Africa's Oil and Gas Economies and the Quest for Sustainable and Inclusive Development:
Investing In SMART Infrastructures

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Abstract

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Advancement in extractive technologies have led to massive discoveries of oil and gas in Africa, raising potential windfall revenues for countries like Ghana, Kenya, and Ethiopia. It has also resulted in discussions on how windfall revenues from natural resources should be effectively managed or invested. Former Secretary-General of the United Nations, Mr. Kofi Annan, has called for natural resource revenues to be invested in people to generate millions of jobs and opportunities for present and future generations. In this study, I take the unique perspective of encouraging oil-rich African countries to invest resource revenues in infrastructures. Specifically, I argue that to facilitate long-term sustainable and inclusive growth that can lead to shared national prosperity, oil-rich African countries must invest short-term revenues in SMART infrastructures, supported by an efficient and inclusive innovation system for development. In other words, the thesis argues that it is not only important that natural resource revenues be invested in infrastructure to propel societal development; it is critical that they be invested in infrastructure intelligently using the SMART principles. The elements of SMART Infrastructure are analysed using four case studies based on four types of infrastructure; water and sanitation (Ghana), transportation (Nigeria), energy (Angola), and information and communication technology (Uganda).

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Chapter 1: Background

In the last two decades, impressive technological advancements within extractive industries have led to significant discoveries of oil, gas and other minerals on the continent of Africa. Many of Africa's fastest-growing economies today have largely been sustained by revenues from natural resources, including Mozambique, Tanzania, Kenya, Uganda and Ghana.[1] In Guinea, Ghana, Liberia, Tanzania and Mozambique, the discovery of oil, gas, gold and coal are reported to be worth over USD 11 billion dollars.[2] Countries such as Ethiopia, Kenya, Malawi, Mauritius, Tanzania, Gambia, and São Tomé are also expected to rake in trillions of dollars in new oil revenue.[3]

In 2010, the "economic rents from minerals (oil, gas and mining) in Sub-Saharan Africa were over USD 169 billion, out of a world total of USD 2.43 trillion.[4] The combined size of rents for Nigeria and Angola alone was over USD 100 billion, while, in four other

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[1] KPMG Africa, "Oil and Gas in Africa: Africa's Reserves, Potential and Prospects," Full Sector Report (KPMG, 2013), 4, accessed November 10, 2014, https://www.kpmg.com/Africa/en/IssuesAndInsights/Articles-Publications/Documents/Oil%20and%20Gas%20in%20Africa.pdf.

[2] "Moves to tackle Africa's 'resource curse' reach turning point," Oxfam International, October 24, 2013, accessed November 10, 2014, http://www.oxfam.org/en/pressroom/pressrelease/2013-10-24/moves-tackle-africas-resource-curse-reach-turning-point.

[3] Larry Diamond and Jack Mosbacher, "Petroleum to the People Africa's Coming Resource Curse—and How to Avoid It," ForeignAffairs.com Essays, September/October 2013, accessed October 20, 2014 http://www.foreignaffairs.com/articles/139647/larry-diamond-and-jack-mosbacher/petroleum-to-the-people.

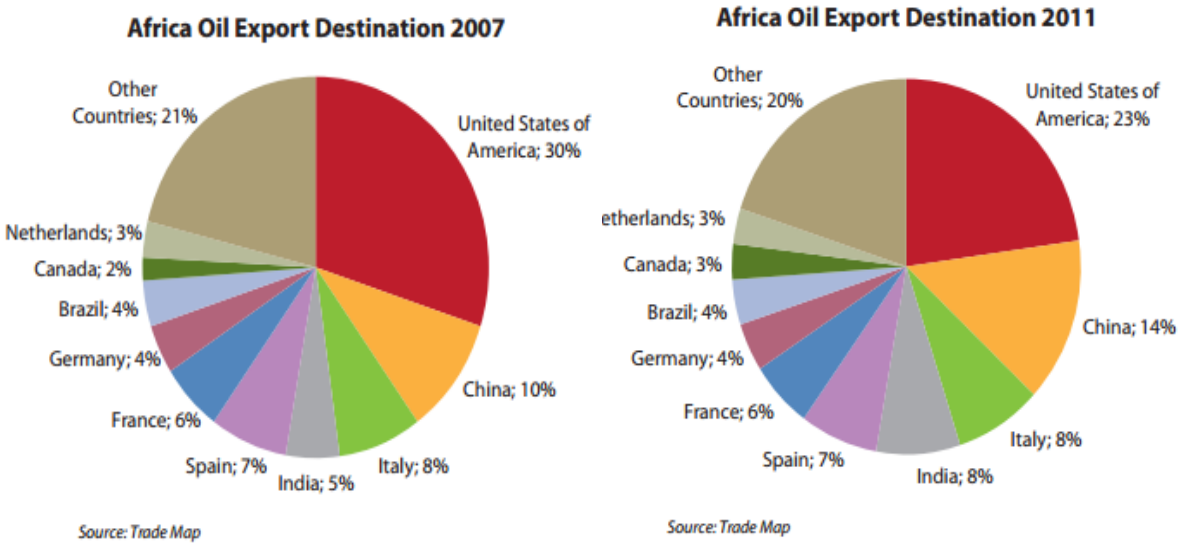
[4] Punam Chuhan-Pole, Manka Angwafo, Mapi Buitano, Allen Dennis, Vijdan Korman, Aly Sanoh, *and c*ontributions from Shanta Devarajan and Wolfgang Fengler, "Sub-Saharan African countries continue to grow at a steady pace; The region's decade-long economic expansion appears sustainable; For newly resource-rich countries, strong governance will be key to harnessing resource wealth for development," *Africa's Pulse* 6 (October 2012): 14, accessed November 11, 2014, http://siteresources.worldbank.org/INTAFRICA/Resources/Africas-Pulse-brochure_Vol6.pdf.

countries, rents were over USD 5 billion a piece.[5] With eight percent of the world's oil supply and seven percent of the world's gas supplies, [6] an Ernst and Young report describes Africa as being "on an upward growth curve, and investors are optimistic about the potential for growth in the oil and gas sector."[7]

Significant changes are also taking place in the export of Africa's oil (See Figure 1 below). According to KPMG, exports to China, India and the United States are on the rise. Whereas in 2007, only 10% of Africa's oil was shipped to China, and 5% to India, these figures increased to 14% and 8% respectively in 2011.[8] Also, an estimated 58% of Africa's total export receipts in value terms belonged to the mineral fuels, oil and distillation products category.[9] In some individual countries, hydrocarbon exports accounted for over 95% of export earnings.[10]

[5] Ibid.
[6] Alex Vines, "Africa's oil and gas potential: Boom or hype?" Chatham House, Special to CNN, September 18, 2014, accessed November 25, 2014, http://edition.cnn.com/2014/09/18/business/africa-oil-gas-potential-boom-hype/index.html.
[7] "African oil and gas: driving sustainable growth," Ernst and Young, last modified 2014, accessed January 5, 2015, http://www.ey.com/GL/en/Industries/Oil---Gas/African-oil-and-gas--driving-sustainable-growth.
[8] KPMG Africa, *Oil and Gas in Africa,* 5
[9] Ibid.
[10] Ibid.

Figure 1: Africa Oil Export Destination - 2007 & 2011 Comparison



Source: KPMG

The Main Concern

The growth potential of Africa's extractive economies has generated several discussions on how resource revenues should be managed to spur socio-economic development. The former Secretary-General of the United Nations, Mr. Kofi Annan, shared that "Africa is standing on the edge of enormous opportunity. Will we invest our natural resource revenue in people, generating jobs and opportunities for millions in present and future generations? Or will we squander this opportunity, allowing jobless growth and inequality to take root?[11] Mr. Annan's trepidations are well placed and nothing new.

[11] Africa Progress Report*: Equity in Extractives: Stewarding Africa's Natural Resources for All* (Africa Progress Report, 2013), 6, accessed November 22, 2014, http://www.africaprogresspanel.org/wp-content/uploads/2013/08/2013_APR_Equity_in_Extractives_25062013_ENG_HR.pdf

This is not the first attempt to offer solutions. Substantial research and advocacy work on how resource-rich countries can utilize their resource revenues to benefit national progress has been done. Several Civil Society Organizations (CSOs) have led efforts to correct some of the ills that have long plagued resource-rich developing countries. Movements, such as the Publish What You Pay (PWYP) campaign have crusaded for transparency in revenues and payments by governments and multinational oil and mineral companies.[12] Scholars like Daren Acemoglu and James Robinson have argued for stronger institutions to help achieve better development like that of the United States and South Korea.[13] I have similarly argued in previous academic work that institutions do matter, particularly in resource-rich countries.[14] Others have also suggested that resource-rich countries mirror the Norwegian experience, focusing on how the Norwegian government ensured that the state reaped the bulk of the oil revenues.[15]

The purpose of this paper is not to duplicate these ideas, but to add to the body of knowledge. It is about challenging existing thoughts on how resource-rich countries, development organizations, private industries and other relevant stakeholders (particularly, international organizations) should approach development to achieve better growth now and in the long-term. This papers take a unique perspective on the

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[12] "Changing the Rules," *Publish What You Pay*, accessed November 12, 2014, http://www.publishwhatyoupay.org/.

[13] Daron Acemoglu and James A. Robinson, Why Nations Fail: The Origins of Power, Prosperity and Poverty (New York: Crown Publishers, 2012). 49

[14] Michael Yamoah," How Can Ghana Avoid an Oil Curse: Lessons from Nigeria," (master's thesis, Carroll College, 2013), accessed October 11, 2014, http://www.academia.edu/3457899/How_Can_Ghana_Avoid_An_Oil_Curse_Lessons_From_Nigeria.

[15] Steinar Holden, "Avoiding the Resource Curse: The Case Norway," (paper presented at Conference Oil Revenue Management in Ghana, April 26-27 2011), 14-15, accessed December 9, 2014, http://folk.uio.no/sholden/wp/resource-curse-norway-13.pdf.

importance and use of infrastructure as a critical investment toward a sustainable and inclusive economy and society. As argued by the African Development Bank (ADB), poor and inadequate infrastructures are "a critical barrier to reducing poverty and accelerating growth on the continent."[16] However, the goal must not only be to develop infrastructure; it must be about developing the correct infrastructure and doing it the right way.

Developing the Research Issue and Framework

Natural resources do present an opportunity for growth in the decades ahead for African countries. As Joseph Stiglitz writes; "resource-rich countries have, on average, done poorly but progress is possible if they get economic and political support."[17] His point establishes the fact that it is not a guarantee, yet a possibility under certain conditions. To realize better growth, countries must understand the need to experiment, plan strategically, save and invest wisely and put the national interest first. The focus of inquiry in this paper is oil-rich African countries, as the oil commodity holds a large share of the African continent's entire export receipts in value terms. To set the stage for a rigorous inquiry, I provide what I refer to as the Fundamental Assumption;

Fundamental Assumption:

The primary purpose of finding and harnessing a valuable natural resource, like oil and gas, is to spur economic growth and opportunities for the promise of shared national prosperity.

[16] African Development Bank, *Liberia: Infrastructure and Inclusive Growth*, (Tunis: African Development Bank, 2013), 2, accessed November 11, 2014, http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Liberia_-_Infrastructure_and_Inclusive_Growth_-_Full_Report.pdf.

[17] Joseph Stiglitz, "Africa's natural resources can be a blessing, not an economic curse," The Guardian, last modified August 6, 2012, accessed September 30, 2014, http://www.theguardian.com/business/economics-blog/2012/aug/06/africa-natural-resources-economic-curse.

The ideal scenario is when revenues from natural resources are well-managed by governments, coupled with a better planning regime as well as competent and committed institutions. That potentially leads to a socio-economic and development environment with the capacity to improve development outcomes, such as increasing employment opportunities, and building productive infrastructures (water, energy, information technology and transportation). All other things being equal, an improved policy and practice system could help achieve critical development benchmarks such as those of the Millennium Development Goals (MDGs).[18] This assumption takes as an a priori that natural resources are significant assets in engineering a country's prosperity. Furthermore, the Organization for Economic Cooperation and Development (OECD) has said that natural resources are an important catalyst for growth and can help sustain it.[19] In addition, they also contribute to reducing poverty and support the achievement of the MDGs.[20]

Although the Fundamental Assumption may hold true in general, it is clear that not many African resource-rich countries have been able to attain the eventual promise of shared national prosperity. Critical challenges, such as the finite nature of natural resources like oil and gas; institutional weaknesses; market volatility; the Dutch disease; and

[18] The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty rates to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by all the world's countries and all the world's leading development institutions. They have galvanized unprecedented efforts to meet the needs of the world's poorest. *See full Details at* http://www.un.org/millenniumgoals/.
[19] OECD DAC Guidelines and Reference Series *Natural Resources and Pro-Poor Growth: The Economics and Politics* (OECD, 2008), 16, accessed October 18, 2014, http://www.oecd.org/greengrowth/green-development/42440224.pdf.
[20] Ibid.

environmental impacts and climate change agenda, have consistently thwarted hopes of avoiding the resource curse. They make the dependency on natural resources unsustainable and raise a Fundamental Question;

Fundamental Question:

How then do oil-rich African countries engineer their economies for the short term benefits of their resource while charting long-term progress toward the promise of shared national prosperity?

To answer the Fundamental Question, I offer a value-added plan or what I call a Critical Plan. It also represents the thesis statement to this paper;

Critical Plan:

In order to facilitate long-term sustainable and inclusive growth that can lead to shared national prosperity, oil-rich African countries must invest short-term revenues in SMART Infrastructure, supported by an efficient and inclusive innovation system for development.

In essence, I argue based on Mr. Annan's concerns that Africa should invest in SMART infrastructure to create the enabling environment, opportunities and capacity toward shared prosperity, now and in the future. Table 1 below contains the elements of SMART infrastructure.

