an automated systems for the capture, storage, retrieval, analysis, and display of spatial data" (Clarke, 1995).

- Definition 2: A GIS is an information system

"An information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data (Star and Estes, 1990).

Collect, organize and relate spatial and non-spatial data , is what GIS is all about

- Measure and calculate variables in a 'spatially sensible' fashion
- Make inferences and test hypotheses about relationships that might have spatial structure, and about the spatial structure itself.

3.3.2 Benefits of GIS

- Automated map making and updating.
- Providing a unified database.
- Linking location and descriptive attributes of feature(s).
- Manipulating & analyzing Geographic Information in ways that not possible manually.
- Higher accuracy, higher costs.

Note:

- Data preparation, and data collection, in any GIS project is about 80% of time and cost of consuming.
- Requires data in high accuracy.

3.3.3Elements of Geographic information

There are four fundamental types of geographic representations:

- Features (collections of points, lines, and polygons)
- Attributes
- Imagery
- Continuous surfaces (such as elevation)

- **Features - Points, lines, and polygons**

- Points define discrete locations of geographic features too small to be depicted as lines or areas, such as well locations, telephone poles, and stream gauges. Points can also represent locations such as address locations, GPS coordinates, or mountain peaks.

- Lines represent the shape and location of geographic objects too narrow to depict as areas (such as street centerlines and streams). Lines are also used to represent features that have length but no area such as contour lines and administrative boundaries. (Contours are interesting, as you'll read later on, because they provide one of a number of alternatives for representing continuous surfaces.)

- Polygons are enclosed areas (many-sided figures) that represent the shape and location of homogeneous features such as states, counties, parcels, soil types, and land use zones. In the example below, the polygons represent parcels.

3.3.4 Maps

A map is a collection of map elements laid out and organized on a page. Common map elements include the map frame with map layers, a scale bar, north arrow, title, descriptive text, and a symbol legend. A map can be organized by superimposing several layers, depicted in Figure 3.2.

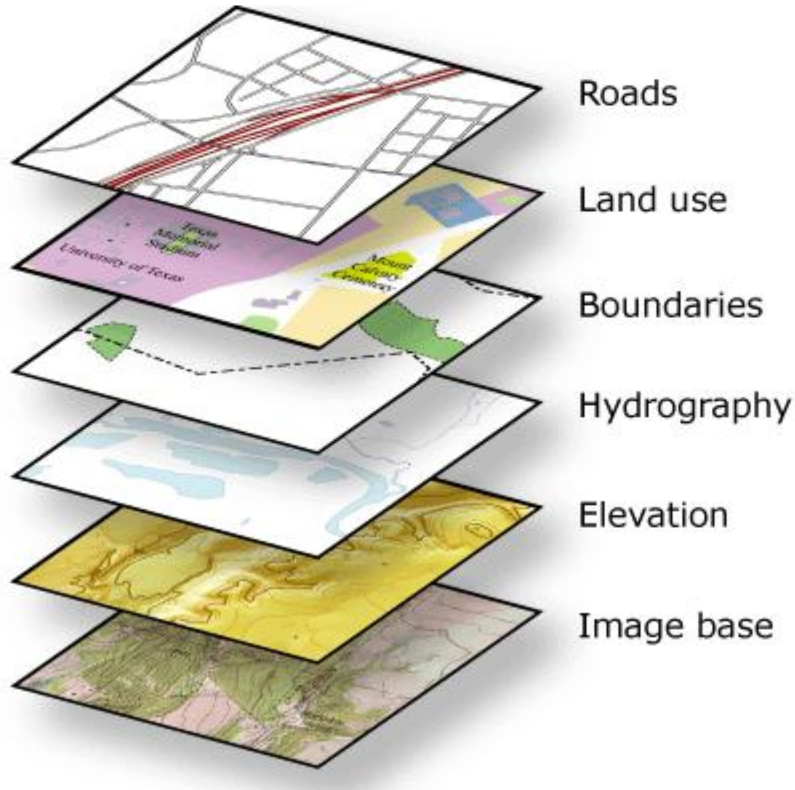


Figure 3.2. The map layer principle

Geographic databases as such consist of spatial and non-spatial data with complex data structures used for complex analysis.
Using the Esri ArcGIS software which is using three core “workhorse” programs

- ArcCatalog
- ArcMap
- ArcToolbox
-

3.3.5 Data Sources of GIS

- Photogrammetry

Photogrammetry is the science making 2D, 2.5D and 3D object reconstructions using aerial and close range photographs and techniques for making accurate measurements from them. Photogrammetry is the source of most data on topography (ground surface elevations) used for input to GIS.

- **Surveying**

Provide high quality data on positions of land boundaries, buildings, etc. using baseline surveying, levelling, theodolites and Total Stations.

- **Geodesy**

Is the source of high accuracy positional control for GIS, using satellite gravimetry and terrestrial gravimetry as well as geodetic engineering methods.

- **Statistics**

Many models built using GIS are statistical in nature; many statistical techniques are used for analysis. Statistics are important in understanding issues of errors and uncertainty in GIS data.

- **GPS**

By using GPS devices we can create points in real world, and calculate the distance with certain techniques then to add them in the GIS system as data.

3.3.6 Shape files

Shape files are the data format once introduced by Esri as. a standard for vector data. In the following we will mainly work with Shape files

In more detail a shape file is a group of files having the same prefix but varying file extensions).

- **Required:**

.shp - the file that stores the feature geometry.

.shx - the file that stores the index of the feature geometry.

.dbf - the dBASE file that stores the attribute information of features.

- **Optional:**

.sbn and .sbx - the files that store the spatial index of the features.

.prj - the file that stores the coordinate system and projection information

.xml - metadata for using shapefiles on the Internet.

.fbn and .fbx – read-ony indexes.ain and .aih - active field indexes.

