Using GIS for Analysis of the Runway Extension of Margaret Ekpo International Airport, Calabar, Nigeria

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Abstract

This study investigates the proposed extension of the existing runway of Margaret Ekpo International Airport, Calabar, Cross River State, Nigeria. The process involves the application of Geographic Information System (GIS) and several geospatial techniques for analysis and result presentation.

The aim of the study was achieved with the following resources: satellite imagery downloaded from the Landsat webpage and processed to generate a land use map of the study area; a Digital Elevation Model (DEM) covering the study area which was downloaded from the Consortium for Spatial Information’s (CSI) webpage and observed ground spot heights along the straight path of the proposed runway extension covering a total length of 2.5km and 200m wide. These datasets were modified, processed and assigned the same coordinate system in order to make them conformal for analysis. A GIS was created with the foregoing resources in conjunction with other geospatial applications such as ERDAS Imagine and Surfer 8 to carry out the analysis.

The analysis covered the environmental impacts of the proposed project, its effects on already existing human settlements and the huge cost implications based on certain conditions like the mandatory straight path which has to be maintained as an extension of the existing runway. Other factors considered are; the land use of the extension area, the economic benefits of the project, the accessibility of the area, noise pollution as well as the safety and security issues involved.

A summary of the result of our analysis shows features such as residential settlements, roads, swampy areas, valleys and areas of high elevation which will act as obstructions along the proposed runway path. Also, the total surface area of the proposed runway and the volume of earth material required were calculated. The results achieved from this study shows that GIS and other geospatial tools are indispensable resources in complex planning processes such as facility maintenance and management.

Keywords: Runway Extension, GIS, DEM, Environmental impacts, Cost analysis.
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<tr>
<td>AELP</td>
<td>Airport Expansion and Location Problem</td>
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<td>CAD</td>
<td>Computer Aided Design</td>
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<td>CSI</td>
<td>Consortium for Spatial Information</td>
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<td>DEM</td>
<td>Digital Elevation Model</td>
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<td>EIA</td>
<td>Environmental Impact Assessment</td>
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<td>EIS</td>
<td>Environmental Impact Significance</td>
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<td>ESRI</td>
<td>Environmental Systems Research Institute</td>
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<td>FAA</td>
<td>Federal Airports Authority</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>HSE</td>
<td>Health, Safety and Environment</td>
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<td>LCA</td>
<td>Life Cycle Analysis</td>
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<td>SBG</td>
<td>Svensk ByggnadsGeodesi</td>
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<td>SIAM</td>
<td>Spatial Impact Assessment Methodology</td>
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<td>UTM</td>
<td>Universal Transverse Mercator</td>
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<td>WGS</td>
<td>World Geodetic System</td>
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1. Introduction

1.1 Background of the thesis

In 2001, the Cross River State Government of Nigeria made known its intentions to make Cross River State a major tourist destination in Nigeria. Therefore, it embarked on a new Air Survey of the entire state to among other things, identify the potential tourists’ attractions and sites that exist or can be explored in the state. One of the ideas conceived by the state also involves making the state an international trade zone. However, identifying the potentials is one thing, considering the impediments presents some challenges to their exploration and execution.

Then comes a major setback! Investigations show that the capacity of the runway of the only airport in the state is inadequate to receive heavy cargo airplanes such as Boeing 747 which may be used to bring goods directly to the state from outside the country. But the state government was determined to carry out its plans. So, it put into consideration two options. One option was to construct an entirely new airport with large capacity. But this will gulp a huge amount of the state’s finance. Another option, which perhaps may be more acceptable to the decision makers, is to expand the existing airport. The second option was narrowed down to extending and re-stabilising the existing runway by 2,500 metres. Meanwhile, the length of the existing one is 2,451 metres (8,040 feet) of Asphalt with elevation of 64m (210 feet) above mean sea level (Aerospace Management, 2011, Aviation & Africa, Regional Airports).

The foregoing means that if the plan for extending the runway is approved, it will mean that a big and extensive construction work has to be carried out on the existing airport. Likewise, a study of the direction of the existing runway has to be carried out. It also means that certain factors need to be put into consideration. A preliminary investigation shows that two huge valleys and settlements exist in the direction of and within the 2.5 kilometres proposed for the extension. Thus, it is the objective of this thesis to find out the possibility of carrying out this project by the state government taking into consideration factors that have large effects to the construction of the new project.

The major problem of this research is finding out the enormous nature of the pertinent factors that will be encountered in carrying out this project. Some of the major challenges to this research are that there are no maps, earlier research studies and adequate elevation data about the area. The only elevation data that is available which covers a dimension of 200 × 2,507 metres together with the x- and y-coordinates are of local origin and need to be converted to the national coordinate system. These coordinates were produced when a ground topographic survey were carried out in the area where the new runway will be located. (This was done using a TCRA 1101 plus Total Station in July and August 2004). Hence much research has to be carried out to get adequate information to be able to thoroughly evaluate this plan. This involves exploring and perhaps processing other sources of information such as Landsat images and Digital Elevation Models (DEM). Processing these images and models, and the existing data in local origin also involves using different Geographic Information System (GIS) programs and software. Another source of information involves sourcing and reading earlier literatures that are related to this project. These took into consideration writings that are of immense benefit to the investigation and analysis that are to be carried out in this thesis project. These sources of information were principal
to this thesis thus adding to the reliability of the outcome. Meanwhile, this research is worth carrying out because until this date this project, which was conceived about a decade ago, has not been executed.

1.2 Aims of the Research

The overall aim of this research is to evaluate the factors that have a large impact in the construction of the new runway. In doing this, a careful study was made on previous research works on airport expansion. For example, May & Hill (2006) carried out a study on the expansion of the Canberra International Airport in Australia. They pointed out that in carrying out this project; local issues have to be considered. The major issues specified are aircraft noise and the declining quality of life of affected residents (Van Eeten, 2001 as cited in May & Hill 2006, p. 438). They also mentioned conflicts on Land use that likely result from this extension. Similarly, Deelstra et al. (2003), in their studies using two cases: the project “Main Rotterdam” (the enlargement of the port of Rotterdam) and the project “A fifth runway for Amsterdam Airport (Schiphol)” stressed the importance of Impact Assessments and Decision-making process in the expansion of existing projects. Also, in the paper titled Proposed Extension of Runway at Norman Manley International Airport – A Rapid Ecological Assessment which was a report prepared for the Airports Authority of Jamaica by Environmental Solutions Ltd, a Rapid Ecological Assessment (REA) of an area of seafloor immediately adjoining the western end of the Norman Manley International Airport runway in Kingston, Jamaica, which was to be extended by 500 meters was considered (Environmental Solutions Ltd, 2011).