Table 1: SMART Infrastructure Elements

S	**M**		**A**		**R**		**T**	
Sustainable	Measurable	Meaningful	Attainable	Attributable	Reliable	Resilient	Tailored	Technology-infused

Each element is defined and discussed in Chapter 3. A brief review of the innovation system for development and its relevance can be found in Appendix 1. The types of

infrastructure in this paper consist of water and sanitation, transportation, energy, and information and communication technology.

Research Methodology

The method in this study is primarily qualitative. The SMART Infrastructure elements are analyzed using case studies. The case studies focus on four countries and types of infrastructure: water and sanitation (Ghana), transportation (Nigeria), energy (Angola), information and communication technology (Uganda). They are used in this paper to provide relevant context, and also to answer the "why" and "how" based on the Critical Plan. The case studies are from independent works (with few modifications: only focusing on background and findings) and are referenced to underscore the importance and usefulness of the SMART infrastructure elements to achieving sustainable and inclusive development.

Structure of Paper

The paper began with a background of Africa's natural resources, focusing on resource discoveries, reserves and economic value. I discussed the research framework and provided the critical assumption, challenges and questions that underlie the paper. This section also outlined the thesis statement, methodology and structure to the study.

The next section reviews the academic works on infrastructure and its importance in a development context. Finally, the ensuing chapters focus on the analysis of SMART infrastructure, and the conclusion of the paper discusses the interconnectedness of the SMART infrastructure elements, and how the innovation system for development applies. In addition, I provide a summary of some of the benefits of using the SMART infrastructure approach in oil-rich African countries.

To conclude this chapter, I must note that this research paper is not describing the resource curse, nor is it exploring the problems of resource-rich African countries. Rather, it is focused on how resource revenues can be invested in SMART infrastructures to help usher in new paradigms of opportunities for growth and development.

Chapter 2: Literature Review – Infrastructure

According to the International Finance Corporation (IFC);

> The need for infrastructure improvements in the developing world is critical. Untold numbers of businesses suffer from lack of reliable power for industrial processes or because they cannot get their goods to the market. At the most basic level, millions of lives are threatened every day for lack of clean water or safe sanitation.[21]

Paul Collier shares a similar perspective. Collier notes that "Africa has been starved of economic infrastructure. It really needs to devote serious money to that task of building productive infrastructure."[22] The World Bank also regards infrastructure as a driver of growth.[23] So why is infrastructure such an important part of growth and development?

To better understand this, it is valuable to explore what infrastructure means. Walter Buhr offers an impressive discussion of what infrastructure means, noting that there is not a standard definition.[24] In his discussion paper, *What is Infrastructure*? Buhr digs through the present use of the term and its categories.[25] He defines the infrastructure of an area as "the sum of all relevant economic data such as rules, stocks and measures with the

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[21] "Infrastructure in Africa," International Finance Corporation, accessed November 3, 2014, http://www.ifc.org/wps/wcm/connect/REGION__EXT_Content/Regions/Sub-Saharan+Africa/Investments/Infrastructure/.
[22] "Resource-rich Countries Can Learn from History," IMF Survey Online Magazine: Interview, accessed January 15, 2015, http://www.imf.org/external/pubs/ft/survey/so/2011/INT092711B.htm.
[23] World Bank *Africa Development Report-2012/2013* (World Bank, 2013), accessed January 4, 2015, https://openknowledge.worldbank.org/bitstream/handle/10986/13504/9780821396162.pdf?sequence=1
[24] Walter Buhr, "What is Infrastructure?" Volkswirtschaftliche Diskussionsbeiträge, no. 107-03 (2003):1, accessed November 11, 2014, http://www.researchgate.net/publication/24130529_What_is_infrastructure.
[25] Ibid. 1-15

function of mobilizing the economic potentialities of economic agents."[26] He further identifies the following three categories of infrastructure: **institutional** (to be provided by the state comprises the rules as well as facilities and procedures guaranteeing and implementing the rules with the function of activating the economic potentialities of economic agents); **personal** (represented by the number [quantitative personal infrastructure] and the properties [qualitative personal infrastructure] of the working population that influence the economic potentialities of economic agents), and **material** (refers to the capital stocks that serve the function of mobilizing the economic potentialities of economic agents).[27]

In Buhr's view, although institutional infrastructure is often the dominant category, comprising the entire economy, material infrastructure, and personal infrastructure are also critical. He also establishes the complementary nature of all three categories (See Figure 2 below).[28] The complementariness will prove very relevant in discussing the innovation system for development in this paper.

Gianpiero Torrisi also shares the opinion that there is no standard definition of infrastructure. Torrisi, who cites the work of Buhr, claims that the lack of a precise definition "makes challenging any comparison involving different studies," and "difficult to develop uniform policies in this field."[29]

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[26] Ibid. 16
[27] Ibid. 4-11
[28] Ibid. 22
[29] Gianpiero Torrisi, "Public infrastructure: definition, classification and measurement issues," MPRA, no. 25850, (October 12, 2010): 8, accessed February 1, 2015, http://mpra.ub.uni-muenchen.de/25850/1/MPRA_paper_25850.pdf.

Figure 2: Examples of the Complementary Nature of the Three Categories of Infrastructure

(1)	Medical care:	
	material infrastructure	e.g. hospitals, i.e. buildings for specific medical services and housing of patients,
	complementary personal infrastructure	e.g. doctors with different qualifications, specifically trained nurses, administrative personnel,
	complementary institutional infrastructure	organization of hospital work, medical regulations, remuneration schedules, financial schemes of patient insurance and support etc.
(2)	Information systems:	
	material infrastructure	e.g. buildings and hardware equipment in different fields (telephone services, telecommunication, computer services etc.)
	complementary personal infrastructure	e.g. knowledgeable personnel of information technology in diverse categories
	complementary institutional infrastructure	e.g. laws and norms concerning security of information systems and data protection, international procedures of standardization etc.

Source: Buhr, 'What is Infrastructure', 2003, p. 22

Torrisi's work builds on Buhr's categorization of infrastructure. For example, material infrastructure, Torrisi argues is "essentially characterized by two distinguishing qualities: i) fulfilment of social needs and (economic necessity of) ii) mass production" (under certain preferences, such as; population, technology level, institutional environment, level of development and geographical issues faced by a community).[30] Torrisi also mentions a category called immaterial infrastructure. Immaterial infrastructure "indicate(s) some kind of infrastructure -primarily innovation and education infrastructures- linked to the development of the material one as intended, for instance, research centers, innovation networks, services to the enterprises, etc."[31]

[30] Ibid. 12
[31] Ibid. 14

Although the work of Buhr and Torrisi does not offer a standard definition, they offer important elements from other works to be able to forge meaning and description in the context of this paper. With that in mind, I will proceed to discuss the importance and role of infrastructure in development.

According to Calderón, Moral-Benito and Servén, "estimates of the output of contribution of infrastructure are significant not only statistically, but also economically."[32] Their findings are based on an evaluation of large sets of data drawn from infrastructure stocks covering 88 countries, and spanning the years 1960-2000, with over "3,500 country-year observations, drawn from countries with very different levels of income and infrastructure endowments."[33] The results showed an increase in the level of infrastructure provision from the cross-country median in the year 2000 … to the 75th sample percentile in the same year.[34] This, they argue translates into an increase in output per worker. In a similar analysis, they also demonstrate that:

> (a) an increase in infrastructure provision from the median level observed among lower-middle income countries … to that of the median upper-middle income country … would yield an increase in output per worker … and (b) raising the level of infrastructure provision from the value observed in the median upper-middle income country to that of the median high-income country … would raise output per worker by 8.7 percent.[35]

The work of Straub, Vellutini, and Warlters also provides some similar outcomes as Calderón, Moral-Benito and Servén, but in a limited, and narrow way with mixed results.

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[32] César Calderón, Enrique Moral-Benito and Luis Servén, "Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach," *Journal of Applied Econometrics* 30, no. 2 (2015): 24, accessed February 11, 2015, http://www.bde.es/f/webbde/SES/Secciones/Publicaciones/PublicacionesSeriadas/DocumentosTrabajo/11/Fich/dt1103e.pdf.
[33] Ibid. iii, 10
[34] Ibid. 24
[35] Ibid.

Results based on a sample of five countries (South Korea and Singapore as the two most developed economies, and Indonesia, Thailand and Philippines as the less developed), rejects the hypothesis that the coefficients on the three infrastructure variables (number of telephones and telephone main lines; electricity generating capacity; total roads (railways and paved roads)) are zero for South Korea and Singapore.[36] The authors "recall that the interpretation of this result is not that infrastructure is not productive but rather that there is no evidence from the exercise that it is more productive than other types of capital."[37] On the other hand, the sample of Indonesia, Thailand and Philippines provide a "preliminary evidence that some infrastructure variables are significantly more – or less – productive than other types of capital."[38] The conclusion was that in Indonesia and the Philippines, telecommunications investment generated externalities and contributed to growth more than other types of capital; and with roads, the finding was a positive influence on Total Factor Productivity (TFP) growth in only one country, Thailand; whereas in South Korea and Singapore (two countries that have markedly higher GDP than the other countries in the sample), they saw no significant effect of infrastructure on TFP growth.[39]

Zhang and Fan also attempt to reconcile this debate, by outlining a causality test strategy for a panel data set and undertaking an empirical test of the relationship between infrastructure capital and productivity in rural India; and also estimating its impact of

[36] Stéphane Straub Charles Vellutini Michael Warlters, "Infrastructure and Economic Growth in East Asia," Policy Research Working Paper 4589 (April 2008): 12-13, accessed October 30, 2014, http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/04/14/000158349_20080414114032/Rendered/PDF/wps4589.pdf.
[37] Ibid.
[38] Ibid. 13
[39] Ibid. 21

increases in the capital stock on productivity growth.[40] According to them, "infrastructure development and productivity often affect each other in the long term but not in the short run," stressing the "important implications for evaluating infrastructure investments."[41] To sum up their work, the authors offer the following conclusion:

> In order to examine the magnitude of the productivity impact of infrastructure, we further explored different model specifications. In general, a model in levels yields positive and larger effects, while a model in differences gives insignificant results. This is consistent with findings in the literature. Because the autocorrelation coefficient is below 15 one, estimation in differences cannot be justified in our Indian data set. After further controlling for autocorrelation and accounting for possible endogeneity problems, we find that the magnitude of relationship decreases slightly. Nevertheless, infrastructure development has a significant and positive impact on growth in productivity.[42]

Finally, Alicia Munnell, whose work investigated infrastructure investment and economic growth, questions, "if infrastructure has substantial payoffs, does this imply that public capital is undersupplied, and higher levels of investment are warranted?"[43] Her response is that "at this time, production function estimates provide little guidance on this point, but some other evidence seems to support the notion that profitable public investment opportunities exist."[44] Munnell's work focused on United States infrastructure, referring to the fact that the country's stock of public capital is enormous, at least compared to

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[40] Xiaobo Zhang and Shenggen Fan, "How Productive is Infrastructure? New Approach and Evidence from Rural India," International Food Policy Research Institute, no. 84 (October 2001): 2-3, accessed November 7, 2014. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1.2668&rep=rep1&type=pdf.
[41] Ibid. 14
[42] Ibid. 14-15
[43] Alicia H. Munnel, "Infrastructure Investment and Economic Growth," Journal of Economic Perspectives 6, no. 4 (Fall 1992):195, accessed January 2, 2015, http://www.researchgate.net/profile/Alicia_Munnell/publication/4727276_Infrastructure_Investment_and_Economic_Growth/links/54c115400cf2d03405c4da13.pdf.
[44] Ibid.

private capital.[45] Although her work navigates some of the policy, political, and advocacy debates around infrastructure investments in the U.S, Munnell's conclusion is what is particularly worth mentioning:

> This is an area ripe for research that could have important policy implications. Researchers should focus on explaining the variations in the coefficients by level of government, disentangling the causation question, and examining the cointegration issue. Aggregate results, however, cannot be used to guide actual investment spending. Only cost-benefit studies can determine which projects should be implemented … For the evidence suggests that, in addition to providing immediate economic stimulus, public infrastructure investment has a significant, positive effect on output and growth.[46]

Her deduction is perhaps a good transition to summarizing the literature unearthed so far. For each of the academic works cited, there is a fundamental consistency, which is, that infrastructure can have a considerable positive effect on growth and development, but it also does not inherently have such an effect if it is not properly implemented. Although this might not be an absolute 'touch-down' conclusion, I strongly believe that when infrastructure is built for the right reasons; such as based on need, demand, and how it is tailored to meet certain economic, territorial or institutional space, the outcome will be highly beneficial. It backs the point that infrastructure is not one size fits all. This point is stressed by all of the authors cited here so far, and is demonstrated by some of the causality tests across different countries and types of infrastructure that they conducted. Each region, country or location must understand its economic, social, geography and capacity to knit together an infrastructural system that is efficient, effective, and relevant. The need for infrastructure must relate to a productive outcome that can better production processes, increase human mobility and help make progress an achievable promise for

[45] Ibid. 190
[46] Ibid. 196-197

all. In essence, infrastructure is not just building roads, but also having meaning and attribution. Take water and sanitation; we build reservoirs or canals and pipes not for esthetic purposes. Rather, we do so in order to contribute to a better quality of life so that citizens can have improved health to participate actively and efficiently in the national economy.

The definitional challenges of infrastructure are significant in this paper because any specific form of infrastructure, will have different meaning to different communities, or nations. In my opinion, citizens must have some connection to the use of new infrastructure; it must mean something to them directly or indirectly. For instance, if citizens can understand that one of the reasons why the cost of food items are going down is due to better roads, rail or port systems, then they can value the need for infrastructure development, and perhaps yearn for more of it.