3.3.7 GIS Data Types

- Vector

Points represented in pairs of (x,y)coordinates. A line is a set of point coordinates to form polylines. Polygons are sets of coordinates defining boundaries that enclose areas. Example for points, lines and polygons are given in Figure 3.3.

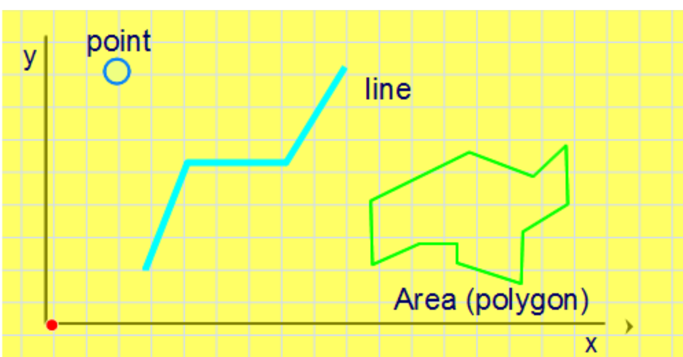


Figure 3.3: Vector Data Types

- **Raster**

In the raster model, the world is represented as a surface that is divided into regular grid of cells (see Figure 3.4).

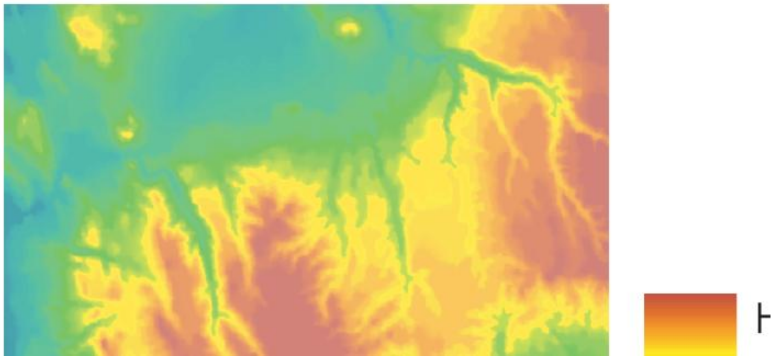


Figure 3.4: Raster Data Types

A special case of spatial data organization is a TIN (Triangulated Irregular Network)

A TIN is used quite often to regionalize elevation points. These are connected by lines to form polygons that contain topographic information (see Figure 3.5).

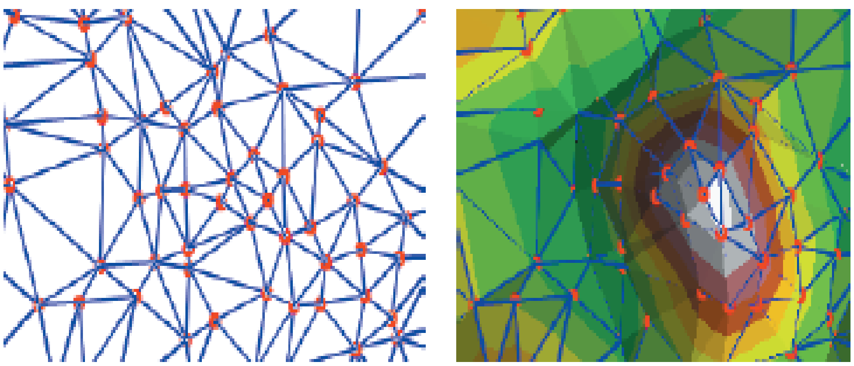
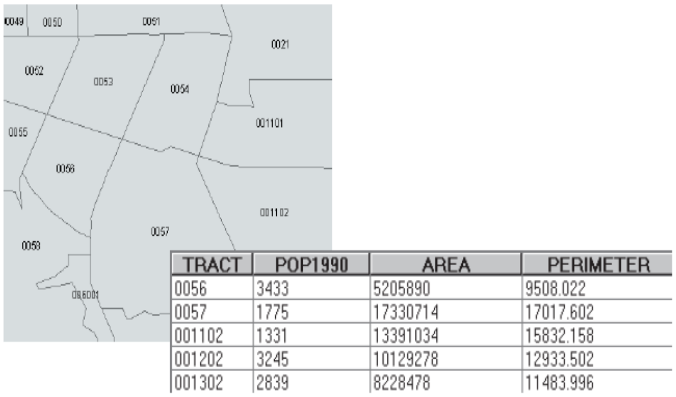


Figure 3.5: Raster Data Types

- **Tabular Information (attribute table)**

These are the columns and rows that hold the data about the feature (see Figure 3.5)



TRACT	POP1990	AREA	PERIMETER
0056	3433	5205890	9508.022
0057	1775	17330714	17017.602
001102	1331	13391034	15832.158
001202	3245	10129278	12933.502
001302	2839	8228478	11483.996

Figure 3.6: Tabular Data Types

3.3.8 Types of Geo-Databases

A geo-database which uses an object-relational database approach for storing spatial data. A geo-database is a "container" for holding datasets, tying together the spatial features with attributes. The geo database can also contain topology information, and can model behavior of features, such as road intersections, with rules on how features relate to one another. When working with geo databases, it is important to understand about feature classes which are a set of features, represented with points, lines, or polygons. With shape files, each file can only handle one type of feature. A geo database can store multiple feature classes or type of features within one file.

Geo databases in ArcGIS can be stored in three different ways including:

- **File Geo-database**

File geo database stores information in a folder named with a gdb extension. The insides look similar to that of coverage but is not, in fact, a coverage. Similar to the personal geo database, the file geo database only supports a single editor.

- **Personal Geo-database**

Personal geo database, there is virtually no size limit. By default, any single table cannot exceed 1TB, but this can be changed. Personal geo-databases store data in Microsoft Access files, using a BLOB field to store the geometry data. The OGR library is able to handle this file type, to convert it to other file formats. Database administration tasks for personal geo databases, such as managing users and creating backups, can be done through ArcCatalog. Personal geo databases, which are based on Microsoft Access, run only on Microsoft Windows and have a 2 gigabyte size limit.