Other papers also focused on criteria for consideration in both expansions of existing airports and siting of new airports in general. Vreeker et al. considered these as main criteria and sub-criteria using a multi-criteria decision approach for a case study on conflicting plans (and policy views) for airport expansion options in the Maastricht area in the southern part of The Netherlands. The criteria considered economic benefits, social implications and environmental effects (Vreeker et al. 2002, p. 27 & 41). Ballis (2003) equally considers the use of multi-criteria analysis techniques in making decisions concerning important factors in siting a new airport. Such factors are land use, earthworks, impacts on river beds, interference with road, hydraulic works, high embankments, environmental factors, air pollution and noise (distance from city), vibration (distance from archaeological resources), cost, impacts on aesthetics and expropriation. According to them, these factors will determine if alternative sites could be decided for the location of the new project.

The foregoing shows that previous research papers on airport expansion considered factors such as Aircraft Noise, Land use, Impact Assessments and Decision-making processes. But it is obvious that these are not the only problems/factors affecting the extension of an existing runway project. Further study of papers on similar projects (see section 2 of this paper) points out other important factors. Some of these factors are the cost and the economic benefits of the new project. Other factors are the safety and security of both flight operations, and the construction personnel and equipment. All these factors can be summarised as:

- Land use
- Environmental factor or the Ecosystem
- Displacement of humans
- Economic benefits
- Cost
- Noise pollution
- Accessibility
- Safety and Security

All these factors are confronting the extension of the runway and they are considered in the analysis carried out in this thesis work. Meanwhile, Ko et al. (2011), Ballis (2003), Vreeker et al. (2002), Antunes et al. (2001), have used GIS and MCA to study some of these factors such as noise and environmental impacts analysis. But, this research work goes further than the ones considered in previous papers on runway extension and/or airport expansion. A very disturbing fact in this case is that the runway direction have already been determined, being the extension of an existing one. In road construction, it is possible to introduce curves where necessary to avoid major obstacles. But in this case, there is absolutely no choice. Preliminary investigations have already revealed the presence of two big valleys, swamps and buildings in the direction of the runway. Thus, the specific aims of this thesis, therefore, are to carry out the following:

- Use GIS to process maps and elevation models of the study area by using downloaded Landsat images, downloaded DEMs, and observed coordinates of the proposed extension area,
- Use the eight main factors affecting this project to evaluate these maps and elevation models to see the possibility of carrying out the project,
- Make recommendations for further study and research on the runway extension in relation to these factors and sub-factors such as geotechnical test and analysis of the area of the extension.

1.3 Possible Outcomes of the Research

This research when finished will be able to show the major factors that should be considered for the extension of the runway of Margaret Ekpo International Airport as well as examine their extent and impacts. Most importantly, it will help the Cross River State Government to know the implications of carrying out such a huge project while at the same time leading to further research works in such areas as costing and possible economic/future benefits of the project.
2. Literature Study

Some pertinent factors need to be considered before the government can embark on this type of project. Some of these have been enumerated in earlier researches about similar construction projects. Anavberokhai (2008) mentioned that in planning for such projects, certain factors need to be considered. These factors include the land use of the proposed area and the governmental interest in the project. In his view, these considerations can make the planning process a complex one but that employing the use of geographic information system (GIS) and multi-criteria analysis (MCA) can be extremely beneficial.

According to Berry (2000), a super highway evolved from meandering animal tracks. This makes it clear that it will take a team of engineers to meet and discuss about certain factors such as the environmental and social concerns of the project.

In the estimation of the impact of noise pollution, Ko et al. (2011), proposed a scheme to develop a traffic noise map using GIS and application of the noise map to perform a noise impact assessment. The road traffic noise map was created using GIS and digital maps of the study area - Chungju, Republic of Korea. They developed a GIS database containing topography, building, traffic and population information. The information content in the GIS was used to create a three dimensional urban spatial model which was used to develop the noise map. The result of their analysis shows that they were able to estimate areas and population that were exposed to the exceeded environmental noise standards.

In their study of the application of GIS to determine Environmental Impact Significance (EIS), Antunes et al. (2001), presented a new methodology for impact assessment called SIAM (Spatial Impact Assessment Methodology). This methodology assumes that dependent variables such as spatial distribution of the effects and of the affected environment are important factors of environmental impacts. Raster data format information stored in a GIS from an EIA can be used to implement the computation procedure adopted in SIAM. In their application of SIAM in the context of a case study based on the EIA of a highway in central Portugal, the IC7 between Venda de Galizes and Covilla, a georeferenced GIS database was built in IDRISI (a GIS software) comprising elevation data, land use, protected areas and areas of ecological interest, meteorological, population and project data. The results obtained from the computation of the impact indices for air pollution, noise impacts, affected ecosystems were observed to be consistent with those presented in the EIS that was used as a basis for their study.

Sumathi et al. (2008), notes that developing countries are often characterised by exponential rise in urban populations. Nigeria, where this project is to be carried out is not an exception. This population rise always give rise to re-construction and/or expansion of existing infrastructures to cater for new and higher demands. In doing this, it is imperative to consider other land use sub-components and to develop strategies that will result in less damage or complete displacement of them especially the human factors.

Other factors that required consideration for this type of project include the physical, political, social, legal processes and in particular, the economic benefits of the new project to the state and national economy at large (Yildirim et al. 2006).
In carrying out a project of this dimension, it is good to have a well planned survey of the area involved. According to the report submitted by Environmental Solutions Limited with regard to the proposed extension of runway at Norman Manley International Airport: A rapid ecological Assessment, such survey requires data to be collected in a grid form over the area of the extension or construction (Environmental Solutions Ltd, 2011). In the case of Margaret Ekpo International Airport project, this idea was applied in the field observations made on the site in the area of the extension and covering a distance of 2,507 metres. The grid was done as a 25 x 25 metre grid. The easting and northing coordinates as well as the elevations of those points were taken and were used in the study analysis. These grid elevations will be of immense benefit in producing digital elevation models of the place being studied.

Construction or upgrading of airports as a result of congestion of existing ones or increase in the number of airport traffic should also consider capacity and budgetary restrictions. Attention should equally be paid to increase in population growth and increase in the popularity of air transportation over a projected period of time; this is the opinion of Min et al. (1997). Although the construction of a new airport or expansion of the capacity of an existing one comes with long term economic benefits, this may lead to local opposition due to possible negative effects such as increased noise pollution, automobile traffic and the potential for catastrophic accidents (Min et al. 1997, p. 403). This includes what they called airport expansion and location problem (AELP). These authors go further to enumerate a number of factors that should be considered in locating new airports or expanding existing ones. These include the following;

- **Cost:** the cost associated with such an airport project may involve land acquisition cost, relocation costs, compensation costs, insurance for a potential liability to nearby residents, environmental clean-up, airport construction, operating and maintenance costs (Min et al. p. 404). Among these costs, those of land acquisition and airport construction costs are the most enormous, gulping perhaps billions of dollars (Rosato, 1996; Wood and Johnson, 1996 as cited in Min et al. 1997, p. 404). The huge cost associated with the initial airport construction may have an effect on the subsequent funding of its development and expansion due to the financial strain on the government sponsoring the initial airport construction (Min et al. 1997, p. 404).

