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EXAMINING THE STATE OF INFRASTRUCTURE DEVELOPMENT IN SUB-SAHARAN AFRICA

Infrastructure services are not only crucial for enhancing the welfare of the people but to also foster economic growth and development. Despite these essential services, there is a glaring infrastructure gaps in Sub-Saharan Africa more than any other region in the world. In the light of this and measurement problems associated with infrastructure development, it is therefore necessary to highlight the state of infrastructure development in SSA. This study examines the state of infrastructure development in SSA by considering 43 nations over the period of 2000 to 2018. Infrastructure development was proxied by the composite infrastructure index which include both the physical and social infrastructure. The study employed Principal Components Analysis (PCA) in building the aggregate or composite index, and descriptive statistics, stylized facts and correlation analysis were employed for the analysis of the data. Findings from this study reveal that infrastructural development has improved significantly in SSA for the period of study even though this is very low compare to the development attained in other regions of the world, and most of the improvement are from physical infrastructure, most especially telecommunication sector, and to a lesser degree, in health and water infrastructure. The study therefore recommends that stakeholders should engage in policies design that will improve infrastructure development in SSA most especially for the low income countries as majority of them were found at the bottom of ranking. This will help in closing the wide gap of inequality in access to infrastructure services among the SSA countries and other developing countries in other regions of the world.

Key words: Infrastructure development, Composite Infrastructure Index, Principal Components Analysis, Physical and Social Infrastructure.

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Сахараның оңтүстігіндегі Африкадағы инфрақұрылымның даму жағдайын зерттеу

Инфрақұрылым адамның әл-ауқатын жақсарту үшін ғана емес, сонымен бірге экономикалық өсу мен дамуды ынталандыру үшін де маңызды. Осындай маңыздылыққа қарамастан, Сахараның оңтүстігіндегі Африкада (СОА) әлемнің кез келген аймағына қарағанда инфрақұрылымдық кемшіліктер бар. Осыған байланысты, сондай-ақ инфрақұрылымды дамытумен байланысты өлшеу проблемаларын шешу үшін СОА-да инфрақұрылымның даму жағдайын анықтау қажет. Бұл зерттеу 2000 жылдан 2018 жылға дейінгі 43 елді қамтитын СОА-дағы инфрақұрылымдық даму жағдайын зерттейді. Инфрақұрылымның дамуы физикалық және әлеуметтік инфрақұрылымды қамтитын құрама инфрақұрылым индексімен анықталады. Зерттеуде жинақталған немесе құрама индексті құру үшін негізгі компоненттер анализі (PCA), ал деректерді талдау үшін сипаттамалық статистика, стильдендірілген фактілер және корреляциялық талдау қолданылды. Зерттеудің нәтижелері СОА-дағы инфрақұрылымның дамуы зерттеу кезеңінде едәуір жақсарғанын көрсетті, дегенмен бұл әлемнің басқа аймақтарында қол жеткізілген дамумен салыстырғанда өте төмен деңгей, ал жақсартулардың көп бөлігі физикалық инфрақұрылыммен байланысты, әсіресе телекоммуникация секторы және аз дәрежеде денсаулық сақтау және сумен қамтамасыз ету инфрақұрылымында. Осылайша, зерттеу мүдделі тараптарға СОА елдерінде, әсіресе табысы төмен елдерде инфрақұрылымның дамуын жақсартатын саясатты әзірлеуге қатысуды ұсынады, өйткені олардың көпшілігі рейтингтің соңында тұр. Бұл СОА мен әлемнің басқа аймақтарындағы дамушы елдер арасындағы инфрақұрылымдық қызметтерге қол жетімділіктегі елеулі теңсіздіктерді жоюға көмектеседі.

Түйін сөздер: инфрақұрылымды дамыту, инфрақұрылымның құрама индексі, негізгі компоненттерді талдау, физикалық және әлеуметтік инфрақұрылым.

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Изучение состояния развития инфраструктуры
в Африке к югу от Сахары

Инфраструктура имеет решающее значение не только для повышения благосостояния людей, но и для стимулирования экономического роста и развития. Несмотря на это важнейшее значение, в Африке к югу от Сахары (АЮС) наблюдаются явные пробелы в инфраструктуре больше, чем в любом другом регионе мира. В свете этого, а также проблем измерения, связанных с развитием инфраструктуры, необходимо определить состояние развития инфраструктуры в АЮС. В этом исследовании изучается состояние развития инфраструктуры в АЮС, которая включает 43 страны, за период с 2000 по 2018 год. Развитие инфраструктуры отражается составным индексом инфраструктуры, который включает как физическую, так и социальную инфраструктуру. В исследовании использовался анализ основных компонентов (PCA) для построения агрегированного или составного индекса, а для анализа данных использовались описательная статистика, стилизованные факты и корреляционный анализ. Результаты этого исследования показывают, что развитие инфраструктуры в АЮС за период исследования значительно улучшилось, хотя это очень низкий уровень по сравнению с развитием, достигнутым в других регионах мира, и большая часть улучшений связана с физической инфраструктурой, особенно в секторе телекоммуникаций и, в меньшей степени, в инфраструктуре здравоохранения и водоснабжения. Таким образом, исследование рекомендует заинтересованным сторонам участвовать в разработке политики, которая улучшит развитие инфраструктуры в странах АЮС, особенно в странах с низким уровнем дохода, поскольку большинство из них находятся в нижней части рейтинга. Это поможет ликвидировать значительный разрыв в неравенстве доступа к инфраструктурным услугам между странами АЮС и другими развивающимися странами в других регионах мира.

Ключевые слова: развитие инфраструктуры, составной индекс инфраструктуры, анализ основных компонентов, физическая и социальная инфраструктура.

Introduction

Most existing literature have emphasized the important of infrastructure as a significant factor in supporting economic growth and development various countries across the world. Improving infrastructure services such as energy, education and health are not only enhancing the welfare of the people but also foster economic growth and development. Availability of infrastructure unlocks the economic growth and social benefits and progress. Infrastructure enhances the provision of the fundamental basis for a modern functioning society and economy (Jenkinson et al., 2017).