There is one final and important aspect of infrastructure that should be stressed in this literature review. It relates to some of the damaging impacts of infrastructure, particularly on our ecosystem. People's life or history, valuable species necessary for human existence and the ecosystem as a whole can be entirely altered or ruined by infrastructure development. According to Margaret Palmer, "projects such as building dams and diverting watercourses enhance water security for humans. But they do little to protect the biodiversity of associated ecosystems, and that's a long-term necessity."[47] Of course nobody has forgotten about 'The Three Gorges Dam' in China. The dam, which is

[47] Margaret A. Palmer, "Beyond infrastructure," Nature 467, (September 2010): 534, accessed December 22, 2014, http://www.palmerlab.umd.edu/Palmer_2010_Nature.pdf.

considered the largest hydro-electric in the world,[48] is designed to produce more than 18,000 megawatts of electricity—twenty times the power of Hoover Dam,[49] or fifteen nuclear power plants.[50] While the dam is extremely powerful, its environmental impact is considered to be a nightmare.[51] Figure 3 below shows some of the damaging effects of the construction on lives, communities, history, economic activities and the environment as a whole. The lesson from this infrastructure effort is that there needs to be a consideration of the environmental and sustainability impact of any new infrastructure projects. Such projects must weigh the balance between the social and economic good done by supplying electricity to people with the negative impacts it creates for the environment. Consideration must be given to how and where infrastructure is built, the mitigation factors as well as the resiliency of the infrastructure to withstand adverse natural phenomenon and pressures. As Palmer writes about water systems infrastructure:

> All life — terrestrial and aquatic, ranging from microbes to vertebrates — depends on and is shaped by water and watershed dynamics. Yet only a small subset of conservation and natural-resource management plans, and few national or international research initiatives, use the watershed as an organizing framework. It will never be possible to eliminate all impacts on biodiversity and ecological processes if the growing human demands for water are to be met, and I am not suggesting that this should be the goal of watershed-based management, planning or research. However, societies

[48] Chris Buckley, "China says Three Gorges mega-dam threats controlled," Reuters, November 27, 2007, accessed December 15, 2014, http://www.reuters.com/article/2007/11/27/environment-china-threegorges-dc-idUSSP22542620071127.
[49] "China's Three Gorges Dam, by the Numbers," National Geographic News, October 28, 2010, accessed December 5, 2014, http://news.nationalgeographic.com/news/2006/06/060609-gorges-dam_2.html.
[50] "Three Gorges Dam, Yangtze River, China" COE, Montana State University, ENGR 125CS, 2, accessed January 5, 2015 http://www.coe.montana.edu/ee/rmaher/ENGR125_FL06/Three%20Gorges%20Dam.pdf.
[51] Blake Campbell-Hyde, "Breaking Ground: Environmental and Social Issues of the Three Gorges Dam in China," American University, accessed November 11, 2014, http://www1.american.edu/ted/ICE/china-dam-impact.html.

can try to balance ecological and human needs, for example by considering where in a river network a new dam is planned, or where increased water extraction will be allowed.[52]

Figure 3: Three Gorges Dam, Fact and Figures

Facts and Figures

- The Three Gorges Dam will consist of a 610-foot high wall running 1.3 miles from bank to bank.
- The reservoir created by the backflow of the dam will extend 360 miles up river to Chongqing ("Chong-ching"), a distance equal to nearly half the length of California.
- Once operational, the dam will produce the energy of 15 nuclear power plants.
- The project is estimated to be completed in 2009 at a cost of over $30 billion.

- In the past 2,000 years, the Yangtze River has experienced 215 catastrophic floods.
- In 1998 flooding in the area expected to be controlled by the dam resulted in 4,000 dead, 14 million left homeless and $24 billion in economic loss.
- When the dam is completed, 13 cities, 140 towns and over 1,300 villages will be submerged by the Three Gorges Reservoir.
- To make way for the Three Gorges Dam, 1.5 million people will have to abandon their homes. More than 160,000 citizens have already been relocated.
- Upon the dam's completion, 1,300 known archeological sites will be lost forever under water.
- Over 265 billion gallons of raw sewage are dumped into the Yangtze annually. Currently the river flushes this downstream and out into the ocean. Upon completion of the Three Gorges project, the sewage will back up in the reservoir.

- Over 1,600 factories and abandoned mines will be submerged when the dam is completed. Environmentalists predict that toxins associated with industry and mining will create a hazard for the animals and people who depend on the river for survival.
- Over 700 million tons of sediment are deposited into the Yangtze annually, making it the fourth largest sediment carrier in the world. Experts believe that this sediment will build up behind the dam, with only an unproven system of sluice gates to release it.
- Over 360 million people live within the watershed of the Yangtze River. If the one in one thousand chance of a dam collapse occurred, the millions of people who live downstream would be endangered.

Source: College of Engineering, Montana State University, ENGR 125CS

This paper takes into consideration long term sustainable and inclusive growth for resource-rich countries. It would be inappropriate to advocate for infrastructure without bearing in mind some of the negative consequences it can create, and encouraging a better approach to addressing them. As mentioned in chapter 1, underlying the Fundamental Assumption is the promise of shared national prosperity, as such, it will be unproductive to view infrastructure as key to socio-economic development only to have it adversely affect the quality of lives and standard of living of a people over the longer term. In other words, for resource-rich African countries, the problems unearthed through

[52] Palmer, *Beyond infrastructure*, 535

the academic literature means that not only must the revenues from natural resources be invested in infrastructure; they must be invested in SMART infrastructure. Taking the SMART approach to infrastructure development ensures that all of the problems related to infrastructure projects discussed in the academic literature are addressed in project design and implementation.

The next chapter will focus on analyzing the SMART infrastructure concept. As mentioned earlier, the focus on infrastructure will be water and sanitation, transportation, energy, and information and communication technology. By definition, these will be considered by Buhr as material infrastructures. However, the other categories as pointed out by Buhr will be applied to show their complementariness. The innovation system for development approach (See Appendix 1) supports the complementariness of the categories by providing issue areas that can advance long-term growth.

Chapter 3: SMART Infrastructures

SMART infrastructure is described here as a catalyst for shared national prosperity. For oil-rich African countries, it is about realizing the critical challenges at hand and leveraging short-term benefits of a natural resource like oil. The goal is to advance infrastructures to spur opportunities, growth, enable diversification, improve citizens' social and economic well-being, and attract more investments. Whether designing or building small or large scale infrastructures, it is important to consider the elements of SMART as part of the planning and evaluation process. The SMART approach is an interactive and innovative concept to designing and building infrastructures that underscore critical benchmarks, such as; community and stakeholder involvement, environmental impacts, economic and social impacts, as well as short-term and long-term development strategies of developing countries. Each of the elements of SMART is important as they tend to build on each other.

The rest of this chapter analyzes the elements and concept of SMART infrastructure. Table 2 below provides the definitions to each of the element of SMART Infrastructures, and following is a brief background to each of the infrastructure types.

Table 2: Definitions of SMART Infrastructure Elements

SMART Element	Definition
Sustainable	Built to meet present socio-economic and political needs, such as population size and demography, but also allows for future alterations and maintenance that might be required to meet new and emerging trends in order to achieve shared prosperity.[53] It also deals with environmental impacts assessments and mitigations that must be met now and in future.
Measurable	Able to estimate or assess the extent of inputs and impact on communities, the environment, like flood risk, and national development goals, such as health, employment opportunities, market expansion, agglomeration of businesses.
Meaningful	Means something to targeted locations, communities, or regions and they have better understanding of the need to have and use an infrastructure. It is also affordable and create equal accessibility
Attainable	Can be accomplished or achieved within a reasonable amount of time, given the scope of work, cost, future maintenance and financial instruments. Also in meeting end goals of use.
Attributable	Is about eliminating other possibilities as actual catalyst for the positive changes that we see taking place in a community, and that we can directly link the new infrastructure project to such changes
Reliable	Built to be efficient, dependable and effective at delivering purpose intended.
Resilient	Structures absorb disturbances, such as natural and man-made hazards or pressures and still function as designed.[54]
Tailored	Should meet community, region or national needs and activities. Designed to fit present and future socio-economic and cultural changes as well as geographical challenges.
Technologically Embedded	Uses basic to advance technology to enhance and manage use, data collection for maintenance, expansion or evaluation, and efficiently support and sustain productivity and intended use of infrastructure.

[53] "Brundtland Report: Chapter 2. Towards Sustainable Development," Wikisource, last modified on 5 June 2013, accessed May 2, 2015, https://en.wikisource.org/wiki/Brundtland_Report/Chapter_2._Towards_Sustainable_Development.

[54] "Sustainable and Resilient Civil Infrastructures," University of Texas, Arlington, accessed May 2, 2015, http://www.uta.edu/sarci/.

Types of Infrastructure

Only 29 percent of roads are paved in Africa, a quarter of the continent's population has no access to electricity, and fewer than three landlines are available per 100 people.[55] Below, I offer a brief background to each of the infrastructure types being discussed in this paper.

Water and Sanitation

The World Health Organization (WHO) claims that "safe and sufficient drinking water, along with adequate sanitation and hygiene have implications across all Millennium Development Goals (MDGs) – from eradicating poverty and hunger, reducing child mortality, improving maternal health, combating infectious diseases, to ensuring environmental sustainability."[56] Across the globe, about 2.5 billion people lack access to improved sanitation; 1 billion people practice open defecation (nine out of ten in rural areas); 748 million people lack access to improved drinking-water and about 1.8 billion people use a source of drinking water that is faecally contaminated; and hundreds of millions of people have no access to soap and water to wash their hands, preventing a necessary act that would empower them to block the spread of disease.[57] The situation in Africa is descrbed as shocking, with about 400 million Africans living in water-scarce

[55] Jenny C. Aker and Isaac M. Mbiti, "Mobile Phones and Economic Development in Africa," Journal of Economic Perspectives 24, no. 3 (Summer 2010): 207, accessed October 2, 2014, http://sites.tufts.edu/jennyaker/files/2010/09/aker_mobileafrica.pdf.
[56] "Water supply, sanitation and hygiene development," WHO, accessed February 2, 2015, http://www.who.int/water_sanitation_health/hygiene/en/.
[57] Water supply, sanitation and hygiene development, *WHO*

countries; 300 million people not having reasonable access to safe drinking water and an estimated 230 million people defecating in the open.[58]

Transportation

According to the United Nations (UN), "adequate, efficient, and effective transport systems are important for access to markets, employment, education and basic services critical to poverty alleviation," and that "current patterns of transportation development are not sustainable and may compound both environmental and health problems."[59] Africa's transport infrastructures are underdeveloped, and on the world stage, only seven African countries (Tunisia, South Africa, Namibia, Mauritius, Morocco, Seychelles, and Gambia) are above par.[60] Broken into the different transport modes, only eleven African countries have better than average road transport, six when it comes to rail, and air transport is very limited, whereas ports fall far short of international standards in terms of loading and unloading containers.[61]

Information and Communication Technology (ICT)

Globally, the World Bank claims more than 6.319 billion people have mobile subscriptions.[62] This number is expected to increase.[63] Africa is said to have the least of

[58] John Vidal, "Water and sanitation still not top priorities for African governments," The Guardian, August 30, 2012, accessed February 11, 2015, http://www.theguardian.com/global-development/2012/aug/30/water-sanitation-priorities-african-governments.
[59] "Sustainable Transport," Sustainable Development, United Nations, accessed January 29, 2015, https://sustainabledevelopment.un.org/topics/sustainabletransport.
[60] KPMG Africa, "Transport in Africa," Full Sector Report (KPMG, 2013), 4, accessed January 10, 2014, http://www.kpmg.com/Africa/en/IssuesAndInsights/Articles-Publications/Documents/Transport%20in%20Africa%20-%20final.pdf.
[61] Ibid. 5-8
[62] World Bank, accessed January 11, 2015, http://www.worldbank.org/en/topic/ict/overview#1.

subscriptions, with 63 subscriptions per 100 inhabitants.[64] There is no denying that existing mobile technology systems have brought about new opportunities to people on the continent, including but not limited to access to information and services, banking, and farming.[65] Mobile payments, in particular, are very popular in Africa.[66] In Kenya, "nearly seven-in-ten Kenyans (68%) who own a cell phone say they regularly use their mobile device to make or receive payments," and "half in Uganda say this as well."[67] Yet, African countries will still need tremendous amounts of investments in ICT infrastructures to effectively compete on the global market, provide better services to citizens (including health, banking, and agriculture), and create a better climate to attract investments.[68]

Energy

Energy is deemed "an essential factor for sustainable development and poverty eradication."[69] Yet, across the globe, "2.8 billion people have no access to modern energy services and over 1.1 billion do not have electricity, and about "4.3 million people are dying prematurely every year due to indoor pollution resulting from cooking and heating

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[63] "Mobiles 'to outnumber people next year', says UN agency," BBC, May 9, 2013, accessed February 3, 2015, http://www.bbc.com/news/technology-22464368.
[64] Ibid.
[65] Aker and Mbiti, *Mobile Phones and Economic Development in Africa*, 207
[66] "Emerging Nations Embrace Internet, Mobile Technology," Pew Research Center, February 13, 2014, accessed February 18, 2015, http://www.pewglobal.org/2014/02/13/emerging-nations-embrace-internet-mobile-technology/
[67] Ibid.
[68] Rebecca Mayer, Ken Figueredo, Mike Jensen, Tim Kelly, Richard Green, and Alvaro Federico Barra, "Connecting the Continent: Costing the Needs for Spending on ICT Infrastructure in Africa," AICD (2009) 1-15, accessed December 27, 2015, http://infrastructureafrica.org/system/files/ICT_spending_needs_summary.pdf.
[69] "Energy for Sustainable Development," Sustainable Development, United Nations, accessed January 29, 2015, https://sustainabledevelopment.un.org/topics/energy

with unsustainable fuels."[70] Power in Africa is the "largest infrastructure challenge, with 30 countries facing regular power shortages and many paying high premiums for emergency power."[71] The energy situation in Africa is an indication that more needs to be done in order to spur growth, productivity, to achieve sustainable and inclusive shared prosperity. The UN claims that "the challenge lies in finding ways to reconcile the necessity and demand for modern and sustainable energy services with its impact on the environment and the global natural resource base in order to ensure that sustainable development goals are realized."[72]

The next section of this chapter will look at each of the elements of SMART infrastructure as it relates to the four infrastructure types briefly discussed above. I will start with Sustainable, and continue as structured in Table 2. References will be made to the four case studies in Appendix 2.