- **Noise Pollution:** noise from aircrafts causes a lot of disturbances to residents living near the airport and this result in a lot of complaints from them. The extent of noise resulting from aircrafts at an airport is often related to the number of flights, aircraft types, flight routes, flight hours, etc (Min et al. 1997, p. 405). Consequently, increased public complain can result to the cancellation of the airport construction plan because it may be far too expensive to relocate all the affected residents.

- **Economic Development:** another major factor identified is the economic benefits of the new project. The benefits of a new airport are always the main stimulus of the project. The benefits could be short term and long term such as short-term construction jobs and long-term employment in tourism, hospitality services, airport operation services, associated ground transport services and more tax revenue for the government (Min et al. 1997, p. 405).

- **Accessibility:** an airport should easily be accessible to both business and residential areas while at the same time, it should not be the source of traffic congestion in the area in which it is located.
All these factors should also be balanced with the changing regulations of the Federal Airports Authority (FAA).

Daniel (2002, p.149), in his writing narrows down the analysis of airport construction to its cost and benefit assessment; the benefits he mentioned include reduced taxiing time, improved airport access, increased safety, decreased emissions, and reduced noise while the cost involve the general cost of constructing the project.

Cost evaluation is also inevitable considering time for all the required analysis in the project, the research budget and the available data. Thus, it is important to emphasize what is economically viable to the public and discarding what is not “rather than on arriving at a precise estimate of project return” (Jorge & de Rus 2004, p. 311).

In his paper entitled *Balance Space in Airport Construction: Application to the North Sea Island Option for Schiphol Airport*, Galperin (2002, p. 759), emphasised that to build or not to build an airport depends solely on decision-making bodies and processes. He further explained that these decision-making issues comprise the finance, politics, environment and the market which affects the project. This can be seen as placing a heavy duty and sense of responsibility on the government and its agencies which have the responsibility to provide infrastructure that are essential to the well-being of its citizens.

However, it is important to take seriously the impact a construction project can have on the environment. This area of concern is the focus of Douglas and Lawson (2003, p. 178). They emphasised that an Environmental Impact Assessment (EIA) must be carried out in order to determine the effect of the transport development project on the natural and social environment as well as the cost of such activity (Tsamboulis & Mikroudis, 2000 as cited in Douglas & Lawson, 2003, p. 178). In order to find out the total impact of transporting the materials, it was suggested that the best way to do this is to carry out a Life Cycle Analysis (LCA) which includes soil and water pollution, damage to landscape, land use claims as well as ecosystem fragmentation (Douglas & Lawson, 2003, p. 178 & 179). In addition to this, a Material Flow Analysis (MFA) should be carried out on all materials produced on the site. These materials comprise “the extraction, production, transformation, use, recycling and disposal of materials. It considers flows of substances, raw materials, base materials, products, manufactured goods, wastes and also emissions to air. MFA can help us to understand how changes in land use, industrialisation, consumption and population affect the land surface and alter the natural circulations of chemical elements in the environment (biogeochemical cycles)” (Douglas & Lawson, p. 179). Furthermore, they also pointed out that the geomorphology and earth science of the area have to be properly considered before such a construction will proceed (Douglas & Lawson, p. 179). This implies that every earth material involved in the construction activities need to be accounted for. These can be said to include materials from clearing, topsoil removal, excavation and dredging, filling, compaction, transported materials and so on.

Evaluation of airport sitting, construction and/or expansion cannot be complete without considering among other important issues a very important aspect of construction; safety and security. This comes as the focal point of the writing by Khalafallah & El-Rayes (2011). Areas identified in this activity are four main modules which are:
1. A comprehensive multi-objective optimization engine that integrates and optimizes construction work zone safety, construction-related aviation safety, construction-related airport security, and all relevant site layout costs;
2. A relational database that integrates planning data and stores all the generated optimal solutions;
3. An Input/output module to facilitate specifying planning and optimization parameters and retrieving the generated optimal site layout solutions; and
4. A visualization module that communicates with external computer aided design (CAD) software in order to support the visualization of the generated optimal site layout plans (Khalafallah & El-Rayes, 2011, p. 313).

These issues should be included in the priorities of planners engaged in carrying out the construction work.

These factors from previous literatures are among the major issues that are considered in this thesis work.
3. Study Area

The project area is Calabar, the capital city of Cross River State of Nigeria. It will be good to have some knowledge of this region of the world in order to better appreciate the significance of this project. Thus, brief explanations will be made about the country, the state and the city of Calabar.

3.1 Nigeria

Nigeria is a country located in West Africa. As can be seen in figure 1 below, it is bounded in the North by Niger Republic, in the north-east by Chad and Cameroon, in the south-east by Cameroon, in the south by the Atlantic Ocean (Gulf of Guinea) and in the west by Benin Republic. It is divided into 36 states and the federal capital territory, Abuja (Map of Nigeria showing States, 2011). Geographically, Nigeria is located in the tropics at latitude 10°N and longitude 8°E and covers a total land area of 923,768 square kilometers. Nigeria is a country endowed with a good number of mineral resources both explored and yet to be explored such as natural gas, petroleum, tin, iron ore, coal, limestone, niobium, lead, zinc and arable land among others and it is made up of a population of 155,215,573 million people according to July, 2011 estimate.

![Map of Nigeria showing country boundaries and state](http://www.bookdrum.com/images/books/142344_m.png)

This shows that Nigeria is the most populous nation in Africa and any black nation. Moreover, it is made up of over 250 ethnic groups with over 500 languages with the major languages being English (official), Hausa, Yoruba, Igbo, Fulani, Ijaw, Igala, Kanuri, Ibibio, Efik and Tiv (Central Intelligence Agency, CIA, The World Fact Book
Nigeria, 2011). Going by the enormous human and natural resources including its diverse and numerous cultures, it shows that Nigeria is not only an investment region but also a tourist destination. Most states are already exploring these opportunities and Cross River state seems to be in the forefront of this.

3.2 Cross River State

Cross River State with its capital in Calabar is located in the south-east part of the country at the boundary with Cameroon (see figure 1 and figure 2). Both for Calabar and the entire Cross River state, the popular acronym goes *Come and live and be at Rest* showing that visitors to this state are always safe while enjoying the relaxed atmosphere in the state.