3.3.9 Feature classes

Each feature class in the geo-database is a collection of geographic features with the same geometry type (point, line, or polygon), the same attributes, and the same spatial reference. Feature classes can be extended as needed to achieve a number of objectives. Table 3 shows some of the ways that users extend feature classes using the geo-database and why.

Table 3.1: Working with Feature Classes in the Geodatabase

Use:	**If you need to:**
Feature Dataset	Hold a collection of spatially related feature classes or build topologies, networks, and terrains.
Subtypes	Manage a set of feature subclasses in a single feature class. This is often used on feature class tables to manage different behaviors on subsets of the same feature types.
Attribute Domains	Specify a list of valid values or a range of valid values for attribute columns. Use domains to help ensure the integrity of attribute values. Domains are often used to enforce data classifications (such as road class, zoning codes, and land-use classifications).
Relationship	Build relationships between feature classes and other tables

Classes	using a common key. For example, find the related rows in a second table based on rows selected in the feature class and so on.
Topology	Model how features share geometry. For example, adjacent counties share a common boundary. Also, county polygons nest within and completely cover states.
Network Dataset	Model transportation connectivity and flow. (Must have Network Analyst installed to use)
Geometric Network	Model utilities networks and tracing.
Terrain	Model triangulated irregular networks (TINs) and manage large lidar and sonar point collections.
Address Locator	Geocode adressess.
Linear Referencing	Locate events along linear features with measurements.
Cartographic Representations	Manage multiple cartographic representations and advanced cartographic drawing rules.
Versioning	Manage a number of key GIS workflows for data management, for example, support long update transactions, historical archives, and multiuser editing.

3.3.10 Spatial Analysis

Spatial analysis or spatial statistics includes any of the formal techniques which study entities using their topological, geometric, or geographic properties. The phrase properly refers to a variety of techniques, many still in their early development, using different analytic approaches and applied in fields as diverse as astronomy, with its studies of the placement of galaxies in the cosmos, to chip fabrication engineering, with its use of 'place and route' algorithms to build complex wiring structures. The phrase is often used in a more restricted sense to describe techniques applied to structures at the human scale, most notably in the analysis of geographic data. The phrase is even sometimes used to refer to a specific technique in a single area of research, for example, to describe geo statistics.

3.3.11 Coordinate System Definition

Coordinate systems enable geographic datasets to use common locations for integration. A coordinate system is a reference system used to represent the locations of geographic features, imagery, and observations, such as Global Positioning System (GPS) locations, within a common geographic framework.

3.3.11.1 Importance of the coordinate system

- Creating spatial data (collecting GPS data).
- Import into GIS and overlay with other layers.
- Acquiring spatial data from other sources.
- Display GPS data using maps.

3.3.11.2 Types of coordinate system

There are two types of coordinate systems.

- **Geographic coordinate system**

  Coordinate systems identify locations by making measurements on a framework of intersecting lines that resemble a net.

  Latitude (f) and Longitude (l) defined using an ellipsoid, which is an ellipse rotated about an rotation axis. The elevation (z) is defined using a geoid, a surface of constant gravitational potential. The earth datum's define standard baseline values of the ellipsoid and geoid.

- **Projected coordinate systems (Cartesian)**

  The projected coordinate system is a Cartesian coordinate system with an origin, a unit of measure (map unit), and usually a false easting or false northing.

  A map projection is the systematic transformation of locations on the earth (latitude/longitude) to planar coordinates.

  Projected coordinate systems are used in conjunction with a specific map projection. Each projected coordinate system depends, among other factors, on the map projection that is being used to project points from the Earth's surface to a plane.

3.3.12 ArcGIS Desktop

With the ArcGIS 9.3 release, ESRI has implemented many of your enhancement requested and addressed a significant number of common technical support issues to help make users more productive.

