Application of STEEP Systems Sustainability Framework: A Case Study of Lagos State, Nigeria

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Abstract

In this research, we examine the complexities of developing sustainable city policies in the Global South (GS). The rapid urbanisation and population growth in the GS has led to several sustainability challenges. These necessitate effective policy frameworks that balance economic, social, and environmental concerns. This research seeks to address these challenges by adopting a holistic and integrated approach to city planning and management, through Systems Thinking. It highlights the significance of sustainable development in the GS, particularly in urban areas. Drawing on literature from urban planning, environmental studies, and policy analysis, this paper identifies key challenges to sustainable city policy development in the Global South and examines how a Systems Thinking approach can be applied to the development of sustainable cities in the GS. The implications of the chosen approach are that it allows critical analysis of the subject and includes the benefits of a holistic and integrated approach to urban planning, policymaking, and management.

Keywords: Sustainability, Sustainable City, Systems Thinking, Global South, Lagos

1. Introduction

The global urban population has been witnessing exponential growth since the industrialisation revolution due to employment opportunities, education, and better quality of [1]. According to the United Nations (UN), more than fifty per cent (50%) of the global population lives in cities of both Global North (GN) and Global South (GS), and this is predicted to reach seventy per cent (70%) by the year 2050 [2]. This problem is even more prevalent in GS where the urban population has been projected to double to 4 billion by the year 2050. While this would create new opportunities, they also contribute to a wide range of environmental, economic, and social problems. Due to the increasing population and industrialisation, there is a constant need for more energy production; water supply, transportation, and effective management of waste generated from the increased consumption. These challenges and their implications call for the sustainable development of cities as crucial to meeting the UN Sustainable Development Goals (SDGs) on cities (Goal 11). However, the implementation of sustainability in cities is a complex problem as they consist of different interrelated systems and various stakeholders with differing needs. Decision-making and policy development are therefore difficult due to a lack of understanding of these nonlinear systems. This calls for a holistic planning method in addressing the nonlinearity, feedback, and delay caused by the system's interconnections [3].

2. The Concept of Sustainability

According to the 1987 Brundtland report, sustainability is "the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs". A comprehensive assessment of sustainability requires a consideration of the interdependencies and interactions between economic, social, and environmental criteria [4].

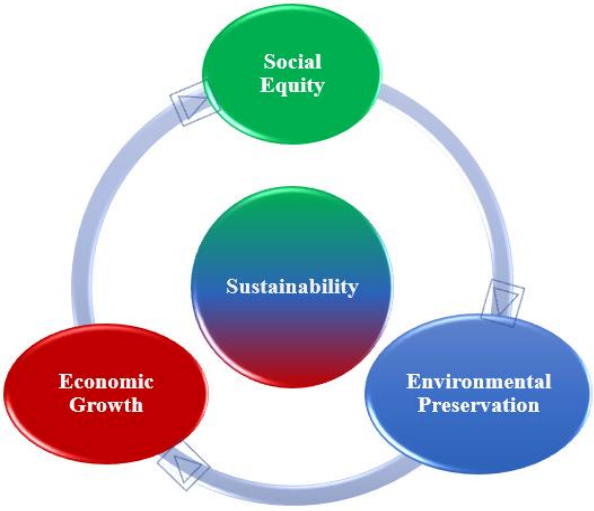

Figure 1. Aspects of Sustainability

 | DOI: 10.20533/ijsed.2046.3707.2023.0067

The economic criteria are those related to the city's economic development and growth, such as GDP per capita, income distribution, and employment. Social criteria, on the other hand, are related to the quality of life of the city's residents, such as education, health, and social welfare. Environmental criteria are related to the natural environment, such as air quality, water quality, and biodiversity. Sustainability in the built environment requires a balance between social, economic, and environmental considerations. Olaniyi (2008) illustrated the multifaceted nature of sustainability in urban contexts, emphasising the need for holistic and integrated approaches that prioritise social, economic, and environmental concerns [5].

3. Sustainable Cities and Sustainable Development

The growing awareness and concern for the environment, technological advancements, and urbanisation have all contributed to a pressing need to address the way cities are designed and managed. Filion (2017) described sustainable cities as a result of sustainable development, which seeks to create suitable conditions within cities in order for human societies to be sustainable [6]. Sustainable cities and cities for sustainable development are often used interchangeably in management studies, but there is a difference between the two concepts [7]. Sustainable cities emphasise environmental sustainability and focus on reducing negative impacts on the environment. Cities for sustainable development, on the other hand, consider social, economic, and environmental sustainability, aiming to improve the overall quality of life in urban areas while minimising negative impacts. While this paper will also consider cities for sustainable development, the main focus will be on environmental sustainability.