![Map showing Calabar and its neighboring Cities](image)

*Figure 2: Map showing Calabar and neighbouring cities, and the project area - inset image (Source: Google maps 2011, Calabar, Cross River State, Nigeria).*

This state is a well known tourist destination in Nigeria. Among the popular tourist attractions include the Christmas Festival and the Calabar Carnival, the TINAPA Business Resort with its nearby Water Park, the Obudu Ranch Resort with its mountain Cable car, Marina Resort and the 18-hole municipal golf course. The tourist attractions in the state goes even further and these include Old Residency Museum, Agbokin Waterfalls, Etanpim Cave, Mary Slessor’s Tomb, Cross River National Park, Kwa Falls, Obubra Lake and Calabar Cenotaph. In fact, “from river cruises in the south to horseback riding in the north, Cross River State has attractions to satisfy a diverse set of tourists year round.” (Cross River State of Nigeria, Nigeria Information & Guide, 2011).
Cross River State have a lot of investment opportunities ranging from tourism to hospitality, industry to agriculture and solid minerals. In Agricultural sector, investments can be made in the production and processing of cassava, rubber, oil palm, cocoa, fruits, fish as well as livestock farming. In the area of solid minerals, the state is blessed with minerals such as clay, salt, limestone, sand, kaolin, barite, granite, basalt, quartzite, gold, uranium, iron ore, tin ore, manganese, titanium, coal, mica, zinc, galena, feldspar, graphite, tourmaline and laterite. Other investment areas include “oil & gas, power and energy, waste conversion and management, information and communication technology, human capital development, paper/newsprint manufacturing, wood processing, spring water bottling, manufacturing and infrastructure” (Cross River State Government, 2011a, About Cross River).

3.3 Calabar

Calabar, *The Canaan City or The People’s Paradise* as it is popularly known, is the capital city also known to be a city where one gets a metropolitan experience but without the hassle, commotion and congestion that are common in big Nigerian cities. A good number of the tourist attractions in Cross River State are in Calabar and its environs. Also, Calabar is considered to be a very clean city in Nigeria with nice and friendly people. The influx of people to this city especially from major Nigerian cities like Lagos and Abuja has resulted to a tremendous increase in the number of flights going to and from the city of Calabar and Obudu Ranch Resort (Cross River State Government, 2011b, Tourism; Cross River State of Nigeria, Nigeria Information & Guide, 2011; Federal airports authority of Nigeria, 2011, Airports, Margaret Ekpo International Airport – Calabar). This together with a determination to boost business and trade in the popular TINAPA Business Resort and Obudu Ranch Resort, prompted the former governor of the state, Donald Duke, to propose the expansion of the infrastructures in the existing Calabar Airport. Some of the facilities has been upgraded and modernized, but the biggest hurdle remains the extension of the existing runway which is the focus of this project.
4. Materials and Methods

4.1 Materials

The materials and data for this project were from three main sources and they are:

- Landsat images which were downloaded from Landsat website www.landsat.org
- Digital Elevation Models (DEMs) which were downloaded from the website of the CGIAR Consortium for Spatial Information (CGIAR-CSI) http://srtm.csi.cgiar.org.
- Coordinates of the proposed 2.5 kilometer runway extension which was observed directly on the site.

4.2 Software Used for the Project

A number of applications were used to carry out this thesis project. Some of the most important software applications include: ArcMap and ArcCatalogue, ERDAS Imagine, Geo, Surfer 8, AUTOCAD.

ArcMap and ArcCatalogue are part of the ArcGIS desktop suite. These applications were used to create, edit, display and explore GIS datasets.

ERDAS Imagine is a remote sensing application basically used for spatial raster data processing, modification and display. It was used for the satellite image processing and display.

SBG Geo is measurement data preparation software which is preferably used by construction professionals for data preparation, editing and reporting. It was primarily applied for coordinate transformation for this study.

Surfer is an application used for contouring, gridding, terrain and surface modeling.

AutoCAD is a CAD software application used for 2D and 3D design and modeling presentation. It was used for the 2D design of the runway and details along the proposed extension.

4.3 Methods

Several methods were employed during the course of this thesis project. The methodology involved downloading, processing and analysis of the data. The Landsat imagery and DEM were downloaded from online sources. The downloaded imageries, although in their correct projection and presentation had to undergo some processing in order to make them conformal to the same scale and unit before incorporating them into our analysis. Primary topographic data was acquired from a direct site observation of the proposed 2.5 km extension area. The area covers a dimension of 200 by 2,507 meters. These observations (x, y and z) were done with the use of a Total Station (TCRA 1101 plus) and the coordinates were of local origin. The field work which was carried out in the year 2004 is made up of 583 points made up of spot heights and detail points. Details of the processes implemented to prepare the images and data in order to achieve the results of our objectives are further described below.
4.3.1 Processing of the Landsat images

The downloaded Landsat images contain eight bands and out of these seven bands were used. In order to use these images for the required analysis, they were processed. The processing of the image was done in ERDAS Imagine.

4.3.1.1 Image Processing

The first operation was stacking the images. Stacking involves joining the different Landsat image bands to produce one image containing the seven bands. To do this in ERDAS Imagine, the Layer Stack function was used. After the stacking, it is obvious that the area covered by the Landsat Image covers a very large area that is far beyond the area of study. Therefore, there was a need to subset the image which involved the cutting out of a particular part of an image that is the area of interest. This was also done in ERDAS Imagine through the Subset Image function.

To do the subset, there is also need to get the exact area of concentration (in this case, the spatial extent of the study area). Thus, the required coordinates, Easting (X) and Northing (Y), were derived by taking the Universal Transverse Mercator (UTM) coordinates in meters of the center of the end of the existing runway. Then coordinates covering five kilometers radius of this centre were generated by adding five kilometers to the north, south, east and west directions of the center coordinates, and these were used for the subset (figure 3). These coordinates are:

Center of end of runway; Easting (X) = 428 222.98, Northing (Y) = 551210.19

Upper Left Easting Coordinate (UL X) = 423 286.31

Upper Left Northing Coordinate (UL Y) = 556 387.42

Lower Right Easting Coordinate (LR X) = 433 318.31

Lower Right Northing Coordinate (LR Y) = 546 355.42
It should be noted that when the Landsat Image was stacked, it was in a slanting position as can be seen above. Hence, the image was rotated to make it perpendicular before the subset was applied to get the area where the project was carried out. The next process after the subset was derived was to classify the image.

### 4.3.1.2 Image classification

Classification was carried out on the Landsat image to determine the land use of the various parts of the area around the existing and the proposed runway. This was done in ERDAS Imagine by using the *Classifier* function. The unsupervised method of classification was used to classify the land use. Unsupervised classification was made
using 30 classes in order to establish a good representation of the various land use classes. The unsupervised classified map was recoded with 6 classes by merging similar classes together. The final classification shows River, Forest, Marsh or swamp, Open Areas, Urban areas and Grassland. These classes were subsequently assigned appropriate colors. To ascertain the accuracy of the classified map, a classification accuracy assessment was carried out on the recoded map. To achieve a mean accuracy, 250 reference points were used for the accuracy assessment. The result from table 3 below shows that 200 correct reference points were classified to produce an overall classification accuracy of 80%.

