

STEEP Systems Modelling for Sustainable Policy Development: A Case Study of the Transport System in Onitsha, Nigeria

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Abstract

This paper applies the STEEP systems modelling to the transport sector, using Onitsha, Nigeria as a case study. The increase in population due to rural-to-urban migration and economic growth has resulted in increased demand for transport in urban cities. The evolution of transportation has a correlation with economic development given that it connects people to their social and economic activities. Onitsha is a commercial city with the biggest market in West Africa with a population of 1.6 million people. Road transportation is the only mode of transportation in Onitsha, despite a large capacity in the waterways that are underutilised. As a result, the public transportation system is characterised by heavy congestion, environmental pollution, depilated infrastructures, and inadequate regulations and policies. These have a significant detrimental impact on the city's economy and call for transportation solutions that are readily available, quick, and inexpensive. The level of unsustainability challenges that Onitsha Transportation faces suggest that current government measures have not yielded intended result due to lack of adequate planning and understanding of the interacting systems. This paper argues that to better understand and plan for sustainability, the relationships and interactions of five interconnected systems must be analysed and modelled. These systems are the social, technology, economic, environmental and policy. Systems Thinking (ST) is then used to model the relationships for better understanding to help decision-makers develop policies that will ensure sustainability in the public transport sector.

Keywords: Transport, Sustainability, Policy, STEEP Systems Analyses, Systems Thinking

1. Introduction

Public transport is an integral part of urban life and determines the form and socio-economic development of a city [1]. Public transport provides mobility for those who cannot afford to buy a car and helps in creating and maintaining livable communities by

relieving highway congestion and assuring long-term sustainability in terms of resource consumption and the environment [2]. Public transportation provides a very efficient means of moving large numbers of people with considerable flexibility in order to meet demand throughout the city. It plays a key role in shaping urban and rural landscapes through its influences on the form and size of settlements, facilitating trade; permitting access to people and resources, and enabling greater economies of scale [3].

Transportation is a crucial aspect of modern societies, facilitating economic growth, social interactions, and the movement of goods and services [4]. Its importance extends beyond merely moving people and goods from one place to another. Efficient transportation networks are vital for the exchange of raw materials, finished products, and resources that drive economic growth and development. A well-developed transportation system provides access to employment, education, healthcare, and other essential services [5]. It allows individuals to reach job centres, educational institutions, and medical facilities, enhancing the overall quality of life and opportunities for social mobility. Transportation infrastructure, including airports, roads, and railways, facilitates tourism and travel, boosting local economies and exposing people to new experiences and cultures [6]. Different means of transportation include road, sea, air, and rail. The predominant use of road transportation over all other modes of transportation in the Global South has resulted in environmental problems with road transportation and a high occurrence of road traffic accidents, which has greatly affected the economic development of the Global South as a whole [7].

The challenges of the transport sector in the Global South include inadequate and poor-quality infrastructure, the mismatch between demand and supply, and an increased rate of accidents [8]. The problems are triggered by interrelated trends such as urban population growth, and rapid, unplanned, and uncoordinated growth of cities. The increase in population has caused an increase in the demand for mobility without a corresponding public transport

infrastructure capable of meeting the demands. The outcome is an increase in waiting times and congestion in public transport. The best way to solve it is to look at it linear/holistic way. To attain a sustainable transport system in any country, a precise understanding of the dynamism involved in the system is needed. This paper aims to use Systems Thinking and STEEP analyses as a tool for a better understanding of the sustainability issues as they relate to the public transport system in Onitsha.



Figure 1. The Unsustainable Transport System in Onitsha [9]

2. The Complexities of the Transport System

Public transport is defined as multidisciplinary issues that involve engineering, where the network has to be mapped out to have the right connections and coverage and designed for easy and effective maintenance [10]. It is also an economic problem, where the various players like operators, asset owners, Government and commuters will have the right incentives to do the right things. It is further viewed as a sociopolitical problem – an economic mobiliser and social equalizer [11]. The main purpose of public transportation is to provide vehicles and networks for people who want to use them daily. The complexities of transport system are categorized as social, technological, environmental, economic and political issues (STEEP).