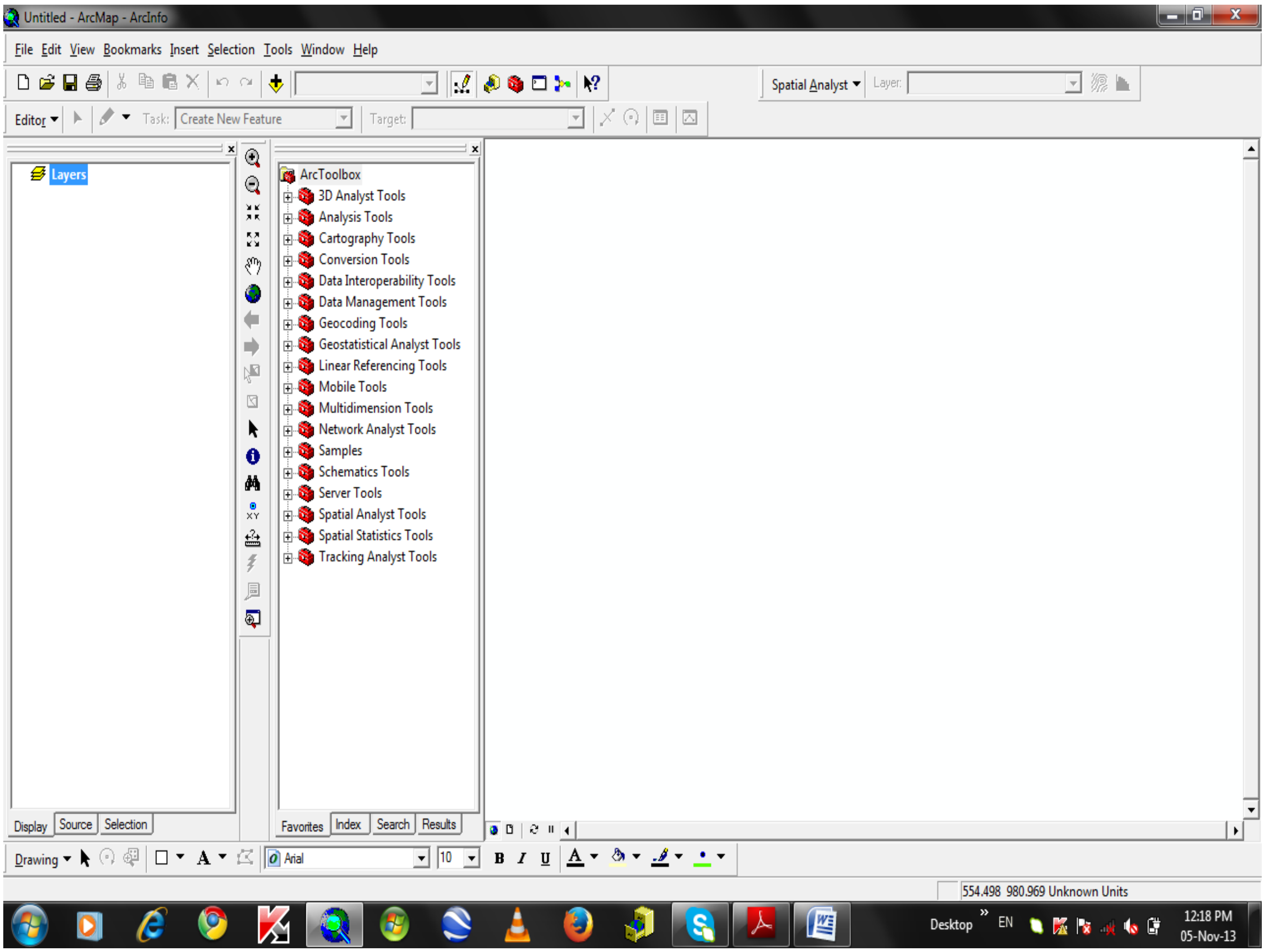


Figure 3.7: Interface for ArcGIS

ArcGIS 9 includes scripting support for many of today's most popular scripting environments, such as Python, VBScript, JScript, and Perl. A new ArcObjects component, the geo-processor, manages all the geo-processing functions available within ArcGIS. It is an object that provides a single access point and environment for the execution of any geo-processing tool in ArcGIS, including extensions. The geoprocessor implements automation via a coarse-grained scripting object. This scripting object can be created in three different ways at 9.3:

i. Using the native arcgisscripting module, setting a 9.3 version

```
import arcgisscripting

gp = arcgisscripting.create(9.3)
```

ii. Using the native arcgisscripting module

```
import arcgisscripting

gp = arcgisscripting.create()
```

iii. Using COM IDispatch interface

```
import win32com.client

gp = win32com.client.Dispatch("esriGeoprocessing.GpDispatch.1")
```

We are going to use geo-scripting.

The geo-processor makes it possible for interpretive and macro languages to access the more than 500 available tools.

Although there are a number of good scripting languages available, for simplicity, three of the more popular languages that meet the necessary criteria—VBScript, JScript, and Python—are discussed. VBScript and JScript are familiar to many people and are relatively simple languages. Similar to Visual Basic and C, they are designed to operate in a Windows environment. Python is an easy-to-learn language similar to C. Python has the ease of use of a scripting language, along with the programming capabilities of a complete developer language. Moreover, Python is platform independent and can operate on a variety of operating systems including UNIX, Linux, and Windows.

3.3.13 Geo-processing

Geo-processing is a GIS operation used to manipulate spatial data. A typical geo-processing operation takes an input dataset, performs an operation on that dataset, and returns the result of the operation as an output dataset. Common geo-processing operations include geographic feature overlay, feature selection and analysis, topology processing, raster processing, and data conversion. Geo-processing allows for definition, management, and analysis of information used to form decisions. Mainly it's the use of the tools to simplify the task of executing geo-processing tools.

3.3.13.1 The geo-processor contains properties and methods which make it possible to:

i. Execute tools.
ii. Set global environment settings.
iii. Examine the resulting messages.

3.3.13.2 Geo-scripting:

It's the native program language-module, this module is used to create the geo-processor. The module works on any platform

3.3.14 Models and tools:

Models are stored as tools in toolboxes.
Toolboxes may be stored in a folder as a .tbx file or in a geo-database
Toolboxes may be easily shared by sharing the .tbx file or a personal geo-database.

4.1 System requirements:

A Geographical information system is mostly maps and complex data processing. All three types of data (vector, raster or tabular) used in GIS require particular hardware requirements. Though technology has advanced tremendously, to be able to work comfortably with GIS software you have to have a device with high processing power and RAMs. Most data in GIS have all three data types combined.

For the project implementation Sudan's political map was used. A shape file representing the Nile River was also used. The shape file had to be processed to adjust it for proper use.

The lowest hardware requirements for running the system and checking the Maps are as given below (table 4).

Table 4.1: System Requirements:

	ArcInfo, ArcView, ArcEditor ,ArcMap , ArcCatalog
CPU Speed	1.6 GHz recommended or higher
Processor	Intel Core Duo, Pentium 4 or Xeon Processors
Memory/RAM	1 GB minimum, 2 GB recommended or higher If using the ArcSDE Personal Edition for Microsoft SQL Server Express software, 2 GB of RAM is required.
Display Properties	24 bit color depth
Screen Resolution	1024 x 768 recommended or higher at Normal size (96dpi)
Swap Space	Determined by the operating system, 500 MB minimum.
Disk Space	3.2 GB In addition, up to 50 MB of disk space maybe needed in the Windows System directory (typically C:\Windows\System32). You can view the disk space requirement for each of the 9.3 components in the Setup program. If using ArcGlobe (as part of 3D Analyst), additional disk space

	may be required. ArcGlobe will create cache files when used.
Video/Graphics Adapter	24-bit capable graphics accelerator An OpenGL 1.3 or higher compliant video card is required, with at least 32 MB of video memory, however 64 MB of video memory or higher is recommended.
Networking Hardware	Simple TCP/IP, Network Card or Microsoft Loopback Adapter is required for the License Manager.
Media Player	DVD-ROM drive is required to install the application.

