Multi-Criteria and Spatial Suitability for Siting ICT Hub in Ibadan, Nigeria

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Abstract – This work used numerous types of geospatial data to accomplish the objectives of the study which were to locate the most suitable site(s) for specific ICT sector operations (which are manufacturing and services locations) in Ibadan, Oyo State of Nigeria. The geospatial data included railway, road network, rivers, industries, markets, institutions, and settlements which were vectorized from the Ibadan Master Plan of 2017. Thereafter, Euclidean distance analysis was carried out on the vectorized layers. The shuttle radar topographic mission (SRTM) data were integrated in ArcGIS environment in order to produce the slope map used for this study. Previously classified settlement map was downloaded from the Worldpop for Nigeria where the study area of Ibadan was clipped from. Weights were then assigned according to percentage influence to each of the reclassified classes using the pairwise comparison table and important matrices of the Analytic Hierarchy Process (AHP), and then multi-criteria analysis and weighted overlay analysis were done so as to determine the most suitable site(s) for ICT hub in Ibadan. Exactly 2% of the land area of Ibadan representing 5512 hectares was highly suitable for ICT services whereas only approximately 1% of the total land area equivalent to 3359 hectares was highly suitable for ICT manufacturing. However, other levels of suitability ranging from least suitable, to moderately suitable and suitable locations with their respective percentages for both ICT services and ICT manufacturing were discovered in the study.

Key words: AHP, ICT Manufacturing and Services, GIS, SDGs, GDP, Ibadan, Nigeria.

1 INTRODUCTION

BUILDING a new capital improvement facility is a major, long-term investment for owners and investors. Site allocation for a large investment project is a critical judgment made by stakeholders/venture capitalists that impact on their profitability. The choice of locations of business facilities influence where individuals work and reside, it in turn influence the way people live in the area. Therefore, business site allocation is multidimensional, whether determined with respect to amounts of money, expert knowledge involved, workforces affected, or the socioeconomic and environmental impacts on the region. Site selection process tries to improve the functionality of any locational project by considering several factors that are beneficial or that may bring restrictions before actual site allocation for the project (Eldrandaly *et al.,* 2003).

Information and Communication Technologies (ICTs) hubs are vital business facilities for any nation to attain innovative and economic sustainability. It is generally accepted that ICT hubs continue to play important roles in both economic and urban growth in many cities in countries like United States of America, Japan, China, Brazil, Indonesia, Mexico, Singapore, South Africa and many more. Thus, many countries in Africa like Nigeria, Kenya, and Rwanda are now adopting ICT hubs as a key economic infrastructure to provide much needed telecom services, business tech-support, employment and human capacity development that promote new industrial development to support fast population growth recently recorded in their urban centres (Jacobs and Herselman, 2005, Kelly and Firestone, 2016; Mahlangu *et al.,* 2018).

In the year 2011, one of the top groups of African technology hubs creator (AfriLabs) was introduced with the objectives to fast-track, develop creation of hubs like Silicon Valley across African countries. By 2016 five African nations namely: Nigeria, Egypt, Kenya, Morocco, and South Africa have in the present over 300 of such hubs in their major cities. These developments have been noticed by World Bank and attracted the creator of Facebook Mark Zuckerberg to come to Nigeria and Kenya in 2016 to see the Co-Creation Hub. He believed in the high prospective in the development of Africa's technology hubs as a key factor for inhabitants of the continent toward economic and social diversification from current challenges faced in Africa (De Beer *et al.,* 2016).

This study seeks to address important factors that will influence site allocation for siting ICT hub in Ibadan using Remote Sensing and GIS techniques. Ibadan the capital of Oyo State is one of the paramount and biggest cities located in Southwestern Nigeria. It is a crucial transportation hub and trading centre for its geographic location, approximately 119 kilometers north-east of Lagos and 120 kilometers east of the border with the Republic of Benin. The population of Ibadan is about 6 million and it is ever increasing at a rate of 3.32 percent per annum with a 20-year projection reaching a population size of 11.6 million by 2036 (Dar, 2017). This rapid growth puts pressure on social and urban infrastructure highlighting major gaps in provision across the city. An ICT hub being one of such gaps, the need for an ICT hub that will meet the needs of the populace in terms of IT solutions cannot be overemphasized as the current situation in the city is such that ICT shops are scattered across the city. There is a need to have specific location that houses everything ICT wise from sales, servicing, repairs, and manufacturing. This in turn will create more internally generated revenue for Oyo State thereby attaining innovative and economic sustainability. Considering this challenge and the opportunities possible,

there is the need to explore the possibility of siting an ICT hub within the city. Several techniques were used in this study to determine the proper site for ICT hubs facilities in Ibadan. These techniques include Expert Systems (ES), Geographic Information Systems (GIS), and Multi-Criteria Decision-Making (MCDM).

