Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10, 854-877
2025
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v9i10.10556

Analysis of the sustainability of secondary cities in Africa: Evidence based on data from the Sarh Town in Southern Chad

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Abstract: Although slower than that of metropolitan areas, the growth of secondary cities in Africa is nonetheless a major phenomenon influencing urban, socio-economic, and environmental dynamics. This research aims to assess the urban sustainability of Sarh based on the indicators of Sustainable Development Goal 11 (SDG 11). The methodology adopted is based on a mixed approach, combining documentary analysis, the use of demographic and spatial data, a survey of household heads, the calculation of SDG 11 indicators, interviews, and statistical analysis. The results reveal that the majority of SDG 11 indicators show significant negative deviations. Furthermore, the performance of these indicators is statistically associated with several socio-economic variables, including income, occupation, age, and residence status. Analysis of the correlation matrix highlights synergistic relationships between the indicators for SDG 1, SDG 6, SDG 8, SDG 9, and SDG 11. Finally, five main obstacles to urban development in Sarh were identified: weak governance (47.30%), urban poverty (15.06%), low citizen participation in urban planning and management (13.41%), insufficient infrastructure (12.23%), and social tensions (12%). This research highlights the critical need for effective urban policy strategies to address the challenges posed by the implementation of Sustainable Development Goal 11 (SDG 11) in secondary cities.

Keywords: *Sarh Town in southern Chad, Sustainability indicators, Sustainable development goals, Sustainable urban development, Secondary city in Africa.*

1. Introduction

Rapid urban expansion and its implications for spatial structuring, the environment, society, and the economy are major concerns for the 21st century, particularly in developing countries [1, 2]. Globally, trends show rapid increases in urbanization, leading to urban sprawl and significant land use changes [3-5]. More than half of the world's population lives in cities, and by 2050, two out of three people (6.5 billion people) will live in cities [6]. This urban expansion often results in the occupation of peripheral areas without supervision by the public authorities responsible for urban planning, which poses a serious challenge for environmental management in urban areas [2, 7]. The fundamental and persistent challenge is to ensure sustainable and inclusive access to essential urban services, including adequate housing [8]. While megacities attract a great deal of attention due to their size and influence, small and medium-sized cities are generally marginalized in development policies. Yet, they play a central role in decentralization, economic development, and the management of internal migration flows [2, 9]. However, they are characterized by uncontrolled growth, urban heat islands, degradation of natural spaces, weak infrastructure, increased vulnerability to climate shocks, and a lack of specific data on

History: Received: 24 July 2025; Revised: 25 September 2025; Accepted: 29 September 2025; Published: 14 October 2025
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urban issues [10, 11]. In 2015, the United Nations adopted seventeen Sustainable Development Goals (SDGs) as a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030 [6, 12-14]. These SDGs have 169 associated targets with 231 measurable indicators [15]. SDG 11 (inclusive, safe, resilient, and sustainable cities and communities), comprising 10 targets and 15 indicators, pays particular attention to urban issues. In this context, urban sustainability appears to be a crucial issue for ensuring balanced and inclusive growth. Since then, research on urban sustainability has been high on the agenda of scientists and policymakers and has been highlighted in major international reports and policy frameworks [16].

Numerous studies on sustainable development goals have been conducted in recent years. Dahani and Compaore [17] assessed the city of Ouagadougou in Burkina Faso in terms of sustainability, based on documentary and field research. Their findings highlighted the urgent need for urban development policies to fully integrate the principles of sustainable cities and technological innovation in order to achieve a more environmentally friendly economy. Conducted a systemic analysis of urban sustainability indicators, focusing on the city of Moundou in Chad; the conclusions highlight the need for systemic urban governance capable of enabling integrated, evidence-based decision-making for sustainable urban development. Kaur and Garg [18] presented a comprehensive review of the literature on the most widely used urban sustainability assessment tools; the results reveal that most of them consider sustainability from different angles, placing greater emphasis on infrastructure and resource management, while ignoring other aspects such as culture, business, and innovation. Sharifi [16] assessed urban sustainability based on a bibliometric analysis; he showed that environmental aspects remain dominant in the field and that major socio-economic issues are not well represented. Other studies have examined the spatial extent of urban areas, sought to understand urbanisation processes, and monitored Sustainable Development Goal 11.3.1 [15, 19].

However, despite these important contributions, there are gaps in the literature. Research on the sustainability of secondary cities in Africa is still in its infancy. Most scientific studies focus on large metropolitan areas, leaving a gap in our understanding of the specificities of their urban development [2]. These studies often offer a normative assessment without really taking into account the social, economic, and institutional specificities of African secondary cities [20]. This approach can lead to inadequate indicators, a disconnect from local realities, and consequently to ineffective development strategies. Research has not considered developing a model to systematically organize the causal relationships between sustainability indicators and socio-economic factors. Furthermore, their interdependence has not been integrated, which could limit the ability to analyze cross-effects. In addition, research is mainly based on single case studies, which limits the generalization of results to other urban contexts.

Some authors argue that the use of global indicators, such as those proposed by the United Nations, can mask local particularities and lead to inaccurate or inappropriate assessments Merino-Saum, et al. [21]; Sterling, et al. [22] and Tan, et al. [23]. Haou, et al. [8] argue that urban sustainability goals and strategies differ significantly between developed and developing countries, shaped by institutional capacities, economic resources, divergent pollution responsibilities, and varying levels of exposure to pressing issues. Others argue for the contextual adaptation of these sustainability indicators to better reflect unique socio-economic dynamics and development imperatives in urban areas and to ensure their operational usefulness [24-27]. The lack of a clear consensus on these issues partly explains the difficulty in developing effective public policies.

In Sarh Town, a secondary city located in southern Chad, urban sustainability is rarely considered in development projects or in the design of urban planning tools. Although the 2017 National Development Plan (PND) incorporates sustainable development goals, implementation remains limited [8] their implementation remains limited and faces numerous challenges. Certain actions have been taken in the health, education, and infrastructure sectors to accelerate the achievement of certain SDG targets by 2030 [28]. In addition, reforms have been undertaken to improve the availability and quality of data needed to assess sustainable development indicators in Chad. Despite these multisectoral efforts,

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

the results achieved in implementing the SDGs remain mixed due to the many structural and contextual challenges facing the country [28]. As part of the 2021 High-Level Political Forum (HLPF) on Sustainable Development, Chad committed to assessing progress on the first eight goals. However, SDG 11 received limited attention [28]. The majority of SDG 11 indicators, such as access to adequate housing, the availability of affordable public transport, citizen participation in the planning process, urban solid waste management, and the expansion of public spaces, show significant gaps between the targets set and the local realities. This situation reveals significant institutional and operational shortcomings that hinder the spatial development of cities, compromise the social, economic, and environmental living conditions of populations, and increase the vulnerability of households. These findings raise fundamental questions about the progress made in achieving SDG 11 in secondary cities in sub-Saharan Africa in general, and particularly in Chad.

The research question that emerges from this issue is: how sustainable is Sarh Town? This raises three subsidiary questions: how well do sustainability indicators perform in Sarh Town? Are there any links between sustainable development indicators? What are the obstacles to urban development in Sarh Town? The issue of urban sustainability is crucial, as it affects not only the quality of life of local residents but also the sustainability of natural resources in a rapidly changing environment [2].

The production of scientific knowledge on the sustainability of secondary cities could be an important step in enabling urban planners and local authorities to monitor progress toward achieving objectives, streamline the approval processes for development proposals, and facilitate more informed decision-making [29]. Few studies have explored the issue of sustainability in secondary cities in developing countries based on empirical data. It is therefore crucial to fill this gap in academic research in order to make a meaningful contribution to sustainable urban development.

