Measurements for sustainable infrastructure development: A review on sustainable development goal 9

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Abstract

Plans to develop infrastructure in any developing economy is crucial for the wellbeing of the public and the productiveness of the country, however the existing plans fall short in completely addressing measurements of sustainable infrastructure development. In support of the United Nation's Sustainable Development Goal 9, on the need for building resilient and sustainable infrastructure this study further assesses measurements for sustainable infrastructure development. The desk study used secondary data to determine key measurements for sustainable infrastructure development. The research paper is part of a broader ongoing study on sustainable infrastructure development thus the need to collect primary data for this research paper at this stage was not necessary, additional literature still needs to be reviewed before undertaking any field work. The reviewed literature revealed that economic, social, environment, project administration/management, stakeholder engagement, technology and innovation, health and safety and service performance were crucial measurements of sustainable infrastructure development. The study further identified policy as a significant measurement that assists in carefully planning and recognising how infrastructure facilities and services meet the needs of the end user. Every nation should prioritise the development of its own indexes similar to the ones by World Bank (Logistics Performance Index) and World Economic Forum (Global Competitiveness Index), to carefully measure and improve infrastructure development, more so, measures to prioritise and prepare for risks of the existing infrastructure should be pursued, this should clearly show consequences and probabilities of the expected risk. The study is limited to secondary data, no primary data was collected. The study is relevant to the ongoing project on sustainable development and can also be of support to researchers and institutions that are tasked with conceptualising the delivery and monitoring of sustainable infrastructure facilities and services.

Keywords: Infrastructure development, Sustainable development goals, Logistics Performance Index, Global Competitiveness Index, Gross domestic product

Introduction

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and development, 1987). Current existing infrastructure fails to live up to the expectations of the definition. Even with the performance benchmarks for infrastructure development established by both the Global Competitiveness Index (GCI) and the World Bank (Logistics Performance Index (LPI)) (Ugwu and Haupt, 2005). World Economic Forum (2015) shares that there is still a great need for infrastructure development in developing economies. Achieving sustainable development and ensuring environmental sustainability are key goals for infrastructure development, as means to ensure the socio-economic well-being of different communities. This study addresses

sustainable infrastructure development measurements that have not yet been considered collectively in the current literature. Sustainable development encompasses advancing infrastructure development through economical, societal and environmental pillars. Hong Kong and South Africa have taken extra steps to promote sustainable development, programmes and initiatives have been put in place to ensure that the objectives stipulated in Rio Declarations on Environment and Agenda 21, as well as the South African summit held in 2002 will be met (Ugwu and Haupt, 2005).

With the rapid growth of socio-economic demands in urban cities, developing economies desperately need to accelerate infrastructure investment, to ensure the operation, maintenance and restoration of the existing infrastructure assets. Sharp *et al.* (2015) enunciates that developing countries greatly depend on infrastructure development for the sustainability of their economies, which includes effective communication systems, safe roads and sustainable power infrastructure. Development Bank of Southern Africa (1998) posits that infrastructure must be divided into economic and social infrastructure. Social infrastructure is defined as built assets that provide social services for the well-being of the people, while economic infrastructure refers to assets that supports business activities in the country (Fedderke and Garlick, 2008).

The need for building infrastructure that is sustainable and resilient is emphasised in the United Nation's Sustainable Development Goals (SDGs). Goal 9 of the SDGs posits on "building resilient infrastructure, promoting inclusive and sustainable industrialization and foster innovation" (Statistics South Africa, 2019). For the purpose of this study only the first part (building resilient and sustainable infrastructure) of goal 9 was addressed. The study further moves further from emphasing undisputed grounds of knowledge on building infrastructure that is sustainable and resilient to elucidating on measurements of the then built sustainable and resilient infrastructure.

Measurements of Sustainable Infrastructure Development

The study discusses measurements for sustainable infrastructure development. Ugwu and Haupt (2005) articulates that South Africa has contributed a mouthful to the existing body of knowledge with sustainable research in socio-economic issues (Talukhaba *et al*., 2005), health and safety improvement, and most importantly the sustainability of the environment in affordable housing (Dalgleish *et al*., 1997). Fedderke and Garlick (2008) have emphasised the pivotal role of sustainable infrastructure development, especially in South Africa's economic growth. Bogetic and Fedderke (2006) acknowledged that an increase in the capital expenditure of infrastructure development has a direct impact on the output of the economy, since infrastructure is regarded as a direct input for economic growth (Development Bank of Southern Africa, 1998). Inadequate or deteriorated infrastructure negatively affects commercial businesses from maintaining or increasing productivity, thus firms now need to establish contingency plans against the malfunction of the existing infrastructure, which negatively affects the efficiency of micro and macro enterprises. Sustainability is essential for continuous and persistent infrastructure development.