According to [12], the social challenges of the transport system in the developing countries include poverty, individual preferences and rapid urbanisation. There are linkages between poverty and transportation in the Global South, and effective transportation policy is a successful measure for addressing the intergenerational poverty transfer [13].

The political issues are lack of transportation policy, poor policy implementation, Weak governance, inadequate regulatory frameworks, and fragmented institutional structures [14]. These have resulted to

insufficient road networks, inadequate public transport systems, and limited connectivity. As a result of lack of public transport systems, people tend to own private cars. Private cars contribute largely to CO₂ emission which pollutes the environment and negatively affects people’s lives. In the Global South, 0.5 million people die annually as a result of air pollution brought on by transportation [15]. Unsustainable transportation has resulted in issues that include air pollution on human health, climate change and the degradation of the ecosystem. CO₂ emissions from vehicles and automobile dependency all add to lower quality of life in the cities. Data from IEA (International Energy Agency) shows that between 2000 and 2022, “passenger road vehicles” 3.6 GT of CO₂.

It can therefore be deduced from the above that unsustainable transport lead to environmental pollution, which has negative effect on both human health and the economy. If these practices are not curbed through technology and policies, then it will continue to grow exponentially to the detriment of the society. The carbon emissions from vehicles generally affects the economy of the city which includes the GDP, high cost of public transportation, high cost of living, percentage of unemployment, inflation, interests and exchange rates and commodity (oil, steel, gold, etc.) prices [16]. All these factors affect the transportation system in the Global South. The technological factors include lack of transportation technologies and infrastructures like traffic lights, pedestrian crossings, flyovers, GPS, quality roads, and bridges [17]. The lack of these has led to difficulties in accessing essential services, education, and job opportunities in the Global South.

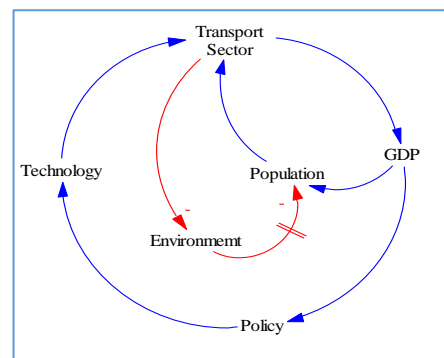


Figure 2. STEEP Interactions with the Transport Sector [19]

The sustainable transport solutions listed by [18] include identifying transformative pathways; applying science, technology and innovation; strengthening governance; improving finance; directing capacity-building, technology cooperation and data; and

changing through individual and collective behaviour. The author further argues that demographic trends, globalisation and trade, urbanisation, digitalisation, and climate change are those that are most important for sustainable transportation.

Understanding probable causal relationships between system factors and their behaviour allows for tracing the possible indirect impacts of transport policy intervention. Usually, the complete picture of the system's complexity is not typically brought to bear on decision-making processes. This paper utilises Systems Thinking as a methodological paradigm to analyse the social, technological, economic, environmental and policy (STEEP) as interacting systems in public transport (see Figure 2). Adopting such whole systems approach also provides an opportunity to assess policies at an early stage, therefore avoiding potentially harmful or costly negative consequences occurring at implementation or beyond.

3. Systems Theory and Complexity Theory

Systems theory is a multidisciplinary framework that aims to understand the complex interactions and behaviour of systems [20, 21]. It provides a holistic approach to studying systems by focusing on the relationships and interdependencies among their components rather than analysing them in isolation. The key concepts addressed by the systems theories are discussed below.

Systems: A system refers to a set of interconnected and interdependent elements that work together to achieve a common purpose [22]. It can be a physical entity, such as a biological organism, a social organization, or an ecological system. Systems can be open, interacting with their environment, or closed, operating independently [23].