However, the provision of infrastructure services to meet the needs of the users has become one of the main problems of economic development globally, many countries in both the developed and developing countries have been paying insufficient attention to the maintenance and expansion of their infrastructure assets which create economic inefficiencies and allowing critical systems to erode. Actually, there is a glaring infrastructure gaps in the developing countries most especially in SSA but advanced economies are also not in exception (Woetzel et al., 2016). Huge infrastructure deficit has been generally observed as one of the main obstacles that hinder the growth and development of the SSA. There is no region in the world that lack infrastructure and need more crucial and potentially transformational than in SSA (Foster & Briceno-Garmendia, 2010).

However, despite these challenges, infrastructure has been one of the major factors responsible for improved growth in the last two decades in SSA which still has the potential to contribute more in the future if the region acquires more critical and modern infrastructure that can aid economic growth and development (Infrastructure Consortium for Africa- ICA, 2010). Also, Africa Development Bank – AfDB (2018) stated that the recent improvement in economic growth in Africa was largely attributed to the investment in infrastructure which still has the potential to contribute even more. Even though there are some countries in SSA that have made a great effort toward improving their infrastructure networks but considering the competitiveness at regional level, SSA performs below the rest of the regions globally. This is largely associated with the huge deficit in the quality, quantity, and ease of accessing infrastructure services (AfDB, 2018).

In the light of these fundamental issues raised on the importance of infrastructure, it is therefore necessary to highlight the state of infrastructure development in SSA. Inadequate knowledge on the level of infrastructure development in the region will hinder the stakeholders to be aware of the status and progress of various infrastructure services and policies to be put in place in order to boost infrastructure development as well as the sectors and projects to be prioritized over the coming years.

To address the problem of infrastructure deficits in SSA, a considerable number of literature have investigated the economic benefits of infrastructure in the region. Also, studies have proxied infrastructure development with investments in infrastructure which may not reflect the actual infrastructure development because of inefficiency and corruption in the region (Randolph et al., 1996; Dao, 2008; Valila et al., 2010). However, available evidence on the state of infrastructure development in SSA are mostly from international organization reports such as AfDB and WEF. In addition, studies such as Akanbi (2013), Onikosi-Aliyu (2014) and De (2010), proxied infrastructure development with the combination of power, telecommunication and transport infrastructure (physical infrastructure) through principal component analysis (PCA), these studies have paid less attention to the social infrastructure, they have largely ignored the fact that physical infrastructure alone is inadequately means infrastructure development, it can only means a necessary but not sufficient condition.

However, despite these studies, there are still gaps that are needed to be filled, and to the best of my knowledge, no study has measured and incorporated both the indicators of physical and social infrastructure in the measurement of infrastructure development in SSA. It is an attempt to fill these gaps that prompt this study, which has the objective of including social infrastructure to the composite infrastructure index to proxy infrastructure development in SSA.

Specifically, in relation to the core issues raised above, objectives of the study include: investigating the state of infrastructure development in SSA in the last two decades; comparative analysis of the sub-regional infrastructure development in SSA; comparing the outcome of the composite infrastructure development index in the present study with that of African Infrastructure Development Index (AIDI); examining the relationship between the outcome of the composite infrastructure development index in the present study with AIDI. The remainder of this study is organized as follows: Section two presents the review of relevant literature; Section three presents the details of the methodology employed in this study; Section four presents and evaluates the results; and Section five presents the conclusion and recommendations of the study.

Literature Review

Conceptual Review

Infrastructure is defined as the totality of those buildings, installations and communication networks require for supplies, especially in relation to the movement of goods and messages (Schneider & Jager, 2001). The word 'infrastructure' is originated from the Roman Languages, and since then the concept has been widely used till today, even though it is very difficult to find a generally accepted definition of infrastructure (Jochimsen, 1966; Snieska & Simkunaite, 2009).

Conventionally, infrastructure can basically be classified to two groups, namely; physical and social infrastructure. Physical infrastructure is referred to the infrastructure that aids economic activity, such as roads, highways, railroads, airports, sea ports, electricity, telecommunications. This is also regarded as physical infrastructure, while social infrastructure is regarded as the facilities that stimulate health, education and cultural standards of the population (Snieska & Simkunaite, 2009).

The above definitions of infrastructure are therefore implying that infrastructure involves facilities that aid both the economic and social activities of the society which include electricity, transport, telecommunication, health, education, water and sanitation etc. Infrastructure development therefore involves the construction and improvement of foundational services with the aim of promoting economic growth and the quality of life. It plays important role in the development of any economy but requires large capital installation or large social overhead capital with long gestation period but the benefits have multiplier effect in the economy which is essential for the improvement of the welfare of the people and economic development.

Theoretical Review

Although there are theories on infrastructure demand models which include the theory of demand and consumption theory based on the previous studies (Ziramba, 2008; Amusa et al., 2009; Hussain et al., 2013; Kwakwa, 2017), but this study is not aware of the existence of any received theory on infrastructure supply model. Thus, since infrastructural development is a form of investment

in real assets, infrastructural development is treated as investment and accelerator theory of investment is considered to be more relevant for this study.

The theory was developed by Nixon and Aftalion before Keynesian economics, but become widely known in twenty century when the Keynesian theory dominated the discipline of economics (Ganti, 2019). Accelerator theory is a special case of the neoclassical theory of investment which is based on the notion that capital stock is determined by the level of output (Eklund, 2013). That is, there is a fixed relationship between the capital stock and output level. The accelerator theory is a simple model that involves the kind of feedback from current output to investment and it is based on the assumption that capital-output ratio is roughly constant. This means that the capital stock at any period t is proportional to the level of output in t. That is:

$$K_t = \sigma Y_t \qquad (1)$$

where K_t is the capital stock, Y_t is the level of output and σ is the capital-output ratio. Equation (1) is simply a well known simple accelerator principle where the capital stock is determined by the level of output.

It can therefore be concluded that infrastructure development is majorly influenced by the level of output, this is in line with the Equation (1). Apart from the theoretical evidence, gross domestic product (GDP) is commonly used in infrastructure studies as a measure of the level of output (Dao, 2008; De, 2010; Akanbi, 2013; Steckel et al., 2017).