In sub-Saharan African cities, where rapid urbanisation has resulted in significant environmental, social, and economic challenges, there is a glaring difference in the standard of living between the metropolitan sector and neighbourhoods, and this difference has been growing steadily [8]. This is illustrated by the various municipal structures, where wealthy communities are growing side by side with impoverished residents in run-down areas and slums. Urban planners face difficulty in creating adequate strategies to address these issues because of the constant urban growth and the complexity brought on by new connections between city components and people's lives.

Sustainable city development requires a holistic approach that considers the interdependence of social, economic, and environmental factors and involves the active participation of residents, stakeholders, and policymakers.

4. Characteristics of a Sustainable City

The harmonious interplay of energy, water, waste, and transportation converges to shape the cities and plays an integral part in their sustainability. In the pursuit of ecological balance and resilience, these four pillars stand as cornerstones in the construction of urban landscapes that prioritise efficiency, conservation, and a reduced environmental footprint. From innovative energy solutions harnessing renewable sources to intelligent water management, waste reduction strategies, and the evolution of sustainable transportation, these characteristics collectively propel cities toward sustainability. Thoughtful design and forward-thinking practices of these core elements pave the way for a thriving, interconnected, and eco-conscious urban existence.

4.1. Energy

Energy is a critical component of sustainability in cities. Energy use in cities is a key contributor to climate change, as well as other environmental and social problems. Nwankwo, Olaniyi, and Morgan, (2022) highlight the need for cities to transition to more sustainable energy systems sources, such as solar and wind power, as well as energy-efficient buildings and infrastructure to reduce the carbon footprint and minimise negative impacts on the environment [9]. Sustainable energy is important in cities to reduce greenhouse gas (GHG) emissions, improve industrialisation and economic growth, and upgrade the health of the residents by providing enough sustainable energy to keep the healthcare system functional.

4.2.Transportation

Transportation is a crucial aspect of urban sustainability due to its significant environmental impact, including air pollution, greenhouse gas emissions, and noise pollution. Transportation accounts for approximately 30% of global carbon dioxide emissions, making it a significant contributor to climate change [10]. Therefore, promoting sustainable transportation systems that reduce the reliance on fossil fuels and minimise carbon emissions is critical for achieving sustainable cities.

Overall, promoting sustainable transportation systems that prioritise active transportation modes, such as walking and cycling, and public transit can significantly contribute to achieving urban sustainability goals, such as reducing greenhouse gas

 | DOI: 10.20533/ijsed.2046.3707.2023.0067

(GHG) emissions, improving air quality, improving the health and wellbeing of residents, and enhancing accessibility to essential services.

4.3. Water

Water means life, and in a future marked by climate change, the access, distribution, and handling of water will become ever more critical. Water is essential for economic growth, human health, and the environment. More than two-thirds (2/3) of the world's population are projected to be living in urban areas by 2050, therefore the need for innovative and sustainable solutions is more urgent than ever [2]. Liveable and sustainable cities around the globe require efficient water management and proper sanitation and sewerage treatment to achieve a reliable and clean water supply.

4.4. Waste

The efficient and sustainable management of waste is crucial for the sustainability of a city. Municipal solid waste management contributes significantly to GHG emissions in urban areas. Therefore, waste reduction, recycling, and energy recovery from waste can significantly reduce the emission of GHGs and improve the sustainability of the city. Using recycled materials can significantly reduce carbon footprint. Recycled materials reduce landfill waste, saving the energy and resources required to extract and manufacture new materials. It is also important to convert waste to sustainable energy to reduce reliance on non-renewable energy sources. This approach can lead to the production of clean energy, reducing the carbon footprint and contributing to sustainable urban development. Also, waste prevention policies need to be strengthened to reduce the amount of waste generated in cities and promote sustainability.

5. Complexities of Achieving a Sustainable City

Cities are complex systems that are influenced by various characteristics, including energy, transportation, water, social, and economic factors, which are interconnected and affect each other. Increasing infrastructures and other economic factors are also intertwined with social and governance factors and have implications for sustainable development in cities [11]. These dimensions are interconnected, and the sustainable well-being of individuals and communities is influenced by their interactions.