Saeima (2010) defines infrastructure as "components of the territorial structure of the national economy, which transport systems, water infrastructure, power and communication systems play a pivotal role towards sustainable development". There are two forms of infrastructure, soft and hard infrastructure. Soft infrastructure is more of a framework developed to maintain and monitor different institutions, this include both physical and non-physical infrastructure (Kularatne, 2006; Spacey, 2017). Infrastructure development involves the growth or expansion of infrastructure projects. This is guided by government policy, which represents the public at large (Shen *et al*., 2011), and these policies need to show how the constructed and restored infrastructure is going to benefit the people economically and socially. Infrastructure development further means the growth or expansion of telecommunication systems, water and power supply systems, roads, dams, railways and transport systems (World Bank, 1994).

Performance indicators of sustainable infrastructure development

Sustainable infrastructure development performance indicators are required for accountability, to ensure that existing infrastructure is performing according to the pre-determined standards. Sharp *et al.* (2015) as well as the Department of Public Works and CIDB (2017) discuss the importance of infrastructure performance. They highlight how it assists in identifying needs and careful prioritising of the infrastructure needs. Service performance is one of the measures used to recognise how the infrastructure meets the needs of the end user. Sharp *et al*. (2015) continues to affirm that amongst other indicators service performance is the most significant, as this assists parastatals to prioritise investment, and this can only be executed properly if an understanding of how the outcomes of that investment is valued by the end user. Quality of the service provided by specific infrastructure as one of the measurement for outcome metrics can be further categorised into reliability, stability, safety and resilience of the infrastructure facility (Sharp *et al.,* 2015).

Other indicators include the environmental impact of infrastructure development on key local, regional, provincial, national and international stakeholders, and its influence on societal development. The performance of infrastructure development will thus be determined by infrastructure outcomes, impact on the economic growth (Coetzee and Le Roux, 1998) and ecological systems. Determining current performance can identify how to improve the performance of the existing infrastructure for present and future generations.

Additionally, The World Economic Forum (2015) previously established the Global Competitiveness Index (GCI) to measure the competitiveness of an economy, which includes infrastructure development as a key component to a competitive economy. The World Bank, as stated by Ojala and Celebi (2015) and Skorobogatova and Merlino (2017) established the Logistics Performance Index (LPI), which measures the quality of infrastructure, amongst other things, to determine the performance of infrastructure development. Table 1 represents key indicators of sustainable infrastructure projects determined by existing literature, these indicators are extracted from different sectors, such as water, building and construction as well as the energy sector.

Table 1. Measurements for sustainable infrastructure development from previous studies

Related literature	Selected sustainability indicators in previous studies	Perspectives
Timmermans and Beroggi (2000)	Economic sustainability, social sustainability, technological safety, attractiveness for living, attractiveness for businesses	Planning of infrastructure projects
Lundin and Morrison (2002)	Annual freshwater withdrawal/annual available volume, water use per capita per day, water treatment projects' performance, chemical use for drinking and waste water treatment	Urban water infrastructure projects
Balkema *et al*. (2002)	Minimal technical requirements of the solution projects; costs of investment, operation, and maintenance; optimal resource utilization; institutional requirements and acceptance	Wastewater infrastructure projects

Sahely *et al*. (2005)	Construction materials usage; energy and water usage; capital, operation, and maintenance costs; expenditures in research and development change; performance in building function; accessibility; health and safety acceptability	Buildings, transportation, and water supply infrastructure projects
Ugwu and Haupt (2007)	Initial cost, life-cycle cost, extent of land acquisition, extent of loss of habitat or feeding grounds, extent of encroachment on concerned areas, complaints from local parties/villages	Civil engineering infrastructure projects
Klevas *et al*. (2009)	Growth in GDP; effect on environment expressed in external costs; effect on job market, equity, technological innovation, and security of energy supply	Energy infrastructure projects

Source: Shen *et al*. (2011)

Environmental aspect: Impact on the existing ecosystems

Sustainable infrastructure development also speaks to the wellbeing of the environment, Venter (2009) alludes that the constitution of South Africa refers to the quality of our environment as having an impact on our daily lives, that environmental contamination such as air, water and noise pollution have a negative impact on the existing ecosystems, and this can be as a result of the existing infrastructure facilities. As a result the study envisioned to understand and determine the impact of infrastructure development to the surrounding ecosystems in South Africa.