Examining SMART Infrastructure Elements

Note: All case studies used in this section can be found in Appendix 2.

Sustainable

According to the Institute of Sustainable Infrastructure (ISI), "there is a strong and compelling indication that civil engineering infrastructure projects are falling behind the societal and functional expectations of what is needed both for today and into the

[70] Ibid.
[71] "Transport in Africa," Infrastructure Africa, accessed January 19, 2015, http://www.infrastructure-africa.com/sectors/
[72] Energy for Sustainable Development, *Sustainable Development*, United Nations

future."[73] To back its point, the ISI cites to this scathing report from the American Society of Civil Engineers (ASCE):

> Wide collection of infrastructure systems will require major investments — in excess of $2.2 trillion — to be rehabilitated to their desired performance capacity. Population growth of as much as an additional 100 million people by the year 2050 (US Census Bureau), natural resource limitations, continuing societal desires for enhanced environmental protection, a constrained fiscal setting and the public interest, as expressed through policy, regulation and community expression, are all factors that must be considered by infrastructure managers.[74]

The reality-check offered by the ISI underscores the very definition of 'sustainable' as defined in Table 2. So, why is this element relevant?

Consider Case Study A (water and sanitation situation in Nima and Teshie - Ghana). The residents of the communities shared that existing water supply from the national water company, GWCL, is unable to meet their needs, both in quality and quantity. As a result, they have had to resort to fetching water from other sources, including rainwater harvest and hand dug wells. Based on the element 'sustainable,' one of the solutions, will be to look into providing an infrastructure system that can adequately address the higher demand for water, or perhaps create a system around the emerged sources to deliver conveniently to the communities. In many ways, it is about building a water and sanitation infrastructure that evolves with a growing population and alternative sources of water. But that is not the only challenge facing the two communities in this case study. Available toilets (particularly public toilets) are described as being far from the homes of residents (adult women are reportedly not using these facilities for that reason). Human

[73] "The Support for a National Sustainable Infrastructure Rating Tool System," Institute for Sustainable Infrastructure, accessed March 11, 2015, http://www.sustainableinfrastructure.org/rating/support.cfm.
[74] The Support for a National Sustainable Infrastructure Rating Tool System, *Institute for Sustainable Infrastructure*

excreta were reportedly discovered in drinking water, exposing residents to various health risks. It is also an environmental hazard within the water and sanitation infrastructure system. Furthermore, some residents also claimed that they cannot afford the cost of disposing of waste, therefore dumping them into public drains (another environmental hazard).

In case study B (impact of road transport on agricultural development - Nigerian), an area with large presence of farmers, lacked good transportation services to move goods to markets, and access farm plots . The study found that many of the existing roads, and the only main rail line in the region, were of poor condition. This reflects a lack of proper maintenance. The significance of the element 'sustainable' in case study B is the understanding of the need to create infrastructures that can be maintained and altered over time to meet exiting needs. It should not be in the case of Uganda, where the EU built so many roads that are now well beyond the size and standard the country can afford to maintain.[75]

Measurable

According to Glenda Gallardo, "as a society we are always interested in knowing where we are and where we are headed. No one could deny that information and measurement are essential tools to this purpose and without them it becomes difficult to perform an assessment of how much progress the society has made."[76] I am in agreement with

[75] Jason Groves, "UK wasted millions of aid on building African roads that were never finished or doomed to fall into disrepair," The Daily Mail-UK, December 10, 2012, accessed January 2, 2015, http://www.dailymail.co.uk/news/article-2246134/UK-wasted-millions-aid-building-African-roads-finished-doomed-fall-disrepair.html.
[76] Glenda Gallardo, "The Human Development Index as an Effort to Measure Well-Being in Honduras," (paper presented at the 3rd OECD World Forum on 'statistics, knowledge,

Gallardo. The ‘measurable’ element highlights the understanding that any form of infrastructure must be examined based on its inputs (such as cost of materials, labor, etc.) and outcomes (such as employment, health impact, etc.). They are essential to determining how relevant or critical an infrastructure is, as well as the likely impact it will have on society, the environment, and whether or not the investment is worth it.

The definition of ‘measurable’ in Table 2 supports the above argument. Take case study A. ‘Measurable’ could mean looking at the cost (labor, materials, environmental impacts, etc.) of building a new water and sanitation infrastructure. It could also mean the cost of expansion or major overhaul of the existing infrastructure systems to accommodate emerging trends of new water sources. Another aspect of ‘measurable’ could also be about understanding how much time is reduced for women and children who take 4 to 5 hours looking for water, or building water and sanitation infrastructure to be closer to the homes of residents, or factoring in the fact that for adult women and children, public toilets might not be the best option, rather, creating an infrastructure system that allows them to have in-home toilets. This might require the use of an institutional infrastructure such as enforcing old or passing new building codes that require private houses to have in-home toilet facilities. Measurable could also look at health impacts, particularly for women and children.

Similarly, in case study D (challenges and opportunities in ICT educational development - Ugandan), ‘measurable’ could mean the cost of building computer labs, or the number

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and Policy’: Charting Progress, Building Visions, Improving Life, Busan, Korea, October 27-30, 2009), 1, accessed January 21, 2015, http://www.oecd.org/site/progresskorea/44110008.pdf.

of students expected to benefit from the CFA program, and likely employment opportunities.

Meaningful

The element ‘meaningful’ is about identifying the purpose of an infrastructure project, which can also be very useful in measuring. Here are a few meaningful questions: what does this project mean to a community, or the economy? How is it going to affect, enable, enhance or create better opportunities? How is it going to improve the quality of citizens’ lives? The answer to these questions lies in identifying the purpose of an infrastructure project and what it means to a community. Is it something expressly sought by residents or will it directly or indirectly benefit them? Meaningful is about the context in which projects are established, and giving relevance to a physical structure within a complex space of need and wants.

The meaning of an infrastructure should be carved out of the needs of the targeted location, community or country. It should be based on a thorough understanding of what is going on now, what will likely change tomorrow based on trending events, and whether or not it is even worth the effort to embark on the project. ‘Meaningful’ infrastructure establishes attribution, as well, which will be addressed further below. Another aspect of meaningful infrastructure is access, and affordability. In case study C (Angola’s infrastructure: A Continental Perspective - Angola) for example, supplying power to communities, businesses and other users at a higher cost can alienate them, excluding citizens, particularly the poor and vulnerable. Similarly, when power is unreliable, as in case study C, businesses might resort to alternative sources, such as

generators, ofthen at higher cost. This alienation makes the infrastructure meaningless as the benefits are not felt.

Meaning can refer to building efficient and accessible transport infrastructure as in case study B from llorin East L.G.A, which helped local farmers reduce cost of business, and reach their scatterd farm plots. In case study A, meaning is established by communities gaining access to dependable water and affordable sanitation systems. The functionality of 'meaningful' is very important. In my opinion, infrastructures should have multiple meanings, and identifying as well as understanding them is critical to building productive and sustainable infrastructure.

Attainable

The element 'attainbale' is imperative as many projects start but are not completed because they have not been feasible. For example, in Mozambique, it was reported that an EU-funded (BP 60 million) road project, a 60-mile stretch of road, began and was never finished. [77] Such scenarios should be avoided at all cost because they waste resources, dash hopes and create a precedent of mistrust in communities. 'Attainable', as defined in Table 2, reflects why it is important to know the cost of inputs (as discussed in measurable). It is also about knowing the time frame for finishing a project. This means understanding the challenges, such as environmental risks, as well as availability of funds. It is important to ensure that infrastructure projects are not just planned, but that the financial mechanisms and other resources are in place or will be in place.

Case study D illustrates this point particularly well. If computer labs are built but not furnished with computers or even trained staff, the project becomes just another 'white

[77] Groves, *UK wasted millions*

elephant.'[78] The consideration of 'attainable' is that there are enough computers to supply any beneficiary community of the CFA. Similarly in case study B, building a rail or road project should consider the different 'measurable' inputs and outcomes to completing them. It should also include projected future maintenance or alteration cost and scenarios. In case study C, building power lines to supply communities and businesses should consider the element 'attainable' both in completion and in meeting goals of use. The idea behind 'attainable' is that there is an understanding of the importance of thinking of the end at the beginning, thereby ensuring that the timeline and goal of the project is met, notwithstanding usual project incidentals.

Attributable

'Attributable' provides a stronger basis to measuring the impact of an infrastructure project. When measuring the impact of an infrastructure project on a community or country, the role of 'attributable' is to ensure that the measured impact is a result of the new infrastructure project. In other words, 'attributable' means eliminating other possibilities as an actual catalyst for the positive changes taking place in a community, and that we can link the new infrastructure project to such changes. In case study B, for example, the building of new roads or rail infrastructure can help the agricultural industry of the community, in terms of market access as well as cost reduction. Attributable essentially asks the question of whether the reduction in cost of doing business and improvement in market access can be primarily linked to the new transport modes and not to other causes. In case study C, if new electric power lines are built to help

[78] A **white elephant** is a possession which its owner cannot dispose of and whose cost, particularly that of maintenance, is out of proportion to its usefulness. *See;* "White Elephant," Oxford Dictionaries, accessed June 10, 2015, http://www.oxforddictionaries.com/definition/english/white-elephant.

manufacturing industries improve production efficiency, there ought to be a direct link of the outcome to the new infrastructure , that is, the improved efficiency should be attributable to the new power lines. Similarly, in case study A, if a new water and sanitation infrastructure is built to help reduce the number of hours women and children spend searching for water and public toilets, then, the 'attributable' elements warrants that the outcome if realized, must be linked to the new infrastructure and not some other cause.

Reliable

'Reliable' is also about dependability. It is ensuring that an infrastructure can and will continue to serve its purpose efficiently and effectively; allowing citizens, businesses, and other stakeholders to benefit and identify with it. Case study A illustrates this principle well. If sources of water are closed for 2 to 6 months in a year and only work once in a week when in good condition, communities are more less likely to become dependent on it and lose confidence in the service. It undermines the faith, trust and meaning of an infrastructure to the people. It does not build trust in governance, and people do not see it as a valuable part of their livelihood. Similarly, when the quality of water is considered to be subpar, particularly at the end-user phase, it is not only putting the health of citizens at risk but also alienating them from using it. As one participant in the project from case study A put it, "the pipe water is not good. I will not drink water from the taps." This is not how an efficient and effective infrastructure should function. In case study C, we see that businesses cannot depend on existing energy infrastructures to supply them reliable power to run their operations cost-effectively, and consequently they are more likely to lose faith and seek alternative means (often at higher-cost).

'Reliable' infrastructures also depend on good maintenance initiative (as discussed under 'sustainable'). In Uruguay, the government has a program in place "to improve transport efficiency through rehabilitation and maintenance of the national road infrastructure and enhanced public sector capacity to plan, regulate and monitor transport and logistics services."[79]

Resilient

'Resilient' infrastructures are very important as natural disasters continue to increase. The talk of resiliency has become a crucial concept and practice. According to Frederick Krimgold, "pre-disaster planning is essential to post-disaster resilience."[80] Krimgold also notes that "initially, the focus was on the physical design side—architecture, engineering, planning—because it was buildings that fell down and killed people. But recently there's been a realization that we are totally dependent on infrastructure, especially in urban areas."[81] Krimgold's argument points to the fact that when disasters happen, we still need infrastructures to recover, such as water, power, hospitals, etc. Above all, it is important that we build infrastructures that can mitigate some of the outcomes.

A 'resilient' infrastructure, as defined in Table 2 is also about the ability of the infrastructure to withstand increased use and other man-made hazards. Case study A demonstrates this point well. We must ask how much pressure existing infrastructure can withstand from an increase in population, as the limited capacity might not accommodate

[79] "Uruguay: Road Rehabilitation and Maintenance Program," World Bank, accessed July 30, 2015, http://www.worldbank.org/projects/P125803/uy-transport-infrastructure?lang=en.
[80] Frederick Krimgold, interview by PWC, transcript, http://www.pwc.com/gx/en/capital-projects-infrastructure/disaster-resilience/functional-importance-buildings-disaster-planning.jhtml.
[81] Krimgold, interview by PWC

increasing use. Similarly, in case study B, it is important to understand how roads or trains can be built to manage traffic efficiently, as well as withstand natural phenomenon such as erosion.

Tailored

A 'tailored' infrastructure should be able to address some community or national needs. 'Tailored' can be derived from the 'meaningful', 'attributable' and 'sustainable' elements. In building a water and sanitation system to fix problems identified in case study A, the design must be done to fit the needs of the communities involved. As in case study A, public toilets cannot simply be built, because as pointed out, more people (mainly adult women) did not prefer that. Essentially, building water and sanitation systems in the two communities must be well tailored to the behavior patterns, the standard of living, and needs of the community based on access and affordability.

In case study C, addressing power issues for businesses and citizens at large is not only a 'meaningful,' and 'attributable,' endeavor but also 'tailored.' In case study B, 'tailored' means associating new roads or rail lines to agricultural farmers. Similarly in Case study D, addressing the educational needs of the country by providing technology to students can be deemed 'tailored.' Infrastructures can be 'tailored' to multiple needs, beneficiaries or issues.

Technology-Infused

The use of advanced and modern technology is essential to building productive and efficient infrastructures. For instance, embedding new technologies in water and sanitation systems to monitor risk for breakdowns, as well as supply clean and quality water for end-users as in case study A can prove to be very useful. They can also be used

to understand infrastructure use and patterns, such as road traffic. New technologies are also emerging for effective and efficient distribution of power. The use of SMART Grid[82] in case study C, for example could potentially transform power delivery in Angola and offer a more efficient way to do so.