This research aims to analyze the sustainability of Sarh Town based on empirical data produced between 1994 and 2022. More specifically, the objectives of this research are to (1) evaluate the performance of SDG 11 indicators in Sarh Town and the socio-economic factors influencing their performance; (2) analyze the relationships between SDG 11 indicators and those of other SDGs; (3) identify issues related to urban development in Sarh.

This document is divided into five sections. The materials and methods are explained in the following section. The results are presented in section 3. They are discussed in section 4. Finally, the last section concludes the study by highlighting the main implications and making some recommendations for future research.

2. Materials and Methods

2.1. Presentation of the research area

This research was conducted in Sarh Town, the capital of the Moyen-Chari province and Barh-kôh department in Chad, located between 09° and 10° north latitude and 18° and 19° east longitude [30]. The town of Sarh is bordered to the north and east by the municipality of Hellibongo, to the south by the municipality of Banda, and to the west by the municipality of Balimba [2, 31]. It is subdivided into 6 districts and 30 neighbourhoods with a population of 97,224 in 2009 according to INSEED [32] and a total estimated population of 192,102 in 2022 [33]. It covers an area of 38.04 km², or 0.003% of the national territory [2], and ranks fourth among cities in Chad in terms of population after N'Djamena, Moundou and Abéché [34]. The administrative division of Sarh Town was mapped using geospatial analysis performed with QGIS 3.24 software. This analysis was based on shapefile datasets obtained from the Global Administrative Boundaries Series (GADM 3.6) platform, accessible at https://gadm.org/data.html, as well as from the mapping service of the National Center for Development Research (CNRD). The location of the Sarh Town is shown in Figure 1 below.

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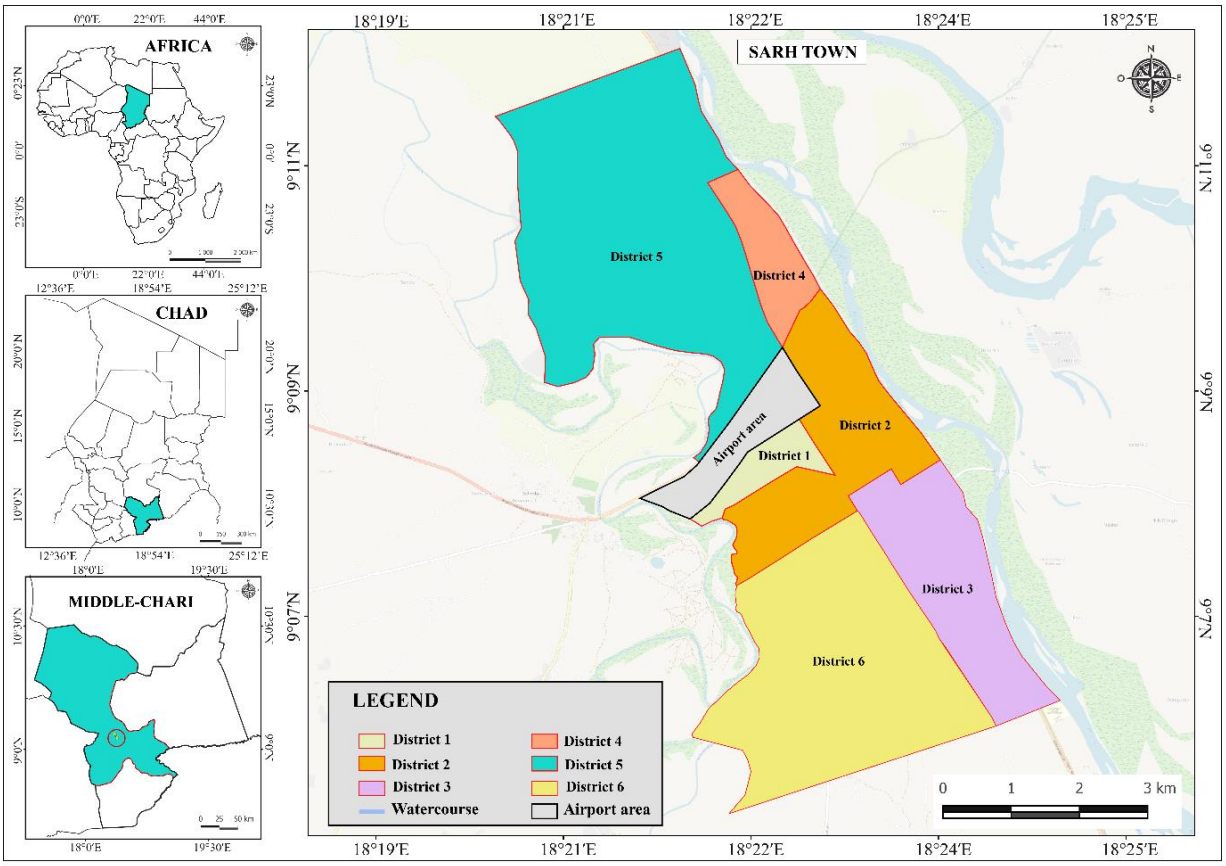

Figure 1.
Location of the research area.

2.2. Documentary Research

The documentary research focused on work carried out in Sarh Town, as well as studies conducted in other countries. It took into account various types of sources, including general works, reports, theses, dissertations, scientific articles, and specialised dictionaries. This research was conducted both online and on-site, in documentation centres and university libraries in Sarh Town, N'Djamena, and Lomé. Urban data was collected from the Chadian Ministry of Land Use Planning and Urban Development, as well as from the municipality of Sarh Town.

The literature review provided an overview of current knowledge on the implementation of Sustainable Development Goal 11 in the general context and particularly in African cities. It also identified gaps in research on sustainable development goals in general and SDG 11 in particular.

2.3. Secondary Data Collection

The administrative boundaries of Sarh Town were obtained from the mapping department of the National Center for Development Research (CNRD) [2]. In addition, demographic data obtained from the National Institute of Statistics, Economics and Demography (INSEED) were used in this study [32, 35]. Furthermore, data on land use in the town from 1994 to 2022 obtained from the work of Teadoum Naringué, et al. [2] were also analysed.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
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2.4. Household Survey

A survey was conducted among a random sample of 425 households spread across six districts of Sarh Town, with the aim of collecting socio-economic data on households. All heads of households in the districts of Sarh Town were considered as samples [31].

The information collected from households is based on the following variables:

- Socio-economic characteristics of heads of households (age, gender, occupation, income, level of education, residence status in Sarh Town).
- Household living conditions (means of transport, type of housing, basic infrastructure and services, waste management methods, participation in the planning process);
- Perceptions of obstacles to the development of the Sarh Town.

The sample size was determined using Schwartz's formula, as described by Teadoum Naringué, et al. [31] and Allarané, et al. [36].

The formula is as follows (1):

$$N = \frac{[(Za)^2 x\, P(1 - P)]}{d^2} \quad (1)$$

With Za: fixed deviation or deviation reduced to a risk of 5% (1.96), corresponding to a 95% confidence interval; P: the proportion of the population of Sarh Town relative to the population of the province; and d: the margin of error set at 5% in this study [31, 37]. Table 1 shows the distribution of households surveyed.

Table 1.
Distribution of household heads surveyed.

Districts	Number of neighbourhoods	Number of head of households	Percentage
District 1	5	49	11.53
District 2	5	89	20.91
District 3	2	66	15.53
District 4	7	48	11.30
District 5	8	113	26.60
District 6	3	60	14.13
Total	30	425	100.00

Source: Teadoum Naringué, et al. [31].