1.1 ICT Growth in Africa and the World

Across the world, Information and communication technology has transformed the business world at large. ICT Hub is where Technology, Commerce, Innovation and Industrialization are supported by building agglomeration of both local and international organization to develop the abilities of various ICT experts. ICT Hubs are utilized in numerous nations worldwide as an instrument to advance improvement of both demand and supply of ICT components for financial gains and economic growth of the nation (NITDA, 2018).

During the 1990's, the global economic switch was linked with the development of the cyberspace, and this resulted in the evolution of the digital economy. However, throughout the 2000's and 2010's, a new cycle emerged that is ICTs that changed the economic landscape again. Nowadays, the incorporation of internet-enabled digital sensors into most devices and these devices are part of our life (cell phones, smartphones, digital tabs, additive manufacturing, laptops, and computers); new digital models (cloud computing, digital platforms, digital services) artificial intelligence, big data, data analytics, and algorithmic decision-making; and new automation and robotics genomics; biomimicry and biotechnology (OECD 2015).

OECD (2002) stated that OECD member nations in 1989 defined ICT sector as an amalgamation of two operations, manufacturing and services industries that represent, transmit and display of data and information electronically. ICT services sector involves software and app development, telecommunications activities, electronic media, digital publication, film or movie and sound production, radio and TV transmission and others. ICT manufacturing sector includes production of techno hardware, computing machinery, wire and cable, telecom components, television and radio transmitters and apparatus, sound or video recording or reproducing appliances, gadgets for measuring, monitoring, testing, navigating, industrial process equipment and many more.

The San Francisco Bay Area in United States of America is the home to the Silicon Valley that is highly attracted to many local and foreign technology companies that are leading and pursuing international growth in tech innovation globally. According to Startup Genome (2019), the position of Silicon Valley was the first among the world tech hubs, trailed by Boston, San Diego, New York, London, and Los Angeles. The ranking was based on 6 components (performance, funding, knowledge, talent, infrastructure and policy), but came second in the 5th component (Infrastructure). Also, major cities like Tel Aviv, Berlin, Paris, Stockholm, Beijing, Shanghai and others benefited from several factors associated with innovative and tech ecosystem classification.

Before now, Silicon Valley was considered the most important thing in the world of tech hubs. In recent time, such sector of economic growth zone can be found internationally. Be that as it may, there are various criteria that must be met before some place can be viewed as one of world's premier tech centre points. It takes something other than gathering a high convergence of brilliant personalities and invisible thoughts in a single area. It requires modern infrastructures — including excellent living conditions, best information communication services, excellent urban infrastructure and robust education system. Beijing - China's fast-growing capital is perhaps closing in to top the Silicon Valley's as the world's leading tech centre with huge amount of tech-based funding flowing to the country (Primalbase, 2018).

China's information and communication technology (ICT) industries are amongst the most important parts of her economy. The market is anticipated to reach 8.1 trillion dollars by the year 2021 and this will represent about 55% of China's Gross Domestic Product (GDP). The country's ICT imports in 2017 summed to about 528 billion dollars, and the supply to abroad was 781 billion dollars. China's ICT sales and manufacturing firms create a strong rivalry internationally with regards to the standard of ICT components, smart platform/vehicle operating system, artificial intelligence (AI), and 5G that are produced by them (Export.gov, 2019). One of the major contributors to China's ICT sector is the Zengcheng Development Zone, which was introduced in 2017 with the Zengcheng Economic and Technological Development Zone policy to boost economic development in Guangzhou's region. This development concept is committed to innovation and development, and implementation of innovative assets, aimed at 3 main concerns specifically on seeking potential investors, business services, and building ICT industries in the region. The Guangzhou's region and many major cities in China continue to get needed local and foreign investments to attain multiple economic growth from Technological Development Zone policies (Guangzhou.gov.cn, 2019).

There are many international tech firms like Google, Oracle and Facebook that establish research centres in Tel Aviv because of availability of many successful local tech firms. For instance, Google recently bought GPS navigation app 'Waze'- local to Tel Aviv- for 1 billion dollars, and Amazon opened an office in Tele Aviv to add to the fast-growing services provided by Israel tech industries (Hoffower, 2019). ICT hubs serve as means of generating revenue, employment and providing solutions to problems. Such hubs exist in India the world's largest sourcing

destination for ICT, accounting for approximately 52 per cent of the US$ 124-130 billion market while employing about 10 million Indians thereby contributing significantly to the social and economic transformation of the nation (Kulkami, 2015).