Empirical Review
Cross-Country Studies on Infrastructure

Large number of the studies on infrastructure focuses more on measuring the growth and development gains from infrastructure. Although there is some literature on infrastructure financing, but the literature on infrastructure development and financing or determinants of infrastructure development is thinner, most especially in the SSA. For instance, Dao (2008) examines the determinants of infrastructure indicators in developing countries. The study applies the least-squares estimation techniques in a multivariate linear regression and found that infrastructure indicators are influenced by the share of public expenditures on pensions in GDP, public spending for education as a percentage of government expenditures, the share of public spending for health in GDP, public saving (% of GDP), and civil service wages as a fraction of government spending. The study also revealed that only private spending for telecommunications (%

of GDP) was statistically significant in explaining cross-country variations in the number of fixed and mobile telephone lines.

De (2010) provides a comprehensive and empirical analysis of the linkages between governance, institutions, and regional physical infrastructure. The study covers the period of 1991 to 2006 for 124 countries in Asia, Europe and Latin America. It estimated the empirical relationship between governance and infrastructure using panel data. The model of the study also considered per capita income, population, trade openness, manufacturing value added and geographical regions as the determinants of infrastructure apart from the governance. The study employed Generalized Method of Moments to address the problem of endogeneity among the variables. The empirical results indicated that governance and institutions are important determinants of regional infrastructure development. Specifically, an improvement in governance will leads to 1 to 1.5 increase in regional infrastructure.

Donaubauer et al. (2016) assess the possible complementarities between aid and foreign direct investment by identifying the transmission mechanisms through the index of infrastructure. Apart from the aid and FDI models, one of the specific objectives in their study is the determinants of infrastructure development (Transportation, Communication, Energy and Finance). They used a composite infrastructure index generated through PCA for 81 aid-recipient countries that comprises both the developed and developing countries, for the period of 1990–2010. The study employed 3SLS method to estimate the model and found strong and robust evidence that aid is one of the key determinants of the recipient countries' infrastructure development. The study therefore concluded that, carefully selected aids will help in improving the development of economic infrastructure.

Steckel et al. (2017), employed both the cross-section and time series data of 154 countries over the period of 1990 to 2010, empirically examine the determinants of access rates to the key infrastructure services such as electricity, telephony services, water and sanitation. The study used both descriptive and inferential (fractional logit model) statistics to analyze the trends and global patterns in access to these infrastructure services. The findings from the study showed that population density and GDP are the most crucial determinants of infrastructure services. Also, for all forms of infrastructure that are considered, it was found that access levels are higher in urban than rural areas, this implies that

the urban are given more priority than rural ares in infrastructure buildup. In addition, the result revealed that water has the highest in terms of considering the contributions of infrastructure indicators to development and access levels. This is followed by sanitation, electricity and telephony in sequence order.

In a study conducted by Akanbi (2013), the determinants of physical infrastructure that would promote the productive potential of SSA were empirically examined. The study made use of a panel of 21 selected SSA countries covering 2000 to 2010, employing 2-stage least squares (2SLS) estimation methodss. Infrastructure variable was derived from the three physical infrastructure stocks (electricity, road and telecommunication) that were generated with the use of PCA, and governance was proxied by the worldwide governance indicators. The findings from the study revealed that government capital expenditure, real GDP, inflation and external balance are important drivers of physical infrastructure in SSA.

Country-Specific Studies on Infrastructure

Perkins et al. (2005) analyze long-term trends in the development of South Africa's economic infrastructure and discusses their relationship with the country's long-term economic growth. Data on energy, transport and telecommunication were utilized for the analysis of the study. Evidence from the study showed that there was potential simultaneity between GDP and specific types of infrastructure, and concluded that adequate investment in infrastructure could help to create opportunities for promoting economic growth. The study therefore suggested that policymakers should embark on the right type of infrastructure at the right time.

Nnanseh & Akpan (2013) assess the impact of internally generated revenue (IGR) on infrastructural development in Akwa Ibom State, Nigeria. Specifically, the study examined the extent to which IGR contributed to the provision of infrastructure such as electricity, road and water. The study made use of secondary data that were analyzed with descriptive and simple regression techniques. The findings from the study showed that IGR has positive contribution to the provision of electricity, roads and water but the contributions were skewed more to roads than electricity and water.

Onikosi-Aliyu (2014) investigates the impact of infrastructure on employment and economic growth in Nigeria between 1970 and 2010. Apart from the main objective of the study, one of the specific objectives of the study was to examine

the determinants of infrastructure in Nigeria. In the infrastructure model, economic growth, real interest rate, public debt, recurrent and capital expenditure were identified as the determinants of infrastructure in Nigeria. The infrastructure variable was measured by a linear combination of three main economic infrastructures (electricity, transportation and telecommunication) using PCA. The study used secondary data sourced from Canning (1999), Central Bank of Nigeria and the National Bureau of Statistics, and employed 2SLS method to estimates the models. The results from the study showed that the major determinants of infrastructure in Nigeria are real interest rate, capital expenditure and recurrent expenditure of the government. The study further showed that both real interest rate and capital expenditure negatively impacts infrastructure in Nigeria while the recurrent expenditure positively impact infrastructure.

Li et al. (2017) investigate the critical factors that influence municipal infrastructure development in urban China. Based on the information on five main urban infrastructure systems (energy efficiency, sustainable urban transport, waste management, water/wastewater, and urban ecosystem management) and ten municipal composite infrastructure indexes (per capita road area, road network density, buses per 10,000 residents, drainage pipe density in built-up areas, water coverage, gas coverage, per capita gas consumption, green space ratio in built-up areas, green space coverage in built-up areas and water flush toilet ratio in built-up areas), they employed factor analysis (FA) to generate the aggregate index for the municipal infrastructure development of the 113 cities in China. The study identified urban population, per capita GDP, per capita maintenance capital, fixed asset investment, industrialization and industry structure level as determinants of municipal infrastructure development. The stochastic model STIRPAT (stochastic impacts by regression on population, affluence and technology) was employed to estimate the model. The findings from their study revealed that the municipal infrastructure development in urban China was primarily determined by income, industrialization and investment.