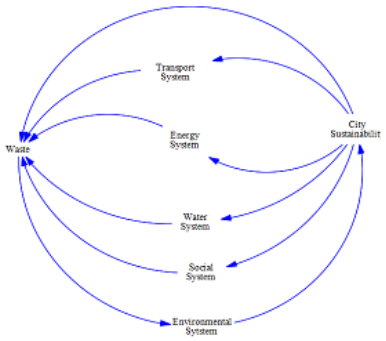

Figure 2. Complexity of a Mega City

A better understanding of the complexity between these characteristics is important for achieving sustainable development in cities.

As shown in Figure 2, energy system, transport, water, social, waste, environmental, and other economic factors are interconnected, and their interactions are important for achieving sustainability in cities. The complexity between these characteristics should be considered when developing sustainable development policies and strategies. A systemic approach that considers the interactions between these systems would provide a better understanding of developing policies that will be geared toward sustainability.

6. Systems Thinking Methodology

Systems Thinking is a discipline for seeing wholes [12]. It focuses on the interrelationships and patterns of change. Systems Thinking is an approach to sustainability that emphasises the interconnectedness and complexity of social, economic, and environmental systems. This approach recognises that any action taken in one area of the system can have unintended consequences in other areas, and therefore requires a holistic understanding of the entire system in order to identify and address the root causes of sustainability challenges. By applying system thinking to sustainability, individuals and organisations can work towards more effective and sustainable solutions that consider the long-term impacts on the entire system.

The Systems Thinking methodology (see Figure 3) involves archival research of a case study, using thematic analysis and content analysis to conceptualise the problem under investigation, and visually represent the causal relationships and feedback loops inherent in the systems being studied using Casual Loop Diagrams (CLD).

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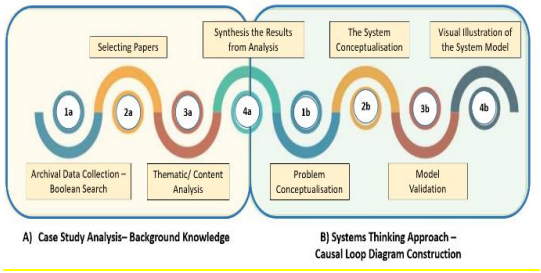

Figure 3. The Systems Thinking Methodology Phases

The CLD modelling focused on drawing a visual representative of a system and the relationship between the important elements and the feedback loops. It uses a qualitative investigation of the dynamic relationships to map the complexities within the analysed problem thus providing a more in-depth insight and better understanding of the system, which can be used to guide the policy makers in policy development.

7. Systems Thinking Strategy to Achieve Sustainable City in Lagos State

To achieve sustainability in Lagos, it is essential to understand the intricate relationship between the various components of the city. There are four key characteristics of a city that should be considered when working towards sustainability, namely Energy, Transportation, Water, and Waste. Each of these characteristics represents a system that is essential to the functioning of the city. These systems are complex and interrelated. Changes made in one system can have a significant impact on other systems, sometimes in ways that are not immediately obvious. Therefore, it is crucial to examine each of these systems and their interactions with each other.

Figure 4 provides a Systems Thinking strategy to achieve sustainability by depicting the relationship between these systems. The transportation system affects the energy system by influencing the demand for fossil fuels, while the waste system impacts the water system by contributing to pollution. Thus, addressing one system without considering the others can lead to unintended consequences.

It is imperative that policymakers and city developers should take a holistic approach when addressing sustainability in Lagos. By considering all the characteristics of the city and their interdependence, they can develop effective solutions that address the root causes of sustainability problems. This approach will ensure that the solutions implemented are sustainable in the long run and do not create additional problems in other systems.

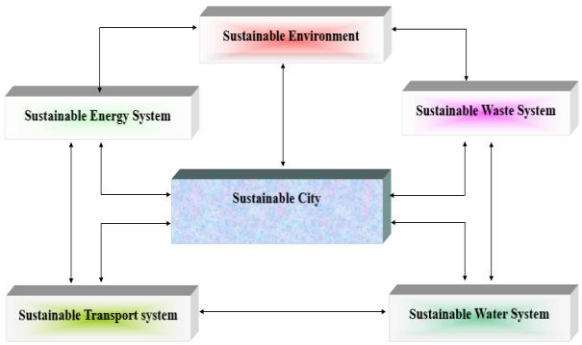

Figure 4. Systems Thinking Strategy to Achieve Sustainable City [5].

The subsequent sections of this research delve into the current state of these systems in Lagos state, examining their strengths, weaknesses, and areas for improvement. They also explore various solutions that can be adopted to enhance the sustainability of the city's systems, based on the insights gained from Section 4 and the Systems Thinking approach.