According to the Dubai Statistics Centre, the Dubai's ICT sector revenue made 4.2 billion dollars in 2016, equivalent to 3.9% of GDP and increased from 3.7% in 2014 and 3.8% in 2015. In 2016 the International Data Corporation predicted telecoms sector would generate over 51% of total UAE ICT expenditure, coming after is hardware (27%), IT services (15%) and packaged software (7%). The group anticipated the national IT market to expand at about 5% yearly between 2017 and 2022 (Oxford Business Group, 2018). The city is at the centre of the Middle East and Africa's ICT sector and regional home to the world's most famous global tech company, software and hardware providers, telecommunication merchant and Electronic media worldwide including Google, Facebook, Microsoft, LinkedIn, Oracle, EMC/Dell, and Twitter (Dubai Tourism, 2019). The Dubai Statistics Centre put the recent resident population of Dubai at 3,338,231 as at 28th of November 2019. This showed that the city have similar population size with Ibadan city.

Rwanda's Mara Group claimed to launch first Made in Africa smartphones on October 7, 2019, with the determination to boost the country's regional technology hub in Rwanda. Also, Mara Group opened South Africa's first smartphone factory at the Dube Trade Port in Durban on October 17, 2019. Mara Group planned to make big revenue from African Free trade agreement that promote African products first. The "Made in Africa" model is an opportunity to surely boost the group's desires to become the leading regional tech provider and compete with other smartphones like Samsung. Mara Group hopes to build its industrial capabilities and establish new industrial hubs across Africa in the future (Reuters, 2019; Cape Business News, 2019).

However, in 2017 AfriOne introduced Gravity Z1 first locally produced smartphone in Nigeria out of their new factory located in Lagos, Nigeria. AfriOne promote socio-economic development, by supporting "Made in Nigeria" through Innovative technology that echoes modern designs for their smartphones, educational tablets PCs and android smart watches with active research and development and capacity development in Nigeria. Nigeria is the major market in Africa for smartphones with about 35% of Nigeria's population using mobile phone. This presented huge opportunities for local tech producers like AfriOne to thrive. (Guardian, 2017 and CGTN Africa, 2017). According to the National Bureau of Statistics (NBS) result presented by Nigerian Communications Commission (NCC) (2019) there is evidence that at the rate ICT is thriving in Nigeria, perhaps in the next two or three years, the influence of the ICT to the Gross Domestic Product (GDP) will be twice that of oil sector. Nigeria's depends on the oil sector but the difference between the 2 sectors' input to GDP now is wide, Oil and Gas was 8% and Information and Communications Technology's (ICT) 13%. The praise should be given to every stakeholder in the Tech sector in the country.

National Information Technology Development Agency (NITDA) had identified that there is clear lack of adequate skilled manpower that will drive local content development and industrialization in the country. Therefore, the establishments of ICT Hubs in strategic locations in major cities in Nigeria that have the basic human capacity and urban Infrastructure will encourage needed foreign investment needed to help industrialize Nigeria ICT sector.

2 IBADAN SOCIO-ECONOMIC CONTEXT

The capital of Oyo State Ibadan is the third biggest city in Nigeria in terms of demography coming after Lagos and Kano in that order. The city is located at 145 km Northeast of Lagos and approximately on longitude 3° 55' 00" East and latitude 7° 23' 47" North. Ibadan city comprises of 11 local government areas. There are 5 major urban local government areas at the centre of the city with dense urban development and the remaining 6 are located at the outer surrounding suburban areas of Ibadan city (Azeez *et al.*, 2016), see figure 2.1.

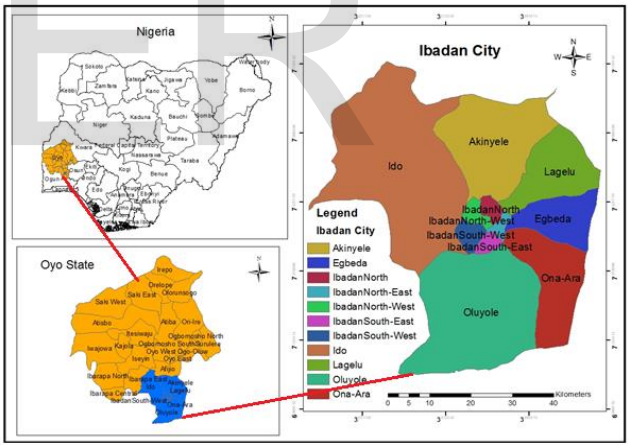

Fig 2.1 Map showing the study area – Ibadan City.

The population of Ibadan is currently about 6 million and it is forecasted that the population may likely add more than 5 million inhabitants by 2036. Hence, it is pertinent to be well prepared to create employment for the working population that is expected to gradually increase to about 65% by the year 2036. Majority of this growing middle class are now active user of e-commerce and related telecom services. Therefore, this is the right time to start planning on ways to domesticate market for manufacturing of telecom components and services. As a result, this will allow Nigeria to intensify progress made from its efforts to promote non-oil base economic diversification strategies in recent years. The Table 2-1 below showed the projected employment by economic activity (2016-2036) in Ibadan as reflected by analysis presented by Dar (2017).