Assessing the impact of internally generated revenue on infrastructure development in Lagos State, Nigeria, was conducted by Olayinka & Phebe (2019). The researchers adopted non-experimental research design in carrying out the study and secondary data were used. The set of data used for the study were sourced from State and Local Government Program reports, Lagos State Ministry

of planning and budgeting with detailed report of IGR and Infrastructural Development Budget from 1996 to 2015, spanning a period of 20 years. The study employed OLS to analyze the data collected. The result of the analysis revealed that IGR positively impact infrastructural development. The results further showed that taxes, earnings and sales, which are the major components of internally generated revenue, did not have any impact on the infrastructural development while licenses, fines and fees had.

Methodology

Nature of the Data
The secondary sources of data on various indicators of infrastructure across 43 countries in SSA, from different sources for the period of 2000 to 2018 are deployed. The list of the countries and the period covered were both dictated by data availability.

Population and Sample Size
SSA has a total number of 49 countries, thus, the total population of the study consists of all the SSA countries. Therefore, the sample for this study consists of 43 SSA countries selected from the total 49 SSA countries. These include the following countries: Angola, Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Cameroon, Central African Rep., Chad, Comoros, Congo DR, Congo Rep., Cote d'lvoire, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe

Data Measurements and Sources
Energy infrastructure is measured by the population with access to electricity (in percentage) to determine infrastructure development in energy sector in SSA, rather than electricity generation per 1,000 people. The reason is that the percentage of the population with access to electricity measures the actual number of the people with access to electricity rather than generation which may not eventually lead to accessibility. The data was sourced from the World Bank's WDI (2019).

Basically, there are three indicators of measuring telecommunication which include mobile lines, fixed lines and access to internet. Thus, all the three indicators of telecommunication will be aggregated into a single composite index through PCA to capture the infrastructure development in the

telecommunication sector. These are measured by the mobile phone subscribers per 1,000 people, fixed telephone subscriptions per 1,000 people and fixed broadband internet subscribers per 1000 people. The justification for these indicators is because of their rapid improvement after the liberalization in most of the countries in SSA, in addition to data availability. The data was sourced from the International Telecommunication Union (2019).

Transport infrastructure is measured as the road density (km of road per 100 sq. km of land area) to determine infrastructure development in the transport sector. The road network consists of all roads in the country such as motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads (World Bank, 2019). We are aware of other measurements of transport infrastructure but availability of data limits us to the use of road density. The data is sourced from the International Road Federation (2019).

Health infrastructure is proxied by the number of hospital beds per 100,000 people, measuring infrastructure development in health sector. It is used to indicate the availability of inpatient services. Although, we are aware of other measurements such as number of hospitals per number of people but this is informed by the availability of the data. Data on hospital beds per 100,000 people is sourced from the World Health Organization (2019).

Education infrastructure is measured by the number of classes per 100 pupils in primary school, measuring infrastructure development in education sector. This is used as a proxy for infrastructure development in education sector and the choice not only due to the availability of data but also as a result of the fact that the primary education is the basis or foundation of education attainment. This further shows the capacity of each class and the available facilities it contains. The variable was sourced from the United Nations Educational, Scientific and Cultural Organization (2019).

Water infrastructure is measured as the percentage of people with access to improved water sources, measuring infrastructure development in the water sector. The justification for this is that, apart from availability of the data, it has been widely used as a measurement for infrastructure development by many previous studies (Gopalan & Rajan, 2016; Steckel et al., 2017; Gomez et al., 2019) and international organizations such as World Economic Forum (WEF) and Africa Infrastructure Development Index (AIDI). This variable was also sourced from the World Bank's WDI (2019).

Infrastructure development is proxied by a composite infrastructure index, which involves a linear combination of all the aforementioned six infrastructure indicators of both economic infrastructure (energy, roads and telecommunication) and social infrastructure (health, education and water). The approach adopted in constructing an aggregate or composite index that combines the six infrastructure stocks is PCA method and this had similarly been used in the previous studies (Akanbi, 2013; Onikosi-Aliyu, 2014; De, 2015; Sama and Afuge, 2016; David, 2019).

Estimation Technique for Infrastructure Development: Principal Components Analysis (PCA)

The PCA is a process of taking high-dimension sets of indicators and transforming them into new indices that retain information on a different dimension and are mutually not correlated. This procedure reduces the set of observed variables into principal components which capture information from the original set of variables as much as possible (Akanbi, 2013). The justification for using PCA to measure index is because it uses optimal weight which devoid researcher's bias unlike other methods of measuring index, such as the UNDP methodology and the distance-based method, where the weight allocated to the dimensions is subjective and the value of the resultant index is restricted between 0-1 or 1-100 (Shlens, 2003).

For instance, the result for the component of infrastructure shows that the first factor or principal component has an eigenvalue of 3.491 that explains 58 percent of the total variation. The second component has an eigenvalue of 0.845 that explains 14 percent of the total variation and the third component has an eigenvalue of 0.581 that explains 9 percent of the total variation, and so on. Since the first factor or principal component has an eigenvalue larger than 1 and explains the highest percentage of the total variation, we chose the first principal component for making a composite index to represent the combined variance of various aspects of infrastructure development captured by the six infrastructure variables.

From the results, the first eigenvectors were used as the required weights. Thus, each of this weight was multiplied by the correspondent indicators and added together to derive the aggregated index for infrastructure development. In other words, this can be explained by following this linear combination:

$$K = \alpha_1 \, ene + \alpha_2 \, tel + \alpha_3 \, tra + \\ + \alpha_4 \, heal + \alpha_5 \, edu + \alpha_6 \, wat \qquad (2)$$

Where K is the aggregate index for infrastructure development, α_1, α_2, α_3, α_4, α_5 and α_6 are the eigenvectors (weights) from the PCA, and *ene* is energy, *tel* is for telecommunication, *tra* is transport, *heal* is health, *edu* is education and *wat* is water. These are the six synthetic composite index of infrastructure. Since physical and social infrastructure are the components of infrastructure development.