4.2 System description:

As mentioned earlier, achieving the initial goals and aims of the project required the use of hardware, namely GPS devices. Since the equipment were not available, another solution had to be found.

The project scope was reduced to only one state, the Northern state. The state boundary was clipped from the rest of the map to set anew scope for the project covering only the Northern state.

A new shape file that represents the Nile was added. Since the Nile has more than one path, a new feature class in a form of a line had to be created. This meant that some features were not to be considered, however this isn't a problem since they fall within the radius of the points.

After finishing the reconstruction of the line representing the shape file of the river, it had to be divided to points. This was achieved through the use of "construct points" which is part of the "create feature" tool within the software. This function allows us to define and chose the criteria based on which the points are to be constructed.

The environment was set and the criteria were determined then the software was run for the first time. The results were recorded and observations were made. It generated a certain number of points then the XY coordinates of these points were calculated also by using ArcMap.

The criteria changed and another execution was made. This generated a new set of points and the XY coordinates were calculated to these points also.

The process continued again and again eventually some results were taken as the outcome for the study.

The basic criterion was the radius and the distance between each set of two distinct points. This radius was assumed to be equivalent to the radius of the coverage most common ground stations provide. The assumption was that, having ground stations equal to the number of points generated will provide full coverage to the whole target area.

The following diagram shows the analysis of the system and how it works. The system has two main users. The first is the regular user, could be an employee or a government official. The user has the ability to do only things. Ha can view existing maps or re-run the system with the same pre-determined criteria and generate maps to show

The second user is the admin or the GIS engineer. Plus the privileges of the regular user, he also has the authentication to change and alter the criteria of the system. The points generated are radius bound. Meaning that if we changed the radius, the positions and hence the coordinates of these points changes. Even the number of reference stations, since they are determined by the number of points, will also change.

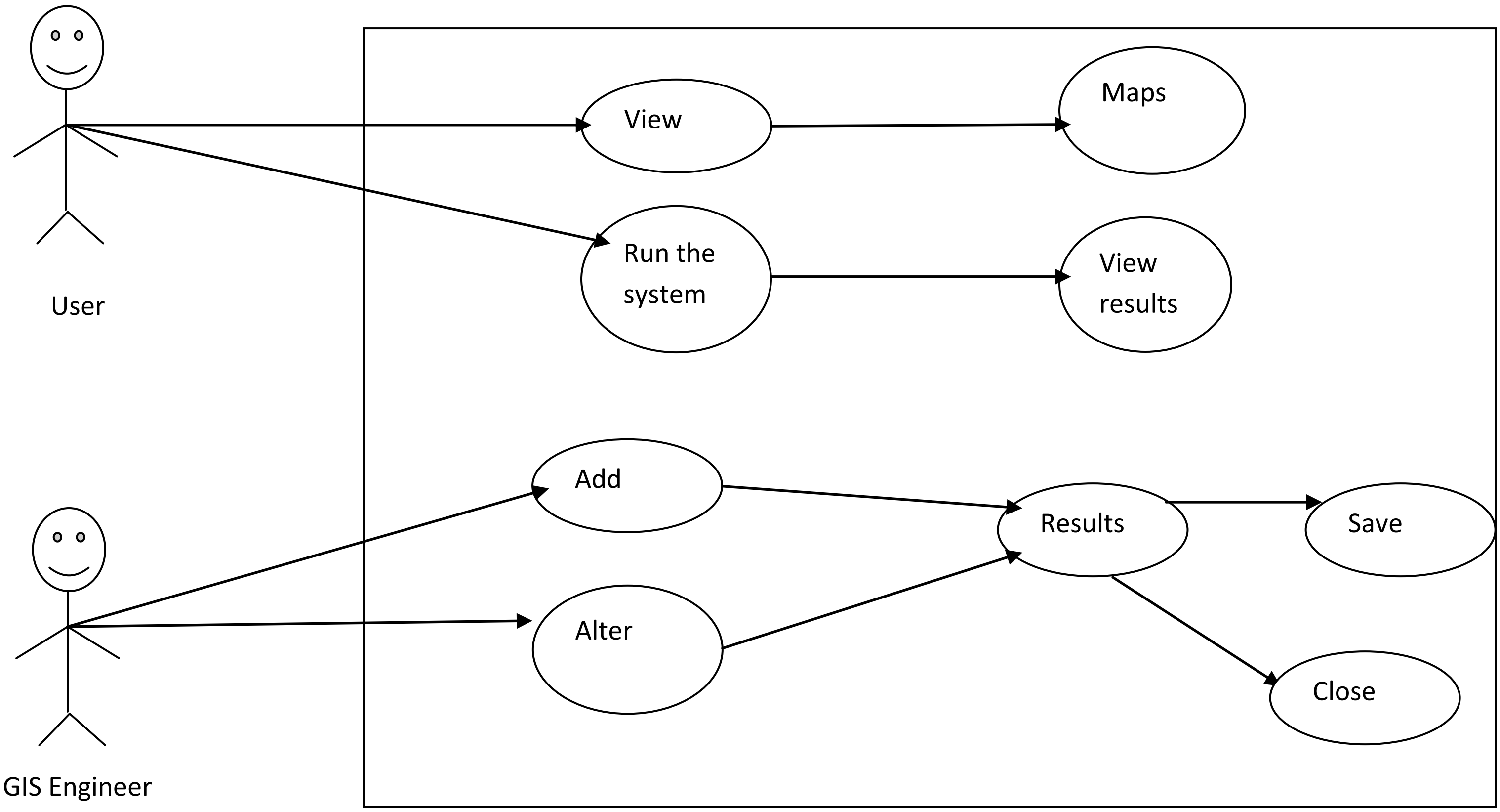


Figure 4.1: Use Case diagram

5. Methodology Implementation and Results

To determine the approximated points which represent suggested locations for the Differential GNSS fixed stations, more than one group of points was found.