Table 2.1 Employment Projections by Economic Activity, 2016-2036

EMPLOYMENT BY ECONOMIC ACTIVITY	2016	2021	2026	2031	2036	CAGR (2016-2031)
Agriculture, Hunting, Forestry and Fishing	478,756	483,611	488,110	492,230	587,565	1.03%
Mining and Quarrying	28,600	30,810	33,163	35,665	42,573	2.00%
Manufacturing	212,419	319,866	481,262	723,475	863,598	7.27%
Construction	63,339	68,334	73,662	79,338	94,704	2.03%
Electricity, Gas and Water/ Utilities	17,828	26,559	38,516	54,340	64,864	6.66%
Wholesale & Retail and Restaurants & Hotels	835,734	1,027,545	1,230,024	1,432,708	1,710,194	3.64%
Transport, Storage and Communications	233,151	291,991	355,968	422,198	503,969	3.93%
Financing, Insurance, Real Estate & Business Services	128,577	160,134	194,137	228,976	273,324	3.84%
Public Administration & Defense	10,160	11,766	13,264	14,547	17,364	2.69%
Education and Human Health	106,404	124,622	142,079	157,589	188,111	2.89%
Other Services	124,699	167,377	219,336	280,602	334,948	5.06%
Total	2,239,667	2,712,616	3,269,520	3,921,667	4,681,214	3.75%

The inhabitants of Ibadan enjoy the socio-economic services provided by different Public institutions, agriculture, trade, and manufacturing services that helped in the rapid change of the land-use of the city over the years. Among the Institutions are the University of Ibadan and Nigerian Television Authority Ibadan (NTA Ibadan) both first in Africa, The Polytechnic Ibadan, University College Hospital (UCH), Nigerian Institute of Social and Economic Research (NISER), International Institute of Tropical Agriculture (IITA), Institute of Agricultural Research and Training (IAR&T), Nigerian Horticultural Research Institute (NIHORT), and many more. Some of the notable places in Ibadan people socialize are Premier Hotel Mokola Hill, Cocoa Mall house, Shoprite, Botanical Garden, Zoo and Liberty Stadium etc.

The industrial institutions within Ibadan include heavy, medium and light industries, with key industries sited primarily beside the main transportation networks. These comprise industries along Oluyole, Old Lagos Road, Olubadan Industrial Estate near Express Toll Gate, Olubadan Estate along New Ibadan/Ife Express Road and Ajoda New Town, Eleyele Light Industrial Estate, and Nigerian Breweries PLC close to Olubadan Estate with some smaller industries sited around it. Traditional industries and other light industrial productions are scattered all over the city. Several industries have also been settled on the city suburbs. In addition, the Federal Government is taking actions and has selected sites for key industrial development in Ibadan. The upcoming industrial developments include Oyo State Industrial Park (Lagos-Ibadan express road), Burnt Brick Plant (Oloba and Adeyoooye villages), Inland Container Depot/Dry Port (Erunmu), Trailer Park (Alarobo Area, Monatan, along Lagos/Ibadan Expressway), Chinese Village – Industrial Estate (along Lagos/Ibadan Expressway), Oluyole Free Trade Zone (along Lagos/Ibadan Expressway), African Regional Centre for Engineering Design and Manufacturing (Wofun, Iwo Road), Mechanic Village (Olukunle village) and Ibadan Logistics Centre (Dar, 2017).

Ibadan has diverse Micro, Small and Medium enterprises sectors that are actively involved in both formal and informal businesses that can provide huge support for ICT hubs in terms of necessary skilled and unskilled labour, finance and large distribution of markets. These commercial centres comprised of over 82 markets spread strategically all over the city, 35 of which can be found in the five central LGAs and 47 in the outer LGAs. The city also has importance Modern shopping centres, Cocoa Mall, Ventura Mall, Adelabu Shopping Complex, the underutilized Agbowo Shopping Complex, and Oluyole LGA hosts the relatively new Palms Shopping Mall home to the largest Shoprite largest outlet in West Africa. These commercial centres serve as economic and social institutions needed to support the retail, sales and related activities to build social and urban infrastructure to accommodate the proposed ICT hub in the city.

Goal 9 of the Sustainable development goals is targeted at building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation that will support economic development and human well-being, with focus on affordable and equitable access for all (United Nations, 2019). In Nigeria, the telecommunications sector plays a dual role in economic activities, not only in itself as a distinct circle in the economic system, but also a supplying means to other sectors. The share of Nigeria's telecoms sector in total GDP has stabilized in the last six quarters as released by the National Bureau of Statistics (NBS) report. The contribution of the telecommunications sector in the first quarter of 2017 is ₦1.452 trillion to the GDP, i.e. 9.16 %. This is an increase of 0.2% compared to the First Quarter of 2016, indicating stable growth in the sector (Danbatta, 2017).

