

Urbanization and Sustainable Urban Infrastructure Development in Africa

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Abstract Urbanization profoundly affects the realignment of urban infrastructures through its multiple dimensions. With an unprecedented rate of population growth of 26% between 2019 and 2050 worldwide and 46% in northern African countries, most of this growth is expected to happen within cities. This significant increase in urban population is a major challenge to current and future built-up infrastructures. The urban system as a dynamic ecosystem is directly impacted by ongoing urbanization, which brings into sharp focus the multifaceted challenges of urban infrastructures as the main supplier of urban services. It is, therefore, essential to point out the discrepancy between the current urbanization trend and urban infrastructure development in the African region. This article thereby focuses on examining the effect of urbanization and urban growth on sustainable urban infrastructure development on the African continent. It highlights then the discrepancy between urban infrastructure and urbanization in Africa and the challenges that impinge on their sustainable development throughout diverse levels: 1) infrastructure overload 2) lack of investment 3) deficiency and inadequacy. These discrepancies will be examined following the categorization of urban infrastructures that are namely composed of transport, energy, water and sanitation, and Information and Communication Technology (ICT). In conclusion, multiple approaches and actions to meet the sustainable development of urban infrastructures have been proposed.

Keywords Urbanization, Urban Sustainability Challenge, Urban Infrastructure, Sustainability Assessment

1. Introduction

The world's urban population is expected to nearly double by 2050. This unprecedented growth makes urbanization one of the most transformative trends of this century. This growth tends to be faster in less developed regions. Africa and Asia account for the majority of the increases in the urban population due to their rapid urban growth rates and rising proportions in the global urban population [1]. The majority of this population is increasingly concentrated in cities requiring massive urban infrastructures, raising significant urban sustainability challenges.

Understanding urbanization as a multidimensional process and the impact of its consequences on urban infrastructure is a key question in urban studies. The role and importance of urbanization in economic growth and in achieving sustainable urban transition are crucial as it affects every aspect of the urban system.

Infrastructure system core elements range from water, energy, sanitation, transport, and ICT, which directly affect the livelihood and the health of people. With the rapid urbanization that dominates the trends in recent decades across the globe, urban infrastructures are facing enormous pressure. In less developed regions, particularly in Africa, these infrastructures, which determine assets for delivering services for the currently ever-growing population, face enormous obstacles. Hence, urban infrastructure studies that span urbanization threats are essential to guide and inform urban development decisions. Sustainable cities,

according to the United Nations Sustainable Development Goal (SDG 11), are those that are committed to achieving environmental, social, and economic sustainability. We argue that urban infrastructures are key assets in achieving an overall urban transition toward sustainability. This development is supposed to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation (SDG 9) [2]. The interest in the urbanization process has been investigated extensively in the literature. However, this interest mainly focuses on the interrelationship between urbanization as a process and economic growth. It is rather unexpected, in this aspect, that infrastructure research has grown independently of the wider literature on urbanization and urban growth [3].

2. Evidence of Discrepancy between Urban Infrastructures and Urbanization

Urbanization trends in the very last decades appear to differ from historical pathways namely in terms of scale, rate, and function [4]. The rapid rate of population growth is one of the key demographic challenges. Current projections foresee a vast expansion of the global population growing from 7.7 billion in 2019 to a further 9.7 billion in 2050 (a 26% increase). The North African region is mainly impacted by this upward trend with an almost 46% growth rate increase [1]. Most of this growth is within the cities. In the last few decades, the world witnessed a major shift to urban settlement, with the proportion of urban rising from 30% in 1950 to 55% in 2018 [1]. It is projected that the proportion of the population living in the urban area will continue in the coming years reaching 68% with urban dwellers enumerating 6.7 billion by 2050 [1].

This significant increase in urban population is a major challenge to current and future built-up infrastructure. More than 60 per cent of the area projected to be urban in 2030 has yet to be built. Most of the growth is expected to happen in small and medium-sized cities, not in megacities [1]. Urbanization has a profound impact on the realignment of urban infrastructure through its multiple dimensions ranging from cultural, environmental, economic, and political dimensions. In this way, urbanization is involved namely in the acceleration of the urban sustainability transition.