Interactions and Interdependencies: Systems theory emphasises the interactions and interdependencies among the components of a system. Changes in one component can affect other components and the system's overall behaviour [23]. These interactions can be linear or nonlinear, feedback loops can be present, and emergent properties may arise from the system's complexity. In the context of the road transportation, Systems thinking recognises that every element within road transport, from infrastructure to human behavior, is interconnected. For instance, road design influences traffic flow, which in turn affects vehicle emissions and safety.

Boundaries: Systems have boundaries that separate them from their environment. These boundaries define what is considered part of the system and what is

external to it. Understanding the exchanges and flows across system boundaries is important for analysing the system's behaviour and its interactions with the broader context [20]. In other words, Systems thinking acknowledges that the behavior of the entire road transport system can exhibit emergent properties that are not evident when examining its individual components. These properties can include traffic flow patterns and congestion dynamics.

Feedback and Control: Feedback mechanisms play a critical role in systems theory. Feedback can be positive, amplifying a system's behaviour, or negative, regulating and stabilizing the system [24]. Control mechanisms are employed to maintain stability, adapt to changes, and achieve desired system goals.

Emergence: Systems theory acknowledges the concept of emergence, which refers to the appearance of novel properties or behaviours at the system level that cannot be explained by the properties of individual components alone [25]. These emergent properties are a result of the interactions and synergies among the system's elements.

Holistic Perspective: Systems theory emphasises the importance of considering the system as a whole rather than focusing solely on its individual components. It encourages a holistic perspective that recognises the interconnectedness and interdependencies among different parts of the system [23, 25].

According to [24], systems theory finds applications in various fields, including biology, engineering, social sciences, management, and environmental studies. It provides a framework for analysing complex phenomena, understanding the dynamics of systems, and guiding decision-making processes. By considering the interactions, interdependencies, and emergent properties of systems, systems theory helps in developing a more comprehensive and integrated understanding of complex real-world situations [24].

Non-linearity: Complex systems often exhibit non-linear relationships, meaning that small inputs can lead to disproportionately large outputs [26]. This characteristic is evident in various phenomena, such as phase transitions in materials or the spread of diseases.

4. Systems Thinking Paradigm in Road Transport

The road transport sector is a critical component of modern society, facilitating the movement of people and goods across vast networks of infrastructure [27]. However, managing and improving road transport systems presents complex challenges that extend far beyond the asphalt and vehicles. To address these challenges effectively, a paradigm shift is needed, one

that places systems thinking at the forefront of transportation planning and management. This section discusses the application of systems thinking in road transportation.

Traffic Management: Systems thinking provides a framework for designing traffic management strategies that consider the dynamic nature of traffic flow [28]. Instead of simply adding more lanes to alleviate congestion, it encourages a broader view that includes public transportation, congestion pricing, and intelligent traffic control systems.

Infrastructure Planning: When designing or upgrading road infrastructure, systems thinking calls for a holistic assessment that takes into account the impact on the surrounding environment, urban planning, and the potential for inducing changes in travel behavior [29].

Sustainability: Addressing sustainability concerns in road transport requires a systems perspective. This means not only reducing emissions from vehicles but also considering the entire lifecycle of transportation, including manufacturing, maintenance, and disposal.

Safety: Road safety initiatives are more effective when they consider the entire system, from vehicle design and road conditions to driver behavior and education [30].

However, challenges such as data integration, stakeholder coordination, and resistance to change must be overcome for the successful implementation of systems thinking in road transport.

5. Discussion and Findings

5.1. The Challenges of Road Transportation in Onitsha

Onitsha is facing various transportation challenges due to rapid urbanisation, population growth, and inadequate infrastructure. Some of the key transportation challenges in Onitsha include traffic congestion, limited public transportation options, parking challenges and inadequate pedestrian infrastructure.