The proposed Ibadan City Master Plan 2017 did not take into consideration or make provision to accommodate siting of an ICT hub for Ibadan with the ever-increasing population especially around institutions and markets. This is therefore a setback as many developed and developing countries have such ICT hubs within their major cities and technology hubs may indeed be among the most significant drivers of global engagement with Africa's entrepreneurs. There is, however, very little research on this important new

phenomenon whereas, other developed and developing countries have such IT hubs in cities such as Guangzhou, China etc. Ibadan city is a city blessed with agglomeration of markets, industries, education and other urban institutions but the city lacks an ICT hub where solutions to the needs regarding ICT can be met.

In summary, Ibadan, being the third largest city in Nigeria and the Capital of Oyo state, is currently experiencing continued population growth and urbanization. The main objective of this section is to identify primary drivers of growth in Ibadan on the short to medium term to justify that the city is ready with regards to large population with various economic sectors to accommodate ICT hubs to support the economic growth of the city.

3 GIS IN SITE SELECTION

There are vast and increasing awareness created by published studies indicating the significant roles GIS and Remote Sensing can contribute to effective allocation of industrial and commercial facilities to boost economic development of cities around the world. Shouman (2008), scientifically integrated GIS, Expert systems, Multi-criteria decision-making methods to provide solutions to challenges associated to allocation of space for industrial purpose. The proposed method, expert system was adopted to aid the decision maker to identify values for examining criteria of the site screening stage, structuring the choice model and allocating weights to the attributes employed in the assessing criteria for the site appraising phase. GIS tools are employed in carrying out geospatial analysis that are vital in the selection stage of proposed sites, and the Analytic Hierarchy Process (AHP) and MCDM technique, are used to find the most suitable site.

In the work published by Wei and Ding (2015), they used Multi-Criteria Decision Analysis (MCDA) for site allocation in Guangzhou, China. They concluded that the old labour intensive method of planning using surveyed biophysical information and hierarchical method are not suitable for site selection since geospatial data is increasingly modernized and more readily available. At present time, GIS integrated with MCDA offers solutions for evaluating the important compromise and strategies for assimilating and recording the best decision value of interested stakeholders for site selection related development. Remotely sensed images, digital elevation model (DEM), and various thematic layer of Guangzhou were employed in the study and all the data were used to generate restriction and factor maps for MCDA. Thereafter, weights for MCDA were gotten using an analytic hierarchy process (AHP) by measuring how relevant each factor are to the one another. This produced a suitability map for housing development in the study area. The result showed the ability of GIS and remote sensing technologies to aid urban planning with a geospatial method.

Caradima (2015) presented a Multi-criteria suitability analysis and spatial interaction modeling for trading outlet sites selection in Ontario, Canada. The work intellectualizes and presented 9 criteria in a GIS integrated with MCDA method to examine 4.7 million possible stores locations. The research used wide range of geospatial criteria to examine the statistical and spatial distribution of most suitable positions for a trading outlet. In addition, the work analyzes how the spatial locations of criteria relate to the Huff's model and its effects on the spreading of suitable sites. The results of the work demonstrated that the combination of network-based spatial interaction costs in Huff's model generate a more spatially interactions sales estimations than Euclidean-based spatial interactions.

Several scholars trying to make finest decisions influenced by numerous factors that may impact the result of the spatial decision use a combination of geographic information systems (GIS) and different systems and method like decision making (DSS), multi-criteria decision making (MCDM). These systems are known to be integrated to form the multi-criteria analysis, sometimes referred to as Multi-Criteria Decision Making (MCDM) or Multi-Criteria Decision Aid methods (MCDA) by various researchers in the field of Operation Research model. MCDA which is a GIS-based tool offers answers to geospatial problems related to site allocation by factoring various values allocated to each criterion using mathematical or weighted overlay methods to make finest spatial decision (Rikalovic *et al.*, 2014). Saaty (2008) showed that Analytic Hierarchy Process (AHP) is the most widely used techniques of Multi-Criteria Decision Making (MCDM) and it was introduced by Saaty in 1980 using pairwise comparisons of criteria to establish a relationship matrix (proportion). Analytic Hierarchy Process (AHP) is a method which aid decision makers to come out with unsurpassed explanation and facts that fits their objective and their considerations of the difficulties, prompted by a planned likelihood solution guided by baseline knowledge of the challenge. AHP try to mimic the impression of the natural ways we humans view and make reasonable conclusions about strategic planning. GIS combined with other systems has shown a suitable and dominant base for investigating the most suitable location for siting of ICT hub in Ibadan which is the major aim of this work.

4 METHODOLOGY

This work used numerous types of geospatial data to accomplish its objectives which is to find the most suitable site for specific ICT sector operations i.e. manufacturing and services locations in Ibadan. Bulk of the geospatial data used in this research was vectorized from the Ibadan Master Plan. The coordinate system of all these data: railway and

road network, rivers, industries, markets, institutions and settlements were projected to WGS 1984 31°N. The Euclidean distance analysis was carried out on all the vectorized layers. Euclidean distance analysis determines the association between each cell to a specific location, or separate locations based on the straight-line distance (ESRI, 2016). The Euclidean distance raster result comprises the measured distance from each raster cell to the adjacent source. The integration of the SRTM data was done in ArcGIS to produce the slope map for the study area using the slope tool in the ArcGIS environment. The settlement map of Nigeria was downloaded from the WorldPop webpage.