8. Energy System in Lagos State

As the largest city in Nigeria and one of the largest cities in Africa, Lagos has a diverse mix of energy sources, which contribute to the city's emissions. Lagos state accounts for sixty per cent (60%) of the industrial and commercial activities in Nigeria, and as such, is by far the largest energy consumer in the country. The primary sources of energy in Lagos are Fossil fuels, Hydroelectric power, Biomass, and Solar**.** Fossil fuels, mainly oil and gas, are the most significant sources of energy in Lagos, as Nigeria is one of the largest oil-producing countries in the world. The use of fossil fuels contributes significantly to Lagos' emissions, as these fuels release carbon dioxide (CO_2) and other pollutants into the atmosphere. Figures 5.1 and 5.2 show Nigeria's historical oil and natural gas consumption, which is seen to have always been on the rise [14].

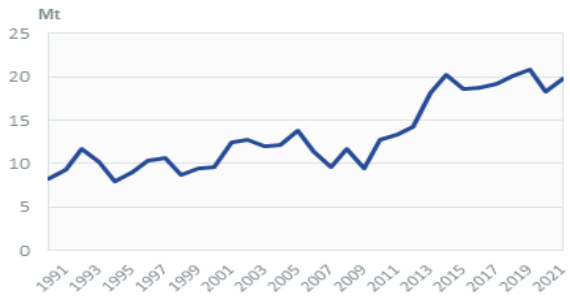

Figure 5.1. Oil consumption in Nigeria [14]

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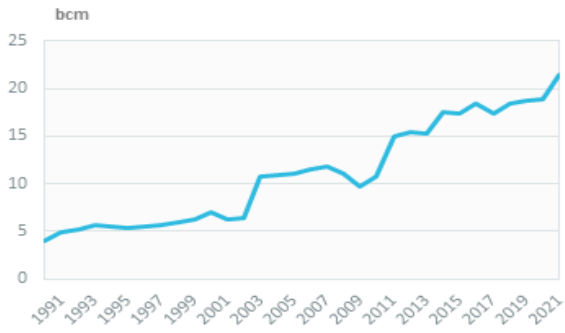

Figure 5.2. Natural gas consumption, in bcm [14]

It is estimated that over fourty per cent (40%) of the Nigerian electricity demand is from Lagos however, Lagos is allocated just about 20% of the required electricity [13]. As shown in Table 1 below, energy demand outweighs its supply due to the exponential growth of population, inadequate capacity (due to generation and supply of power by generating companies (GENCO's)), low-capacity transmission lines, and high (20%) transmission loss.

Although this problem is not peculiar to Lagos state, it is responsible for the increased use of oil and diesel generators to bridge the energy gap by both industries and households. This has a detrimental effect on human health and the environment.

Table 1. Power Generation and Distribution in Lagos State [13]

Power supply	2,000MW
Power demand	10,000MW
Electricity consumption per capita	500MJ/inhabitant
The proportion of households with access to electricity	40%
Energy loss through transmission	20%

The complexities of the Lagos state Energy system are represented in Figure 6. The model has six (6) loops- three (3) positives and three (3) negatives. The positive loops are named R1, R2, and R3 whilst the negative loops are B1, B2, and B3. These are discussed below.

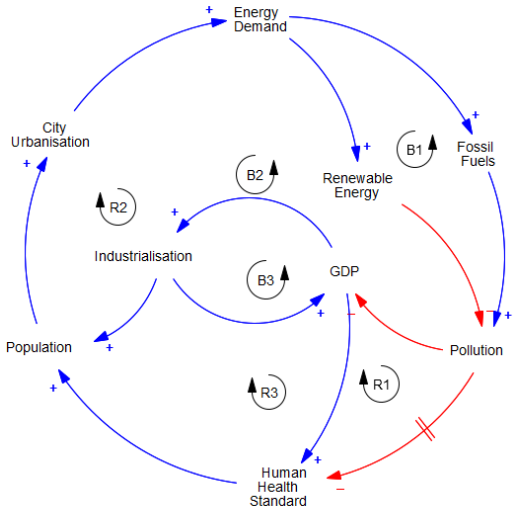

Figure 6. Energy- City Urbanisation Causal Loop Diagram (CLD)

B(n) represents the Balancing (Negative) Loop: This means that the Loop is negative and affects the sustainability of the city. One (1) or any odd number of negative (red) variable(s) in a loop will make the entire Loop a balancing (negative) loop.

R(n) represents the Reinforcing (Positive) Loop: This means that the Loop is positive and is good for the sustainability of the city. Two or any even number of negative (red) variable(s) in a loop will make the entire Loop a reinforcing (positive) loop.