Economic aspect: Infrastructure investment

In developing economies, such as South Africa, the central government is the sole custodian of infrastructure investment, with limited involvement from the private sector. To supplement government funding public institutions (Eskom and Transnet) are established in each sector of the country to fund, construct, operate, maintain and restore infrastructure facilities. The central government from the national revenue fund in the year 2006 set aside 40% of R372 billion for both Eskom and Transnet (Venter, 2009) for infrastructure development R84 billion and R47 billion was allocated to Eskom and Transnet respectively (Venter, 2009). While R5.2 billion and R19.7 billion was allocated for airport improvement and water infrastructure respectively (Venter, 2009). In specific situations the expertise of foreign companies is brought in to build, operate and maintain these facilities, for a fee. It is clear that the macro-economy of the country matters for sustainable infrastructure development. There have been discussions over the years on the importance of public, private and international funding for infrastructure development (Perkins *et al*., 2005) funding decisions taken by either party depends immensely on detrimental macroeconomic effects. When funds are borrowed from international agencies interest and capital repayments in foreign currencies affect countries that are borrowing the most.

Project administration/management aspect

Existing literature has continuously relegated sustainable infrastructure development to solely project performance. The Dutch Committee Elverding (2008) asserts that sustainable infrastructure development has over the years been negatively affected by the continuous outcome of projects showing deficiencies in cost and time overruns. Additionally, quality has also emerged as a key indicator for the advancement of sustainable infrastructure development. Projects are measured according to different stages of the project, namely; conceptualisation of design, construction, operation and decommissioning (Blomquist *et al.,* 2010) Utilising project performance as a sole indicator means encouraging collaborative partnerships in various projects, inclusive of local, consortia of private parties, even international agencies (Lenferink *et al.,* 2013). In such instances, contracts procurement systems such as Design-Build-Finance-Maintain (DBFM) are employed where a private consortium is responsible for all the phases of the project. Such systems are similar to Build-Operate-Transfer (BOT) and Build-Own-Operate (BOOT) (Pietroforte and Miller, 2002). A team that is employed to carry out the works is invited through open, negotiated, nominated, qualified or quotation tendering (Venter, 2009).

Stakeholder involvement

There has been hesitation shown in the existing literature towards introducing citizen participation as a key performance metric for sustainable infrastructure development, Ugwu and Haupt (2005) opine that, even though much progress has been made towards sustainable development, policies and strategies continue to sideline micro-level (citizen participation) decision making (Anex and Focht, 2002). Existing research continues to isolate stakeholder from the key performance metrics, Ugwu and Haupt (2005) agree that the initial condition for the sustainability of the any project is for the stakeholders to develop the performance metrics. The study encompassed both stakeholders and project management as part of the performance metrics for sustainable infrastructure development.

Lessons Learnt on Measurements for Sustainable Infrastructure Development

Sustainable development refers to the urgent need to protect the existing resources for future generations, this includes investing in the existing infrastructure and using water and electricity more efficiently, minimising pollution, investing in green building, and ultimately raising awareness on sustainable living. The above is addressed in the United Nation's 17 Sustainable Development Goals (SDGs), which have the potential to transform the world to be a better place (Klapper, El-Zoghbi and Hess, 2016). Morton and Pencheon and Squires (2017:81) asserts that the objective of the United Nations on the development of SDGs is to to end poverty, protect the environment and ensure people live prosperous lives. The focus of the study however was on Sustainable Development Goal 9, on "building resilient infrastructure, promoting inclusive and sustainable industrialization and foster innovation". SDG 9 focuses on infrastructure, industrialization and innovation, but for the purpose of this study the aspect of infrastructure was the main focus.

Building infrastructure that is sustainable and resilient include enhancing and extending financial, technological and technical support to countries with deteriorating infrastructure, and investing in regional and trans-border infrastructure for the purpose of improving the global economy and the wellbeing of the people (Statistics South Africa, 2019). In addition to plans of building resilient infrastructure the study completed the circle of infrastructure development by discussing critical measures of monitoring the performance of sustainable infrastructure development. Almost every nation through national, regional, continental or global agendas have plans for sustainable

infrastructure development, but not every nation has invested in monitoring, measuring and comparing standards of sustainable infrastructure development. The study thus placed its focus on critical measurements for sustainable infrastructure development.

From the reviewed literature it is evident that sustainable infrastructure development has an impact on the performance of developing economies. The performance of the developing economies is thus dependent on the construction, maintenance and performance of built infrastructure facilities and services, ranging from transport systems, water and power infrastructure to telecommunication facilities and services. Infrastructure is differentiated between social and economic. Both the activities of social and economic infrastructure contribute to the performance of the Gross Domestic Product (GDP), poor performance of the GDP increases possibilities of high unemployment rate, increased petrol prices and higher government borrowing thus relegating the country into recession. Amongst key indicators of a poor performing economy is rapid deterioration and decay of infrastructure systems and lack of limited budget to maintain and upgrade the facilities. Another indicator is lack of a comprehensive measurement metrics that is representative of different infrastructure systems. The main criteria for sustainability is the ability of assets to currently and in future operate in a manner that considers and is accommodative of the needs of the people. Currently with the existing infrastructure and with the existing measurement tools the public sector is unable to determine and plan for the maintenance and expansion of the current and future infrastructure facilities and services.