The major steps of data processing and analysis techniques used in this study are Euclidean distance, Analytic Hierarchy Process (AHP), Multi-Criteria Analysis and Weighted Overlay. The Euclidean distance was performed to the vector layers with the aid of the ArcGIS spatial analyst toolbar. The purpose of this process is to determine distances of the various datasets which will serve as criteria such as railway and road network, rivers, industries, markets, institutions and settlements. In siting ICT hubs, proximity to these various geospatial datasets are a necessity as these distances to the proposed sites should be as minimal as can be allowed. Individual class weights and map scores were assessed based on Satty's (1980) Analytic Hierarchy Process (AHP), in this method the relative importance of each individual class within the same map were compared to each other by pair-wise and important matrices were prepared for assigning weight to each class. The AHP was used to classify the zones into least suitable, moderately suitable and highly suitable. The last step involved the weighted overlay tool. The tool only makes use of integer raster. Continuous (floating-point) raster must be reclassified to numerical value before they can be used. The values of the raster were grouped into ranges. Each range was allocated a value before it was used in the weighted overlay tool. Thereafter, all reclassified raster layers were combined by using the weighted overlay tool to depict the final result for the most suitable area(s). A numerical weighting influence is allocated to each thematic layer with regard to its relative rank compared to other layers, (GITTA, 2006). The weighted overlay function was used to overlay all the raster data using a common measurement scale and weighed according to its importance. The ranking technique was adopted from the work of (Rad and Haghyghy, 2014). Three ranking categories for scale of suitability was used with the values 1, 2, and 3 signifying least suitable, moderately suitable and highly suitable respectively. The different datasets were entered into the weighted overlay table and the influence was set according to preference/ranking.

4.1 DISCUSSION AND RESULTS

This section discusses the results of the research and presents the said results as maps and tables. Nine parameters were evaluated comprising railway and road network, rivers, industries, markets, institutions and settlements. Each of the thematic layers were examined with respect to influence value obtained from pair wise comparison matrix of Analytical Hierarchy Process. Suitability maps for specific ICT sector operations i.e. manufacturing and services locations in Ibadan were reclassified to classes from not suitable to highly suitable based on the cumulative evaluation of the criteria and weightages given.

4.1.1 Industries, Markets and Institutions

In retail, stores draw commerce from a geographic zone known as a service or trade area. Retailers often delineate and analyze trade areas based on several markets, industries, institutions and demographic statistics, and describe potential site locations relative to their trade area statistics. In particular, site suitability may be inferred from the trade area using a variety of matrices, such as the density of institutions, industries and markets within the trade area (Caradima, 2015). In addition, the number of institutions, industries and markets per square kilometer within a trade area provide measures of competition and agglomeration within the trade area of a potential site. In this study, the socioeconomic and environmental impacts that ICT services and manufacturing industries might have on existing industries, markets and institutions areas are considered major factor as one of the criteria in site selection. With this regard, the percentage Influence of the proposed ICT Services hub have on the thematic layers of industries, markets and institutions were assigned 16%, 12% and 12% influence respectively. On the other hand, the percentage Influence of the proposed ICT manufacturing hub have on the thematic layers of industries, markets and institutions were assigned 12%, 16% and 12% influence respectively as shown in Table 4.1 Most importantly in this analysis to obtain final suitability map, industries and markets were given more weightages as it cannot be ignored while considering any area ICT services and manufacturing hubs can be located. All these thematic layers were reclassified in to 3 classes: least suitable, moderately suitable and highly suitable.

Table 4.1 Details of Weighted Overlay Analysis for ICT services and manufacturing industries.

S/N	Thematic Layer	% Influence on ICT Services	% Influence on Manufacturing	Field Value	Scale Value ICT Services	Scale Value ICT Manufacturing
1	Industries	16	12	1 2 3	1 2 5	1 2 9
2	Market	12	16	1 2 3	1 2 9	1 2 5
3	Landuse	12	12	1 2	5 1	1 5
4	Institutions	12	12	1 2 3	1 2 5	1 2 5
5	Rail	12	12	1 2 3	1 2 3	1 2 3
6	Road	12	12	1 2 3	1 2 3	1 2 3
7	Slope	12	12	1 2 3	1 2 3	1 2 3
8	River	12	12	1 2	5 1	1 5

4.1.2 Transport Networks

Accessibility can be considered of great importance to the location of an industry, market or enterprise in general. The location of ICT services and manufacturing industries are of no exception to easy access to transport networks as it is vital to the selection of whichever site to be proposed. Service providers and manufacturing industries are often located along major arterial roadways and rail lines with high traffic volumes to increase store visibility and accessibility. The economic effect of access roads cannot be overemphasized as it directly impacts the technical and commercial purpose of the proposed site. As such the site should be located within an acceptable distance to major transportation network. As indicated in Table 4.1, the railway and road network were assigned an influence of 12% to site allocation for the proposed ICT services and manufacturing industries. Areas nearer to the transportation networks with scale value of 3 were reclassified as highly suitable, those with scale value of 2 were considered Suitable and those with scale value of 1 were considered least suitable. This is shown in Figure 4.1. The Construction of new access roads for transportation of goods and equipment is very expensive and is one of the unavoidable factors in the construction of ICT hub.