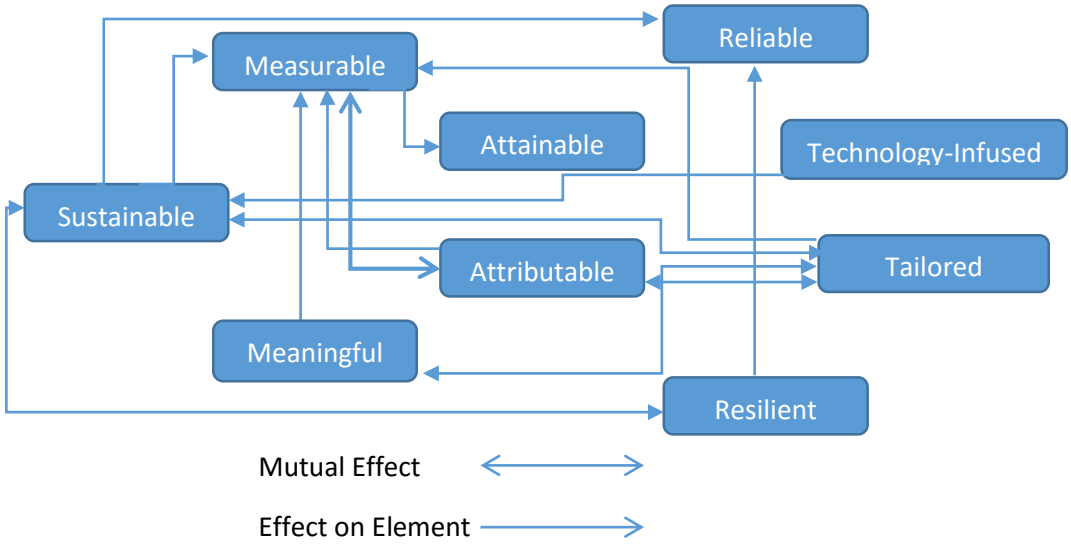
[82] "Smart grid" generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices. *See;* U.S Office of Electricity Delivery and Energy Reliability, "Smart Grid," accessed May 3, 2015, http://energy.gov/oe/services/technology-development/smart-grid.

Chapter 4: Conclusions

Interconnectedness of SMART Infrastructure Elements

As mentioned earlier, each element of SMART infrastructure is important and cannot be employed in isolation. They are dependent on each other, and sometimes the ability to actually achieve one leads to the success of the other. As demonstrated in Figure 4 below, when technology is incorporated into infrastructures, they can have an impact on reliability and resiliency, as well as the sustainability of the infrastructure. Similarly, identifying the meaning of an infrastructure project can help in measuring and its attribution, which also affects attainability. There is also a mutual effect between measurable and attributable because the measuring of a project is related to showing that an infrastructure resulted in either more jobs or better livelihoods.

Figure 4: Interconnectedness of SMART Infrastructure Elements



Applying the Innovation System for Development

The goal of an innovation system for development under the SMART infrastructure approach is to help oil-rich African countries understand the need for an enabling environment to realizing sustainable and inclusive development. As I mentioned in the literature review, Burh's classification of infrastructure (material, personal and institutional) provides some complementariness that could be explained and supported by the innovation system for development. The innovation system is about taking SMART infrastructure beyond material infrastructure and providing some of the complementary factors that can achieve sustainable and inclusive growth. In Appendix 1, I provide a brief background to this concept of innovation and offer three areas I deem relevant to supporting SMART infrastructures and development in oil-rich African countries.

1. *Availability and quality of human resources*: I consider this to be within Burh's *personal infrastructure* category. There is no sustainability, if roads or water and sanitation infrastructures are built without quality expert engineers or general labor to maintain over time. The SMART infrastructure approach should be an opportunity to create the next generation of African quality human capital, partnering with experienced international experts based on local knowledge and education to build new and maintain old infrastructure. Partnerships between the private sector, research and educational institutions as well as governments must focus on taking advantage of this vacuum to create experts and vocational skill programs to advance a country's infrastructure systems. A new breed of engineers, architects, social scientists, and trained citizens with trade and vocational skill backgrounds also means better employment opportunities now

and in the future. It allows the educational system to produce quality labor that could increase productivity. It is also an opportunity to create jobs that will continuously drive the future of a nation.

2. *Investment in Research and Development and R&D Infrastructure*: This falls under Burh's *institutional infrastructure* category. Governments must extensively support, lead and enable research and development focused on infrastructure. The obvious starting point is partnerships as mentioned earlier, not only with local educational institutions, but also with the private sector, international organizations, and governments. In other words, it is an opportunity for resource-rich African countries to generate ideas within the local context to help drive the next wave of infrastructures that are based on SMART principles.
3. *Foreign Direct Investment and Industrial Clusters*: This also falls under Buhr's *institutional infrastructure*. It represents an opening for a country to engage new technologies, financial instruments, and resources that can adequately support its growth and upgrading of infrastructures. It is obvious that Africa needs a lot of borrowed technology that can advance and modernize its infrastructural developments and maintenance. It could also mean the creation of new industrial clusters to include local and multinational corporation partnerships to support systems for building SMART infrastructure.

All three of these areas of innovation for development are significant. They are also supported by academic research, going back decades which argue for the importance of strong institutions and the role of quality labor in development. Only through such innovation and a SMART approach to infrastructure can African states utilize their

new-found natural resource wealth to enhance and provide the right environment for a more sustainable and inclusive development.

For every development agenda, there are competing interests and desired outcomes. A SMART infrastructure plan is no different. It offers several benefits to national and local governments, private industries (local and international), citizens, and particularly other sectors of the economy (agriculture, manufacturing and services) besides oil and gas. In essence, it can create a more balanced and diversified economy, providing more opportunities for all citizens and businesses, and it can reduce transaction costs, helping make governments more effective.

SMART water and sanitation infrastructures can help address key community health and sanitation issues, which lead to stronger and healthier citizens (particularly for women and children) who can effectively participate in national development. SMART transportation infrastructure also facilitate sustainable and meaningful construction of roads, rails and other systems, which help famers get their produce to markets at lower cost, and increase industry efficiency. For citizens, when the prices of food items are affordable and accessible due to better transport systems, the impact on livelihood cannot be understated. It can also mean more citizens can take part in and contribute to the national economy because of affordable, reliable and accessible transportation systems.

A SMART energy infrastructure translates into reliable and affordable power for homes and businesses. Reliable power can help businesses do away with expensive generators to reduce cost. It can increase foreign direct investments, and result in the growth of small and large businesses. As mentioned in this study, accessible and affordable energy can also improve the quality of life of average citizens. It allows homes to be powered

effectively and affordably, discouraging the use of dangerous and hazardous indoor alternative energy-use. Hospitals also become better providers of care with reliable power, allowing them to store vaccines that are needed and ensure that critical medical equipment is always operational.. SMART information and communication technology can also lead to a cleaner water supply, better transport management, and the use of smart grid to supply reliable power to users. It also facilitates faster internet services that can bridge the digital divide by helping citizens' access information and greatly enhancing the educational sector.

The inclusiveness that the SMART infrastructure approach offers are based on its meaningfulness. Who are you building this infrastructure for and for what purpose? These are some of the questions that can help address critical issues such as affordability and accessibility. When the right infrastructures are in place, it can also reduce citizen backlash and avoid the replication of the many 'white elephant' failed infrastructure projects that have long plagued the continent. Infrastructure built using the SMART approach can open many doors for oil-rich African countries to grow beyond oil and gas, considering some of the critical challenges they face. Revenues should, therefore, be invested in various forms of infrastructure based on the SMART approach.

Future Research

Further research on SMART infrastructure could focus on applying the approach to a set of countries across different development and economic spectrums, as well as at different levels of quality infrastructure. It can also test the approach by applying it to infrastructure projects at different stages of project management and development.

Bibliography

Acemoglu, Daron and James A. Robinson. “Why Nations Fail: The Origins of Power, Prosperity and Poverty.” New York, NY: Crown Publishers, 2012.

African Development Bank. Liberia: Infrastructure and Inclusive Growth. Tunis: African Development Bank, 2013. Accessed November 11, 2014. http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Liberia_-_Infrastructure_and_Inclusive_Growth_-_Full_Report.pdf.

Africa Progress Report. Equity in Extractives: Stewarding Africa’s Natural Resources for All (Africa Progress Report, 2013). Accessed November 22, 2014. http://www.africaprogresspanel.org/wp-content/uploads/2013/08/2013_APR_Equity_in_Extractives_25062013_ENG_HR.pdf.

Aker, Jenny C. and Isaac M. Mbiti. “Mobile Phones and Economic Development in Africa,” Journal of Economic Perspectives 24, no. 3 (Summer 2010). Accessed October 2, 2014. http://sites.tufts.edu/jennyaker/files/2010/09/aker_mobileafrica.pdf.

A.M, Tunde and Adeniyi, E.E. “Impact of Road Transport on Agricultural Development: A Nigerian Example.” Ethiopian Journal of Environmental Studies and Management 5, no. 3 (2012): 232-238. Accessed November 18, 2014. http://www.ajol.info/index.php/ejesm/article/view/77955/68350.

Atkinson, Robert D. “Understanding the U.S. National Innovation System.” ITIF (June 2014). Accessed March 16, 2015. http://www2.itif.org/2014-understanding-us-innovation-system.pdf.

BBC. “Mobiles 'to outnumber people next year', says UN agency.” BBC, May 9, 2013. Accessed February 3, 2015. http://www.bbc.com/news/technology-22464368.

Buckley, Chris. “China says Three Gorges mega-dam threats controlled.” Reuters, November 27, 2007. Accessed December 15, 2014. http://www.reuters.com/article/2007/11/27/environment-china-threegorges-dc-idUSSP22542620071127.

Buhr, Walter. “What is Infrastructure?” Volkswirtschaftliche Diskussionsbeiträge, no. 107-03 (2003). Accessed November 11, 2014. http://www.researchgate.net/publication/24130529_What_is_infrastructure.

Calderón, César, Enrique Moral-Benito and Luis Servén. “Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach.” Journal of Applied Econometrics 30, no. 2 (2015): 24. Accessed February 11, 2015. http://www.bde.es/f/webbde/SES/Secciones/Publicaciones/PublicacionesSeriadas/DocumentosTrabajo/11/Fich/dt1103e.pdf.

Campbell-Hyde, Blake. “Breaking Ground: Environmental and Social Issues of the Three Gorges Dam in China.” American University. Accesses November 11, 2014. http://www1.american.edu/ted/ICE/china-dam-impact.html.

Chuhan-Pole, Punam, Manka Angwafo, Mapi Buitano, Allen Dennis, Vijdan Korman, Aly Sanoh, and contributions from Shanta Devarajan and Wolfgang Fengler. “Sub-Saharan African countries continue to grow at a steady pace; The region's decade-long economic expansion appears sustainable; For newly resource-rich countries, strong governance will be key to harnessing resource wealth for development,” Africa’s Pulse 6 (October 2012). Accessed November 11, 2014. http://siteresources.worldbank.org/INTAFRICA/Resources/Africas-Pulse-brochure_Vol6.pdf.

COE, Montana State University. “Three Gorges Dam, Yangtze River, China.” COE, Montana State University, ENGR 125CS. Accessed January 5, 2015. http://www.coe.montana.edu/ee/rmaher/ENGR125_FL06/Three%20Gorges%20Dam.pdf.

Diamond, Larry and Jack Mosbacher. “Petroleum to the People Africa’s Coming Resource Curse—and How to Avoid It,” ForeignAffairs.com Essays, September/October 2013. Accessed October 20, 2014. http://www.foreignaffairs.com/articles/139647/larry-diamond-and-jack-mosbacher/petroleum-to-the-people.

Ernst and Young. “African oil and gas: driving sustainable growth,” Ernst and Young, last modified 2014. Accessed January 5, 2015. http://www.ey.com/GL/en/Industries/Oil---Gas/African-oil-and-gas--driving-sustainable-growth.

Fan, Qimiao and Douglas Zhihua Zeng. “Introduction and Summary.” in Innovation for Development and the Role of Government: A Perspective From the East Asia and Pacific Region, ed. Qimiao Fan, Kouquing Li, Douglas Zhihua Zeng, Yang Dong, Runzhong Peng. Washington: IBRD/World Bank, 2009.

Fan, Qimiao, Yang Dong, and Douglas Zhihua Zeng. “Innovation, Competitiveness, and Economic Development.” in Innovation for Development and the Role of Government: A Perspective From the East Asia and Pacific Region, ed. Qimiao Fan, Kouquing Li, Douglas Zhihua Zeng, Yang Dong, Runzhong Peng. Washington: IBRD/World Bank, 2009.

Feinson, Stephen. National Innovation Systems Overview and Country Cases. Center for Science, Policy, and Outcomes. Accessed May 7, 2015. http://archive.cspo.org/products/rocky/Rock-Vol1-1.PDF.

Fiasorgbor, Doris A. "Water and sanitation situation in Nima and Teshie, Greater Accra Region of Ghana." Journal of Toxicology and Environmental Health Sciences 5, no. 2 (February 2013): 23-28. Accessed November 18, 2014. http://www.academicjournals.org/article/article1379668595_Fiasorgbor.pdf.

Gallardo, Glenda. "The Human Development Index as an Effort to Measure Well-Being in Honduras," 3rd OECD World Forum on 'statistics, knowledge, and Policy': Charting Progress, Building Visions, Improving Life, Busan, Korea, October 27-30, 2009. Accessed January 21, 2015. http://www.oecd.org/site/progresskorea/44110008.pdf.

Groves, Jason. "UK wasted millions of aid on building African roads that were never finished or doomed to fall into disrepair." The Daily Mail-UK, December 10, 2012. Accessed January 2, 2015. http://www.dailymail.co.uk/news/article-2246134/UK-wasted-millions-aid-building-African-roads-finished-doomed-fall-disrepair.html.

Holden, Steinar. "Avoiding the Resource Curse: The Case Norway." Conference Oil Revenue Management in Ghana, April 26-27 2011. Accessed December 9, 2014. http://folk.uio.no/sholden/wp/resource-curse-norway-13.pdf.

IFC. "Infrastructure in Africa," International Finance Corporation. Accessed November 3, 2014. http://www.ifc.org/wps/wcm/connect/REGION__EXT_Content/Regions/Sub-Saharan+Africa/Investments/Infrastructure/.