Therefore, this study employed PCA to generate the aggregate infrastructure development. Aggregating infrastructure development helps to reduce the measurement error related with a single-infrastructure indicator. This study made use of the Stata 14 software to generate the aggregate index for the variables required. From the result that was generated, the first principal component that account for the highest proportion of variance was extracted as the index of infrastructure development. The summary statistics of the first principal components that were used to generate the composite for composite infrastructure index are reported in the Table 1, while presenting the descriptive analysis in the next section.

Results and Discussion

Principal Components Analysis (PCA) Results

The derivation of infrastructure variables for this study involves a linear combination of six underlining infrastructure indicators – energy, transport, telecommunication, education, health and water, using PCA, the mechanism of which has been explained fully in Methodology. The results of this statistical exercise are shown in the Table 1 and then discussed.

Table 1 – Eigenvectors of Original Values

| Composite Index Variables	Indicators	Weight
Infrastructure Indicators	ENE	0.463
	TRA	0.398
	TEL	0.454
	EDU	-0.257
	HEAL	0.409
	WAT	0.433

Notes: 1) compiled by the author
2) K is the composite infrastructure index, TEL is the Telecommunication infrastructure index, ENE is energy, TRA is transport, EDU is education, HEAL is health and WAT is water infrastructure.

Therefore, following the procedure in equation (2) where each of the weight generated in Table 1 is multiplied by the correspondent indicators and added together to derive the aggregate index for the variable under consideration. For instance, in order to compute the composite infrastructure index, the value of energy infrastructure for a particular country in a particular year is multiplied by its weighted value (0.463) plus the value of transport infrastructure for a particular country in a particular year multiplied by its weighted value (0.398) plus the value of telecommunication infrastructure for a particular country in a particular year multiplied by its weighted value (0.454) plus the value of educational infrastructure for a particular country in a particular year multiplied by its weighted value (0.257) plus the value of health infrastructure for a particular country in a particular year multiplied by its weighted value (0.409) plus the value of the water infrastructure for a particular country in a particular year multiplied by its weighted value (0.433).

Trend Analysis of Infrastructural Development in SSA, 2000 – 2018

The aggregate or overall infrastructure development is presented in Panels I and II of Figure 1. The trend analysis of average infrastructure development in SSA countries between the year 2000 and 2018 is shown in the panel I, while Panel II shows the trend of average infrastructure development from year 2000 to 2018 for the SSA region.
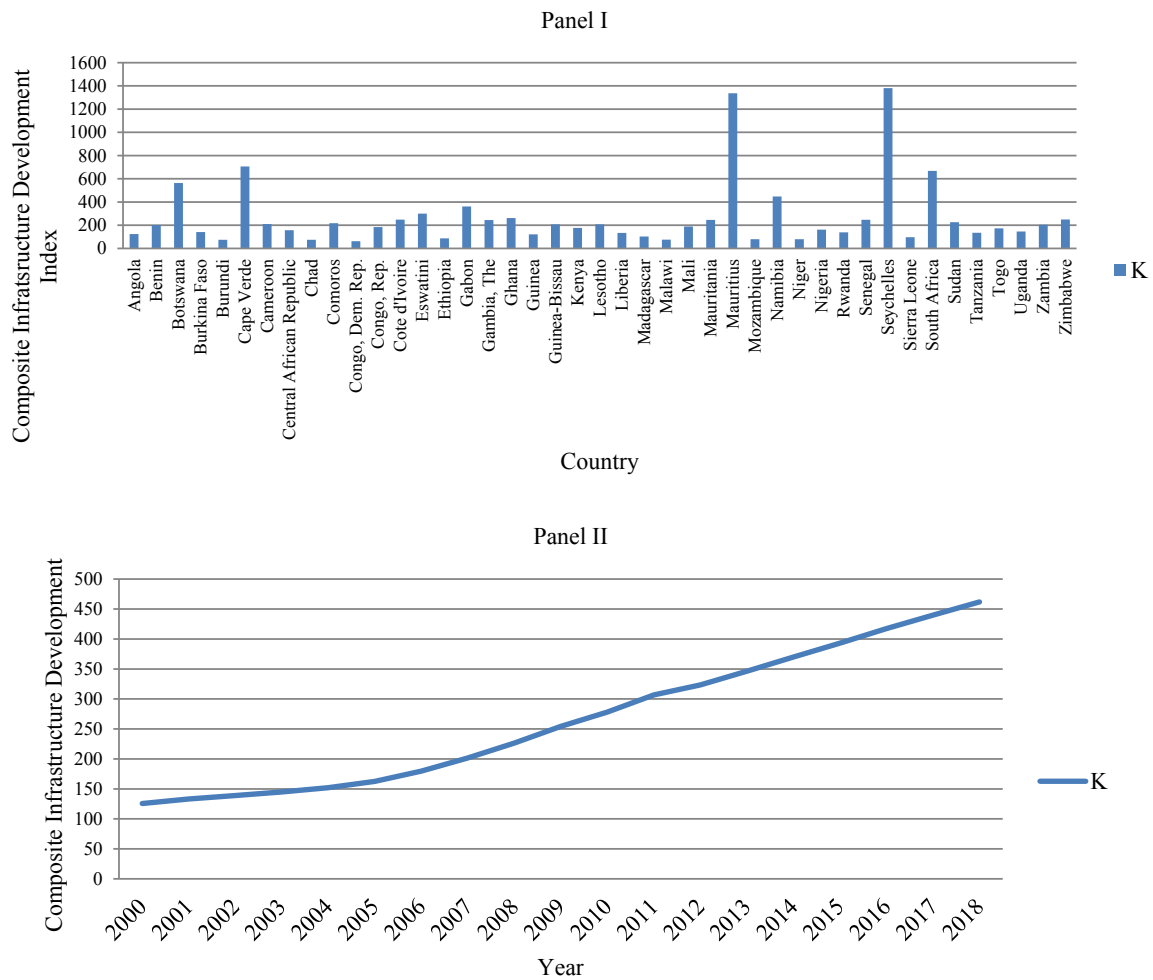
Figure 1 – Aggregate Trend Infrastructure Development in SSA (2000-2018)
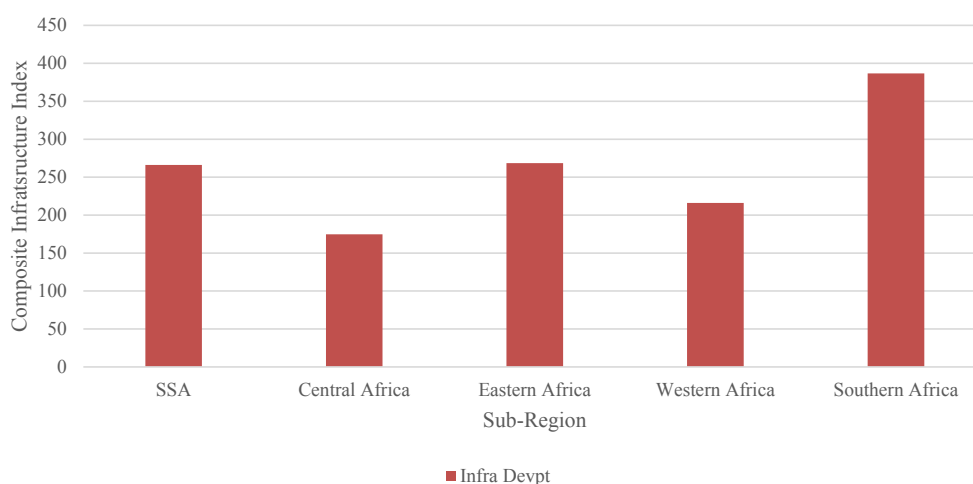Note – compiled by the author