4.1.3 Land use and River

The settlement or built-up areas helps to locate the available locations of the established factories and other land use types that exist. Due to the various unfavorable environmental impacts on the populated centres and urban growth in this study, distance from residential areas is considered a key factor as one of the criteria in site selection. As shown in Table 4.1, the land-use layer was assigned an influence of 12% for siting the ICT services and manufacturing industries. Built-up areas are assigned scale value of 5 and classified as highly suitable for the proposed ICT services locations and vegetation/bare land were considered least suitable with a scale value of 1. But the land-use scale value for ICT manufacturing industries was assigned the other way round because of the negative impacts manufacturing industries might have on houses close to such location. Figure 4.1 shows the suitability map for land use and river. Rivers generally are very important factor for siting the ICT services and manufacturing industries. Therefore, flood prone areas are delineated and considered as criterion, due to the significance of water to humans, pollutions of water bodies are foreseeable, so thoughtful measures are considered during the proposed ICT hub site selection. Thus, distance from the rivers was reclassified into two. As a result, area close to rivers were reclassified as least suitable and marked restricted and highly suitable areas are given scale value 1. This is shown in Table 4.1 as rivers layer area assigned was 12% influence.

4.1.4 Slope

As previously mentioned, the slope data was generated by using the Shuttle Radar Topography Mission (SRTM) elevation with a resolution of 90m in ArcGIS. The purpose of using such layer in this study is to consider the areas that have a high slope area. Areas with gentle slope are considered more suitable for construction of large structures. Moreover, stability issues are considered during the construction phase. Steeper slope areas are generally avoided to reduce the risk of instability during construction. The slope raster was reclassified in to 3 classes: least suitable, moderately suitable and highly suitable. Table 4.1 showed 12% influence was assigned to the slope layer.

4.2 Weighted Overlay and Multi-criteria Analysis

To get the final suitability maps for the proposed ICT services and manufacturing hubs, a final step of aggregating the criteria using MCA model, is needed. The MCA model consists of the combination of criteria maps: railway and road network, rivers, industries, markets, institutions and

Suitability level	ICT Services (ha)	Percentage	ICT Manufacturing (ha)	Percentage
Least Suitable	142248	44%	60062	19%
Moderately Suitable	96731	30%	71676	22%
Suitable	76148	24%	185433	58%
Highly Suitable	5512	2%	3359	1%

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settlements maps. Using the weighted overlay tool in ArcGIS, all raster layers were aggregated based on their individual weights to get the final suitability maps with scores ranging from one to four depicting least suitable, moderately suitable, suitable and highly suitable as shown in figures 4.2 and 4.3.

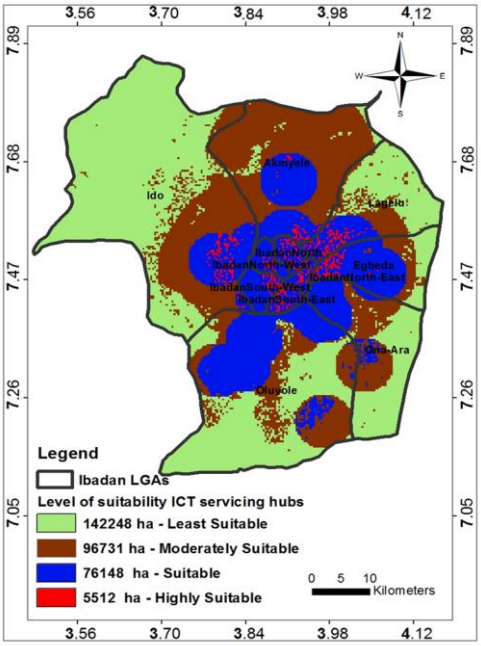

Figure 4.1: Level of suitability ICT servicing hubs

The final suitability level in Table 4.2 encapsulated all the geographic areas considered for potential areas for siting ICT services and manufacturing hubs by suitability ranking from least suitable to highly suitable areas. The result for the ICT hubs suitability analysis reveals that approximately 5512 hectares and 3359 hectares of the study area is highly suitable for siting ICT services and manufacturing hubs as shown in the table below.