The Loops identified in Figure 6 are as follows:

i. Balancing Loop (B) 1: Energy Demand (ED) - Fossil Fuel (FF) - Pollution - Human Health Standard (HHS) – Population – City Urbanisation (CU) – Energy Demand (ED).

ii. Balancing Loop (B) 2: Energy Demand – Fossil Fuel (FF) - Pollution - GDP – Industrialisation - Population – City Urbanisation – Energy Demand.

iii. Balancing Loop (B) 3: Energy Demand (ED) – Fossil Fuel (FF)- Pollution – GDP - Human Health Standard (HHS) – Population – City Urbanisation (CU) – Energy Demand (ED).

iv. Reinforcing Loop (R) 1: Energy Demand (ED) – Renewable Energy (RE) - Pollution - Human Health Standard (HHS) – Population – City Urbanisation (CU) – Energy Demand (ED).

v. Reinforcing Loop (R) 2: Energy Demand (ED) – Renewable Energy (RE) - Pollution – GDP - Industrialisation – Population – City Urbanisation (CU) – Energy Demand (ED).

 | DOI: 10.20533/ijsed.2046.3707.2023.0067

vi. Reinforcing Loop (R) 3: Energy Demand (ED) – Renewable Energy (RE) - Pollution – GDP - Human Health Standard (HHS) – Population – City Urbanisation (CU) – Energy Demand (ED).

Loop **B1** demonstrates a positive relationship between Energy demand and Fossil fuels. This means that as energy demand increases and is being met by fossil fuels (as in the case of Lagos State), the pollution from fossil fuels would be on the increase. The pollution resulting from fossil fuel usage has a negative impact on the human health standard (HHS) of the residents of the city however, this effect is not immediate. It can take decades until the effect of pollution is seen on human health standards hence, the double line which depicts "delay". Also, pollution can have a negative impact on the GDP of a city (**B2**). Pollution would lead to global warming which can result in damage to property and infrastructure, lost productivity, mass migration, and security threats.

A reduced GDP would negatively impact industrialisation as people would have less money to invest in businesses. However, there is equally a relationship between GDP and the HHS, as the GDP increases, people can afford better health services and a better standard of living therefore increasing the lifespan and birth rate which would increase the population. An increase in population would lead to an increase in the city thereby also leading to an increase in energy demand.

The model further demonstrates how the use of renewable energy (as one of the various options) can be used to reduce the pollution from energy use thereby making the city more sustainable. This is represented in loop R3.

8.1. Waste System in Lagos State

According to a report by the Lagos state's formal waste management agency (LAWMA), Lagos generates around 13,000 tonnes of waste daily, with only fourty per cent (40%) being collected by the Lagos Waste Management Authority [16]. The remaining (60%) waste is disposed of in uncontrolled dumpsites or open landfills, creating environmental pollution and health risks for residents.

Figure 7 below depicts the complexities that emanate as a result of waste in Lagos state. The model has eleven (11) loops- six (6) positives and five (5) negatives. The positive loops are named R1, R2, R3, R4, R5, R6 whilst the negative loops are B1, B2, B3, B4, and B5. These are discussed below.

Loops B1, B2, B3, B4, and B5 demonstrate how the wastes generated in Lagos state can negatively contribute to the sustainability of the city if not properly channelled. The loops show the positive relationship between Wastes and Environmental Pollution (EP).