Measurements for sustainable infrastructure development exist to ensure and monitor the performance of infrastructure systems, without monitoring measurements systems cannot be compared to their predetermined standards set either by government or regulatory bodies. In South Africa the Department of Public Works (DPW) and Construction Industry Development Board (CIDB) are tasked with the duty of monitoring the construction, commissioning, operation, maintenance and replacement of infrastructure systems. According to the DPW and CIDB (2017) the most commonly used measurement apart from social, economic and environmental metrics is service performance. The importance of service performance for sustainable infrastructure development cannot be over emphasised, the metric clearly interrogates and confirms the current performance of the systems with the developed performance standards and further recognizes how the infrastructure system meets the needs of the end user.

The importance of social, economic and environmental elements as measurements of sustainability even in this study remains undisputed (Coetzee and Le Roux, 1998; Venter, 2009; Sharp *et al.* 2015). Social sustainability in the development of infrastructure acknowledges the welfare and empowerment of the people. There is indeed no development without the development of people, this also includes community engagement. In the three underpinnings of sustainability social sustainability is the least discussed and prioritised. It is of utmost importance that in the plans of developing communities through improved infrastructure and services that social responsibility is incorporated in the decision-making. The economic aspect of sustainability in the development of infrastructure indicates the need for funding for the life cycle of the facilities or services, alternative means of funding in the form of public-private partnerships, through local financial institutions, development banks and the World Bank have played an important role in financing the construction of many infrastructure facilities and services (Coetzee and Le Roux, 1998; Perkins *et al.,* 2005; Bogetic and Fedderke, 2006). But the conditions of borrowing including lending rates by institutions such as the World Bank are structured in a way that affects the policy decision-making or sovereignty of the country. As a result caution must be applied before any attempts of approaching such institutions.

In addition to the three well-known measurements of sustainability project management, stakeholder engagement, technology and innovation, service performance, health and safety and policy were rated as critical measurements for sustainable infrastructure development (Dalgleish *et al*., 1997; Timmermans, 2000; Sahely *et al*. 2005; Klevas *et al*., 2009). Policy for sustainable infrastructure development is the study's contribution to the existing conceptualisation of sustainable infrastructure development measurements. Ugwu and Haupt (2005), The Dutch Committee Elverding (2008), Venter

(2009) and Lenferink *et al.* (2013) have shown the importance of project management (the management and controlling of time, cost and quality) and stakeholder participation. Stakeholder participation referred to in this study by Ugwu and Haupt (2005) is the micro-level decision making in the communities. Communities are not consulted on any infrastructure development plans, and this in turn negatively affects the relationship of the communities within the municipalities. Ugwu and Haupt (2005) and Anex and Focht (2002) postulate that stakeholder participation is key for infrastructure development and must be prioritised.

Conclusion and Recommendations

This desk study used secondary data to determine key performance indicators for sustainable infrastructure development. The research paper is part of a broader ongoing study on sustainable infrastructure development thus the need to collect primary data for this research paper at this stage was not essential, additional literature still needs to be reviewed before undertaking any field work. The primary focus of this study is thus to identify gaps in literature and provide a foundation of knowledge on the subject of sustainability for the envisaged stage of primary research.

From reviewing literature, this study has identified economic, social, environment, project administration, stakeholder engagement, technology and innovation, service performance, health and safety and policy as critical measurements of sustainable infrastructure development. Policy on sustainable infrastructure development is the study's contribution to knowledge, policy completes the framework of the already established measurements. With clear policies on sustainable infrastructure development stakeholders are able to engage better and fulfil their mandates. More so, lack of models to guide sustainable infrastructure development in developing economies is amongst many factors delaying sustainable development. The identified measurements complement each other for a sustainable environment, and addresses key issues of service performance encountered post occupancy. It is recommended that nations develop their own measurement metrics like the Logistics Performance Index (LPI) and Global Competitiveness Index (GCI) by the World Bank and World Economic Forum respectively, to monitor the performance of the infrastructure facilities and services. LPI and GCI allow nations to measure and improve their own infrastructure development against the world's standards. Nations developing their own indices has the benefits of locally determining areas of concern and solutions to better improve the sustainability of infrastructure development and improve the growth of the economy. These indexes should further be categorised according to different business sectors. Criteria to prioritise investment, maintenance and risk should clearly be defined. Lastly, measures should be taken to prioritise and minimise poor quality, unsafe facilities, water, air, and noise pollution that show a negative impact on sustainable infrastructure development, so as to ensure the safety and quality of the environment. The findings of this study are relevant to the ongoing project on sustainable development and can also be of assistance to researchers and institutions that are tasked with the delivery and monitoring of sustainable infrastructure facilities and services.

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