2.5. Interviews With Key Informants and Experts

In order to strengthen the analytical robustness of all the data used for this research, qualitative information was collected using semi-structured interview guides conducted with key informants [2]. These were civil servants/employees from the land registry, environment, urban planning, development, and planning departments of Sarh Town Council. The interviews focused on the measures implemented to achieve SDG 11, the priorities identified for sustainable urban development, and the main obstacles to Sarh's transition to a sustainable city. This qualitative data was analyzed in conjunction with quantitative data in order to better understand the degree of implementation of SDG 11 in the urban context of Sarh, Chad.

2.6. Selection and Justification of Sustainability Targets and Indicators (SDG 11)

In 2015, the United Nations adopted seventeen Sustainable Development Goals (SDGs) to be achieved by 2030 [15]. SDG 11, dedicated to inclusive, safe, resilient, and sustainable cities and communities, pays particular attention to urban issues. This research aims to assess the urban sustainability of Sarh using the SDG 11 indicators. To ensure the scientific rigor and relevance of the analysis, it is essential to define the context and limitations of this research.

Given the global nature of the SDGs, their scope, relevance, and challenges vary according to geographical context, from one continent to another, from one country to another, and even between different cities within the same country. It is therefore necessary to adopt a formal analytical framework

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
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adapted to local specificities. With this in mind, a rigorous methodology was adopted to select the SDG 11 targets and indicators most relevant to assessing the sustainability of Sarh Town.

First, a thorough reading of the ten targets and fifteen indicators of SDG 11 as defined by the United Nations in 2015 [38] was carried out. Next, a critical analysis of their applicability to the local context was conducted. Some targets, such as 11.4 and 11.5, are global in scope, while others, such as 11.a, 11.b, and 11.c, are more oriented towards national policies. This study focused on locally relevant targets and indicators, which were deemed more relevant to the urban context of Sarh. The selection was based on four main criteria:

Local relevance: only targets and indicators directly related to local urban dynamics were selected. Targets and indicators with global or national relevance were excluded.

Measurability and data availability: the indicators chosen had to be quantifiable and supported by data that was accessible or could be collected locally [39].

Data reliability and quality: the data used had to be verifiable to ensure its accuracy and robustness [40].

Alignment with local priorities: targets and indicators were selected based on their potential contribution to the sustainability of Sarh.

Applying these criteria resulted in the selection of five targets, broken down into six indicators. Although targets 11.6 and 11.7 were initially selected, their respective indicators (11.6.2 and 11.7.2) were discarded due to their inappropriate scope and the difficulty in accessing the data needed to evaluate them. Table 2 below presents the targets and indicators selected for this research.

Table 2.
Selection of SDG11 targets and indicators

Selected targets	**Selected SDG 11 indicators**
Target 11.1: By 2030, ensure access for all to adequate, safe, and affordable housing and basic services, and upgrade slums.	SDG 11.1.1: proportion of urban population living in slums, informal settlements or inadequate housing
Target 11.2: affordable and sustainable transport systems	SDG 11.2.1: proportion of the population that has convenient access to public transport, by sex, age, and persons with disabilities.
Target 11.3: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management in all countries.	SDG 11.3.1: ratio of land consumption rate to population growth rate
	SDG 11.3.2: proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically.
Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.	SDG 11.6.1: proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities.
Target 11.7: By 2030, provide universal access to safe, inclusive, accessible, green, and public spaces, in particular for women and children, older persons, and persons with disabilities.	SDG 11.7.1: average share of the built-up area of cities that is open space for public use for all, by sex, age, and persons with disabilities.

2.7. Calculation of Selected Indicators

2.7.1. SDG 11.1.1 Indicator

SDG 11.1.1 indicator is defined by the United Nations [41] as the proportion of the urban population living in slums, informal settlements, or inadequate housing. For the purposes of this study, inadequate housing is defined as housing built with precarious materials and lacking essential services such as drinking water, electricity, and sanitation. The urban population taken into account corresponds to the heads of households in Sarh Town, who constitute the survey units providing relevant information on the households for which they are responsible. In this analysis, households constitute units of analysis forming a representative sample for the study. This indicator makes it possible to

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
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assess the level of informality in the town, which is often associated with a reduced quality of life and inadequate infrastructure. SDG 11.1.1 indicator was calculated using the following formula (2):

$$I_{11.1.1} = \frac{N_{NH}}{T_{NH}} \times 100 \quad (2)$$

Where N_{NH} is the number of heads of households in the Sarh Town living in substandard housing without essential services.; T_{NH}, the total number of heads of households in the Town.

2.7.2. SDG 11.2.1 Indicator

SDG 11.2.1 indicator is defined by the United Nations [41] as the proportion of the population that has convenient access to public transport, by sex, age, and persons with disabilities. In the context of Sarh Town, public transport includes land transport by bus (urban and intra-urban), river transport (motorized canoes), and alternative transport (shared taxis and minibuses). The analysis, therefore, focused on these types of transport available in Sarh Town. This indicator makes it possible to assess the proximity and availability of public transport options in relation to residential areas. It was calculated using the following formula. (3):

$$I_{11.2.1} = \frac{N_{TP}}{T_{NH}} \times 100 \quad (3)$$

Where N_{TP} is the number of heads of households in the Sarh Town with convenient access to public transport; N_T, the total number of heads of households in the city.

2.7.3. SDG 11.3.1 Indicator

SDG 11.3.1 indicator is defined as the ratio of land consumption rate to population growth rate [19, 41]. It is expressed using the following formula (4):

$$I_{11.3.1} = \frac{LCR}{PGR} \quad (4)$$

Where LCR is the land consumption rate and PGR is the population growth rate between two dates [2].

The average land consumption rate is an important indicator for understanding a city's rate of expansion [2, 42, 43]. It is calculated using equation (5):

$$LCR = \frac{LN\left(\frac{U_2}{U_1}\right)}{n} \times 100 \quad (5)$$

Where U_2 is a built-up area in the Sarh Town in the last year; U_1 is a built-up area in the Sarh Town in the first year; and n is the number of years between t_2 and t_1 [2].

The average annual population growth rate (PGR) is an important indicator for understanding population growth for the period between two general censuses [2, 35]. It is calculated using equation (6):

$$PGR = \frac{LN\left(\frac{P_2}{P_1}\right)}{n} \times 10 \quad (6)$$

Where P_2 is the population counted in the Sarh Town in the last year; P_1 is the population counted in the Sarh Town in the first year, and n is the number between two censuses [2].

2.7.4. SDG 11.3.2 Indicator

SDG 11.3.2 indicator is defined by the United Nations [41] as the proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically. In this study, the assessment of this indicator is based on the participation of heads of households in urban planning and management in Sarh. It is calculated using equation (7):

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$$I_{11.3.2} = \frac{N_{PM}}{T_{NH}} \times 100 \quad (7)$$

Where N_{PM} is the number of heads of households who participated in urban planning and management in Sarh Town; T_{NH} is the total number of heads of households in the Sarh Town?

2.7.5. SDG 11.6.1 Indicator

SDG 11.6.1 indicator is defined as the proportion of municipal solid waste collected and managed in controlled facilities out of the total municipal waste generated by cities [38]. In the context of Sarh Town, the assessment of this indicator is based on the proportion of households that regularly collect and dispose of solid waste appropriately. Although this does not provide the proportion of waste, it gives an overview of the coverage of the municipal solid waste collection system, with unserved areas likely to suffer from dangerous landfills or fires [40]. It is calculated using equation (8):

$$I_{11.6.2} = \frac{N_{PD}}{T_{NH}} \times 100 \quad (8)$$

Where N_{PD} is the number of households in the town that regularly collect waste and dispose of it properly; T_{NH} is the total number of households.