IMF. "Resource-rich Countries Can Learn from History." IMF Survey Online Magazine: Interview. Accessed January 15, 2015. http://www.imf.org/external/pubs/ft/survey/so/2011/INT092711B.htm.

Infrastructure Africa. "Transport in Africa." Infrastructure Africa. Accessed January 19, 2015. http://www.infrastructure-africa.com/sectors/.

Institute for Sustainable Infrastructures. "The Support for a National Sustainable Infrastructure Rating Tool System." Institute for Sustainable Infrastructure. Accessed March 11, 2015. http://www.sustainableinfrastructure.org/rating/support.cfm.

KPMG Africa, "Oil and Gas in Africa: Africa's Reserves, Potential and Prospects," Full Sector Report (KPMG, 2013). Accessed November 10, 2014. https://www.kpmg.com/Africa/en/IssuesAndInsights/Articles-Publications/Documents/Oil%20and%20Gas%20in%20Africa.pdf.

KPMG Africa. “Transport in Africa,” Full Sector Report (KPMG, 2013). Accessed January 10, 2014. http://www.kpmg.com/Africa/en/IssuesAndInsights/Articles-Publications/Documents/Transport%20in%20Africa%20-%20final.pdf.

Krimgold, Frederick. Interview by PWC, transcript. http://www.pwc.com/gx/en/capital-projects-infrastructure/disaster-resilience/functional-importance-buildings-disaster-planning.jhtml.

Leautier, Frannie. “Keynote Address.” in Innovation for Development and the Role of Government: A Perspective From the East Asia and Pacific Region, ed. Qimiao Fan, Kouquing Li, Douglas Zhihua Zeng, Yang Dong, Runzhong Peng. Washington: IBRD/World Bank, 2009.

Mayer, Rebecca, Ken Figueredo, Mike Jensen, Tim Kelly, Richard Green, and Alvaro Federico Barra, “Connecting the Continent: Costing the Needs for Spending on ICT Infrastructure in Africa,” AICD (2009). Accessed December 27, 2015. http://infrastructureafrica.org/system/files/ICT_spending_needs_summary.pdf.

Munnel, Alicia H. “Infrastructure Investment and Economic Growth.” Journal of Economic Perspectives 6, no. 4 (Fall 1992). Accessed January 2, 2015. http://www.researchgate.net/profile/Alicia_Munnell/publication/4727276_Infrastructure_Investment_and_Economic_Growth/links/54c115400cf2d03405c4da13.pdf.

National Geographic. “China's Three Gorges Dam, by the Numbers,” National Geographic News, October 28, 2010. Accessed December 5, 2014. http://news.nationalgeographic.com/news/2006/06/060609-gorges-dam_2.html.

OECD. DAC Guidelines and Reference Series Natural Resources and Pro-Poor Growth: The Economics and Politics (OECD, 2008). Accessed October 18, 2014. http://www.oecd.org/greengrowth/green-development/42440224.pdf.

Oxfam International. “Moves to tackle Africa’s ‘resource curse’ reach turning point,” Oxfam International, October 24, 2013. Accessed November 10, 2014. http://www.oxfam.org/en/pressroom/pressrelease/2013-10-24/moves-tackle-africas-resource-curse-reach-turning-point.

Oxford Dictionaries. “White Elephant.” Oxford Dictionaries. Accessed June 10, 2015. http://www.oxforddictionaries.com/definition/english/white-elephant.

OECD. National Innovation Systems. Paris: OECD Publications, 1997. Accessed June 2, 2015. http://www.oecd.org/science/inno/2101733.pdf.

Palmer, Margaret A. “Beyond infrastructure,” Nature 467, (September 2010). Accessed December 22, 2014, http://www.palmerlab.umd.edu/Palmer_2010_Nature.pdf.

Pew Research Center. “Emerging Nations Embrace Internet, Mobile Technology.” Pew Research Center, February 13, 2014. Accessed February 18, 2015. http://www.pewglobal.org/2014/02/13/emerging-nations-embrace-internet-mobile-technology/.

Publish What You Pay. “Changing the Rules,” Publish What You Pay. Accessed November 12, 2014. http://www.publishwhatyoupay.org/.

Pushak, Nataliya and Vivien Foster. “Angola’s Infrastructure: A Continental Perspective.” Africa Infrastructure Country Diagnostic (March 2011). Aaccessed November 19, 2014. http://siteresources.worldbank.org/ANGOLAEXTN/Resources/AICD-Angola_Country_Report.pdf.

Stiglitz, Joseph. “Africa's natural resources can be a blessing, not an economic curse,” The Guardian. Last modified August 6, 2012. Accessed September 30, 2014, http://www.theguardian.com/business/economics-blog/2012/aug/06/africa-natural-resources-economic-curse.

Straub, Stéphane, Charles Vellutini, Michael Warlters. “Infrastructure and Economic Growth in East Asia.” Policy Research Working Paper 4589 (April 2008). Accessed October 30, 2014, http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/04/14/000158349_20080414114032/Rendered/PDF/wps4589.pdf.

Torrisi, Gianpiero. “Public infrastructure: definition, classification and measurement issues.” MPRA , no. 25850 (October 12, 2010). Accessed February 1, 2015. http://mpra.ub.uni-muenchen.de/25850/1/MPRA_paper_25850.pdf.

United Nations. “Energy for Sustainable Development.” Sustainable Development, United Nations. Accessed January 29, 2015. https://sustainabledevelopment.un.org/topics/energy.

United Nations. “Sustainable Transport.” Sustainable Development, United Nations. Accessed January 29, 2015. https://sustainabledevelopment.un.org/topics/sustainabletransport.

University of Texas. “Sustainable and Resilient Civil Infrastructures.” University of Texas, Arlington. Accessed May 2, 2015, http://www.uta.edu/sarci/.

U.S Office of Electricity Delivery and Energy Reliability. “Smart Grid.” Accessed May 3, 2015, http://energy.gov/oe/services/technology-development/smart-grid.

Vidal, John. “Water and sanitation still not top priorities for African governments.” The Guardian, August 30, 2012. Accessed February 11, 2015.

http://www.theguardian.com/global-development/2012/aug/30/water-sanitation-priorities-african-governments.

Vines, Alex. “Africa's oil and gas potential: Boom or hype?” Chatham House, Special to CNN, September 18, 2014. Accessed November 25, 2014.http://edition.cnn.com/2014/09/18/business/africa-oil-gas-potential-boom-hype/index.html.

Wells, Ryan and Susan Wells. “Challenges and opportunities in ICT educational development: A Ugandan case study.” International Journal of Education and Development 3, no. 2 (2007): 100-108.Accessed November 19, 2014. https://www.questia.com/library/journal/1P3-1409299631/challenges-and-opportunities-in-ict-educational-development.

Wikisource. “Brundtland Report: Chapter 2. Towards Sustainable Development.” Wikisource. Last modified on 5 June 2013. Accessed May 2, 2015, https://en.wikisource.org/wiki/Brundtland_Report/Chapter_2._Towards_Sustainable_Development.

WHO. “Water supply, sanitation and hygiene development.” WHO. Accessed February 2, 2015. http://www.who.int/water_sanitation_health/hygiene/en/.

World Bank. Africa Development Report-2012/2013 (World Bank, 2013). Accessed January 4, 2015. https://openknowledge.worldbank.org/bitstream/handle/10986/13504/9780821396162.pdf?sequence=1.

World Bank. Accessed January 11, 2015. http://www.worldbank.org/en/topic/ict/overview#1.

World Bank. “Uruguay: Road Rehabilitation and Maintenance Program.” World Bank. Accessed July 30, 2015. http://www.worldbank.org/projects/P125803/uy-transport-infrastructure?lang=en.

Yamoah, Michael. ”How Can Ghana Avoid an Oil Curse: Lessons from Nigeria.” Master’s thesis., Carroll College, 2013. Accessed October 11, 2014. http://www.carroll.edu/library/thesisArchive/YamoahM_2013.pdf .

Zhang, Xiaobo and Shenggen Fan. “How Productive is Infrastructure? New Approach and Evidence from Rural India.” International Food Policy Research Institute, no. 84 (October 2001). Accessed November 7, 2014. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1.2668&rep=rep1&type=pdf.

Appendix 1: The Innovation System for Development

Robert Atkinson writes that "in the conventional view, innovation is something that just takes place idiosyncratically in "Silicon Valley garages" and research and development (R&D) laboratories. But in fact, innovation in any nation is best understood as being embedded in a national innovation system (NIS)."[83] A similar view is shared by Fan and Zeng, who also writes that "the concept of innovation encompasses not only technological innovation, that is, diffusion of new products and services of technological nature into the economy, but equally includes nontechnological forms of innovation, such as organizational or institutional innovation."[84]

The definition of Innovation as offered by Fan et al is simply the concept of new ideas, or "the process to undertake a change in one or more of many aspects of production, distribution, and consumption of economic goods."[85] According to Fan et al, this comprises of new products, new processes, new ways to penetrate new markets, new supply sources or distribution methods, and new industries.[86]

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[83] Robert D. Atkinson, "Understanding the U.S. National Innovation System," ITIF (June 2014): 1, accessed March 16, 2015, http://www2.itif.org/2014-understanding-us-innovation-system.pdf.

[84] Qimiao Fan and Douglas Zhihua Zeng, "Introduction and Summary," in *Innovation for Development and the Role of Government: A Perspective From the East Asia and Pacific Region,* ed. Qimiao Fan, Kouquing Li, Douglas Zhihua Zeng, Yang Dong, Runzhong Peng, (Washington: IBRD/World Bank, 2009), 1.

[85] Qimiao Fan, Yang Dong, and Douglas Zhihua Zeng, "Innovation, Competitiveness, and Economic Development," in *Innovation for Development and the Role of Government: A Perspective From the East Asia and Pacific Region,* ed. Qimiao Fan, Kouquing Li, Douglas Zhihua Zeng, Yang Dong, Runzhong Peng, (Washington: IBRD/World Bank, 2009), 18.

[86] Ibid.

The NIS system, which is widely recognized among industrialized countries, particularly OECD countries, and also gaining wide acceptance in developing countries,[87] is not just an innovation of science and technology, rather a combination "all economic, political, and other social institutions affecting innovation (e.g., a nation's financial system; organization of private firms; the pre-university educational system; labor markets; culture, regulatory policies and institutions, etc.)."[88]

There are several definitions of NIS. However, according to the OECD, NIS usually focuses on the flow of knowledge, and the "approach reflects the increasing attention given to the economic role of knowledge."[89] It also shows the increasing use of systems approaches as well as the growing number of institutions involved in knowledge generation.[90] Essentially, to measure and assess an NIS system, it is important to recognize the following four types of knowledge or information flows as offered by the OECD:[91]

1. Interactions among enterprises, primarily joint research activities and other technical collaborations
2. Interactions among enterprises, universities and public research institutes, including joint research, co-patenting, co-publications and more informal linkages

[87] Stephen Feinson, *National Innovation Systems Overview and Country Cases* (Center for Science, Policy, and Outcomes), 14, accessed May 7, 2015, http://archive.cspo.org/products/rocky/Rock-Vol1-1.PDF.
[88] Atkinson, *Understanding the U.S. National Innovation System*, 1
[89] OECD *National Innovation Systems* (Paris: OECD Publications, 1997), 11, accessed June 2, 2015, http://www.oecd.org/science/inno/2101733.pdf
[90] Ibid.
[91] Ibid. 7

3. Diffusion of knowledge and technology to enterprises, including industry adoption rates for new technologies and diffusion through machinery and equipment
4. Personnel mobility, focusing on the movement of technical personnel within and between the public and private sectors.

There are also some factors that are known to generally influence innovation performance in different countries. Some of these as shared by Frannie Leautier are; competition and market structure, intellectual property rights, availability and quality of human resources, investment in research and development (R&D) and its infrastructure, and foreign direct investment and industrial clusters.[92] For Leautier, it is also important to underscore the significant role of the public sector, particularly governments in fostering innovation, but it must also be understood that "innovation policies and ambitions have to be adapted to the levels of development and institutional capacity of a country."[93] The OECD has also stated that;

> Innovation and technology development are the result of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutes. For policy-makers, an understanding of the national innovation system can help identify leverage points for enhancing innovative performance and overall competitiveness.[94]

Another important thing that Leautier mentions is the South-South learning among developing countries and how that could be used provide a platform to learning about

[92] Frannie Leautier, "Keynote Address," in *Innovation for Development and the Role of Government: A Perspective From the East Asia and Pacific Region,* ed. Qimiao Fan, Kouquing Li, Douglas Zhihua Zeng, Yang Dong, Runzhong Peng, (Washington: IBRD/World Bank, 2009), 13.
[93] Frannie Leautier, "Keynote Address," in Fan, Li, Zeng, Dong, and Peng, 13.
[94] OECD *National Innovation Systems*, 1997, 7

innovation and how to better improve and adapt within individual countries (referencing the Asia-Pacific region).[95]

In this study, the use of the NIS system, simply dubbed Innovation for SMART Infrastructure, will focus on the role of the government and how it can facilitate innovation among key stakeholders such as enterprises, and educational institutions. I focus on three of the five essential things Leautier identifies as influencing innovation performance, and how that can help oil-rich African countries design, implement, sustain and maintain infrastructures.

1. The availability and quality of human resources: Leautier writes that "the quality of human capital, especially in science and technology, is of critical importance for innovation and a country's competitiveness."[96] He underscores the importance of not just basic and higher education, but also "the continuous upgrading of skills and knowledge."[97]
2. Investment in research and development (R&D) and R&D Infrastructure: Under this influencing factor, the understanding it that it is not simply about only scientists and engineers but also the accompanying infrastructures that "provides the technological equipment, research inputs, financing, and other services."[98] As Leautier states "empirical studies have shown that the amount and quality of a

[95] Frannie Leautier, "Keynote Address," in Fan, Li, Zeng, Dong, and Peng, 14
[96] Ibid. 12
[97] Ibid.
[98] Ibid.

country's investment in R&D and its associated infrastructure have an important impact on its innovation performance."[99]

3. Foreign direct investment (FDI) and industrial clusters: According to Leautier, this allows a country to open its doors and bring in new technologies and products that can effectively contribute to the gradual upgrading of innovation capacity.[100] In essence, "innovation is often born out of the blending of indigenous knowledge with the technological and organizational inputs from foreign firms."[101]

[99] Ibid.
[100] Ibid. 13
[101] Ibid. 13

Appendix 2: Case Studies

Note: All case studies are part of the original works of the authors.