As a set of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions, infrastructures are defined as the provision of basic services to industries and households. It typically includes energy (power generation and supply), transport (toll roads, light rail systems, bridges, and tunnels), water (sewerage, wastewater treatment, and water supply), and telecommunications [5]. Infrastructures are facing multi-factor challenges in providing services as fast as this growth. Emerging urbanization trends had called for urgent actions on urban infrastructure development since

this phenomenon challenge spans multiple dimensions.

2.1. Energy and Urbanization in Africa

Meeting the demand of a fast-growing population in terms of infrastructure remains one of the major African challenges. Energy is vital for subsisting worldwide needs across all sectors. Cross-linkages in various use of energy are observable among all urban infrastructure components. Therefore, urban infrastructure development is substantially dependent on how they are performing in terms of their access to energy services. Understanding various mechanisms that have a significant effect on urban infrastructures is essential to assessing the influence of urbanization on energy consumption.

With a fifth of the world's population, Africa accounts only for 6% and 3% of the global energy and electricity demand, respectively. This low access rate is placing most African countries below the world average in terms of average energy consumption [6]. Therefore, overall access to energy remains elusive in Africa. However, according to Ahmad and Zhang forecasts [7], Africa's energy demand will increase by approximately 61% between 2020 and 2040. On the other hand, Africa's total electrical capacity installed will exceed double by 2040.

On the other hand, Africa is expected to experience the fastest urban growth rate in the world by 2050. With an annual rate of 4% of urbanization, much of this growth is likely to happen in small and medium-sized towns whilst the economic growth is at 5% [8], [9]. This growth mainly takes place within cities due to rural migration. Cities' population growth rates have more than doubled in the last decades [10]. Particularly because of their growing population, cities require a lot of energy to run correctly. Urban residents utilize more than 75% of total energy resources because of activities conducted in the urban area [10]. Given this, focusing on urban infrastructures is of extreme importance.

2.2. Water Infrastructure and Urbanization

Results have shown that "population data alone are not sufficient to describe the effects of city development on urban water infrastructure" [11]. However, the same article demonstrated that if no adaptation or extension of the sewer system happens, a two-fold increase in total flooding volume might occur. This is due to the breadth of the effective impervious area resulting from the water system services enlargement.

2.3. Transport Infrastructure and Urbanization

The association between transportation infrastructure and urbanization appears to vary depending on the type of infrastructure, socioeconomic conditions, and political policy decisions [12]. Similarly, several studies conducted in India show the importance and causal relationship of

transport infrastructure on the economic development of the country [13]. The major impact of urbanization is the expansion of land use. Therefore, this massive built-up environment cannot be supported without an adapted urban transportation infrastructure. According to some studies, population growth has a significant positive impact on a country's infrastructure namely road construction. Glover [14], for example, has revealed that population density, which is an important feature of urbanization, appears to have a considerable and strong effect on total road density in a cross-national sample, with an elasticity of 0.7 or higher.

2.4. ICT Infrastructure and Urbanization

Numerous research findings confirm the positive benefits drawn from ICT infrastructure development in Africa and their strong potential to be a source of growth. In his empirical study on a sample of African countries from 1988 to 2007, Andrianaivo and Kpodar [15] found that ICT infrastructures including mobile phone development, greatly contribute to economic growth.

The ICT sector makes up a relatively small portion of the entire economy. However, compared to all other sectors, the ICT infrastructure has been the main driver of improvements. Countries with the most growth in this infrastructure marked the highest rankings on the African Infrastructure Development Index (AIDI) ratings during the previous ten years [16].

Despite this positive progress in mobile phone use, massive growth in coverage extensions, and higher broadband speeds, overall ICT infrastructures have not kept pace with population growth in most African cities. Since 87% of Africans still cannot access the internet, access appears to be a major barrier for the continent, making Africa lag behind other regions (Table 1). Broadband mobile penetration, which is anticipated to increase more quickly, was only approximately 3.8% in 2011 compared to 54% in Europe [17].

Table 1. ICT access indicators in Africa and other regions for 2013 (source: [12]).