Table 1: Accuracy assessment report of the unsupervised classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Reference Totals</th>
<th>Classified Totals</th>
<th>Correct</th>
<th>Accuracy</th>
<th>Users</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Class 1</td>
<td>23</td>
<td>26</td>
<td>20</td>
<td>86.96%</td>
<td>100</td>
<td>0.00%</td>
</tr>
<tr>
<td>Class 2</td>
<td>78</td>
<td>26</td>
<td>69</td>
<td>88.46%</td>
<td>89.61%</td>
<td></td>
</tr>
<tr>
<td>Class 3</td>
<td>24</td>
<td>15</td>
<td>70</td>
<td>78.48%</td>
<td>88.57%</td>
<td></td>
</tr>
<tr>
<td>Class 4</td>
<td>79</td>
<td>62</td>
<td>46.13%</td>
<td>60.00%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 5</td>
<td>33</td>
<td>23</td>
<td>84.85%</td>
<td>59.57%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>250</td>
<td>250</td>
<td>200</td>
<td>80.00%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3.2 Processing of the DEM Images

Two DEMs were downloaded. The first download was made from the CGIAR-CSI website of the area of study. Like the Landsat image, the DEM covers a large area far beyond the area of interest. Therefore, clipping has to be done to cut out the study area for further processing and analysis. The two images have to be merged as the area of interest fell on the two of them. (The first DEM was called srtm_38_11 and the second was called srtm_38_12. These names were given by the elevation model creators). These together with the subset of the Landsat image are shown in figure 4 below.
Figure 4: the DEMs (before merging) with the subset of the Landsat image (inside) showing the extent of the area of study as compared to the extent of the two DEM, and coordinates of the center of the end of the existing runway.

4.3.2.1 DEM Merging

Merging of the two elevation models was done in ArcMap. ArcMap’s Mosaic To New Raster tool was used for this purpose. This can be seen in figure 5.
4.3.2.2 DEM Reprojection

The original as well as the downloaded DEM was in ASCII grid format and it was also in longitude and latitude decimal degrees whereas the Landsat image was in image (.img) format and in Universal Transverse Mercator/World Geodetic System 84 (UTM/WGS 84) coordinate system. Therefore, the DEM has to be reprojected for it to be in the same format, units and system as the Landsat image. First, in ArcMap, the DEM was exported and saved in image (.img) format. Then it was opened in ERDAS Imagine and reprojected through DataPrep function. In the reproject box, the units of the Landsat image were imported to that of the DEM. The pixel size of the DEM was found to be $X = 92.45$ and $Y = 92.58$ while that of the Landsat image was 28.50 for both $X$ and $Y$. The pixel size of the DEM was changed to $X = 28.50$ and $Y = 28.50$ to conform to that of the Landsat image.

4.3.2.3 DEM Processing

The first processing carried out on the merged DEM was to subset it. Like that of the Landsat image, the subset of the DEM was derived from ERDAS Imagine using DataPrep menu and then subset. The X and Y coordinates that were used to subset the Landsat image were also used to subset the DEM image. With the two images (the DEM and the Landsat) being of the same size, orientation and units, it can be perfectly overlaid. Subsets of the Landsat image and the DEM are shown in figure 6 below.
Figure 6: Subsets of the Landsat image and the DEM showing the positions of the existing and proposed runways.

The downloaded DEM contains no easting, northing and height (X, Y and Z) coordinates values which are necessary for the project. Thus, the next activity on the DEM was to extract the (X, Y, Z) coordinates from it. This is necessary in order to produce elevation models from it. A Raster to XYZ script written by Dan Rathert of Resource Data Inc. (www.resdat.com) was used to convert a single-band raster either in GRID or image format to an ASCII delimited text file of X, Y, and Z values (ESRI, 2011, Support, “grid to xyz” search). The conversion script which was included in the readme was inserted in ArcMap. But before applying the script, the DEM in ASCII format was saved in grid format which will be used to extract the coordinates. (The readme is included in this report as Appendix A). The code for the conversion is:

Private Sub Raster2xyz_Click()

    Load frmRaster2xyz

    frmRaster2xyz.Show

End Sub

A new tool was created in ArcMap which could create the XYZ coordinates. The extracted XYZ coordinates are made up of 124,610 points. These points were saved as text files.
The extracted points in text format were opened in Surfer 8 and saved as a data file. This data file was then used to create a grid map of the entire study area. The gridding type used was Kriging. Subsequently, contour map, wireframe map and overlay map of the contour and wireframe maps were produced. Further processing of the DEM involved the production of a Shaded relief map from the hillshade.

### 4.3.3 Processing of the Observed Coordinates

The first thing that was done on the observed points was to thoroughly check there correctness. For these co-ordinates to correspond with those of the Landsat image and the DEM, they have to be converted to the UTM coordinates. This was done using the Geo software. But before doing this, common points have to be established. Thus, the center of the start and end of the existing runway which have coordinates in both the UTM (X,Y,Z) and local origins (x,y,z) were used as common points. The UTM and local coordinates of these points are shown in table 2.

**Table 2:** UTM and Local coordinates used for the transformation in GEO

<table>
<thead>
<tr>
<th>No.</th>
<th>UTM Coordinates</th>
<th>Local Coordinates</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X        Y        Z</td>
<td>x        y        z</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>427020.160  548896.690 61.000</td>
<td>1007.885  3507.488  94.000</td>
<td>Start of existing runway</td>
</tr>
<tr>
<td>2.</td>
<td>428222.980  551210.190 67.000</td>
<td>1000.000  1000.000  100.000</td>
<td>End of existing runway</td>
</tr>
</tbody>
</table>

Different files were created for the two coordinates systems. The transformation was carried out in Geo through the Transformation function using 2D Helmert + Height difference transformation because the heights of the points are needed. After making this transformation the coordinates conformed to that of the Landsat image and the DEM.

#### 4.3.3.1 Gridding and Interpolation in Surfer 8

The X, Y, Z points were interpolated in Surfer 8 and because the data here is smaller when compared to that of the DEM, the interpolation method used was Natural Neighbors as it gives good result with few points.

#### 4.3.3.2 Blanking

Blanking was carried out on the contour map of the observed coordinates. This was done on a dimension of 2,500 by 100 meters. Blanking was done so that if half of the area is to be used for the construction, the area and volume can be known. The blanking parameters (coordinates) were derived by calculating the coordinates of the four corner points at 50 meters to the left and right of the center of the new runway. These blanking parameters are shown in table 3.
Table 3: Parameters used for Blanking of the contour map of the observed coordinates

<table>
<thead>
<tr>
<th>4</th>
<th>0</th>
<th>blankpolygon</th>
</tr>
</thead>
<tbody>
<tr>
<td>428178.618</td>
<td>551233.255</td>
<td></td>
</tr>
<tr>
<td>429331.849</td>
<td>553451.375</td>
<td></td>
</tr>
<tr>
<td>429420.574</td>
<td>553405.245</td>
<td></td>
</tr>
<tr>
<td>428267.342</td>
<td>551187.125</td>
<td></td>
</tr>
</tbody>
</table>

To do the blanking, the Grid then Blank command of the Surfer 8 was used. Moreover, the contour map of the observed coordinates of the proposed extension area, the contour map of the coordinates of the existing runway and that of the DEM coordinates were overlaid. This was done in order to know where the proposed runway falls on the study area and to ascertain the accuracy of their coordinates and positions.