2.7.6. SDG 11.7.1 Indicator

SDG 11.7.1 indicator is defined by the United Nations [38] as the average share of the built-up area of cities that is open space for public use for all, by sex, age, and persons with disabilities. In this study, the calculation was not performed by sex, age, and disability status because it was impossible to spatialize the urban area devoted to public spaces on the basis of these variables. It is calculated using the following equation (9):

$$I_{11.7.1} = \frac{A_{PS}}{T_{AU}} \times 100 \quad (9)$$

Where A_{PS} is the built-up urban area devoted to public spaces; T_{AU} is the total urban area.

2.8. Evaluation of Indicator Performance

- Determination of benchmarks

A mixed evaluation method, combining qualitative and quantitative scoring based on scientific studies, was used to evaluate the performance of the indicators selected for this research. Various evaluation methods have been developed in previous studies. For example, the AfDB adopted a four-level scale, ranging from very unsatisfactory to very satisfactory, to evaluate Gabon's 2011-2020 country strategy BAD [44]. Li, et al. [45] used performance thresholds to evaluate certain indicators. According to the authors, thresholds above 90% correspond to 'high or optimal' performance. On the other hand, a threshold in the interquartile range (IQR) of around 50% highlights a certain disparity. In this study, the following benchmarks were defined in relation to the local context in order to assess the performance of SDG indicators 11.1.1, 11.2.1, 11.3.2, and 11.6.1 (Table 3):

Table 3.
Performance assessment grid for indicators.

SDG 11 indicators	References
SDG 11.1.1	90%
SDG 11.2.1	75%
SDG 11.3.1	1
SDG 11.3.2	75%
SDG 11.6.1	75%
SDG 11.7.1	35%

- Calculation of the degree of deviation (Di)

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The degree of deviation is the difference between the actual value (X_i) of the indicator and the reference value (B_i) [46]. It is measured using the following formula (10):

$$D_i = \frac{X_i - B_i}{B_i} \times 100\% \quad \textbf{(10)}$$

Where D_i denotes the degree of the deviation between the actual value and the benchmark value, X_i the actual value of the i^{th} indicator; B_i denotes the benchmark value of the i^{th} indicator determined by using DTIB [46]. If D_i is positive or zero, the indicator's performance is in line with or better than the reference value. On the other hand, a negative D_i reveals a shortcoming, meaning that the indicator needs to be improved [46].

2.9. Analysis of the Relationships between SDG11 Indicator Variables and Socio-Economic Factors

Binary logistic regression was used to model the relationship between SDG11 indicator variables and several socio-economic variables. Binary logistic regression is a widely used statistical method for modeling the relationship between a dependent variable and an independent variable [47-49]. The independent variables selected for the logistic regression models were gender, age, residence status, educational attainment, occupation, household income, means of transport, type of housing, basic infrastructure and services, waste management practices, and participation in the planning process.

2.9.1. Between The Variable for SDG 11.1.1 Indicator and Socio-Economic Variables

The first model aims to assess whether the fact that a head of household lives in inadequate housing is associated with certain socio-economic parameters. In this context, the dependent variable corresponding to SDG 11.1.1 indicator is the type of housing (adequate or inadequate), while the independent variables are the socio-economic factors. A binary logistic regression was used to model this relationship, according to the following equation (11):

$$\log\left(\frac{P\,(Y_a = 1)}{P(Y_a = 0)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p \quad (11)$$

Where P (Y_a = 1) represents the probability that the head of household resides in inadequate housing (SDG 11.1.1 indicator);

P (Y_a = 0) corresponds to the probability that the head of household does not reside in inadequate housing;

b_0 is the intercept;

b_1, b_2, ..., b_p are the coefficients of the independent variables X_1, X_2 and X_P.

2.9.2. Between the Variable in SDG 11.2.1 Indicator and Socio-Economic Variables

The second model aims to examine whether access to the transport system is associated with socio-economic factors. In the context of SDG 11.2.1 indicator, the dependent variable is access to public transport. This link was modeled using a binary logistic regression, presented in the following equation (12):

$$\log\left(\frac{P\,(Y_b = 1)}{P\,(Y_b = 0)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p \quad (12)$$

Where P (Y_b = 1) represents the probability that the head of household has access to public transport (SDG 11.2.1 indicator);

P (Y_b = 0) corresponds to the probability that the head of household does not have access to public transport;

b_0 is the intercept;

b_1, b_2, ..., b_p are the coefficients of the independent variables X_1, X_2 and X_P.

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2.9.3. Correlation Analysis between Land Consumption and Population Growth (SDG 11.3.1 Indicator)

Pearson's correlation coefficient was estimated to assess the linear correlation between the rate of urban land consumption and the rate of population growth. This coefficient ranges from −1 to +1, where −1 indicates a perfect negative correlation, +1 indicates a perfect positive correlation, and 0 indicates that there is no linear correlation between the variables [2, 50]. Next, the coefficient of determination (R^2) was determined by simple linear regression to estimate the percentage of variance shared between the variation in urban land consumption rates and population growth rates [2, 51]. The simple linear regression model was run using version 4.4.1 of RStudio software. Pearson's correlation coefficient is expressed in equation (13):

$$r_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}} \quad (13)$$

where r_{xy} is Pearson's correlation coefficient between x (urban land area) and y (population), n is the number of observations, x_{Ie} is the value of x (for the i^{th} observation), and y_{Ie} is the value of y (for the i^{th} observation) [2].

2.9.4. Between the Variable in SDG 11.3.2 Indicator and Socio-Economic Variables

The third model aims to determine whether household heads' participation in urban planning and management is influenced by certain socio-economic factors. In the context of the SDG 11.3.2 indicator, the dependent variable is citizen participation, and the independent variables are the socio-economic characteristics of the surveyed heads of households (14).

$$\log\left(\frac{P(Y_c = 1)}{P(Y_{dc} = 0)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p \quad \textbf{(14)}$$

Where P (Y_c = 1) represents the probability that the head of household participated in the urban planning process (SDG 11.3.2 indicator);

P (Y_c = 0) corresponds to the probability that the head of household was not involved in the urban planning process;

b_0 is the intercept;

b_1, b_2, ..., b_p are the coefficients of the independent variables X_1, X_2 and X_P.

2.9.5. Between the Variable of SDG 11.6.1 Indicator and Socio-Economic Variables

The fourth aims to determine whether the proportion of households that regularly collect and dispose of waste properly is linked to socio-economic factors. For the SDG 11.6.1 indicator, the dependent variable is household solid urban waste management, while the independent variables correspond to socio-economic characteristics. This model is estimated using a binary logistic regression, the formulation of which is presented in the following equation (15):

$$\log\left(\frac{P(Y_d = 1)}{P(Y_d = 0)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p \quad \textbf{(15)}$$

Where P (Y_d = 1) represents the probability that the household regularly collected and disposed of waste properly (SDG 11.6.1 indicator);

P (Y_d = 0) corresponds to the probability that the household did not regularly collect and dispose of waste properly;

b_0 is the intercept;

b_1, b_2, ..., b_p are the coefficients of the independent variables X_1, X_2 and X_P.

2.10. Correlation Matrix

A correlation matrix was developed as part of this research to measure the strength and direction of the relationship between SDG 11 variables and those of other Sustainable Development Goal (SDG)

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

indicators. The correlation matrix is a square matrix whose main diagonal consists solely of values equal to 1, representing the perfect correlation between a variable and itself. Each element located at the intersection of row i and column j corresponds to the correlation coefficient measuring the linear relationship between variables i and j [52, 53]. The result is presented in the form of a table grouping together all the correlation coefficients calculated between each pair of variables [53].