Traffic congestion is a major challenge to road transportation in Onitsha. The obvious causes of traffic congestion, as can be seen in Figure 4, include issues with the road design, the presence of vehicles in bad condition, improper parking, careless driving, and lack of designated bus stops, as well as a growth in automobile ownership and/or an excessive number of cars on the road. The presence of law enforcement personnel (police, task force members, and revenue agents) on the roads, the intensification of land uses close to the road space, and heavy pedestrian traffic that interferes with vehicle traffic are further factors.

The road design means the road interconnections, the width of the roads, and the number of lanes (single, double, etc.). All the above factors largely contribute to the traffic congestion in Onitsha. As Onitsha city is growing, transport infrastructure has not kept up, and haphazard construction methods without zoning laws have left behind a chaotic, congested city that is replete with lawlessness. The types of vehicles found in Onitsha include commercial vehicles (public buses, Lorries, tricycles, tippers, trucks, pickup vans and trailers) and private cars. Private vehicles make up 36.18% or 152,000 of Onitsha's daily vehicular traffic, while mini buses make up 39.60% or 166,500. 1.54% or 6580 vehicles are taxicabs and trailers, as evidence in [31] (see Figure 3).

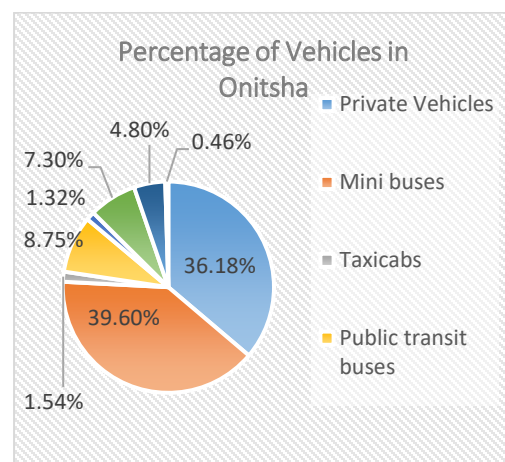


Figure 3. Percentage of vehicles in Onitsha [31]

Onitsha has a daily average internal vehicle traffic flow of 88,668 vehicles [32]. The only 4-lane dual carriageways are Bridge Road and Owerri Road; the other roads are all single lanes. On the other side, it was also discovered that gridlocks have a favourable impact on the income of 83% of traffic vendors in the city.

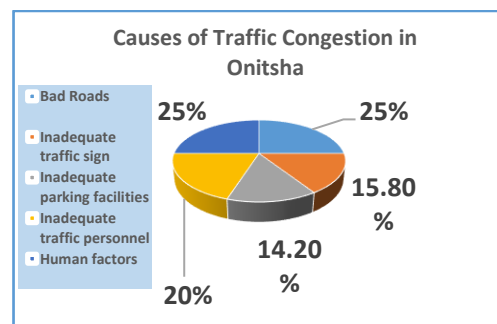


Figure 4. The causes of traffic congestion in Onitsha [32, 33, 34]