The results from the Figure 1 in Panel I bar diagram shows that Seychelles has the highest infrastructure development, followed by Mauritius, Cape Verde, South Africa, Botswana, Namibia, Gabon, Eswatini, Ghana and Cote d'lvoire between 2000 and 2018. On the other hand, the last ten countries with the lowest infrastructure development in descending order include Congo D.R., Chad, Burundi, Malawi, Niger, Mozambique, Ethiopia, Sierra Leone, Madagascar and Guinea.

The result in the Panel II trend chart shows that the composite infrastructure development stood at 126 in the year 2000, then, rose to 278 in 2010. This further increase and attain the highest index in 2018 with 462. This indicates that infrastructure development in SSA exhibit an upward trend between year 2000 and 2018.

Sub-Regional Comparison of Infrastructural Development in SSA

Comparison of aggregate or overall infrastructure development across four sub-regions and average infrastructure development in SSA is shown in Figure 2.

Figure 2 – Sub-Regional Analysis of Infrastructure Development in SSA, 2000-2018
Note – compiled by the author

The results from Figure 2 show that Southern Africa records the highest performance in infrastructure development, follow by Eastern Africa, Western Africa, and Central Africa. Using the average infrastructure development for SSA countries from year 2000 to 2018 as a benchmark, this shows that both Southern and Eastern Africa perform better, while Central and Western Africa perform below the benchmark. This is also supported by the theoretical expectation that the level of economy of a country influence its infrastructural development as majority of the countries in both Southern and Eastern regions are in the categories of lower-middle income and upper-middle income economies, while majority of the countries in both Western and Central Africa regions are in the categories of low-income and lower-middle income economies.

Ranking of Infrastructure Development in SSA

Table 2 shows the composite infrastructure development index (K) ranking for the selected 43 SSA countries, from 2000 to 2018 and their rank positions. For proper understanding of the level of infrastructure development in SSA, the study goes further to compare the outcome of the composite infrastructure development index with the Africa Infrastructure Development Index (AIDI) ranking in 2018.

The results from table 2 revealed that the top ten countries based on the present study infrastructure development index include Seychelles in the first position, followed by Mauritius in the second position, then Cape Verde, South Africa, Botswana, Namibia, Gabon, Eswatini, Ghana and Zimbabwe in the tenth position. This is also corroborated with the AIDI ranking which showed that the first country in term of infrastructure development is

Seychelles, followed by South Africa, Mauritius, Cape Verde, Botswana, Gabon, Ghana, Namibia, Gambia and Senegal in the tenth position. The little discrepancy maybe as a result of the indicators used to compute the index by the AIDI which are mainly physical infrastructure, while the present study used a combination of physical and social infrastructure indicators.

Table 2 – Comparison of Infrastructure Development Ranking among SSA Countries between K and AIDI Rankings

Country	K (2000-2018)	AIDI
Angola	33	22
Benin	21	29
Botswana	5	5
Burkina Faso	29	23
Burundi	41	31
Cape Verde	3	4
Cameroon	17	21
Central African Republic	27	37
Chad	42	42
Comoros	16	15
Congo, Dem. Rep.	43	41
Congo, Rep.	23	24
Cote d'Ivoire	11	14
Eswatini	8	11
Ethiopia	37	40
Gabon	7	6
Gambia, The	14	9
Ghana	9	7
Guinea	34	27
Guinea-Bissau	18	34
Kenya	24	12
Lesotho	19	30
Liberia	32	33
Madagascar	35	39
Malawi	40	19
Mali	22	28
Mauritania	13	25
Mauritius	2	3
Mozambique	38	36
Namibia	6	8
Niger	39	39
Nigeria	26	17
Rwanda	30	20
Senegal	12	10
Seychelles	1	1
Sierra Leone	36	38
South Africa	4	2
Sudan	15	26
Tanzania	31	32
Togo	25	35
Uganda	28	18
Zambia	20	16
Zimbabwe	10	13
Note – compiled by the author based on Africa Infrastructure Development Index (AIDI)		

Rank Correlation

In addition to the tabular comparison of the infrastructure development ranking among SSA countries, the study further examines the relationship between the present study ranking of infrastructure development among SSA countries and that of AIDI ranking. This is expressed in Spearman's correlation coefficient (*r*) as follows:

$$r = 1 - 6\left[\frac{\sum d^2}{n(n^2 - 1)}\right] = 0.830 \qquad (3)$$

where *d* = difference between ranks of corresponding variables K and AIDI

n = number of observation

The correlation coefficient (*r*) takes on values of -1 to +1. A perfect correlation of -1 or +1 implies that there is exact linear relationship between the two groups. On the other hand, if the correlation is near to 0, this implies that no linear relationship exists between the two groups. The value of correlation coefficient (*r*) is 0.830, which shows a similarity in ranking between the present study and that of AIDI ranking. This implies that there is high relationship between the present study's ranking of infrastructure development among SSA countries and that of AIDI ranking.