A: Water and sanitation situation in Nima and Teshie (Ghana)[102]

Study area

Nima is densely populated with 82,329 people in 2008 (UNESCOIHE/SWITCH, 2010). The population is made up of various ethnic groups but predominantly Muslims from the northern parts of Ghana and neighboring West African countries. Water supply in Nima is served by Accra North District of Ghana Water Company Limited (GWCL) while the collection of solid waste is contracted to ABC waste management company. Teshie is located 14 km to the east direction of Central Accra, bordered with Nungua (East) and Gulf of Guinea (South). It is categorized as urban as well, with high density of indigenous people. Population in Teshiewas is about 171,875 (LEKMA, 2012). The water supply service in this area is provided by Accra East District of GWCL. Ledzokuku Krowor Municipal Assembly (LEKMA) provided waste management services where the collection of solid waste is contracted to Daben and Zoomlion waste management companies.

Findings

The residents of Nima and Teshie communities reported that they fetched water from a number of sources. Among these sources are GWCL pipe connections, rainwater harvest

[102] Doris A. Fiasorgbor, "Water and sanitation situation in Nima and Teshie, Greater Accra Region of Ghana," *Journal of Toxicology and Environmental Health Sciences* 5, no. 2 (February 2013): 23-28, accessed November 18, 2014, http://www.academicjournals.org/article/article1379668595_Fiasorgbor.pdf

and hand dug wells for Nima. Contrary to Nima, Teshie had additional sources from tanker services and streams. Recently, “sachet water” (500 ml of water packed in a plastic sachet which is sold either cold or hot) has become one of the most preferred sources of drinking water. None of the two communities had a borehole even though the Nima community indicated it as one of the preferred sources of water. Table 3 shows the sources of water in the study areas. Access to water was found to be difficult in that the taps flowed briefly at midnight when the people were asleep. Taps were also closed for as long as between 2 to 6 months. Whenever the taps were in good conditions, they were opened once in a week. For instance, the poor (especially women and children) spent a minimum of 5 minimum and a maximum 4 h in looking for water by travelling over long distances ranging between a few meters to about 10 km. They used water supplied by GWCL sources, “sachet water” and rainwater harvest. The price of various containers of water varied depending on the season of the year, the source of water and storage system.

The trotter (a container in which trotter/pig feet is stored and exported to the country), also known and commonly called “pig feet container” by respondents is not applicable to the Nima community. Also, about 48% of respondents in Nima said the toilets were far from their homes, thus it is inconvenient for them to always go to the public toilets. In this case, it did not apply to only women but all members of the community. The people of Nima and Teshie who used public toilets and facilities outside their homes reported that they would prefer having the facilities in their own homes, even if they have to share usage with other tenants. Adult women do not patronize public toilet facilities.

Levels of access to water and sanitation services

All the participants from both communities have indicated that service charges were not affordable. In the light of unaffordability of WATSAN services, some of the residents looked for alternatives knowing the implications though. All the FGDs conducted in Nima indicated that residents pay a fee to dispose their garbage into the public refuse containers but residents do not pay to do so in the Teshie community. People who could not afford the fees threw refuse into public drains. All the participants indicated that the quantity of water used for both domestic and commercial purposes in Nima and Teshie was insufficient. All respondents at FGDs conducted in Nima complained that "sachet water" producers use water-pumping machines to divert water to their homes/storage facilities, thus depriving other community members from getting water. The respondents indicated that even though they have reported the situation to the appropriate authorities (GWCL), nothing seemed to have been done about it.

According to the residents of Teshie, insufficient water supply was attributed to undue delay in the completion of the rehabilitation of the under-ground reservoir and overhead tank at the "Cold Store Area" (a suburb of the Teshie community), development of large companies and residential estates, insufficient production of water at the water source and low pressure. It is ironic to note that in the face of all the problems enumerated by the communities, the findings revealed that there were over 50 and 40 "sachet water" producers in Nima and Teshie, respectively. A sachet of water cost 5¢ and 30 pieces packed in a bag is sold at 50¢ by distributors and retailed between 75¢ and $1.50 (US dollars) depending on the brand and location. Access to WATSAN services is considered a major problem in the two communities. The factors that account for this are presented and these factors are ordered according to their importance as expressed by the

participants from the FGDs. Most mentioned problems of access to WATSAN Services in Teshie are:

1. Irregular water supply;
2. Increase industrial use of water by Coca Cola, Printexe etc.;
3. Damaged old pipelines (faulty valves and leakages);
4. Limited number of public toilets and refuse dumps; 5. Unplanned and poor access to Nima, resulting in the inability for tanker services to reach many parts of the community;
6. Springing up numerous sachet water production units;
7. Pay-as-you-use system.

Quantity and quality of water used by the poor

The daily quantity of water used is not sufficient (especially during the dry season) as reported above. The responses revealed that even though the various households would have preferred to use more water than what is served, they have learned over the years to manage water and also adopt measures to access water in difficult times. An average of 5 persons in a family use between 2 and 5 buckets (about 18 liters) of water a day for all their domestic water needs in Nima. In Teshie, a family of 4 persons used an average of 8 buckets of water daily. However, 50% of the respondents from Nima reported that water from GWCL is the most polluted due to the rupture of some pipelines and resultant seepage of foreign materials into the water. Even though the study participants said they promptly reported burst in pipelines to their Assembly men (they represent local government electoral areas within a district) in the local government system of Ghana, they are elected by universal adult suffrage who also report to the GWCL; the company

normally did not act on time. The GWCL officials however maintained when problems were reported, they responded promptly if they had the materials to repair it and delayed if the materials were not unavailable. Also, the research found out that the GWCL did not conduct any end-user quality check. The officials of the Company said they only check the quality of water at the treatment plant, and only supply water to consumers if the water was safe to use. A participant from one of the Nima FGDs has this to say about the quality of water supplied by GWCL:

> "The pipe water is not good. I will never drink water from the taps. It is full of faeces. One day we were fetching from the taps, all of a sudden we realized that the water was dirty and smelly. Thinking it was dirty because the pipes have not been opened for a while. But in no time, we had the information that a burst pipeline was filled with human excreta from a neighbor's over flowing toilet. We had already collected human excreta into our containers. No, I will never drink that thing again".

The research found that those living along the coast in Teshie wash with seawater and rinse themselves with sachet water or a cup of fresh water. Washing of bowls and other utensils was done with seawater.

B: Impact of Road Transport on Agricultural Development (Nigeria)[103]

Study Area

The study area is Ilorin East L.G.A and it is one of the sixteen local government areas of Kwara State. It shares boundaries with Ilorin South L.G.A to the south, Ilorin West L.G.A to the west, Moro L.G.A to the north and Ifelodun L.G.A to the east. The climate of the area is characterized by wet and dry seasons each lasting six months. Average rainfall is about 50.8mm during the driest month (November to April). The average

[103] Tunde, A.M and Adeniyi, E.E, "Impact of Road Transport on Agricultural Development: A Nigerian Example," *Ethiopian Journal of Environmental Studies and Management* 5, no. 3 (2012): 232-238, accessed November 18, 2014, http://www.ajol.info/index.php/ejesm/article/view/77955/68350

minimum temperature is about 21.10C. A large proportion of the land is covered by ferruginous tropical soil which is prone to erosion. It has a land area of 486 km² and a population of 204,310 at the 2006 census. The people of the area are predominantly farmers cultivating crops such as yam, maize, cassava, guinea corn and vegetables among others. The major means of transportation is the road transport system. Road distance from Ilorin the state capital to Oke-Oyi L.G.A Headquarters is 16km. The major feeder roads are in bad condition. Other roads that link rural settlements together and to urban settlements are also in bad condition. The main rail line that links south to the north although not functioning also passes through the local government. There are also some settlements in the L.G.A area.

Results and Discussion: Socio-economic Characteristics of Farmers

The socio-economic characteristics of the sampled farmers revealed that the larger percentage (56.7%) of the farmers in the study area is male while 43.3% are females. This implies that there are more male farmers in the study area than female. Majority of the farmers (74%) are in the economic active age between 18 and 59 and 52% of the farmers are married. About 50% of the farmers do not have formal education and this affects their innovation and diffusion of new ideas. About 30% of the farmers generate below N50, 000, 20% make (N50, 000-N100, 000), 26% earn (N101, 000- N150, 000) while about 24% of the farmers generate above N151, 000 and N250, 000. The farming status shows that 58% are full time farmers against 42% that are part- time farmers. Furthermore, the study reveals that 63.3% of the sampled farmers have over 10years farming experience. This indicates that most of the farmers sampled have enough farming experience.

Types of Crops Grown

Respondents were asked about the major crops grown in the study area. Their responses revealed that they grow crops such as cassava, cocoyam, maize, melon and yam as well as some vegetable plants. They indicated that 41% grow grains such as guinea corn, maize, millet e.t.c. About 36% of the farmers produce leguminous crops such as soya beans, cowpeas and beans. Also, 30% of the farmers indicated that they grow root crops such as yam, cassava, cocoyam among others. It was further revealed that 25% of the farmers produce vegetables such as spinach, garden egg, okro e.t.c. Only 11% of the farmers grow tree crops, this is as a result of the long gestational period of growth.

Mode of transportation of Agricultural Produce to the Town

The study revealed that farm plots were scattered all over the study area at varying distances away from the houses and motorable roads. This is in a bid to search for fertile land and also because of the land tenure system in the study area. Respondents were however asked about the different modes of transportation of produce to their houses as well as the markets (towns). Different modes of transportation were identified by them and these included head porterage, bicycle, motorcycle and public transport (lorries, pickup and buses) all of which are through road transport as the most predominant and readily available mode of transporting their produce from where produced to where needed. 38% used head porterage in all the settlements, 16.7% employed the use of bicycle, 22% use motorcycles, 18.7% indicated pick-up vans and 4.6% used Lorries. The effect of higher percentage use of head porterage is that it has limited the potential level of production because they can only carry certain quantity at a time. Nobody use taxis as taxis are not very common in these areas. More so, cost of engaging taxis and the

quantity of produce they can carry is also important. However, 36% of the respondents indicated the use of bikes in transporting their produce from farm to different towns, 46% employed the use of Pick-up vans while only 18% indicated the use of Lorries to transport their produce from farms to towns. The reason for the use of these modes of transportation is because of the bad condition of the roads from their farm to towns.

Transportation Cost of Agricultural Produce on Farmers' income

Cost of transportation of agricultural produce from the farm sites to the market has a great impact on production and income of farmers. This is because transport charges on agricultural produce vary with type of crops, the efficiency of the transport and distance travelled. 14% spent nothing less than N20,000 annually in moving their produce to the market, 27.3% spent between N21,000 and N40,000, 38% of the farmers spent between N41,000 and N60,000, 20.7% spent between N60,000 and N80,000 annually to transport their farm produce to the various towns where demands are high. This means a significant proportion of the farmers' income had gone to transportation and this is as a result of bad roads in these areas. Farmers that spent less than N20, 000 annually are those engaged in vegetable production. This is given the fact that majority (76%) of the farmers earned less than N150, 000 annually from their farm produce. High cost of transportation would translate to high selling price and if the price is too high when compared with other farmers from other areas, customers will not buy and this may result to selling at a loss.

Farmers' Agricultural Productivity level in relation to Transportation of Produce

Some factors are responsible for the quantity of crops produced by farmers in the study area and these vary from farm to farm and settlement to settlement. Such factors include

availability of transport, markets, farm size and farm input. About 59% of the sampled farmers produced 100-5000kg, while 41% produced less than 100kg. This is attributed to the small scale production of the rural farmers. Most of them produce for subsistence and only sell the excess from their production. Transportation problems and other agricultural problems they encountered have really reduced their production capacities. Transportation cost especially has limited their production capacities hence they produce only little at a time.

Transportation Problems

Respondents were asked to list the transportation problems encountered in the process of transporting their produce from the farm to their houses and markets. According to them these problems included: bad roads, high cost of transportation, irregularity of vehicles, insufficiency of vehicles, insufficient means of transportation and long distance from farm to their houses as well as markets. 14% of the farmers trekked less than 1km from their houses to their farms. Others 30%, 38% and 18% trekked 1-4km, 4- 7km, and 7-10km respectively from their various houses to their farms. All these distances take a very long time for them to get produce from source to destinations. Discussions were held with farmers and transporters in the sampled settlements, from their discussions it was discovered that most of the roads linking these settlements to one another are in bad condition. It was further gathered that road transport does not only have impact on the development of the agricultural production but also on the socio-economic development of the people in all these communities and rural development as a whole. Most of them indicated that they pay high fare in order to get their produce to where needed and this in turn affects their farm income. Invariably they do not realize enough money that can take

good care of their households. The result of the interview with the transporters revealed that they prefer to be plying settlements that are well connected with good roads than those that are not connected with good roads. According to them, they pointed out that bad road conditions affect their cars and lorries to the extent they do not want to patronize the study area again. Furthermore, they indicated that their patronage of these settlements is because most of them are indigenes of these communities.