During the morning and afternoon rush hours, traffic congestion on Awka and Oguta Roads is caused by the different educational and administrative land uses that are situated there. Traffic congestion has significant implications for both individuals and society as a whole. Increased travel time, reduced accessibility, economic costs, environmental impact, stress and health effects, opportunity cost, impact on businesses, and safety concerns are the implications of traffic congestion. It increases fuel consumption and vehicle wear and tear, leading to higher transportation expenses for individuals. For businesses, it imposes economic costs, it can result in delayed deliveries, increased logistics costs, and reduced productivity. Traffic congestion contributes to increased greenhouse gas emissions and air pollution. The idling of vehicles in congested traffic leads to more fuel consumption and worsens air quality, contributing to climate change and respiratory health issues. Congestion can limit access to essential services, such as healthcare facilities and educational institutions, particularly for those living in areas heavily affected by traffic jams. Dealing with traffic congestion can be stressful for commuters. The frustration of being stuck in traffic for extended periods can lead to anxiety, irritability, and overall negative impacts on mental health. Congestion increases the likelihood of accidents due to stop-and-go traffic and impatient driving behavior. This puts both drivers and pedestrians at a higher risk of road accidents. Time spent in traffic congestion represents an opportunity cost for individuals. The time wasted in traffic could have been used more productively for work, leisure, or spending time with family and friends. Traffic congestion can affect businesses' operations, especially those reliant on timely deliveries and transport services. It can disrupt supply chains, increase delivery times, and impact customer satisfaction. Another cause of traffic congestion in Onitsha is poor road conditions. 75% of the arterial and local collector roads in Onitsha are in poor condition, as evidenced in [35], this extends to Iwaka Road, New market road, Old Market Road and Oguta road are in poor condition. The common problems seen on Onitsha roads are potholes, narrow roads, poor drainage systems that cause flooding during the rainy season, and traders who set up their petty businesses on the roadside. 90% of the roads in Onitsha are constructed as a single carriageway. Also, there are no proper road connections between zones/areas. All these are problems causing poor road conditions in Onitsha. The poor road conditions not only slow down traffic but also lead to increased maintenance costs for vehicles and road accidents.

Another key transportation challenge in Onitsha is limited public transportation options. The city's public transportation system, mainly consisting of buses and

minibuses (known as "Keke") is not sufficient to meet the demand. High levels of private car ownership and dependence have been partially held responsible for the prevalence of gridlock in Onitsha. In Onitsha, the percentage of people who own a car has been steadily rising over the past few decades, however, the rate of road development was shifting in the opposite direction. This limited public transportation option leads to overcrowding and discomfort for commuters.

Another key transportation challenge in Onitsha is parking challenges. Finding suitable parking spaces in Onitsha can be difficult, leading to illegal parking and obstruction of traffic flow. In the entire city of Onitsha, there are no public car parks. Insufficient parking spaces in Onitsha have led to illegal parking and vehicles occupying roadways, contributing to traffic congestion. This has slowed down traffic flow, increase travel times, and exacerbated existing transportation issues. Limited parking availability in Onitsha has made it difficult for individuals to access essential services and businesses. Parking challenges have negatively affected businesses in Onitsha, as evidence in [31, 36]. Customers may be deterred from visiting shops and establishments if they cannot find convenient parking, leading to decreased footfall and potential revenue loss for businesses. Because of the absence of regulated parking facilities, informal parking services have emerged, with individuals charging fees for ad-hoc parking spaces. This informal system has severally led to conflicts. Parking challenges have consequently obstructed pedestrian walkways and compromised road safety. Parking challenges have discouraged people from using public transportation since they perceived it to be more convenient to use private vehicles. This has led to increased traffic congestion.

Another key transportation challenge in Onitsha is lack of pedestrian infrastructure. Onitsha has limited pedestrian infrastructure, such as sidewalks and pedestrian crossings, making it difficult for pedestrians to navigate safely. Inadequate pedestrian infrastructure in Onitsha, such as the lack of sidewalks and pedestrian crossings, has exposed pedestrians to safety risks. As there are no designated walking paths in Onitsha, pedestrians are forced to share the road with vehicles, increasing the likelihood of accidents and injuries. The absence of proper pedestrian infrastructure has led to conflicts between pedestrians and vehicle operators, which has resulted in accidents, especially at busy intersections and high-traffic areas. Pedestrians walking on the road due to insufficient infrastructure disrupt traffic flow, causing congestion and delays. Inadequate pedestrian infrastructure in Onitsha has discouraged people from walking, leading to a higher reliance on motorized transportation. This has resulted in longer travel times and reduced

walkability within the city. As the city lacks safe and accessible pedestrian infrastructure, certain areas of the city have become socially and economically isolated, as people try to avoid visiting or doing business in these locations due to safety concerns. It has discouraged foot traffic to local businesses, reducing customer access and potentially affecting their revenue.