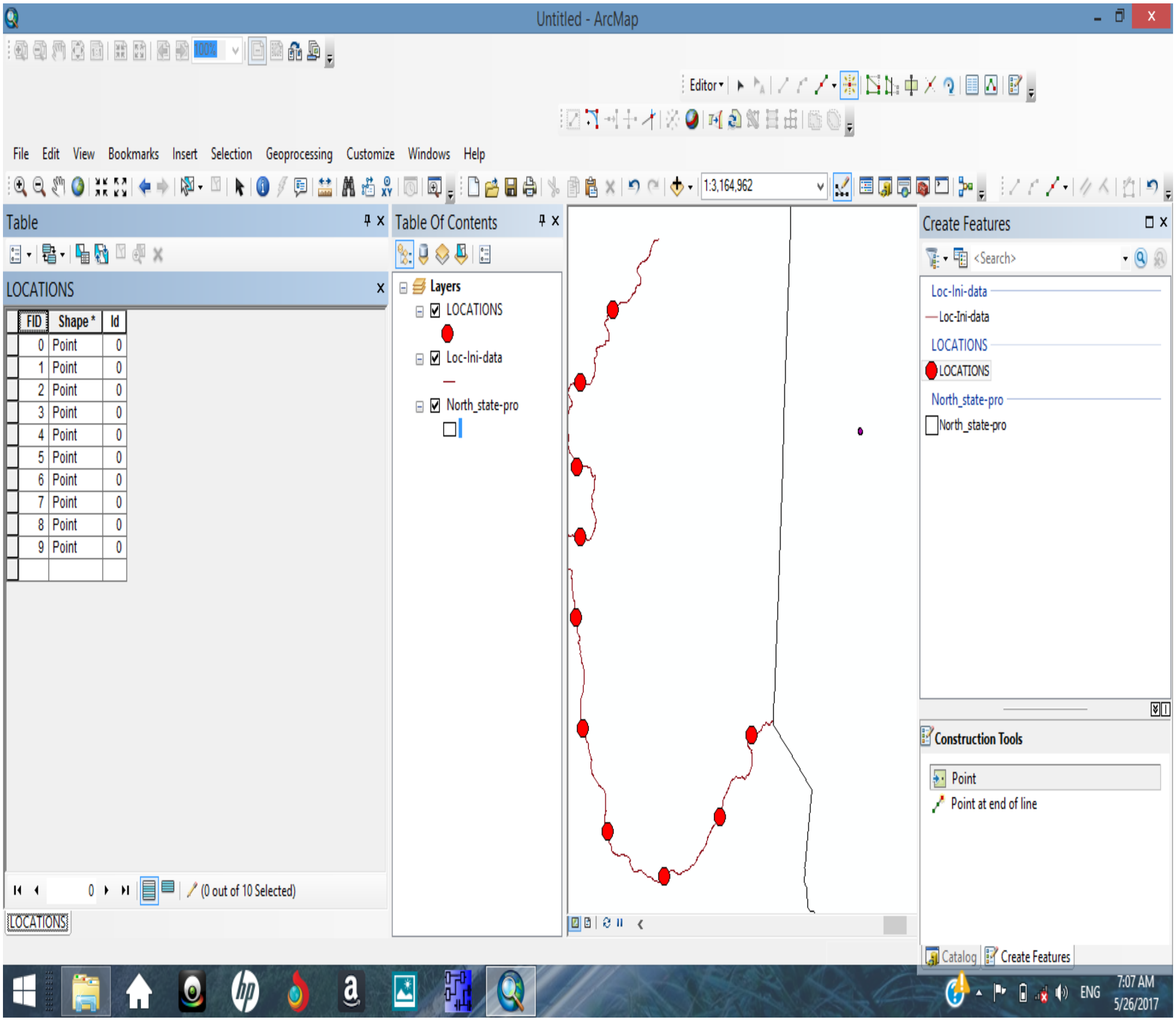
Within the ArcMap software there is a tool called “Editor”. This editor provides the ability to redesign any given shape file as required using some functions. One of these functions is called” construct points”. It allows us to divide a given line into points according to pre-determined characteristics. To determine the points, the shape file (a line representing the river Nile that goes through the whole state) was inserted to the ArcMap and was then divided many times to get the points according to their distances from each other.

There is also to create points by “Number of points” or by “Measure” as construction options that could be used. It also allows you to determine from where does the construction of points’ starts through what’s called the orientation. It also gives the ability of determining the template that will contains the generated points.

Since the locations we wanted to determine are based on the distance that separates them from one another, “distance” was used as the construction option.

The first set of points was generated so that each point is 50km far from the other. This generated 10 points in total. These means that if we are using reference stations that cover a radius of 50km, we need 10 stations to have the whole state covered (see figure 5.1).

Figure 5.1: Selection of reference station for Differential GNSS with 50km distance.



After these points were determined, their precise locations were calculated. This was achieved through the use of ArcMap capabilities, namely "calculate geometry", which is a function that is used to calculate the exact X and Y coordinates of any given points.