C: Angola's Infrastructure: A Continental Perspective (Angola)[104]

Power

Angola has been making substantial investments in the power sector since 2002 to restore and reconstruct the infrastructure that was destroyed during the civil war. Recent estimates from Empresa Nacional de Electricidade (ENE)—Angola's major power-generating company—indicate that these investments led to an increase in generation capacity from around 830 MW in 2002 to over 1,200 MW in 2008 (World Bank 2010a) (table 2). In terms of per capita generating capacity, Angola fares better than the average African fragile state or resource-rich country. Angola has 70 MW per million people compared to resource-rich or low-income fragile countries, which have only 43 or 46 MW per million people, respectively (table 1). Furthermore, a relatively high share of Angola's generation capacity is actually operational. In 2008 almost 1,000 MW or 80 percent of the installed power generation capacity was operational. This is higher, on average, than resource-rich countries, where roughly 66 percent was operational and

[104] Nataliya Pushak and Vivien Foster, "Angola's Infrastructure: A Continental Perspective," *Africa Infrastructure Country Diagnostic* (March 2011), accessed November 19, 2014, http://siteresources.worldbank.org/ANGOLAEXTN/Resources/AICD-Angola_Country_Report.pdf.

generating power. Thus, Angola has been able to rapidly ramp up its power production over the past decade.

This increased generation and operational capacity facilitated a 13 percent average annual growth in power production between 1999 and 2008. As of 2008 around 4,133 GWh of power was produced, a steep increase compared to 1999 production levels of 1,295 GWh (World Bank 2010a). The delay involved in obtaining an electricity connection has fallen dramatically since 2007. Investment climate surveys in 2007 reported that firms encountered delays of over two months in Luanda and over six months in other parts of Angola in order to obtain a new electricity connection (World Bank 2007b). But Angola has achieved tremendous progress in this area—firms in 2010 recorded only a seven day delay, on average, in obtaining a power connection (World Bank 2010b).

Challenges

But increased investments in power infrastructure have not necessarily translated into widespread electrification. As of 2008 only a little more than 30 percent of Angola's population benefited from access to power, lower than the 46 percent average for the nation's resource-rich African peers. No disaggregated data are available on the levels of rural versus urban access in Angola (World Bank 2010a), but it is known that Luanda consumes around two-thirds of the nation's electricity, suggesting relatively high access in the urban and peri-urban areas of the capital. Further, at least 85 percent of Luanda's municipalities indicate that they use electricity for lighting, corroborating that the availability of electricity in urban areas is high (World Bank 2005). It is estimated that about half of the connected residential consumers in Luanda are served by informal providers who pay a bulk tariff of around US$0.04 cents per kilowatt-hour to the utility

and resell to consumers at approximately three times this price. Given the limited attention given to rural electrification to date, rural access can be expected to be quite low.

Additionally, even though power availability has improved, service continues to be relatively unreliable, with growing recourse to emergency rentals to safeguard supply. Despite the steep growth in power production, World Bank investment climate surveys in 2007 reported that around 84 percent of firms experience power outages, lasting around 21 hours, on average 8 times a month. Large firms indicated a more acute problem, with at least 16 outages a month; the manufacturing sector overall was the worst affected. The problems were reportedly worse outside Luanda (World Bank 2007b).

In 2010 results from the enterprise showed marginal improvement, with Angolan firms enduring a modestly better 6 outages a month lasting around 14 hours (World Bank 2010b). Overall 36 days were spent without electricity, twice the time endured by other resource-rich African countries. Inadequate power supply is a huge impediment to private sector activity. In 2007 at least 68 percent of Angolan firms surveyed in the larger cities had their own generation capacity to compensate for intermittent grid supply. Outside of Luanda, 90 percent of firms owned their own generators, producing almost a third of their own power needs. Recent estimates suggest that at least 900 MW of self-generation capacity has been put in place by Angola's firms. This is not far short of ENE's generation capacity, and much higher than in many other resource-rich countries. Around 5 percent of firms' annual turnover was lost due to electricity shortages, which is typical of resource-rich countries in Africa (World Bank 2007b). In 2010 the impact of unreliable power supply was reportedly worse, such that the value lost due to erratic

power supply had increased substantially to 13 percent, much higher than for the peer group (World Bank 2010b). Self-generation by firms is largely diesel-based and can cost as much as $0.40 per kilowatt-hour (kWh) to operate in spite of the relatively low diesel prices in Angola (table 2)—or roughly twice ENE's production costs. Most of the time, self-generation is operated on stand-by mode, as a backup for frequent outages. To ensure steady supply, however, it is not uncommon to have self-generation operating continuously, thereby adding significantly to the costs of power. Further, while the time taken to obtain an electricity connection has reduced in recent years, new connections still impose a large cost to firms in Angola. The cost for firms to obtain an electricity connection is ten times the country's per capita income. Although these costs are lower than elsewhere in Africa, they nonetheless represent a significant burden on firms (World Bank 2010c).

Poor access and erratic power supply can be attributed to the fragmented nature of Angola's power system as well as deficiencies in existing transmission and distribution infrastructure. Angola has three major electric systems that are not interconnected, each operating independently. The north, south, and central systems each have their own networks linking generation sources to load centers (figure 3). The northern system, serving Luanda, accounts for over 80 percent of the country's generation assets, while the central and southern systems have less than 10 percent each. While blackouts are commonplace in Luanda, they are even more so in the central and southern systems. Ironically, the north actually has a surplus of energy—its blackouts are less due to lack of energy than to operational challenges associated with managing the system during peak-load periods. The absence of a national transmission backbone prevents surplus power in

the north being wheeled to the center and south of the country. This problem of regional imbalances in power supply and demand will only become more accentuated as new generation capacity comes on stream, underscoring the importance of improving the transmission network. Power production costs, at $0.16 per kWh, are relatively high by the standards of neighboring countries in southern Africa (figure 4). The higher costs in Angola, particularly when compared to its neighbors, are partly explained by the country's reliance on oil-based generation for about 40 percent of its production, at a cost of around $0.30 per kWh.

Meanwhile, tariffs, at $0.042 per kWh, are among the lowest in Africa, covering only a small fraction of costs. Power tariffs in Angola are low even by the standards of other hydropower-dependent countries, whose power tariffs typically stand closer to $0.10 per kWh. Angola has not revised its power tariffs since 2004. These low power prices, although meant to benefit the poor, largely subsidize the better-off minority that live in larger cities covered by the grid, while the poor remain unconnected. In part due to these low tariffs, Angola's power sector faces a dire financial situation.

D: Challenges and opportunities in ICT educational development (Uganda)[105]

Uganda is home to about 28 million people in East Africa. The various urban areas and cities of Uganda are densely populated but Uganda is primarily an agricultural country and rich in natural resources. Ugandan education takes places in a country comprised of

[105] Ryan Wells and Susan Wells, "Challenges and opportunities in ICT educational development: A Ugandan case study." *International Journal of Education and Development* 3, no. 2 (2007): 100-108, accessed November 19, 2014, https://www.questia.com/library/journal/1P3-1409299631/challenges-and-opportunities-in-ict-educational-development.

more than 20 ethnic groups where the common language of instruction is English. 69.9% of Ugandans over the age of 15 are literate.

Educational ICT in Uganda is similar in many ways to other countries in East Africa. Efforts are being made to integrate ICT into schools and curricula, but with mixed effort and success. One such effort is the New Partnership for Africa's Development (NEPAD) e-schools initiative (Evoh 2007). Bugulumbya Secondary School in Uganda was one of the first to take part in this project on the continent (APC 2005). This and similar local, national, and international initiatives show a recognition of the importance of ICT in education. However, ICT in the schools is still not the norm due to a number of logistical and developmental challenges. Even when computers are available in some schools, evaluation of the actual impact of ICT is rare, and similar to a recent study in Kenya, computers are often only used for specific courses or by specific personnel, and many teachers, students, and subject-areas still lack access to ICT (Wims & Lawler 2007).

Computers for Africa (CFA) was conceived and established by Tim and Ruth Leacock of Omaha, Nebraska in the year 2000 (http://computers4africa.org). They began with the realization that in the United States thousands of older but still serviceable computers were being warehoused and/or melted down. With the initial help of a former missionary in Uganda, they began to acquire and refurbish computers, eventually installing complete computer labs in clusters of schools around the country. They traveled to Uganda to learn more about the beneficiaries of their work. Their time in Uganda made them interested in not only delivering the much needed technology to agencies that served Ugandan youth, but also developing relationships and partnerships with the stakeholders.

Results

Based on interviews and observation, we identified nine key transitions in CFA's development of ICT delivery in Uganda. We present these transitions below. Each is characterized by a challenge that was faced and a solution that was implemented or attempted by CFA.

Challenge 1: long distance operations

Solution: establish a local presence and a network of local stakeholders

As described above, CFA was born in Nebraska, USA. Once a need was identified and CFA determined a way to fill this need, the organization began to send computers to Uganda. Though this was a large task for a small organization, they soon came face to face with another reality.

Challenge 2: communication

Solution: streamline, direct connections, clear messages

Once established within the country, the day to day needs of running local operations became the main concern for CFA. An integral part of running any organization that deals with a diverse group of stakeholders is communication. Communication problems were exemplified by a convoluted and complex chain of phone calls, emails, and word of mouth from CFA staff to a secondary school head mistress, the result of which was more confusion than understanding. In response to this, CFA made conscious efforts to streamline communications with their stakeholders, to have direct communication and not rely on a chain of communication when possible, and to construct communication in the most understandable manner possible.

Challenge 3: cultural competence

Solution: constant awareness and diligence, proactive solutions

The previous challenge leads directly to a challenge that exists at every stage of the international development process: the challenge of cultural competence. This may take the form of language, etiquette, issues of authority or hierarchy, or an understanding of cultural subtleties such as time and relationships. Beyond these culturally constructed differences however, organizations from the global North, must also deal head on with issues of cultural bias, colonialism, imperialism, and hegemony. Though organizations may have the best of intentions, if they do not recognize and acknowledge the historical legacies of power which still have an impact, and with which they might be complicit if they aren't diligent to work against, they are likely to be missing a key cultural ingredient at this stage. CFA recognized this challenge and was alert to the potential dangers if not addressed.

Challenge 4: appropriateness for the local context

Solution: actively receive local input and respond to it

An extension of cultural understanding and the avoidance of hegemonic behavior is the need to understand the local context as it relates the project itself. In other words, how does the organizationally perceived need compare to local desires and local perceptions of need? From step one, CFA had to check their assumptions about what was needed from their viewpoint, and trust in what was needed from the perspective of teachers, students, and administrators in Uganda. These issues may be of a very practical nature. For example, CFA envisioned Linux as the operating system of choice since it was open-

source and freely available. They soon had to adapt, however, when they received feedback informing them that the local context was not favorable to this, and responded by switching to a Microsoft operating system for the computer labs. (See a related discussion in Wims & Lawler 2007).

Challenge 5: defining and documenting success and failure

Solution: evaluation and assessment at every stage

The solution above is, perhaps, over-simplistic since receiving feedback is a challenge in and of itself. This desire to get stakeholder feedback is part of a larger challenge: how do we know if what we're doing is working? To answer this question, CFA first needed to be able to define what success was, and specifically what success was to their stakeholders. From that point on, they were able to include an evaluation component at every stage of their organizational development. This includes formative evaluation as specific projects are underway and summative evaluation when project components are completed. Especially useful in this regard may be practices of participatory evaluation (e.g., Broughton & Hampshire 1997; Cracknell 2000).

Challenge 6: technical sustainability

Solution: build local skills & build a cluster/community of stakeholders

Due in large part to effective evaluation utilized by CFA, their next challenge became apparent via stakeholder feedback. Once computer labs were operational in schools, how could they be sustained? In other words, when computers had problems and needed troubleshooting and/or maintenance, how would this occur – especially in the long term, without CFA assistance? CFA responded to this challenge with a maintenance and repair

workshop which supplied the local community with the skills to repair most common computer problems. In addition, from the beginning CFA conducted operations in a strategic way such that individuals could rely on a community that was organically developing out of a geographical cluster of schools, from which stakeholders could tap collective expertise to solve problems as they arose. This was extended into a virtual community in addition to a geographical one (http://www.bbukka.org) and can serve as a model for other clusters of schools and/or ICT projects in the future.

Challenge 7: organizational logistics and operations

Solution: clarify mission, respond to evaluation, consider staffing and funding

As with any organization, the day-to-day, on-the-ground operations are only a part of being successful. Although CFA had established a substantial presence in parts of Uganda, there were continual issues to deal with both in Uganda and in the United States simply due to running an international organization. As the organization came to understand that operations could be successfully expanded, personnel and funding issues arose. How many staff do we need? Can we utilize volunteers? Can we pay more local workers? How is the financial viability of the organization as a whole? Based largely on quality evaluation, CFA has responded to such issues effectively, in large part because they have a very good understanding both of their organization's mission and capacity, and the stakeholders' needs and desires. They remain small and focused, which allows them to use their resources effectively and efficiently.

Challenge 8: unintended consequences

Solution: anticipation of, vigilant monitoring for, and immediate response to them

As with any development project, and with any evaluation of such projects, unintended consequences must be considered. They should be anticipated to the extent possible, but must also be addressed as they arise. CFA quickly came to the realization that shipping computers into Ugandan schools meant that someday those Ugandan schools would have to deal with getting rid of old computers that no longer work. Typically, this meant unsafe and/or environmentally unfriendly means of disposal in a context that is not equipped to recycle used computers. CFA researched possible solutions and has worked to begin a secondary operation and/or a partnership for recycling computers from Uganda. This issue remains under study and is yet unresolved.

Challenge 9: external obstacles

Solution: research and developing expertise and/or partnerships in other development efforts

As with all development work, there are challenges that arise externally over which the organization has very little control, but which affect operations nonetheless. In Uganda, the local power situation has been crippled due to one of the major hydroelectric dams being taken offline, and also due to crime targeting the recently privatized power company. The result for schools with CFA computers is that they very often do not have power. Six of the seven schools we visited for our observations did not have power at the time we arrived. For schools without generators, this means that the use of computers is inconsistent at the very best. For those with generators, the schools are faced with difficult decisions concerning expensive fuel versus the use of the computers. CFA has responded to this external barrier by working with local stakeholders to research various energy options. In addition to generators, CFA is actively looking into the viability of

solar power solutions for the partner schools. They are examining partnerships with solar power providers and NGOs, and are becoming experts this area of development as it suits the needs of their stakeholders.