5.2. Application of STEEP Systems Modelling to Transportation in Onitsha

5.2.1. Social factors. Along with population growth, Onitsha's transit system has also expanded, though perhaps not to the expected extent. The population of Onitsha is escalating at a startling rate, and so is the number of people who own cars. The percentage of people who own a car has been steadily rising over the past few decades. It has more residents than there are transit infrastructures to accommodate them. Research shows that the current population of Onitsha is 1,600,000 [37]. It rose from 533,000 in 2000, 680,000 in 2005, 869,000 in 2010, 1,100,000 in 2015, 1,400,000 in 2020 to 1,600,000 in 2023, as can be seen in Figure 5. In addition, in Onitsha, one person or one family can have multiple private cars, resulting in increased use of transportation infrastructure. Onitsha's road transport infrastructure is woefully inadequate for the number of residents in the region, and the ones that are present are not properly maintained. Furthermore, the cost of different modes of transportation largely influences the preference to private cars. When the cost of transportation is high, people will prefer to use their private cars as it will save them money.

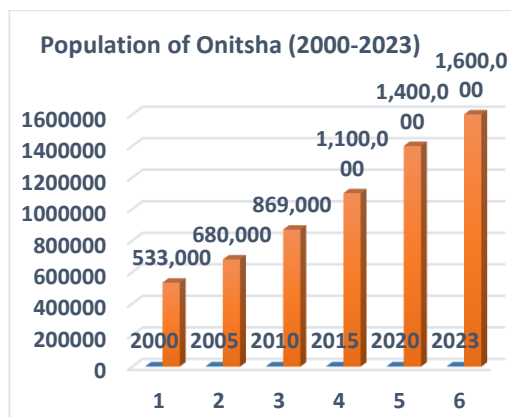


Figure 5. The Historical population of Onitsha. Adapted from [37]

The nature of the transport system people choose can vary based on their individual preferences. Some

people may prefer privacy during their commute, while others actively seek out opportunities for social engagement. This implies that even if the government makes public transportation available and affordable in Onitsha, people can still prefer private cars because of their individual preferences. In Onitsha, people see owning a private car as evidence of high status and good living, meaning that anybody who doesn't have a private car is regarded as being "poor". On the other hand, some people prefer their privacy when travelling, meaning that most people will prefer private cars to the public bus to have their privacy. All these social factors affect transportation demand in Onitsha, as can be seen in Figure 6.

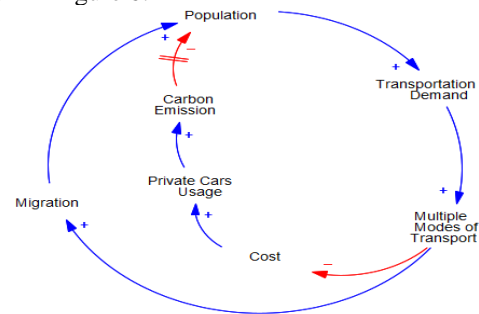


Figure 6. The Social factors of the STEEP systems modelling (Author)

5.2.2. Technology factors. The lack of quality roads, bridges, and other transport technology in Onitsha is affecting the efficiency, safety, and overall development of the transportation system and the city as a whole. Onitsha currently has no transportation technology such as traffic lights, etc. Without modern transport technologies, Onitsha suffers from limited connectivity between different parts of the city and neighbouring areas. This has led to difficulties in accessing essential services, education, and job opportunities, especially for residents living in remote areas like Atani, Idemili North and South.