ICT Indicators in 2013	Africa	Asia	Latin America	Europe
Fixed broadband subscriptions per 100 population	1	6	9	15
Mobile cellular subscriptions per 100 population	73	85	115	119

3. CAUSES of Discrepancy

Although infrastructure development started at roughly the same levels in 1960 across Africa, Asia, and Latin America, it fell in those decades in Africa. This is partially due to the structural adjustment programs that most

African countries adopted under the so-called Washington Consensus. As a result, the share of resources allocated to infrastructure was sharply cut. That partly explains Africa's current lag in infrastructure relative to other regions [12].

Historic and current patterns of urban infrastructure development are not aligned with the urbanization rate. Due to their strong rates of urban expansion, Africa and Asia account for the majority of the increases in the urban population. It is expected that Africa's share will increase, even more, reaching 29% between 2018 and 2030 and 44% between 2030 and 2050 [1]. With this fast-growing population tendency, availability, equity, and access to numerous infrastructural services are difficult for Africans. Meeting the rising demand for these essential services while ensuring equal access is Africa's main challenge. In the energy infrastructure, for example, about 600 million people in sub-Saharan Africa lack access to energy. As a result, the continent's access rate to power is the lowest in the world (approximately 40%) [6], [12]. The ongoing lack of access to electricity and the unreliability of energy are serious obstacles to operational manufactories. For instance, eighty per cent of sub-Saharan African companies had regular electrical outages that resulted in financial losses. Therefore, this limited, non-reliable, and inequity access to basic infrastructures in Africa is another factor of discrepancy.

Land management in light of the fast-growing population is another important cause of this disproportion. The uncontrolled increased built-up area has resulted in the rise of the area devoted to construction per person in Africa. This land use change results in the particular spatial organization of cities that directly shapes and define urban infrastructure layout, use, and provision. For example, the residential density and urban transportation infrastructure impacts travel demand, energy, and overall resource consumption. These drastic changes in land embody direct and indirect changes in urban system structures, namely regarding urban costs related to infrastructure services, and urban productivity. Based on this assumption, increases in productivity of about 3-8% are shown when cities are doubled in size [18]. However, inappropriate land expansion management and planning practices could widen the gap between the rates at which infrastructure development and increasing urbanization took place.

On the other hand, infrastructures are directly linked to the national economy. Therefore, meeting the growing demand of the ongoing population growth requires tremendous investments. Historically, Africa has spent about \$26 billion annually on infrastructure. Africa will require annual investments of \$60 billion in the future [19]. Lack of investment is a major African cause of delay but not the only one. It is essential to consider a range of elements, including connectivity, urban economic performance, and financial innovation, to name a few, to ensure a suitable source of investment. Hence, many cities have failed to invest in sufficient infrastructure due to

inadequate financing tools [20].

4. Urban Infrastructure Vulnerability and Challenges

The importance of infrastructure and its complex structure grows as the population and urbanization rise alongside with transition of cities into metropolises [21].

Economic growth is a major reason for infrastructure development. Every country's progress, both socially and economically, is dependent on its infrastructure. Findings from extensive fieldwork across Africa showed that more than half of Africa's recent improved economic performance might be attributed to infrastructure. These infrastructures have the potential to contribute to enhancing economic growth even more in the coming years [19].

Urbanization is closely dependent on the economic growth of nations. Accordingly, Henderson [22] contended that at a country level, the coefficient of connection between urbanization and per capita Gross Domestic Product (GDP) is 0.85. Hence, it is highly urged to assess the vulnerability of these infrastructures in the context of urbanization since it affects the national economy.

4.1. Urban Infrastructure Overload

In the energy sector, the infrastructure deficiency is largely manifest in terms of both accessibility and reliability. While more than 99% of North African countries have access to electricity, the situation is more delicate for other African countries. Per capita electricity demand, in the whole continent, is very low. It accounts for less than 200 kWh per capita in a year which is projected to be over 430 kWh in 2040; however, this represents less than 15% of the world average of over 3 000 kWh [6]. This puts electricity among Africa's largest infrastructure challenges and thus the most vulnerable one. In addition to the limited access, energy intensity and CO₂ emissions are very high giving evidence of an inefficient energy system.

Another important urban infrastructure asset in fostering sustainable development in Africa is transportation, which includes roads, rail lines, air travel, and ports. This infrastructure enables local, regional, and worldwide trade. Most African cities are experiencing unprecedented population growth. This urban expansion results in informal features of land use setting the ground for per-urban areas proliferation. Coupled with the lack of transport infrastructure, more than half of Africa's road network remains unpaved, obstructing access to basic social services and weighing down local economic operations.