Trend Analysis of the level of Infrastructure Development in Individual SSA Countries (2000-2018)

Since the main objective of this study is to measure the level of infrastructure development in SSA, to achieve this objective, Table 3 below shows the trend of infrastructure development in individual countries for the selected 43 SSA countries, covering 2000 to 2018 and the rank positions.

Table 3 – Trend of the State of Infrastructure Development in SSA

Country	Rank-2000	Country	Rank-2010	Country	Rank-2018	Country	2000-2018
Seychelles	1	Mauritius	(↑)1	Seychelles	(↑)1	Seychelles	1
Mauritius	2	Seychelles	(↓)2	Mauritius	(↓)2	Mauritius	2
Cape Verde	3	Cape Verde	3	South Africa	(↑)3	Cape Verde	3
South Africa	4	South Africa	4	Botswana	(↑)4	South Africa	4
Botswana	5	Botswana	5	Cape Verde	(↓)5	Botswana	5
Namibia	6	Namibia	6	Namibia	6	Namibia	6
Gabon	7	Gabon	7	Gabon	7	Gabon	7
Eswatini	8	Eswatini	8	Mali	(↑)8	Eswatini	8
Gambia	9	Gambia	9	Sudan	(↑)9	Ghana	(↑)9
Zimbabwe	10	Senegal	(↑)10	Zambia	(↑)10	Zimbabwe	10
Comoros	11	Zimbabwe	(↓)11	Mauritania	(↑)11	Cote d'Ivoire	(↑)11
Senegal	12	Cote d'Ivoire	(↑)12	Ghana	(↑)12	Senegal	12
Cote d'Ivoire	13	Ghana	(↑)13	Guinea-Bissau	(↑)13	Mauritania	(↑)13
Guinea-Bissau	14	Mauritania	(↑)14	Coted'Ivoire	(↓)14	Gambia	(↓)14
Ghana	15	Benin	(↑)15	Zimbabwe	(↓)15	Sudan	(↑)15
Lesotho	16	Congo, Rep.	(↑)16	Eswatini	(↓)16	Comoros	(↓)16
Sudan	17	Comoros	(↑)17	Senegal	(↓)17	Cameroon	(↑)17
Kenya	18	Cameroon	(↑)18	Central African Rep.	(↑)18	Guinea-Bissau	(↓)18
Congo, Rep.	19	Lesotho	(↓)19	Cameroon	(↓)19	Lesotho	(↓)19
Rwanda	20	Sudan	(↓)20	Lesotho	(↓)20	Zambia	(↑)20
Nigeria	21	Kenya	(↓)21	Togo	(↑)21	Benin	(↑)21
Benin	22	Guinea-Bissau	(↓)22	Uganda	(↑)22	Mali	(↑)22
Burkina Faso	23	Nigeria	(↓)23	Kenya	(↓)23	Congo, Rep.	(↓)23
Cameroon	24	Angola	(↑)24	Benin	(↓)24	Kenya	(↓)24

Country	Rank-2000	Country	Rank-2010	Country	Rank-2018	Country	2000-2018
Togo	25	Zambia	(↑)25	Liberia	(↑)25	Togo	25
Zambia	26	Togo	(↓)26	Burkina Faso	(↑)26	Nigeria	(↓)26
Burundi	27	Central African Rep.	(↑)27	Congo, Rep.	(↓)27	Central African Rep.	(↑)27
Sierra Leone	28	Mali	(↑)28	Comoros	(↓)28	Uganda	(↑)28
Guinea	29	Uganda	(↑)29	Tanzania	(↑)29	Burkina Faso	(↓)29
Mauritania	30	Tanzania	(↑)30	Rwanda	(↑)30	Rwanda	(↓)30
Angola	31	Guinea	(↓)31	Nigeria	(↓)31	Tanzania	(↑)31
Liberia	32	Rwanda	(↓)32	Ethiopia	(↑)32	Liberia	32
Tanzania	33	Burkina Faso	(↓)33	Gambia	(↓)33	Tanzania	33
Madagascar	34	Liberia	(↓)34	Guinea	(↓)34	Guinea	(↓)34
Mozambique	35	Madagascar	(↓)35	Madagascar	35	Madagascar	(↓)35
Central African Rep.	36	Sierra Leone	(↓)36	Chad	(↑)36	Sierra Leone	(↓)36
Uganda	37	Mozambique	(↓)37	Angola	(↓)37	Ethiopia	(↑)37
Congo, Dem. Rep.	38	Malawi	(↑)38	Niger	(↑)38	Mozambique	(↓)38
Niger	39	Burundi	(↓)39	Sierra Leone	(↓)39	Niger	39
Chad	40	Niger	(↓)40	Congo, Dem. Rep.	(↑)40	Malawi	(↑)40
Ethiopia	41	Chad	(↓)41	Malawi	(↓)41	Burundi	(↓)41
Malawi	42	Ethiopia	(↓)42	Mozambique	(↓)42	Chad	(↓)42
Mali	43	Congo, Dem. Rep.	(↓)43	Burundi	(↓)43	Congo, Dem. Rep.	(↓)43
Note – compiled by the author							

The results from Table 3 show that infrastructure development ranking among the SSA countries for the initial year (2000), has Seychelles as the top performer, followed by Mauritius in the second position, then Cape Verde, South Africa, Botswana, Namibia, Gabon, Eswatini, Ghana and Zimbabwe in the tenth position. While the last ten include; Madagascar, Mozambique, Central African Republic, Uganda, Congo Democratic Republic, Niger, Chad, Ethiopia, Malawi and Mali. Based on our theoretical expectation, it is not surprising that all the countries in the top ten belong to the high income, upper-middle income and lower-middle income economies except Gambia which is in the category of low income economy. While all the countries in the last ten ranking belong to the low income economies. However, it is surprising to find a low income economy such as Gambia among the high ranked infrastructure development in SSA. This indicate that a low income economy like Gambia realize the important of investment in infrastructure so as to foster its economic performance.