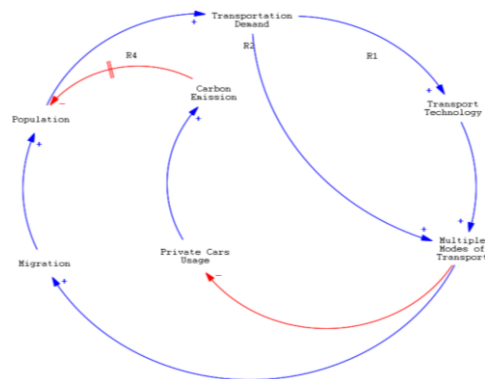


Figure 7. The Technological factors of the STEEP systems modelling

The absence of advanced transportation technologies like intelligent traffic management systems and real-time traffic information in Onitsha also contributes to traffic congestion. Modern transport technologies enable real-time information about routes, schedules, and fares. The lack of such information has made it challenging for commuters to plan their journeys effectively, leading to wasted time and frustration as shown in Figure 7.

5.2.3. Economic Factors. As can be seen in Figure 8, the overall economic performance of Onitsha is impacting the demand for transportation services.

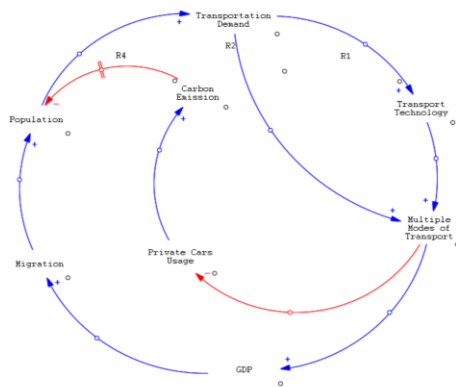


Figure 8. The Economic factors of the STEEP systems modeling

A key contributor to Onitsha's growth as one of the sub-region's commercial hubs is the situation of the "Main market", one of the largest market in West Africa, which attracts the influx of traders from all regions of Nigeria as well as some West and Central African nations. It is also noted as one of the centres for the funding and distribution of Nollywood films, and has contributed creatively to the development of urban life in Eastern Nigeria. There are currently 2.2 million people commuting in the city during the day due to its commercial nature, which has evident effects on the city's vehicular traffic [31]. Study shows that over \$3 billion in commerce occurs annually in Onitsha-Market, with about 40% of that amount moving back and forth through unbanked transactions [38]. This corresponds to Onitsha having one of the highest Gross Domestic Products (GDPs) in Nigeria, which is seen from the absence of extreme poverty there. Onitsha has an estimated value of N5.14 trillion in GDP in 2021 [37]. The average income of residents in Onitsha will influence their ability to afford different modes of transportation and may determine the demand for premium services. Due to the general level of insecurity in the state, including the worry of being assaulted by armed robbers, militants, or kidnappers, the atmosphere in the state recently has

not been attractive to both domestic and foreign investors. As a result, the city loses a lot of foreign investments, which has a bad effect on the economy.

5.2.4. Environmental factors. The transportation system in Onitsha, like in many urban areas, has significant environmental implications. As the city grows and the demand for transportation increases, certain environmental challenges arise. Onitsha experiences high levels of air pollution, primarily caused by emissions from vehicles, especially older, poorly maintained vehicles. The combustion of fossil fuels in cars, buses, and trucks releases harmful pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter, contributing to poor air quality and adverse health effects. These emissions result in air pollution which slows down the population growth of the city.

5.2.5. Political Factors. The transportation system in Onitsha can be significantly influenced by policies, and their implications can impact various aspects of the city's mobility and development. Transport systems are heavily influenced by government policies, such as transportation planning, pricing regulations, and safety standards. The breakdown of roads as federal, state, and local government roads is one of the biggest problems in Onitsha transportation. The state government ignore the fact that many federal roads are in terrible shape by claiming that they are not their responsibility. This has slowed the efficient funding of transport infrastructure in the region. A lack of proper funding and upkeep left these roads in very bad condition, which had a detrimental impact on the study area's economy. Rural roads are in terrible shape because the local government, which has the least financial resources, owns and maintains them. Frequent leadership changes give governments little time to plan effectively and carry out initiatives. The incoming administration nearly invariably revises the policies put in place by the outgoing administration.