4.3.3.3 Calculation of Areas and Volumes

The volumes and areas of this contour map and the blanked contour map were calculated. The Grid Volume command was used and the Constant Z value of 67 metres (the height of the center of the end of the existing runway) was chosen as the Upper Surface while Grid File of the observed points were chosen as the Lower Surface. The same procedure was repeated for calculating the volume and area of the blanked area.

4.3.3.4 Production of Detail Map

A detail map was produced for the area of the proposed runway using the observed points. The map was produced in AutoCAD 2008. The coordinates were saved as a script file and the script was run in AutoCAD. These were then edited by using the detail sketches from the field survey.
5. Results

5.1 Results from the Processing of the Landsat Images

As can be seen from the figure 7 below, there are six main classes of land use in the area of study. The largest land use feature is the forest areas which are largely because of the presence of two big rivers. This is because in Nigeria, many rivers in the rain forest area region are usually surrounded by low lying lands which are always marshy. These lands are always covered by forests which are almost always virgin forest. This is followed by the urban areas with the existing runway in the middle of the study area. Other land features include the rivers, marshy areas, open areas and the grasslands. This result shows that there are buildings, roads and marshy areas within the limit of the proposed runway which has to be taken into consideration in the planning and construction of the new runway.

![Image of land use classification](image)

**Figure 7:** Results of the Land use classification of the Landsat image of the study area.

The reliability of this classification result can be seen from the result of the accuracy assessment which is 80%. Also, this can be seen from figure 8 where a comparison is made of the classified map and a Google Earth map of the same area.
5.2 Results from the Processing of the DEM Images

The processing of the DEM produced a contour map, a wireframe map, a 3D map, and a shaded relief map. A look at them shows that they are all in agreement with that of the classified Landsat image. The highlands are within the urban areas while the lowlands are close to the rivers which are near the sea level. The scale bar shows that the lowest height is 0, which is sea level height, while the highest height is 95 metres, which is largely in the urban areas. Furthermore, these maps show that much of the direction of the new runway is characterized by areas of low elevations. Maps showing the results from the processing of the DEM are shown in figures 9 to 12 below.

Figure 8: comparison of the classified map and Google Earth map of the same area.
Figure 9: Contour Map of the processed DEM (Height – from 0 to 95 metres)

Figure 10: Overlay of Contour and Wireframe maps of the processed DEM (Height – from 0 to 95 metres)
5.3 Results from the Processing of the Observed Coordinates

As in the case of the DEM, contour map, overlay of contour and wireframe map, 3D map and detail maps were produced from the field survey data. Also, this contour map was overlaid with that of the DEM to know its exact location. From the scale bar, it can be seen that the lowest and highest height are about 5 metres and 70 metres respectively unlike that of the DEM which is about 0 and 95 metres. The 3D map gives a good impression of the complexity of the proposed runway. All these are shown in figures 13 to 18.
Figure 13: Contour Map of the field survey Data (location of the proposed runway)

Figure 14: Overlay of the Contour and Wireframe Maps of the field survey Data
Figure 15: 3D Map of the field survey Data of the proposed runway

Figure 16: A profile graph showing the proposed runway extension
**Figure 17:** Detail map of the field survey data

**Figure 18:** Overlay of the contour maps of the field survey data, the existing runway and the DEM
One of the objectives of this investigation is to know the volume of materials that will be needed to fill the low lying elevation areas and the volume of materials that will be removed. This was done by first calculating the volume and area of the entire area of the survey which is 2,507 metres by 200 metres. Also, a second volume was calculated which covers half of the area of the proposed runway. The width of the existing runway is 45 metres and assuming the plan goes to maintain that width and include the grass areas by the left and right sides of the runway, the total dimension to calculate will be 2,500 metres by 100 metres. Areas outside of this were blanked. The results from these two volumes and area calculations are shown in table 4. These results show the volume that needs to be cut or removed (areas higher than elevation of the existing runway), volume that needs to be filled or for materials to be imported (areas lower than the elevation of the existing runway) and the total surface areas.

Table 4: Results of the volume and area calculations of the proposed runway

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Volume to be Filled (A)</th>
<th>Volume to be Cut (B)</th>
<th>Net Volume (A-B)</th>
<th>Total Surface Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,507m x 200m</td>
<td>13,793,206 m³</td>
<td>9,080 m³</td>
<td>13,784,126 m³</td>
<td>513,845 m²</td>
</tr>
<tr>
<td>2,500m x 100m</td>
<td>5,903,022 m³</td>
<td>5,738 m³</td>
<td>5,897,284 m³</td>
<td>172,093 m²</td>
</tr>
</tbody>
</table>

Details of these calculations including the planar areas, that is, the area of the entire region of the new runway taking into consideration the curved and undulating surface of the ground are in Appendix B and Appendix C.
6. Analysis and Discussion

This section of this report is about the analysis of the results obtained during the course of this research work. To do this effectively, consideration has to be taken about the factors which were pointed out by the literatures that were reviewed for this research.

6.1 Analysis of Factors

From the literatures that were studied for this thesis, one can see that there are eight main factors that need serious consideration before the government of Cross River state goes ahead to approve the construction of this new runway. These factors as mentioned in the aims of the research (see section 1.2) are land use, environmental, human displacement, economic benefits, cost, noise pollution, accessibility and, safety and security. It will be good to analyze these factors one after the other.

**Land use:** Land use here refers to the divisions of a land area into different purposes. A look at the classified map shows that it is almost clear that there was no previous city plan to site such a project in the area where the extension is to be made (see figures 7, 12 and 17). The area is made up of forest, swamps, grasses, houses and huge valleys. So, embarking on such a project now will surely change the land use structure of the area which has to be considered seriously.

**Environmental factor or the Ecosystem:** The ecosystem of the place must also be well considered. Constructing the new runway will immensely damage the ecosystem especially the bio life since the area contains swamps, forest and natural valleys. The construction will damage the ecosystem, at least, to some extent no matter the amount of precautionary measures taken. Therefore, if the government decides to go ahead on this project, adequate measures must be taken and strictly adhered to in order to minimize this damage.

**Displacement of humans:** The various maps produced from this study shows that there are a lot of houses within and around the area of the proposed runway. These houses must surely be for different purposes such as residential and commercial. If this project must proceed, it will result to the relocation and compensation of the people living in the area. This involves a lot of time, legal issues and enormous amount of money among other things.