The final table of points and their corresponding geometrical coordinates are given in the below table 5.1.

figure5.2: X, Y coordinates for Locations of the Reference Stations with 50km distance

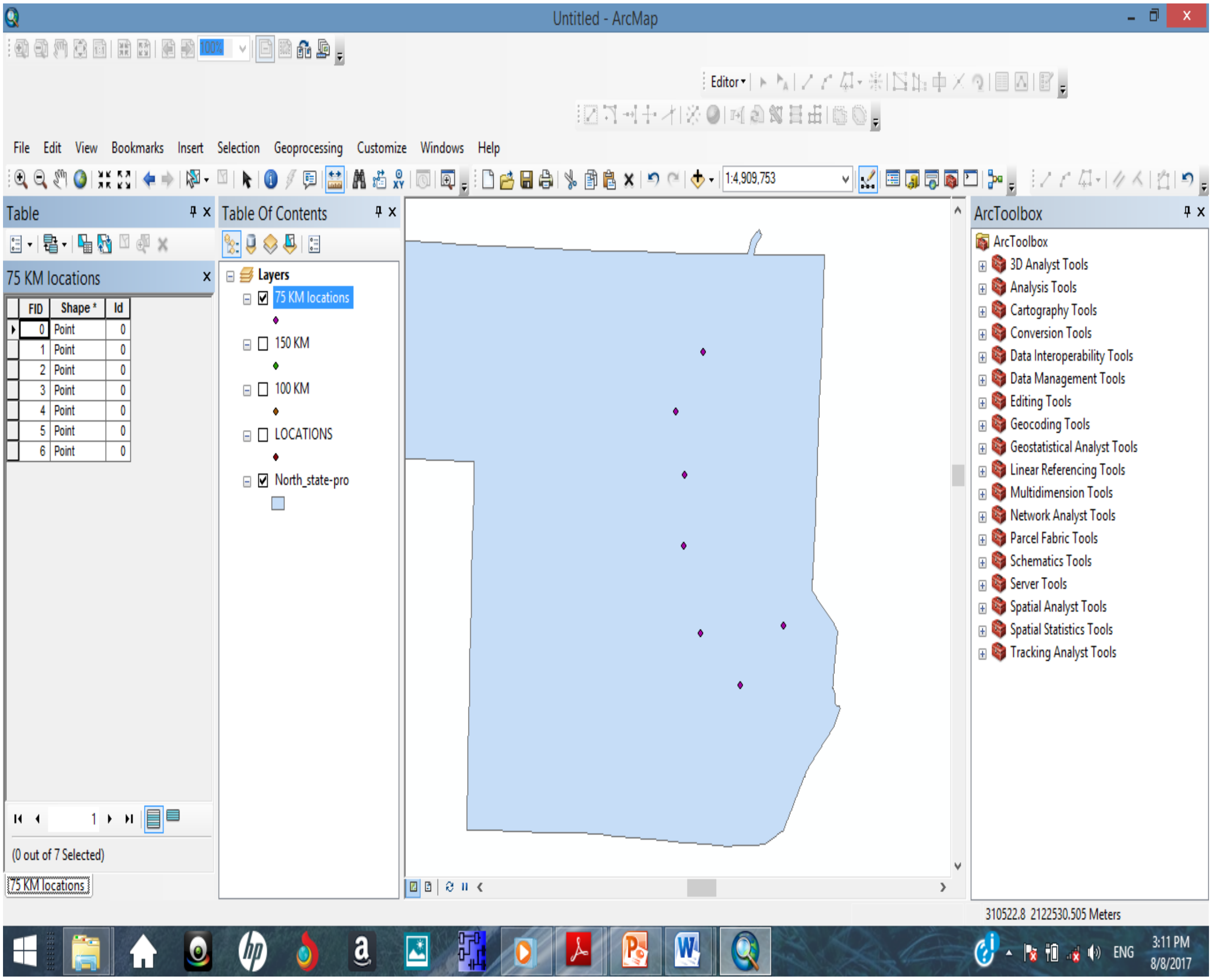
LOCATIONS

FID	Shape *	Id	x__coordin	Y__coordin
0	Point	0	264988	2351610
1	Point	0	233469	2305510
2	Point	0	230111	2251990
3	Point	0	233270	2207020
4	Point	0	228964	2156580
5	Point	0	235594	2086190
6	Point	0	259570	2020330
7	Point	0	315361	1991850
8	Point	0	369868	2029790
9	Point	0	400534	2081490

Through the use of the above coordinates, the precise location of each of the ten points could be located and determined then its geographical features could be evaluated and surveyed.

The second set of points were set so that the interval and the distance between each two points is75km. This has generated 7 points. This means that the number of required reference stations grew lesser from 10 to 7 stations for covering the whole state. In contrast the radius of coverage has grown to 75km (see figure 4.2).

Figure 5.3: Selection of reference station for Differential GNSS with 75km distance.



After the points were determined, the exact X and Y geometrical coordinates of the seven points were calculated. Through the use of GPS technology, these locations could easily be accessed and determined.

The Table 4.2 below gives the seven points and their XY coordinates.

figure5.4: X, Y coordinates for Locations of the Reference Stations with 75km distance

able

5 KM locations

FID	Shape *	Id	X_coordina	Y_coordina
0	Point	0	260832	2333210
1	Point	0	221327	2271760
2	Point	0	233270	2207020
3	Point	0	232544	2133950
4	Point	0	257146	2044160
5	Point	0	315361	1991850
6	Point	0	379700	2052130

These two sets of points give approximated locations where the reference stations for the GNSS could be set. They locations assume the existence of base (reference) stations that can cover areas of the radiuses 50 and 75kms respectively. The radiuses could also be adjusted and the system could be rerun again to determine new locations accordingly.

6.1 Conclusions

The project was set initially to determine locations in a form of points throughout the whole map of the country where reference stations for the differential global navigational satellites system for the Sudan could be placed. This is considered one of the highest technological projects that the whole world is heading towards implementing. Through this DGNSS location, navigational services of higher quality could be provided. The availability of such services has become indispensable in today's world plus the other services that GNSS provides in different fields.