Table 4.2 Suitability Level for ICT Services and Manufacturing in Ibadan

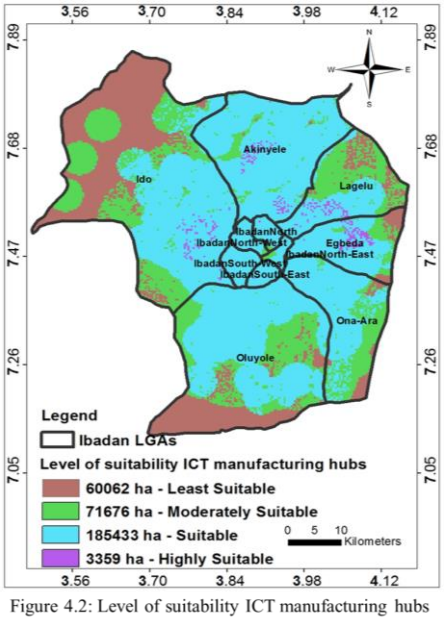

Figure 4.2: Level of suitability ICT manufacturing hubs

The suitability of an IT hub site can be expressed in terms of the existing features. Figures 4.3 and 4.4 showed the composite suitability of some of the criteria layers. The areas of the proposed ICT services in Figure 4.3 and manufacturing hubs in Figure 4.4 are labeled as least suitable, moderately suitable, suitable and highly suitable. The parts of the selected areas that are near the existing transportation networks, industries, markets, institutions are more suitable than those located further.

Generally, highly suitable area for the IT hub can be summarized in terms of the specific objectives set at the beginning of the study. In other words, locating the IT hub within this site ensures minimizing the impact of the hub on the surrounding environment.

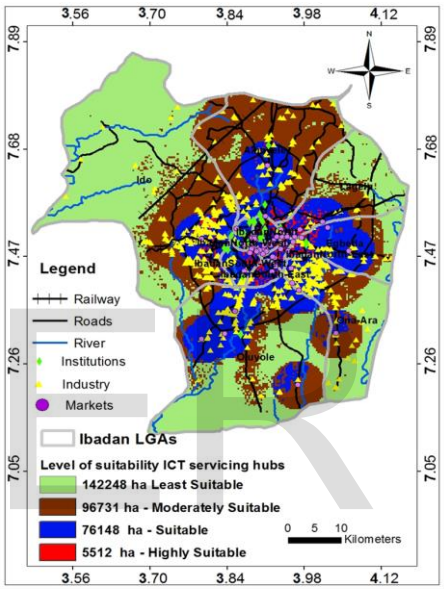

Figure 4.3: Composite suitability of ICT servicing hubs and few criteria layers

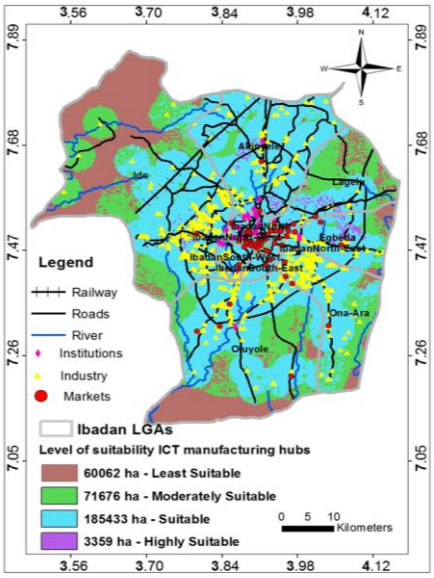

Figure 4.4: Composite suitability of ICT manufacturing hubs and few criteria layers

5 CONCLUSIONS

The establishment of an IT hub supports goal 9 of the SDG goals regarding building infrastructure, promoting inclusive and sustainable industrialization and foster innovation. Siting an IT hub in Ibadan helps to fill the void that was not considered in the Ibadan Master Plan and provide a lasting solution to the problem of large scattering of stores and shops that provide IT solutions across the city.

The spatial way of identifying the potential IT hub sites require a combination of GIS and MCDA methods regarding site analysis for feasible areas with the help of multi-criteria methods. Thus, enabling the performance of various environmental and economic criteria in the screening of IT sites location problem. Main factors being the land use and land cover detail, settlements, institutions and industries, slope of the region, viable road network, rail network, high speed rail link.

5.1 Recommendations

The results of this work should be adopted to develop the resources needed for siting ICT hubs in Nigeria so that States, Local government and people living in major cities can benefit from the ICT sector economic gains. The Oyo state government should implement policies to build Information and communication technology hubs in Ibadan to transform the socio-economic, Innovation and Industrialization development to meet the SDGs by creating employment for the working population. Thus, planners and authorities need to formulate a suitable plan for sustained development of Ibadan city using the application of GIS. Furthermore, with the experience of successful site selection and urban planning using GIS and remote sensing technologies, experts and decision makers can do their job more efficiently.

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