The variables selected for SDG 11 in the correlation matrix correspond to the indicators chosen for this research. Additionally, variables from other Sustainable Development Goals have been included, notably: SDG 1.2.1, SDG 1.2.2, SDG 1.4.1, SDG 1.4.2, SDG 4.3.1, SDG 5.1.1, SDG 6.1.1, SDG 8.3.1, SDG 9.c.1, SDG 10.2.1. These variables were selected because of their relevance to SDG 11 based on the literature, their local scope, their measurability, the availability of data, and their relevance to the specific urban issues facing Sarh Town.

The correlation matrix formula is as follows (16) [54]:

$$R = \begin{bmatrix} 1 & r_{12} & r_{13} & \dots & r_{1n} \\ r_{21} & 1 & r_{23} & \dots & r_{2n} \\ r_{31} & r_{32} & 1 & \dots & r_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & \dots & 1 \end{bmatrix} \quad (26)$$

Where r_{ij} is the correlation coefficient between variables i and j and R is the correlation matrix. The correlation coefficient is symmetric, i.e. the correlation coefficient r_{ji} [52].

2.11. Data Processing

For the processing and analysis of socio-economic data, Microsoft Office (Excel version 2019) was used to organize and format the data collected using a digital form developed on the Kobo Toolbox platform [31]. Subsequently, R-Studio 4.2.2 software was used in conjunction with specific packages to process the data in accordance with the research objectives. Binary logistic regression was used to model the relationship between SDG 11 indicators and several socio-economic variables. In addition, Pearson's correlation coefficient was used to estimate the strength and nature of the association between land use rates and population growth rates [2]. Finally, a correlation matrix was constructed to measure the intensity and direction of the link between SDG 11 variables and those of other Sustainable Development Goal (SDG) indicators.

3. Results

3.1. SDG 11 Indicators in Sarh Town

3.1.1. Socio-Economic Characteristics of the Heads of Households Surveyed

A total of 425 heads of households were interviewed during data collection, including 144 women (33.88%) and 281 men (66.12%). The majority of heads of households (70.82%) are over 40 years of age, of whom 65.41% are non-permanent residents. The level of education is heterogeneous in the study area: a significant proportion of heads of households have primary or secondary education (63.73%). In terms of employment, the private and informal sectors employ the majority of heads of households (75.53%). In terms of income, a majority (58.39%) earn less than 150,000 CFA francs. Additionally, access to essential services, particularly drinking water, electricity, and sanitation, is low, with 69.6% of households lacking access. The detailed socio-economic characteristics of the heads of households surveyed are presented in Table 4.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

Table 4.
Socioeconomic characteristics of household heads surveyed.

Variables	Terms and conditions	Staff numbers	Percentage (%)
Gender	Male	281	66.12
	Female	144	33.88
Age	Under 40	124	29.18
	40 years old and over	301	70.82
Residency status	Permanent resident	147	34.59
	Non-permanent resident	278	65.41
Level of education	Higher education	154	36.24
	Primary and secondary education	271	63.76
Occupation	Public sector	104	75.53
	Private sector	321	24.47
Income	Less than 150,000 CFA francs	247	58.39
	150,000 CFA francs and over	178	41.61
Essential services (drinking water, electricity and sanitation)	Access	129	30.40
	No access	296	69.60

3.1.2. Level of SDG 11 Indicators in the Sarh Town

Table 5 below highlights the SDG 11 indicators in Sarh selected for the research. First, 25.56% of the population lives in inadequate housing (SDG 11.1.1 indicator), while 74.35% live in adequate and affordable housing. Access to public transport is relatively low, with only 41.41% (SDG 11.2.1 indicator) having access, while 58.59% do not. The ratio of land consumption rate to population growth rate between 1994 and 2022 is 1.26 (SDG 11.3.1 indicator). Participation in urban planning (39.4%) is also low (SDG 11.3.2 indicator). A significant proportion (60.6%) of heads of households do not participate in urban planning and management in Sarh Town. Regarding urban solid waste management, only 27.05% of households surveyed regularly collect and dispose of waste properly (SDG 11.6.1 indicator). The majority of solid urban waste in Sarh Town (72.95%) ends up in informal dumps or is incinerated. The urban area devoted to public spaces represents 6.72% of the total urban area (SDG 11.7.1 indicator).

Table 5.
SDG 11 indicators based on data from Sarh Town.

SDG 11 indicators	Descriptions	Results
SDG 11.1.1.	Proportion of heads of households living in inadequate housing	25.65%
	Proportion of heads of households residing in adequate and affordable housing	74.35%
SDG 11.2.1	Proportion of heads of households with convenient access to public transport	41.41%
	Proportion of heads of households without convenient access to public transport	58.59%
SDG 11.3.1	Ratio of land consumption rate to population growth rate	1.26
SDG 11.3.2	Proportion of the population involved in urban planning and management	39.40%
	Proportion of the population involved in urban planning and management	60.60%
SDG 11.6.1	Proportion of solid urban waste regularly collected and disposed of properly	27.05%
	Proportion of solid urban waste that ends up in informal dumps or is incinerated	72.95%
SDG 11.7.1	Average proportion of urban built-up area devoted to public spaces	6.72%

Table 6 below shows the discrepancies observed between the sustainability indicators in Sarh Town and their reference values. It appears that the majority of these indicators show significant negative deviations, revealing major shortcomings in the implementation of urban policies. The SDG 11.1.1 indicator shows a deviation of -15.65%, highlighting the fact that a significant proportion of the population lives in inadequate housing conditions. Deviations in the SDG 11.2.1 indicator (-33.59%) and SDG 11.6.1 indicator (-47.95%) highlight significant deficits in the provision of affordable public transport services and access to urban solid waste management services, respectively. SDG 11.3.2, with a deviation of -35.6%, reflects low public participation in urban planning and management. Finally, SDG 11.7.1 shows a deviation of -28.28%, highlighting a critical shortage of accessible open spaces within the town.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

Table 6.
Deviations from SDG 11 indicators in Sarh Town.

SDG 11 indicators	Reference value	Current value	Degree of deviation
SDG 11.1.1: proportion of urban population living in inadequate housing	10%	25.65%	-15.65%
SDG 11.2.1: proportion of population with convenient access to public transport	75%	41.41%	-33.59%
SDG 11.3.1: ratio of land consumption rate to population growth rate	1	1.26	-0.26
SDG 11.3.2: proportion of heads of households who have participated in urban planning and management	75%	39.40%	-35.60%
SDG 11.6.1 proportion of municipal solid waste that is regularly collected and properly disposed of out of the total municipal solid waste generated	75%	27.05%	-47.95%
SDG 11.7.1: average proportion of urban built-up area devoted to public spaces	35%	6.72%	-28.28%

3.2. Analysis of the Relationships between SDG 11 Indicators and Socio-Economic Factors

3.2.1. SDG 11.1.1 Indicator

The logistic regression model reveals that the proportion of heads of households living in inadequate housing in Sarh Town (SDG 11.1.1 indicator) is significantly associated with their income ($p = 0.001$). Household heads with an income above 150,000 CFA francs are four times more likely (odds ratio = 4.8) to have access to adequate housing than low-income households. On the other hand, gender, age, residence status, occupation, and level of education have no influence on access to adequate and affordable housing in Sarh Town. Table 7 below presents the detailed results of the relationship between the type of housing and socio-economic variables.

Table 7.
Relationship between type of housing and socioeconomic variables.

	Coefficients (b)	p-value	Odds ratio
Intercept	0.332	0.562	1.395
Gender	- 0.342	0.348	0.709
Age	0.100	0.798	1.105
Residency status	- 0.032	0.933	0.968
Income	1.569	0.001 **	4.805
Occupation	1.067	0.120	2.906
Level of education	0.583	0.213	1.791
Significance codes	0 '***'	0.001 '**'	0.01 '*'

3.2.2. SDG 11.2.1 Indicator

The results of our analyses (table 8) indicate that the proportion of heads of household with access to affordable public transport in Sarh Town (SDG 11.2.1 indicator) is associated with their income ($p = 0.0008$) and their occupation ($p = 0.038$). Household heads with above-average income (150,000 CFA francs) have greater access to affordable public transport. In terms of occupation, household heads who are civil servants have greater access to affordable public transport than those who work in the private and informal sectors.