As the project was being implemented, a couple of facts emerged. One of these facts is that achieving the initial project objectives through the use of ArcMap only is not possible. ArcMap does not have the capabilities to allow the determination and insertion of points to a map based on pre-determined conditions such as distance and radius.

The solution that the researcher had come up with is partial. The project scope was reduced to only one state, the Northern state. The selection of this state was because for many reasons. The availability of data was one of the main reasons.

The population and major cities of the state fall within the same range and area. They are all on the banks of the Nile River. This is the new scope and area that the project has covered.

The new solution to the issue took a shape file of the River and through the use of ArcMap tools and functions was able to construct points from the shape file which was in a form of a line shape file. The XY coordinates for each set of points were calculated to precisely determine the locations of the points which are the suggested locations for the differential ground stations.

The number of required reference(ground) stations is usually determined by more than one factor. These factors include; the size of the area; the desired quality of services required and the ground stations that are going to be used. The radius of coverage is different for the ground stations in general from the manufacturers. Because of this fact, the researcher had found different set and groups of points.

Each of these groups has a different radius and different distances between each two consecutive points.

One very important fact to be considered is that there are huge parts of areas within the state that are not included. This is due to the fact that they are far from the river banks therefore they are not inhabited. These areas are mostly desert areas falling to the north-western parts at the local borders with northern Darfur state and international border with Libya.

Overall, the project's goals were not met as adequate and precise as they were stated. As mentioned earlier, it was supposed to cover all Sudan but later the scope had to be reduced to only one state out of 18. This has happened because of the lack of data and hardware equipment.

6.2 Recommendations

If another project that falls within the same line is to be carried out and implemented, we suggest a smaller scope and the use of hardware, namely GPS devices. The data is a huge problem when implementing a project in GIS. The data used in GIS require lots of processing and preparation before they are to be used. Internationally, there companies that are specialized in collecting, preparing and selling geographical data used in GIS. Unfortunately, this is not the case in Sudan. Most of the data are not available. Even the available ones are really hard to get. The field is mainly government owned and they consider these data state owned and national security issues.

Another suggestion would be acquiring a reference station and running a couple of experiments with and without a reference station. This would vividly show the differences in the accuracy of the results and hence the importance of differential global navigational satellite system (DGNSS) to all applications and services.

Acquiring the data ahead before starting project execution makes a huge difference. This study was to include the cities, settlements and many other geographical features if were available.

The GIS software (Arc Map) does not include a tool for inserting points into a map based on pre-determined conditions. I would suggest developing a tool for achieving such tasks as it will enhance and make planning and experimental studies of such type easy and credible.

6.3 List of references:

[1] Charles Jefrry(2010). “ An introduction to GNSS.

[2] Tomlinson, Roger F. (2003). "Thinking about GIS: Geographic Information System, Planning for Managers". Esri.p. 144.

[3] Amin Jamal, Riyanartosarno and Hari Ginardi, "Analyzing the benefit of implementing integrated DGPS and terminal operating system at yard terminal Surabaya", InstitutTeknologiSepuluhNopember, Surabaya Indonesia, February 2017.

4] Dr. G. ManojSomeswar, T. P. Surya Chandra Rao, DhanunjayaRao.Chigurukota, "Global Navigation Satellite Systems and Their Applications",International Journal of Software and Web Sciences (IJSWS).

[5]Arun Patel *, S.K. Katiyar, Vishnu Prasad, “Performances evaluation of different open source DEM using Differential Global Positioning System (DGPS)”, Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal 462051, M.P., India, 2015.

[6] S. BangaruBabu, A. V. Kulkarni, ParijatKishan Vats and Dinesh Gupta, “Deployment of differential global positioning system in regional gravity surveys”,CURRENT SCIENCE, VOL. 111, NO. 11, 10 DECEMBER 2016.

[7] Satish Mittal, MX Marine Leica Geosystems Inc., Torrance Ajay Seth, Elcome Technology Inc., New Delhi and P.P.Sinha, DGLL, India, “Indian Beacon DGPS Broadcasting Stations Network”,

[8] Mohsen Rohani, Denis Gingras, and Dominique Gruyer,“A Novel Approach for Improved Vehicular Positioning Using Cooperative Map Matching and

Dynamic Base Station DGPS Concept”, IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS,2015

[9] Abdel-Monem S. Mohamed a, Ali M. Radwan a,*, Mohamed Sharf b, ZakariaHamimi b, Esraa E. Hegazy b, Nadia Abou Aly a, Mahmoud Gomaa ,“Evaluation of the deformation parameters of the northern part of Egypt using Global Navigation Satellite System (GNSS)”, NRIAG Journal of Astronomy and Geophysics,2016

[10] P. Steigenberger1, O. Montenbruck1, “Multi-GNSS Working Group Technical Report”, 2016.

[11] Aleksander Nowak, ”Dynamic GNSS Mission Planning Using DTM for Precise Navigation of Autonomous Vehicles”, THE JOURNAL OF NAVIGATION, 2017

[12] Xidong Yu and Jingxiang Gao,” Kinematic Precise Point Positioning Using Multi-Constellation Global Navigation Satellite System (GNSS) Observations”, School of Environment Science and Spatial Informatics, China University of Mining and Technology, 2017.

[13] RigasThemistoklis Ioannides, Thomas Pany, and Glen Gibbons ,“Known Vulnerabilities of Global Navigation Satellite Systems, Status, and Potential Mitigation Techniques”,2016.

[14] Wenwu Ding, Felix Norman Teferle, KamilKaźmierski, Denis Laurichesse, Yunbin Yuan ,”An evaluation of real-time troposphere estimation based on GNSS precise point positioning”, American Geophysical Union, 2017.

[15]SafaaDawoud, “GNSS principles and comparison”, Potsdam university,2014

“GNSS principles and comparison”, Potsdam university,2014