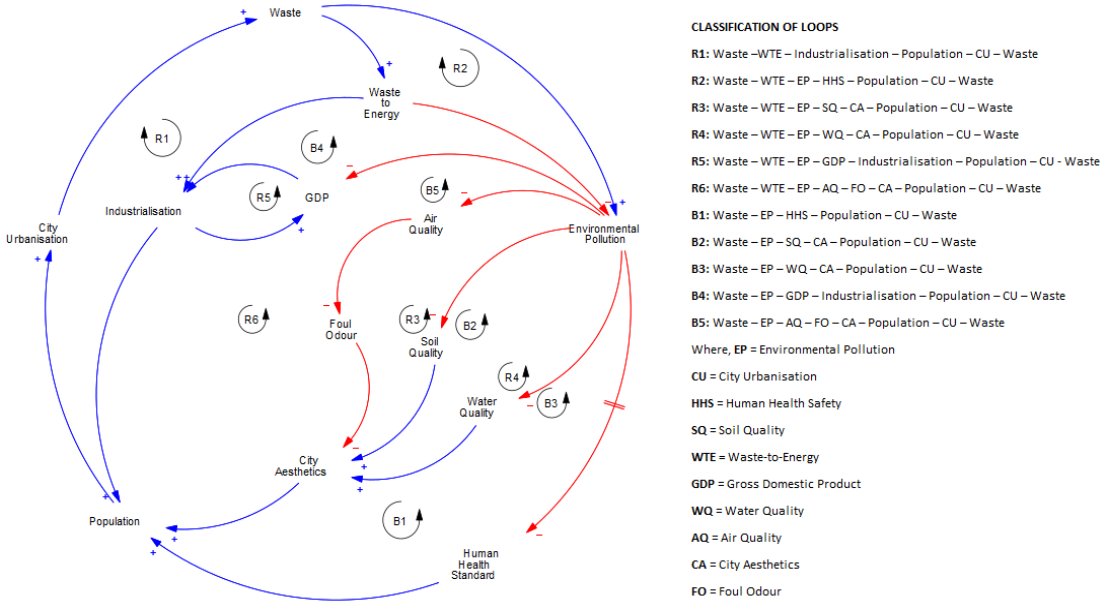

Figure 7. Waste – City Urbanisation Causal Loop Diagram (CLD)

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The generated wastes increase EP thereby reducing the Air Quality (AQ), Soil Quality (SQ), and Water Quality (WQ) since some of the waste will contain contaminants that reduce the qualities of these variables (AQ, SQ, WQ). Air quality shares a negative relationship with foul odour (FO) thus, a reduction in AQ would increase FO which reduces the attractiveness of the city (City Aesthetics). Both SQ and WQ share a positive relationship with City Aesthetics (CA) and if they both are reduced because of EP, there will be a decline in CA. As previously discussed in section 8.1, EP can have a negative impact on both the city's GDP (by posing security threats and reducing productivity) and the HHS of the residents (over the years). GDP shares a positive relationship with Industrialisation therefore, an increase in GDP will promote industrialisation and vice versa. Likewise, the population shares a positive relationship between Industrialisation, HHS, and CA hence, the population will increase in a situation where the three elements are on the rise.

An increase in the population remains a major contributor to city urbanisation. The city will strive to achieve more urbanisation as the population increases and this would result in more waste being generated.

It can be identified from this CLD that Environmental Pollution (EP) as a result of the wastes generated is the root cause of the problems. Whilst it might be impossible to eliminate the generation of waste, it can be mitigated through various methods which include reusing, recycling, reduction, and Waste – to – Energy (WTE) technology. This CLD has demonstrated how the use of WTE technology can improve the sustainability of a city in Loops R1, R2, R3, R4, R5, and R6. The Loops demonstrate how producing energy from the generated wastes by WTE can reduce the level of environmental pollution as opposed to landfill and incineration that are currently predominant in Lagos state.

8.3. Transportation System in Lagos State.

Lagos state like the majority of cities has a significant emission from road transportation. Transportation creates social and economic values, however, has an associated impact on fossil fuel consumption and CO_2 emission. In Lagos state, the population, and the economy, as seen in Figure 8 have been on the rise and adding more pressure on the transport system [17]. There are about 2,600 km of roads that are frequently congested with over 1 million vehicles (petrol and diesel-powered) plying Lagos roads daily [18]. These greatly contribute to air pollution in the city. The combination of the poor road network and huge volume of traffic often leads to increased carbon emissions in Lagos state.

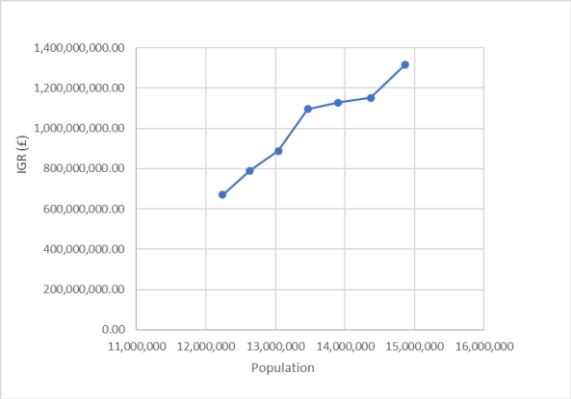

Figure 8. The positive relationship between Economic growth (using IGR) and Population in Lagos State[17]

Road transportation is the dominant mode of transportation in Lagos, accounting for about 95% of passenger traffic. The road network in Lagos is extensive, but it is congested due to inadequate road infrastructure and the high number of vehicles on the roads. In addition, there is a lack of proper traffic management, leading to frequent gridlocks and long travel times.