Table 8.
Relationship between affordable public transport and socio-economic variables

	Coefficients (b)	p-value	Odds ratio
Intercept	- 2.153	0.001 ***	0.116
Gender	0.668	0.064	1.950
Age	0.529	0.178	1.698
Residency status	0.588	0.132	1.801
Income	2.596	0.0008***	13.41
Occupation	1.262	0.038 *	3.53
Level of education	0.404	0.369	1.498
Significance codes	0 '***'	0.001**	0.01 '*'

3.2.3. SDG 11.3.1 Indicator

The results of the simple linear regression model between land use and population growth reveal a strong positive correlation (r = 0.99) that is statistically significant (p = 0.005) between land use and population growth in Sarh Town between 1994 and 2022 (Table 9).

Table 9.
Correlation between land use rate and population growth rate.

Type of correlation	Correlation coefficients (r)	Coefficients of determination (R^2)	Ratios (LU/PG)	P-value
Land use (LU) and population growth (PG)	0.99	0.98	1.26	0.005**
Significance codes	0 '***'	0.001 '**'	0.01 '*'	0.05 '.'

3.2.4. SDG 11.3.2 Indicator

Analyses reveal that household participation in urban planning and management is associated with age (p = 0.004) and residence status (p = 0.013). People over the age of 40 are more involved in the urban planning and management process. This indicates that, as people age, they become more aware of the need to get involved in urban planning and management. Residency status also has a significant influence on participation in the urban planning process. Ordinary residents are more involved in urban planning than displaced persons, refugees, and returnees. Table 10 below presents the detailed results between participation in urban management and socio-economic variables.

Table 10.
Relationship between citizen participation in urban planning and socio-economic variables.

	Coefficients (b)	p-value	Odds ratio
Intercept	-19.73	0.990	0
Gender	0.009	0.992	1.008
Age	4.257	0.004 **	70.591
Residence status	-1.997	0.013 *	0.135
Income	1.410	0.301	40.97
Occupations	-1.964	0.183	0.140
Education levels	-0.131	0.896	0.876
Significance codes	0 '***'	0.001 '**'	0.01 '*'

3.2.5. SDG 11.6.1 Indicator

The logistic regression model indicates that the proportion of municipal solid waste regularly collected and disposed of appropriately (SDG 11.6.1 indicator) is significantly associated with access to essential services, particularly municipal solid waste collection services in Sarh Town (p = 0.00003). On the other hand, gender, age, residence status, occupation, income, and education level have no influence on the urban solid waste management system in Sarh Town. Table 11 below presents the detailed results between the urban solid waste management system and socio-economic variables.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

Table 11.
Relationship between the urban solid waste management system and socio-economic variables

	Coefficient (b)	p-value	Odds ratio
Intercept	-1.555	0.003*	0.211
Gender	0.3939	0.276	1.482
Age	- 0.483	0.203	0.617
Residence status	0.6377	0.070	1.892
Income	0.2188	0.572	1.244
Occupations	- 0.1883	0.678	0.828
Education levels	0.7219	0.073	2.058
Types of housing	- 0.5817	0.137	0.558
Basic services	1.4220	0.00003***	4.145
Significance codes	0 '***'	0.001 '**'	0.01 '*'

3.2.6. Correlation between SDG 11 indicators and other SDG indicators

The results from the correlation matrix reveal correlations between the variables of SDG 11 indicators and those corresponding to certain Sustainable Development Goals (SDGs). There is a strong positive correlation (r = 0.71) between the proportion of heads of households with access to affordable public transport (SDG 11.2.1) and SDG 1.2.2 and SDG 10.2.1 relating to household income. This indicates that as household income increases, the proportion of people with access to affordable public transport also increases significantly. Similarly, the proportion of households with regular and adequate solid urban waste collection and disposal (SDG 11.6.1) shows a strong positive correlation (r = 0.58) with SDG 1.4.1 and SDG 6.1.1 relating to the proportion of people living in households with access to basic services. This result suggests that as the proportion of people with access to basic services increases, the proportion of municipal solid waste collected and disposed of properly is also likely to increase. The correlations between SDG 11.2.1 and SDG 5.1.1 (r = 0.46) and SDG 1.2.1 (r = 0.40) are also positive and weak.

On the other hand, a moderate negative correlation (r = -0.28) is observed between the variable for SDG 11.3.2 (proportion of household heads who participated in urban planning and management in Sarh Town) and that for SDG 9.c (proportion of the population with access to a mobile network, by type of technology). This indicates that the less access households have to a mobile network, the less likely they are to be informed and, consequently, the less they participate in urban planning and management.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

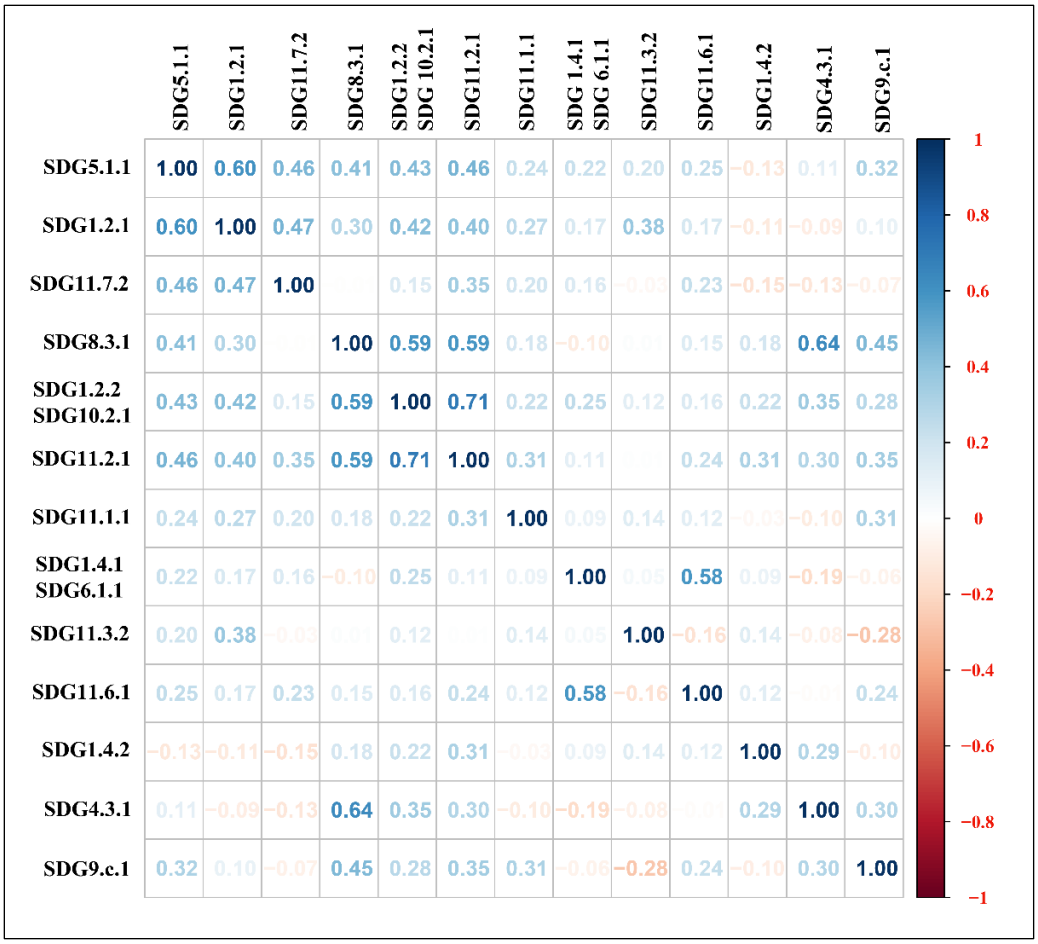

Figure 2.
Correlation between SDG 11 indicators and those of other SDGs.