6. Recommendations

It is recommended that investment in transportation infrastructure, promoting multiple modes of transportation, enhancing transport technology such as traffic management, and implementing sustainable transport solutions will help to improve overall mobility and accessibility of Onitsha. Onitsha City is surrounded by Rivers, which should be used as a means of transportation. Efforts must be put in a coordinated manner to use the water bodies in and around Onitsha as a substitute for road transportation. The installation of traffic management devices on some arterial and motorways that

frequently experience gridlock, the building of flyover bridges on some busy roads, the dualisation of some arterial roads and motorways connecting metropolises will further slow the traffic congestion in Onitsha. Furthermore, it is necessary to establish pedestrian walking and cycling infrastructures, particularly along Ose, Main Market, Iweka, and Venn Roads, as well as the Bridge Road (from the flyover down to Uga Junction). Congestion charges should be charged for private car users, but before congestion taxes are imposed, enough public transportation options should be made available and at a lower cost by the government. Onitsha needs to adopt sustainable transportation strategies and technologies. This may include promoting public transit and investing in electric and alternative fuel vehicles. High-capacity buses should be added to the city's public transport network to complement taxis, minibuses and motorcycles as a means of moving people around the city. This will result in fewer private cars on the road. Additionally, it is necessary to signalise crossings by adding traffic lights and signals as a replacement for the inefficient use of human labour in traffic management. As mentioned above (5.2.1), the cost of the available modes of transport should be stabilised, as it can determine the choice between private cars and available transport modes.

Furthermore, it is necessary to have well-coordinated policies that will guarantee effective maintenance of the transport infrastructure. The local, state, and federal governments must collaborate harmoniously. As a substitute and extra source of finance, the government should turn to the private sector in the interim to close the funding gap needed for infrastructure development and delivery. They will aid in bridging the resource gap in infrastructure delivery and operation. Also, it will hasten the construction of infrastructure, encourage projects to be completed more quickly, and contribute to an improvement in the general level of service provided by the transportation system.

7. Conclusion

Public transportation is an integral part of urban life and determines the form and socio-economic development of a city. Public transportation provides a very efficient means of moving large numbers of people with considerable flexibility in order to meet demand throughout the city. It plays a key role in shaping urban and rural landscapes through its influences on the form and size of settlements, facilitating trade; permitting access to people and resources, and enabling greater economies of scale. The predominant use of road transportation over all other modes of transportation in Nigeria has

environmental problems with road transportation and a high occurrence of road traffic accidents, which has greatly affected the economic development of Nigeria as a whole. As detailed in the discussion section, and as can be seen in Figure 9, it can be noted that there are interactions between the social (population), Technology (different modes of transport), Economic (GDP), Environmental (pollution) and Policy (investment and regulations) with the transport system.

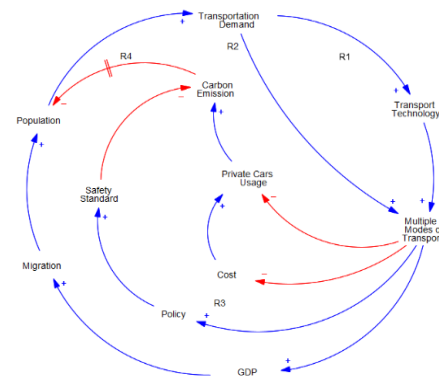


Figure 9. Causal loop diagram with the interlinkages

This research was therefore concerned with the application of STEEP systems modelling to the transport sector, using Onitsha, Nigeria as a case study. A STEEP systems model was adopted and used to evaluate the factors to consider in addressing the road transport challenges in Onitsha. The Causal Loop diagram was drawn with the interlinkages demonstrated as can be seen in Figure 9.

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