Water transportation is also available in Lagos, but it is underutilised. The Lagos State Waterways Authority (LASWA) operates water buses and ferries to transport passengers across the city's waterways. However, water transportation accounts for only a small share of total passenger traffic in Lagos.

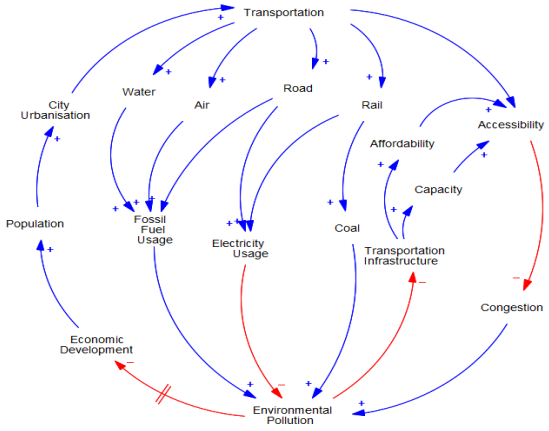

Figure 9. Transportation – City Urbanisation Causal Loop Diagram (CLD)

As demonstrated in Figure 9 above, Transportation in Lagos is in 4 major forms namely Water transportation, Air transportation, Road transportation, and Rail transportation. The CLD shows how the affordability and capacity of a transportation system

 | DOI: 10.20533/ijsed.2046.3707.2023.0067

increase accessibility to goods and services. When there is adequate access to transportation, people tend to use the system at their convenience and not when transportation services are available, hence, this (accessibility) reduces the level of congestion faced in a city. Congestion shares a positive relationship with environmental pollution because when people spend more time commuting because of congestion, it results in more emissions if their mode of transportation is powered by fossil fuels. Furthermore, environmental pollution can result in the dilapidation of transportation infrastructure, likewise, if environmental pollution continues for years, it can reduce economic investment by painting the city in a bad light to investors. In addition, economic development attracts people to the city, which increases the population and city urbanisation.

Summarily, the CLD demonstrates how powering transportation with fossil fuel has negative impacts on the environment thereby reducing the sustainability of the city. It also provides renewable energy sources as one of the solutions to reducing the environmental pollution in the transportation sector of Lagos state to achieve sustainability.

8.4. Water System in Lagos State.

Water is a vital resource for a city's development, but its availability and quality present significant challenges in Lagos state. The city has access to various water sources, such as surface water from rivers, groundwater, and seawater. The Lagos Water Corporation (LWC) is responsible for providing safe drinking water, but the supply is often unreliable, and many areas experience shortages or inadequate supply [19]. Groundwater is also a significant source, but water quality is a major concern, with many sources contaminated by pollutants such as heavy metals, chemicals, and pathogens. The high levels of pollution in water bodies such as the Lagos Lagoon and the Atlantic Ocean has significant environmental and health implications for residents and the local ecosystem.

Figure 10 below shows the complexities of Lagos state's Water system. The model presents four (4) loops (R1, R2, R3, and R4) which show the various elements contributing to water quality (WQ) in Lagos state, and how they interact with each other.

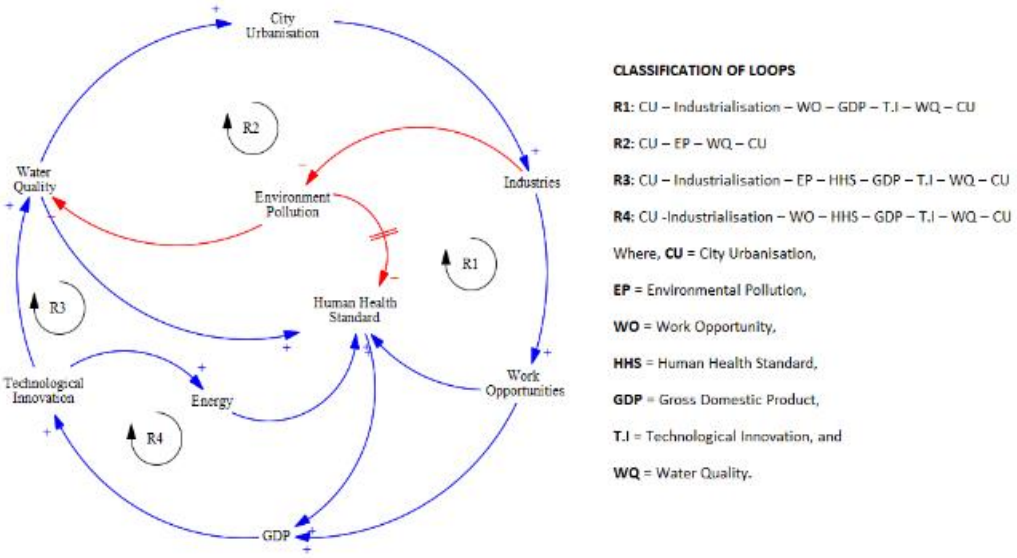

Figure 10. Water – City Urbanisation Causal Loop Diagram (CLD)