Table 3 further shows the infrastructure development ranking among the selected SSA countries in 2010, the result shows that the top ten countries are; Mauritius, Seychelles, Cape Verde, South Africa, Botswana, Namibia, Gabon, Eswatini, Gambia and Senegal. Compare to the 2000 ranking, this shows that Mauritius overtakes Seychelles and emerges as the top performer, and Senegal moves to the top ten while Zimbabwe dropped out of the top ten to eleventh position. Apart from Mauritius and Senegal that moved up in the top ten, two other countries that performed brilliantly between 2000 and 2010 are Mauritania and Mali that moved up by 16 and 15 places respectively. Other countries that improved within this period are; Angola, Benin, Cameroon, Central African Republic, Congo Republic, Cote d'Ivoire, Ghana, Malawi, Uganda, Tanzania and Zambia. The last ten countries remain almost the same with 2000 except Liberia, Sierra Leone and Burundi that dropped to the last ten. Apart from these, Rwanda and Burkina Faso are among the noticeable countries dropped by 12 and 10 places

respectively. Other countries are; Comoros, Lesotho, Sudan, Kenya, Guinea-Bissau, Nigeria, Zambia, Guinea, Madagascar, Mozambique, Burundi, Niger, Chad, Ethiopia and Congo Democratic Republic.

The result of the 2018 infrastructure development ranking among the selected SSA countries shows that Seychelles returns back to the top from the second place in 2010 ranking, this is followed by Mauritius, South Africa, Botswana, Cape Verde, Namibia, Gabon, Mali, Sudan and Zambia. This shows that there are a lot of changes among the top ten countries in the 2018 ranking except Namibia and Gabon that maintained their 6th and 7th positions respectively. Apart from Mauritius and Cape Verde that dropped to the 2nd and 5th places respectively, it is interesting to know that a low income country such Mali has improved significantly from the last ten countries in 2000 to the top ten countries in 2018. Other countries that have improved in ranking include; Sudan, Zambia, Mauritania, Ghana, Guinea-Bissau, Central African Republic, Togo, Uganda, Liberia, Burkina Faso, Tanzania, Rwanda, Ethiopia, Chad, Niger, and Congo Democratic Republic. There is no much improvement among the last ten countries except Guinea and Angola that dropped to the last ten for the first time in the last eighteen years.

The result of the infrastructure development ranking for the overall years of consideration shows that Seychelles still maintained its first position, and as well as other countries in the top ten in 2000 except Ghana that moved to the 9th position, while Gambia was dropped to the 14th position. Other countries that have improved significantly within these periods include; Cote d'Ivoire, Mauritania, Sudan, Cameroon, Zambia, Benin, Mali, Central African Republic, Uganda, Tanzania, Ethiopia and Malawi. Apart from Gambia, other countries that dropped within periods include; Comoros, Guinea-Bissau, Lesotho, Congo Republic, Kenya, Nigeria, Burkina Faso, Rwanda, Guinea, Madagascar, Sierra Leone, Mozambique, Burundi, Chad and Congo Democratic Republic. The last ten countries show that there is no much difference from that of 2000 except both Guinea and Burundi that dropped to the last ten.

Considering the overall infrastructure development for the period of study, findings from this study show that infrastructural development has improved significantly in SSA for the period of study even though this is very low compare to the development in other regions of the world. Despite this, evidence of infrastructure development during the period of study shows that the region still has considerable potential for improving its

infrastructure. It is also necessary to clarify that most of the significant improvement are from physical infrastructure, most especially telecommunication sector, and to a lesser degree, in health and water sector.

Conclusion

In the light of the fundamental issues raised in the literature on the important of infrastructure to the economic growth and development in the world, and measurement problems associated with infrastructure development. It is therefore necessary to highlight the state of infrastructure development in SSA, where despite the huge infrastructure deficits, infrastructure has been one of the major factors responsible for improved growth recorded in the region in the last two decades. Inadequate knowledge on the level of infrastructure development in the region will hinder the relevant authorities to be aware of the status and progress of various infrastructure services and policies to be put in place in order to boost infrastructure development as well as the sector, facilities and sub-region to be prioritized over the coming years.

This study further contributes to the existing literature by examining the state of infrastructure development in SSA considering 43 countries covering 2000 to 2018. Infrastructure development was represented by the composite infrastructure index which include both the economic infrastructure (energy, transport and telecommunication) and social infrastructure (education, health and water). The study employed PCA in building the aggregate or composite index, and descriptive statistics, stylized facts and correlation were employed for the analysis of the data. The findings from this study therefore, reveal that infrastructural development has improved significantly in SSA for the period of study even though this is very low compare to the development attained in other regions of the world. It is also necessary to clarify that most of the significant improvement are from physical infrastructure, most especially telecommunication sector, and to a lesser degree, in health and water infrastructure. At the sub-regional level, the result further shows that there is a wide disparity in the distribution of infrastructure service.

Despite the difference in the methodologies employed by the present study and relevant organization such as Africa Infrastructure Development Index (AIDI), the results of our ranking are almost the same, even though there are some little differences which may be due to

the social infrastructure indicators included by the present study.

In line with the conclusions above, the study therefore recommends that stakeholders should engage in policies design (such as public private partnership, privatization) that will promote infrastructure development in SSA, most especially for the low income countries as majority of them were found at the bottom of ranking. Therefore, this will help in closing the wide gap of inequality in access to infrastructure services among the SSA countries. Similarly, at sub-regional level, this study advocates more efforts should be geared towards improving infrastructure development in Central and Western Africa regions as these two sub-regions are lagged behind compared to the Southern and Eastern Africa sub-regions. In addition, given the evidence

shown in the study that the average performances in some individual infrastructure (such as health, water and transport) are very poor, it is therefore recommended that special consideration should also be given to these sectors. Also, as evidence from the theoretical and empirical literature has shown that strength of the economy of a country determines its infrastructure development, it is highly recommended that the capital expenditure should be given a priority in the annual budgets of SSA countries and this must be judiciously used for the infrastructure sectors that will have a greater spillover effects on the economy. Finally, this study suggests that relevant organizations such as AIDI should include more social infrastructure indicators in their measurement so as to improve their measurements of infrastructure development.

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