4.2. Lack of Investment

Economic growth is fuelled by investment and

consumption. These dynamics appear to have been steadily rebalancing in Africa recently, favouring investment. Consumption's share of real GDP growth decreased from 55% in 2015 to 48% in 2018, while investment contribution increased from 14% to 48% [12]. This shift shows a growing understanding of the importance of investing.

However, the policy gap regarding financing urban infrastructure at the local, national, and international levels exacerbates the challenges of sustainable urban transition. There is no doubt that urbanization is one of the 21st-century transformative trends. The resulting consequences affect many aspects and pressures on urban infrastructure are particularly acute. Infrastructure investment can boost productivity, and connectivity within cities and promote the potential for agglomeration economies [19]. The African region has one of the largest infrastructure deficits. The overall annual spending needs have been estimated at around \$90 billion a year from 2006 through 2015, amounting to 15 per cent of African GDP [19]. The power sector for instance requires roughly \$41 billion each year (see Table 2), representing 40% of the total annual spending needs. This sector's spending needs account for about 6 per cent of the African GDP [19]. Recent studies have demonstrated a growing need in financing African infrastructures. Current estimates of Africa's financing needs range from \$130bn to \$170bn [12].

Even at the lowest estimates, these financial requirements create a substantial issue. Despite the large rise in 2018, which resulted in an average level of engagements of little more than \$83 billion for the 2016-2018 period, a funding gap of \$53 billion to \$93 billion each year persists [12]. According to these projections, many cities would hardly ensure the finance to meet the growing demand for infrastructures.

Table 2. Overall infrastructure spending needs for Africa between 2006 and 2015 (\$ billion per annum) Source [19]

	Capital expenditure	Operation and maintenance	Total needs
Transport	8.8	9.4	18.2
ICT	7.0	2.0	9.0
Water supply and Sanitation	14.9	7.0	21.9
Power	26.7	14.1	40.8
Total	57.7	32.4	90.0

4.3. Deficit and Inadequacy

Underdeveloped infrastructure hampers Africa's economic growth. The availability of adequate and efficient urban infrastructures not only enhances people's quality of life but also supports rapid industrialization and economic growth. Infrastructure development in Africa is

crucial for promoting economic growth and raising Africans' living standards. It makes a substantial contribution to human development, poverty reduction, and the achievement of the United Nations Sustainable Development Goals [16].

The basic infrastructure element of transport, energy, ICT, and water and sanitation are the four essential components of the AIDI index developed by the African Development Bank. The index is normalized to a range of 0 to 100. As a result, the higher the index's value, the more prepared a country is to satisfy its development infrastructure needs. The yearly AIDI updates show a huge and persistent variation among African countries. The first score for example was above 90 (Seychelles) and the last recorded was less-than 5% such as Somalia country [16]. This put forward the sub-regional differences within African countries with top-ranking counties mostly from North Africa and few from southern Africa, while others are still suffering from bad infrastructural assets.

5. The Growing Need for Adaptability in the African Context: A Sustainable Development Perspective

5.1. Sustainable Construction

Rapid urbanization in developing countries may create new opportunities for shifting towards sustainable construction. Nevertheless, this new concept for the construction industry is not given enough attention. The high rate of urbanization is one of the main challenges of sustainable construction, especially in developing countries since large-scale development and massive built-up infrastructures are required. Sustainable building is a comprehensive process aimed at restoring and maintaining equilibrium between natural and built ecosystems. Furthermore, it helps create communities that uphold human dignity and promote economic equity [12]. Through the equal sharing of the world's resources, as supported by the Fair Shares idea, a sustainable building may make a great impact not only on global environmental sustainability but also on socioeconomic sustainability. According to the recent research for the European Union on the consequences of the Fair Share idea, using solely the EU's fair share of the world's resources would entail great savings. It would result in an 85 per cent decrease in cement usage, an 87 per cent reduction in steel consumption, and a 90 per cent reduction in aluminium use in European Union only [12]. The irreversible land transformation resulting from the urbanization process has significant consequences on climate and environmental damages. Particularly, unsustainable materials used for construction. Therefore, the need for and urgency of using sustainable building materials is growing. According to

Moreno-Chimely's study, using sustainable materials like Earth-Fiber Plaster can reduce the impact on the environment and climate change by up to 65% [23].