The Causal Loop Diagram demonstrates how city urbanisation (CU) increases the number of industries to meet the needs of the residents and generally improve the city. It also shows how the rise in industries will create more work opportunities for the people however, these industries also contribute to environmental pollution from the wastes generated through their operations. With time, environmental pollution reduces the HHS of the people whilst also reducing the water quality through possible contamination. More work opportunities for the residents means more chances of making more money. This will directly increase both the GDP of the city and the HHS because the people are more capable of healthcare services and healthier lifestyles.

Furthermore, an increased GDP will facilitate technological innovation (TI) in a city. However, technological innovation requires energy, which in turn

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can facilitate the generation of additional energy. This increased energy production can also have a positive impact on the HHS by providing a more reliable source of power for the healthcare system.

Technological innovations can progress water quality and efficient water management thereby, improving the overall sustainability of water. In addition, improved water quality will enhance the HHS as there would be fewer health issues (like Cholera, Dysentery, Giardia, etc.) arising from poor water quality.

Finally, the presence of good water quality can make a city attractive to people and increase city urbanisation.

9. Recommendations

Given the primary factors and discoveries of this research, the city planner, policymakers, and all relevant stakeholders of Lagos state are advised to adopt the following recommendations to achieve a sustainable city (see Figure 11).

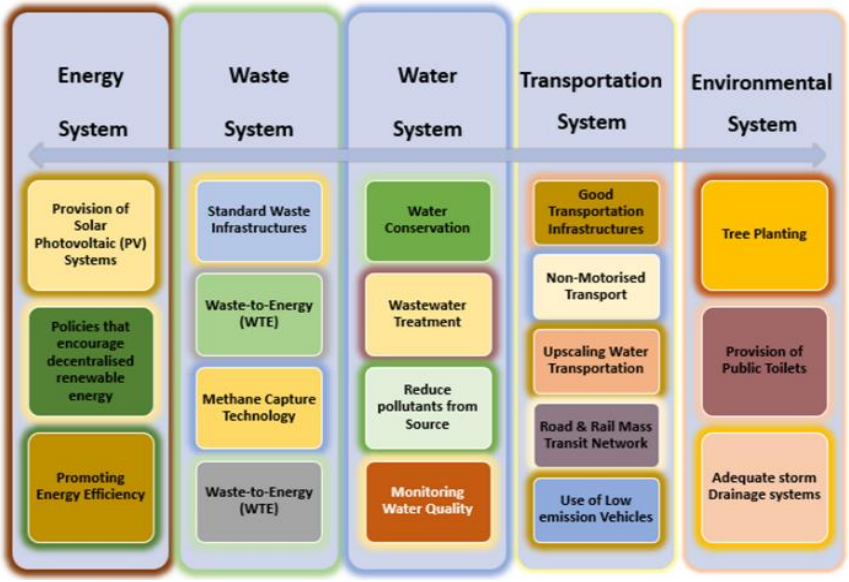

Figure 11. Recommendations

10. Conclusion

The findings of the research showed that Lagos state, like many other cities in Nigeria, faces significant challenges in achieving sustainability. These challenges include but are not limited to poor waste management, poor transport infrastructure, bad energy, rapid population growth and industrialisation, and the impacts of climate change from environmental pollution.

Based on the findings, the research identified opportunities for sustainability and proposed a sustainability strategy for Lagos state (which other Nigerian cities can emulate), which includes the development of a comprehensive waste management system, the promotion of renewable energy sources, the implementation of Mass transits and pedestrian schemes, and the adoption of technologies to improve water efficiency. The research also recommends that policymakers and city developers engage with local communities and stakeholders to ensure that sustainability strategies are inclusive and participatory.

In conclusion, this research contributes to the body of knowledge on sustainability in Nigerian cities and provides insights and recommendations for achieving sustainable development. The study highlights the importance of adopting a Systems Thinking approach to understand the complexities of urban systems and the need for collaboration between policymakers, city developers, and local communities to achieve sustainable cities.

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