4. Obstacles to Urban Development in Sarh

The results of surveys conducted among household heads (Figure 3) indicate five obstacles hindering the development of Sarh Town.

Weak governance (47.30%) was identified as the main obstacle to the development of Sarh Town. Indeed, town councillors do not actively seek out residents' grievances to guide the design of projects that meet their needs. The lack of qualified staff at the town hall is a major obstacle for the municipality. A significant portion of the meager municipal revenue is absorbed by overcharging for purchase orders and expenditure on the governorate, security services, and the supervisory authority, which limits the resources available for projects. Another challenge is the difficulty of collaboration between municipalities and decentralized state services, which encroach on the powers of local elected officials in terms of urban space management and tax collection. The lack of commitment on the part of the population and local authorities to the common good hinders the management of local affairs, particularly with regard to the non-payment of the annual subsidy to municipalities. Finally, the laws establishing the fundamental principles applicable to urban planning do not take into account the realities on the ground and the social context of the population.

Urban poverty (15.06%) is the second obstacle to the development of Sarh Town. Insufficient resources (material, human, and financial) and a lack of monitoring compromise the effectiveness of urban planning initiatives. In fact, most of the planned urban development guidelines and projects (basic

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

infrastructure and services) have not been implemented due to limited financial capacity. Added to this are the low levels of public participation in the urban planning and management process (13.41%), inadequate infrastructure and basic services (12.23%), and the lack of cohabitation (12%).

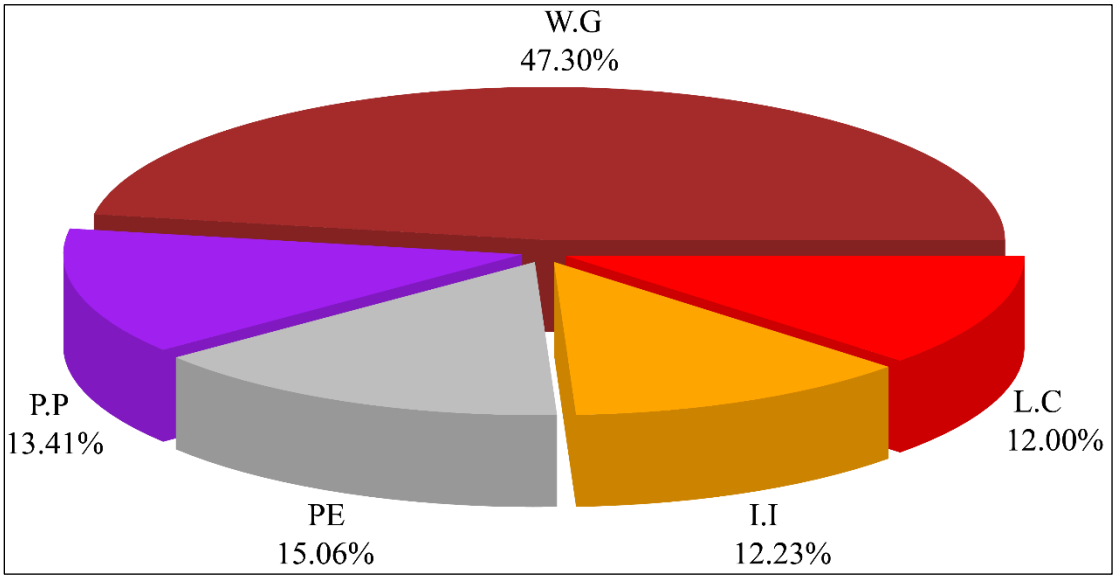

Figure 3.
Households' perceptions of factors hindering the implementation of SDG 11 in Sarh. WG: weak governance; PE: poverty; P.P: low citizen participation in urban management; I.I: inadequate infrastructure; L.C: lack of cohabitation.

5. Discussion

5.1. Socio-Economic Characteristics of Households Surveyed: Negative Discrimination in Public Transport Towards Low-Income Populations

Data collected from households reveals a predominantly male and relatively elderly group, highlighting a challenge in terms of young people's participation in urban life. The majority of respondents have a moderate level of education and are mainly employed in the private sector. This suggests both potential for development through training and a certain dependence on the private sector. Most of those surveyed in the study area have below-average incomes, indicating a low level of income. A study conducted by Smith, et al. [54] on the London metropolitan area, data showed that low-income groups have limited access to the most affordable modes of transport, such as buses and walking. In Sarh Town, this poor accessibility to essential services clearly illustrates the economic precariousness that prevails there. The work of Allen and Farber [55] highlighted the negative discrimination of a public transport network towards many low-income households that are poorly served, making it difficult for them to travel to key destinations. Similarly, Nicoletti, et al. [56] pointed out that low-income and minority communities have significantly restricted access to urban infrastructure.

5.2. SDG 11 Indicators in Sarh Town

The results obtained in this research highlight several major issues related to housing, land management, citizen participation, urban infrastructure, and waste management.

The proportion of heads of households living in inadequate housing (SDG 11.2.1 indicator) reveals a problem of access to adequate and affordable housing in Sarh Town, which could impact the quality of life of its inhabitants. Low-income households are particularly disadvantaged, with much more limited access to suitable housing than those in the middle- or high-income categories. This finding is

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

consistent with the conclusions of Menberu [57] who emphasizes that income is essential to ensuring the accessibility and economic sustainability of housing. Similarly, Serrano Lanzarote and Subirón Rodrigo [58] observed that low-income households spend a disproportionate share of their resources on rent, which increases their vulnerability. Furthermore, Wang, et al. [59] demonstrated that income determines access to urban resources and contributes to social isolation in affordable housing.

The proportion of heads of household with convenient access to public transport (SDG 11.2.1 indicator) is also relatively low, which can hinder access to essential services. In Sarh Town, access to public transport is strongly correlated with the income level and occupation of heads of household. Low-income households have significantly less access to the public transport system than those in the middle- and high-income categories. This finding is consistent with the work of Allen and Farber [55] who demonstrated that many low-income households are disadvantaged by public transport services that are insufficiently adapted to their needs, preventing them from efficiently reaching key destinations. Similarly, Smith, et al. [54] found that in 2011, low-income groups in the London metropolitan area had reduced access to the most affordable modes of transport, particularly buses..

The ratio between land consumption and population growth (SDG 11.3.1 indicator) exceeded reasonable standards, indicating inefficient land use [60]. The result of the simple linear regression model revealed a strong positive correlation between land consumption and population growth. This result corroborates that of Hakim, et al. [61] who reported a similar strong positive correlation in the Singkarak Lake watershed in West Sumatra (Indonesia), where the rate of urban land expansion is attributable to population growth. This rapid expansion has exacerbated disparities in access to adequate housing, basic infrastructure, and services. The finding is consistent with the conclusions of Teadoum Naringué, et al. [2] who highlighted an imbalance in the distribution of basic infrastructure and facilities between the peripheral and central neighbourhoods of Sarh Town. According to Azmi [62] a compact city will be more functional because basic activities and services will be closer to the population, making travel and the provision of urban infrastructure less costly. Wellmann, et al. [63] consider a compact city to be a sustainable urban form.