5.2. Integrated Infrastructures and Sustainable Land Management

In his article, Derrible [24] demonstrated that urban infrastructure systems are highly interrelated. The increased need for integration and distribution is crucial to making these infrastructures more resilient and sustainable. For this reason, more new planning and design practices are required. Whether it is water and sanitation system, electrical grid, buildings, or transportation systems, they are all part of interconnected and interdependent infrastructure systems that keeps cities running.

5.3. Green and Blue Infrastructures

There is a rising interest in urban Green and Blue Infrastructure (GBI) in emerging countries, especially in local sustainable development. This interest is notably higher in Asia and China compared to Africa and Latin America and the Caribbean (LAC). Particularly, many academics in China have explored multiple examples of systematic GBI applications for solving urban difficulties. These GBI are still not used as a low-impact development or innovation method in Africa [25].

5.4. Connected Urban Infrastructures for an Enhanced Sustainability Transition

The city is regarded as a hub of physical infrastructure that enhances the productivity of current and future human socioeconomic activities. The larger global urban studies do not include the hyper-fragmented African cities that are largely characterized by poly-crises, complex growing requirements, and unclear dynamics [26]. These developing cities necessitate an extremely particular research agenda.

Studying single infrastructure systems has taken on increasing importance during the past decade through advanced modelling and simulation tools. However, the study of infrastructures interdependencies and integrated modelling is still in its infancy and has yet to be thoroughly investigated [27]. Therefore, there is a substantial need to develop more holistic infrastructure modelling approaches to complex interdependencies between infrastructures [28]. One possible future integrated approach is to develop system integration tools that take into account the social impact and behavioural component in urban infrastructure systems [28]. Besides addressing short-term and operational issues, methods to analyse long-term implications and support infrastructure investment decisions must also be developed.

The increasingly linked nature of infrastructure networks has opened up new avenues for reevaluating

decision-making, enabling the evaluation of future policies and scenarios as well as their influence on overall urban infrastructure sustainability and inclusivity. For example, future smart cities and the Internet of Things (IoT) will facilitate infrastructure integration by offering informational interdependence thanks to increasing ICT monitoring and drastic advances. In his article, Ersoy [29] investigates whether smart cities, as interconnected infrastructures, can go beyond just integrating the city's physical assets. In the context of mobilizing collective learning and reshaping city infrastructure, the article contends that assuring cooperation, inclusiveness, and institutional capacity are crucial factors for integration.

5.5. Urban Growth Management

Enhancing urban growth management is key to overtaking social, environmental, and economic costs resulting from inadequate urban infrastructure development. Thus, Rather than advocating or discouraging urbanization per se, looking for strategies to enable forms of urbanization that contribute to growth, poverty reduction, and environmental sustainability has to take more attention [30].

Research has demonstrated a positive impact of exploring urbanization's effect on transport infrastructure development for example. As population density seems to have a considerable and strong effect on total road density in a cross-national sample [14]. The effect on paved-road development is significantly more pronounced, with elasticity greater than unity. Unpaved roads have a smaller but still considerable effect, with an elasticity of approximately 0.6.

6. Conclusions

Africa is experiencing rapid urbanization across the continent, which is requiring massive urban infrastructure. Urbanization in the most transformative trend of this century that have direct impact on the urban system as a dynamic ecosystem. Which highlights the many difficulties facing urban infrastructures as the primary provider of urban services. It is of utmost necessity to point out how urbanization affects the creation of sustainable urban infrastructure on the African continent. This disproportion deepens the challenges toward sustainable urban transition. Thus, this article focuses on analysing the discrepancy between the urbanization pace and urban infrastructure development. Urban infrastructures have been approached through a proposed categorization composed of transport, energy, water and sanitation, and ICT. This disparity between urban infrastructure and urbanization evolution in Africa is then highlighted at many levels. Namely through infrastructure overload, lack of investment, deficiency, and inadequacy. This article provides also some insights to meet sustainable

development through some perspectives to build sustainable urban infrastructure.

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