**Economic benefits:** The economic benefits include both short term and long term benefits. The short term benefits include the provision of jobs during the construction process, high demand on the goods and services in the state as a result of the presence of the construction workers while the long term include increased safety in the airport and a great boost to the tourism industry in the state resulting in increased demand in goods and services in the state. There may perhaps be other benefits all of which will necessitate the construction of the new runway. But the government must not quickly be carried away by the immense benefits. Other pertinent factors especially the cost must be considered at the same time as the economic factors.

**Cost:** This is one of the most important factors that need utmost attention. The cost of the project includes but is not limited to the time and money it takes to survey and study the area, plan for the area, carry out all compensation matters and deliberations by the
state congress. Also included are the cost of the construction, more safety measures at the airport and the traffic disruption. A look at the 3D map shows that there is the presence of three valleys and swamps. The volume calculation equally shows that it will require over five million cubic metres (which is the net volume: Fill volume minus Cut volume) of sand to fill these valleys (for a dimension of 2,500 m by 100 m runway). This volume will surely increase when one considers the removal of the topsoil (unsuitable materials which must be removed to reach stable soil before filling) and the extra filling that will be taken by the camber. Figure 19 and table 4 illustrates this fact. Meanwhile, a look at the study area shows that there are not much high elevation areas which will make it more difficult to get nearby suitable soils (materials) to excavate sand to fill the valleys. In fact, it is obvious that other ministries will suffer greatly because of this project because as more funds are devoted to the runway project, funding for other sectors of government will surely be reduced.

Figure 19: Description of valleys and swamps within the proposed runway.

**Noise Pollution:** Noise pollution definitely will be one of the problems that will result from the new project. One of the reasons for the new project is for big aircrafts to be able to land and take off from the airport. This will result to increased noise to the people living within the area. Noise is also expected to increase from the time construction work starts due to the movement of heavy construction machines. It may even require the relocation of additional number of people living there thereby increasing the cost of the project. Effect of noise can be so serious that the complaints from the public can result to lack of support for the new airport project or an expansion of an existing one and if there is little or no public support, the project will likely not be approved by the government. (Min et al. 1997, p. 405).

**Accessibility:** Accessibility includes the access to the airport as well as the access to the construction site and facilities. Increasing the number of airline operations also means increase in the city traffic which may result to additional work on the existing roads. To reduce traffic congestion on the city roads, there may be need to expand the existing roads or even plan for the construction of additional roads. This gives rise to extra work and extra expenditure to say the least. If this becomes necessary, it will definitely add to the cost of this project. Also, construction personnel and equipment must have good access to and from site without constituting a nuisance to the environment.
Safety and Security: This is an area that should also be given maximum attention. In the words of Khalafallah & El-Rayes (2011, p. 313), there must be well planned safety measures that covers all aspects of the construction activities as well as aviation and airport safety and security. This is because the airport will still be in operation while the runway extension work is taking place. Therefore, safety must be a priority.

6.2 Discussion

The complexity of the proposed runway construction can be identified from our results and analysis of the major factors of consideration. The land use and topographic results presented highlight the overall nature of the area. Using the land use classification map produced from this study to analyze factors such as land use change; environmental and ecosystem impacts and human displacement shows to some extent the amount of both man-made and natural features that will be displaced due to this project. A look at the classified map (figure 7) shows consistency with the ground observation figure (figure 17) showing urban features and the swampy or marshy areas along the runway extension. The profile graph shown in figure 20 shows that the proposed runway area is low lying with the highest elevated portion at an estimated height of 67 metres as compared to the built up areas comprising the existing runway where heights are over 70 metres.

![Profile Graph of Proposed Runway Extension](image)

**Figure 20:** Profile graph of proposed runway extension showing relative elevation marks

The materials and data applied to this study were of good quality and they enhanced the outcome of the results. The reliability and accuracy of data is a function of their sources. The set of data applied to this study were generated from reliable sources; images from the websites of landsat and the consortium for spatial information and the spot heights observed with the TCRA 1101 plus total station (accuracy of the total station being 1.5" for angle measurement, 2 mm + 2 ppm for distance measurement and a measuring time of 1 second – Oregon Department of Transportation Surveyor’s Conference).
The images were in corrected form and did not require enhancements; a high resolution of 28.5 m of the landsat imagery was applied, other images were made to conform to 28.5 m resolution. The resolution at 28.5 m also did not slow down the image processing. The only drawback to the landsat imagery we obtained was that images from areas in and around Nigeria were not very bright in relation to images from areas in North America and Europe but it did not prove consequential to the outcome of the result.

The processing methodologies applied to the images and data were done within acceptable accuracy measures. For instance, the unsupervised classification accuracy assessment which is a way to check how good the classification is was done with a required minimum of 250 reference points. An acceptable classification accuracy of 80% was achieved as against the 100% target, showing evidence of some uncertainties in the classification.

Taking consideration of the eight factors described (refer to section 6.1), related work on airport runway expansion or development projects can be facilitated by carrying out more studies and data acquisition to include the following in a GIS for analysis and to optimize the project: a noise contour to determine the extent and coverage of the airport noise level to residential areas before and after the construction; land use map like the one provided for this study showing the designation of land use features; spatial database of residential buildings and parcels within a specified buffer zone measured from the airport (a valuation of these properties can be included in the database for cost analysis); for accessibility, a road network layer of the area can be incorporated into the GIS to provide an insight to the city traffic since the expansion may require the expansion of some roads to ease traffic after the expansion project.

Although we have established to some extent with our results the positive and negative impacts of the project, several shortcomings of this study can be improved by further environmental, economic and transport assessment studies. Data acquired from these studies can be related to the land use and topographical data for extended analysis. Environmental studies will enhance the achievement of more specific results especially in the areas of ecosystem degradation and quantitative noise impact assessment. Also, more cost and economic analysis can be carried out in future studies to generate estimate figures of the number of household and people that will be affected by this project. Further consideration of these results in relation to these factors will assist in minimizing the environmental impacts and enhance future decision making related to this project.
7. Conclusion and Recommendations

7.1 Conclusion

The objective of this study was to demonstrate the application of GIS and other geospatial tools to carry out analysis of a facility expansion project, in this case an airport runway extension. The analysis investigated the factors which are to be considered before embarking on this high cost project. These factors which were stated range from effect on existing land use, human settlement displacement, ecosystem damage, noise pollution, safety and security, etc. From the findings of the study, it is important to note that these aforementioned factors play a major role to the possibility of this project and could act as limitations to its execution.

GIS has proved to be an effective tool in carrying out these study and the results from the analysis of available data highlights obstructions such as dispersed residential settlements, roads, swampy areas, valleys and highland areas along the runway extension path and the possible amount of earth material required from the volume calculations.