The low proportion of heads of households who participated in urban planning and management in Sarh Town (SDG 11.3.2 indicator) highlights significant room for improvement in strengthening citizen engagement in urban planning and management. This participation is influenced by factors such as age and residence status. The higher participation of older people compared to young people reveals a low level of youth involvement in the planning process. Vega-Tinoco, et al. [64] have shown that civic participation contributes to the well-being of older people, with differences according to age and gender. Residency status also determines low inclusion in the urban planning process. Citizen participation is essential to ensure that the interests of the population are taken into account in urban plans. Citizen participation formats are essential at every stage of the development of local sustainable development strategies [65].

The results also indicate poor access by households to adequate final disposal, as shown by the performance of SDG 11.6.1. This situation constitutes a major environmental and health issue. Mor and Ravindra [66] have demonstrated that inadequate waste management leads to air, soil and water pollution and health problems. Similarly, Yang, et al. [67] and Zhang, et al. [68] have highlighted the impacts of inadequate waste management on the environment and public health. Furthermore, the urban area dedicated to public spaces (SDG 11.7.1) remains insufficient, which can adversely affect the quality of life and well-being of residents. Knight, et al. [69] emphasize that the ecological quality of public natural spaces plays an essential role in the well-being of residents. Akshay [70] adds that urban green spaces provide social, economic, and environmental benefits, contributing to an improved quality of life.

5.3. Correlation between SDG 11 Indicators and other SDG Indicators

The results from the correlation matrix reveal relationships between indicators for Sustainable Development Goal 11 and those for other goals.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

The variables of SDG 11.3.2 indicator and SDG 11.6.1 indicator are correlated with the variables of SDG 1.2.1, SDG 1.2.2, and SDG 1.4.1, indicating a synergistic relationship between SDG 11 and SDG 1. This result corroborates that of Fonseca, et al. [14] who showed that poverty eradication (SDG 1) has a synergistic relationship with most other goals. The variables of SDG 11.3.2 indicator are correlated with the variables of SDG indicators 8.3.1 and 10.2.1, which also indicate that SDG 11 has a synergistic relationship with SDGs 8 and 10. Fonseca, et al. [14] confirmed that decent work and economic growth (SDG 8) are related to SDG 7. However, there is a negative correlation between the variables of SDG 11.2.1 and those of SDG 1.2.1, highlighting a negative influence between the level of poverty of populations (SDG 1) and the possibility of access to affordable and sustainable transport (SDG 11).

5.4. Obstacles to Urban Development in Sarh

Five factors have been identified as obstacles to urban development in Sarh, namely weak governance, urban poverty, low citizen participation, inadequate infrastructure, and social conflicts related to cohabitation. Weak governance is the most important factor influencing urban development in Sarh Town. This finding is consistent with the conclusions of Rasoolimanesh, et al. [71] who demonstrated that poor governance has a negative impact on the components of sustainable urban development, social development, and inclusion. Similarly, Cheema [72] emphasized that local urban governance can promote access to services, participation in decision-making, accountability, and transparency, thereby reducing poverty and urban inequalities. The result obtained is also consistent with the conclusion of Baud, et al. [73] that urban governance configurations guide decision-making and urban development outcomes, with diverse knowledge and networks shaping urban development processes and sustainable transitions.

Secondly, urban poverty, identified as an obstacle to urban development, is consistent with the findings of Akpaki, et al. [74] who highlighted the close link between urban poverty and access to livelihoods and employment and, consequently, to the quality of life achievable in cities. However, although perceptions of the obstacles to development in Sarh Town are consistent with statistical analyses based on empirical data, they contradict the study conducted by the African Development Bank. The latter found that urbanisation contributes to poverty reduction through improved income, improved education levels, and improved life expectancy at birth [74]. This contributes to the achievement of certain sustainable development goals.

The low level of citizen participation in urban planning and management highlights a major challenge in raising awareness and involvement in the urban planning process. This observation is consistent with the conclusions of Matamanda and Chinozvina [75] and Salamah [76] who emphasised that citizen engagement is an essential lever for promoting inclusive, sustainable, and resilient urban development. Similarly, Alamoudi, et al. [77] have demonstrated that citizen participation in urban planning and decision-making is crucial for the development of smart cities.

Furthermore, the inadequacy of infrastructure as an obstacle to urban development confirms the hypothesis of Collier and Venables [78] that investment in urban infrastructure is essential for urban growth, promoting density and coordination of private investment decisions, but often fails due to inadequate financing tools and fragmented urban authority.

6. Conclusion

The objective of this research is to inform the scientific community about progress made towards Sustainable Development Goal 11 (sustainable cities and communities) in secondary towns in sub-Saharan Africa, with a view to guiding urban development policies towards more informed decision-making. By adopting a methodology tailored to the specific context of Sarh, this research contributes to a better understanding of urban dynamics in the African context, which is often underrepresented in the literature on SDGs. It also offers an original approach to the selection and evaluation of indicators, emphasizing their local relevance, measurability, and reliability.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

The results obtained indicate that the majority of indicators relating to SDG 11 in Sarh Town show significant negative deviations, revealing major shortcomings in the implementation of urban policies. The performance of these indicators is statistically correlated with several socio-economic variables, including income level, occupation, age, and residential status. Analysis of the correlation matrix highlights synergistic interactions between the indicators for SDG 1 (no poverty), SDG 6 (clean water and sanitation), SDG 8 (decent work and economic growth), and SDG 9 (industry, innovation, and infrastructure), in relation to those for SDG 11. In addition, five major obstacles to urban development in Sarh Town have been identified: weak local governance, persistent urban poverty, low citizen involvement in urban planning and management processes, inadequate basic infrastructure, and recurring social tensions.

To promote sustainable urban development, it is recommended that clear and effective land policies be put in place, affordable housing programmes be developed, urban solid waste management be improved, and the restoration of green spaces be promoted. Urban transport systems and citizen participation in decision-making should also be improved, and a detailed understanding of land occupation and use should be developed. With this in mind, local authorities must be equipped with effective tools for continuously updating spatial data in order to better manage the rapid expansion of urban areas. Finally, strengthening urban governance is recommended in order to promote the effective implementation of the Sustainable Development Goals (SDGs) as a whole, and in particular SDG 11, which relates to sustainable cities and communities.

This study opens up several avenues for future research. First, a comparative study between several African cities could identify common levers and local specificities in the implementation of SDG 11. Second, the integration of participatory approaches and new data collection methods, such as digital technologies or geographic information systems, could further enrich our understanding of urban dynamics. Finally, further analysis of the interactions between urbanization, climate change, and social issues would be an essential step in strengthening the sustainability of African cities in the face of future challenges.

Funding:

This research is funded by the World Bank through the Regional Center of Excellence on Sustainable Cities in Africa at the University of Lome (CERViDA-DOUNEDON). The funding numbers are 6512-TG and 5360-TG.

Institutional Review Board Statement:

This study was conducted in accordance with the ethical principles established by the Declaration of Helsinki and international guidelines for research involving human participants. In the absence of a local ethics committee in Chad, the authors took all necessary measures to ensure respect for the rights, privacy, and safety of participants.

All participants were informed of the study objectives, methods used, and implications of their participation. Informed consent was obtained prior to their inclusion in the study. The data collected were treated confidentially and anonymized to protect their privacy.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 10: 854-877, 2025
DOI: 10.55214/2576-8484.v9i10.10556

Acknowledgments:

We thank CERVIDA-DOUNEDON, the Association of African Universities (AAU) and the World Bank for funding our research. We would also like to thank the municipal authorities of the Sarh Town for their cooperation and authorisation, which made it possible to conduct field surveys in this locality. Our sincere thanks go to our colleagues Vidjinnagni Vinasse Ametooyona Azagoun, Altolnan Parfait Tombar, Abdelkerim Ramadan and Djétabedmbaye Davy for their support.

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