It is pertinent to note that GIS and other geospatial tools used for this study are important applications in complex planning processes. They will play effective roles in the sustenance and maintenance of the airport facilities. If well utilised, they will also enhance high cost cuts and boost the economic benefits of the project.

7.2 Recommendations

Based on the analysis carried out in this study, we propose the following recommendations:

- On conception of a huge facility such as an airport development program, provisions should be made for possible future expansions.

- Pre-analysis should be carried out with tools such as GIS to ensure the possibility of carrying out enormous projects like this before public awareness is made. A possible reason for the suspension or delay of this project could be a failure to carry out a proper pre-analysis of the possibility of embarking on the project by the government of Cross river state.

- Consequent upon these factors, there is need to carry out further research and analysis on sub-sectors of these factors some of which are; geotechnical tests and analysis, compensation processes, construction and aviation related health, safety and environment (HSE), economic effects on other ministries, long-term benefits forecast, effects on bio life and soil structure and their reclamation, among others.

- Finally, the government at all levels should set up well equipped GIS divisions to analyse and monitor airport operations and its environs in order to avoid cases such as encroachment into airport properties which is a common case in Nigeria. This measure will also help in reducing cost of facility maintenance.
References


Appendices

Appendix A

Grid to xyz conversion readme from Dan Rathert.

RASTER to XYZ

**please cite if used for academic work**

--------------------------------------------

Dan Rathert
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Resource Data Inc. 907-770-4107 RDI
Anchorage, Alaska www.resdat.com
--------------------------------------------

Installation:

Installing the form:

1. Open ArcMap

2. Choose Macros > Visual Basic Editor on the Tools pulldown menu (or hit Alt + F11)

3. In the upper left of the VB editor is the project window. Right-click on Normal (Normal.mxt) and choose Import file and then browse to and choose the .frm file you downloaded.

Import the ThisDocument code:

1. If it is not already done, in the VB editor expand the Normal (Normal.mxt) by clicking once on the plus sign next to Normal (Normal.mxt). Then expand where it says ArcMap objects by clicking once next on that plus sign. You should now see a big blue globe and ThisDocument
2. Double-click on ThisDocument – a white window should appear in the main portion of the VB editor.

3. In the window paste in the code:

```vba
Private Sub Raster2xyz_Click ()
    Load frmraster2xyz
    frmraster2xyz.Show
End Sub
```

Installing the UIButton on the ArcMap user interface:

1. Leave the VB editor open, but bring up the ArcMap window.

2. Choose Customize on the Tools pulldown menu.

3. In the resulting window bring up the Commands tab.

4. Scroll way down the list on the left until you find UIControls.

5. Click once on this to highlight and then push the New UIControl… button.

6. Make sure UIButtonControl is selected and then choose Create

7. A new button will appear in the right pane of the window and will be highlighted

8. Click once on the button and change it’s name to Normal.Raster2xyz

9. Now drag the highlighted button Normal.Raster2xyz to any toolbar on the ArcMap interface and let go. A small blank gray button should be there.

10. Right-click on this button and choose an image/icon to use for it from the Change Button Image option.

11. Right-click on this button again and check the Image and Text option so that the button will have the name of the tool next to it.

12. Finally, in the Customize window pick the Options tab and make sure the check box Save customizations to Normal template by default is checked.

13. Choose Close in the Customize window. Close the VBeditor.

NOTE: If you prefer to save the tool to a specific "project" follow the same instructions above but substitute PROJECT for every instance of NORMAL
and, before item #5 in installing the UIButton, be sure to change the "Save in" dropdown in the lowerleft of the pop-up window from Normal.mxt to

whatever project.mxd you desire.
Appendix B

Area and Volumes Calculation Results for the Observed Points

Grid Volume Computations


Upper Surface

Level Surface defined by Z = 67

Lower Surface

Grid File Name: \hig-ad\student\homes\Runway\Runway_trans1_krig.grd

Grid Size: 100 rows x 57 columns

X Minimum: 428110.693
X Maximum: 429469.553
X Spacing: 24.265357142857

Y Minimum: 551017.616
Y Maximum: 553440.527
Y Spacing: 24.473848484848

Z Minimum: -21.226171238659
VOLUMES

Z Maximum: 67.955982929891

Z Scale Factor: 1

Total Volumes by:

Trapezoidal Rule: 13784126.017533
Simpson's Rule: 13803939.171307
Simpson's 3/8 Rule: 13811979.654518

Cut & Fill Volumes

Positive Volume [Cut]: 13793206.467049
Negative Volume [Fill]: 9080.4495154665
Net Volume [Cut-Fill]: 13784126.017533

Areas

Planar Areas

Positive Planar Area [Cut]: 476989.97245331
Negative Planar Area [Fill]: 23936.567188005
Blanked Planar Area: 2791470.3018186
Total Planar Area: 3292396.8414599

Surface Areas
Positive Surface Area [Cut]:  489896.01835327
Negative Surface Area [Fill]:  23949.159383499
Appendix C

Area and Volume Calculation Results for the Blanked Part of Observed Points

Grid Volume Computations

Thu Jul 28 12:32:22 2011

Upper Surface

Level Surface defined by Z = 67

Lower Surface

<table>
<thead>
<tr>
<th>Grid File Name:</th>
<th>\hig-ad\student\homes\Runway\Blanked.grd</th>
</tr>
</thead>
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<td>Grid Size:</td>
<td>100 rows x 57 columns</td>
</tr>
<tr>
<td>X Minimum:</td>
<td>428110.693</td>
</tr>
<tr>
<td>X Maximum:</td>
<td>429469.553</td>
</tr>
<tr>
<td>X Spacing:</td>
<td>24.265357142857</td>
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<tr>
<td>Y Minimum:</td>
<td>551017.616</td>
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<td>Y Maximum:</td>
<td>553440.527</td>
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<tr>
<td>Y Spacing:</td>
<td>24.473848484848</td>
</tr>
<tr>
<td>Z Minimum:</td>
<td>-21.226171238659</td>
</tr>
</tbody>
</table>
Z Maximum: 67.955982929891

**Volumes**

Z Scale Factor: 1

**Total Volumes by:**

Trapezoidal Rule: 5897283.8641986
Simpson's Rule: 5900691.1260833
Simpson's 3/8 Rule: 5918645.9922308

**Cut & Fill Volumes**

Positive Volume [Cut]: 5903021.7046097
Negative Volume [Fill]: 5737.8404110983
Net Volume [Cut-Fill]: 5897283.8641986

**Areas**

**Planar Areas**

Positive Planar Area [Cut]: 156143.66018652
Negative Planar Area [Fill]: 11029.808585301
Blanked Planar Area: 3125223.3726881
Total Planar Area: 3292396.8414599
Surface Areas

Positive Surface Area [Cut]:  161061.39649575

Negative Surface Area [Fill]:  11031.51964863