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Using Logistic Regression to Predict Access to Essential Services: Electricity and Internet in Nouakchott, Mauritania

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Abstract: This study employs a logistic regression model to offer an in-depth understanding of disparities in the access to essential urban services, specifically focusing on electricity and Internet services, in Nouakchott, Mauritania. Through a comprehensive analysis of demographic, geographic, and socioeconomic data, we identify key determinants of access to these utilities. Our findings reveal that the geographic location within the city, particularly in the western regions, and home ownership, significantly bolster the likelihood of having electricity. Conversely, women are found to be disadvantaged in this regard. For Internet access, income level and education, particularly at the Bachelor's level, emerged as significant predictors. This research not only sheds light on the intricate landscape of service provision in Nouakchott but also offers actionable insights for equitable development. These results empower both policymakers and citizens, marking a step toward transforming Nouakchott into a smarter, more inclusive urban environment.

Keywords: urban services; electricity access; internet access; logistic regression; Nouakchott; Mauritania; West Africa

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Citation: Ebnou Abdem, S.A.; Chenal, J.; Diop, E.B.; Azmi, R.; Adraoui, M.; Tekouabou Koumetio, C.S. Using Logistic Regression to Predict Access to Essential Services: Electricity and Internet in Nouakchott, Mauritania. *Sustainability* **2023**, *15*, 16197. https://doi.org/10.3390/su152316197

Academic Editors: Keti Lelo, Salvatore Monni and Federico Tomassi

Received: 25 September 2023
Revised: 21 October 2023
Accepted: 2 November 2023
Published: 22 November 2023

1. Introduction

Access to essential urban services, such as electricity and the Internet, is pivotal for the economic and social development of cities worldwide [1]. In the context of Mauritania, a West African nation situated in the Sahel region, this significance is further amplified. The country experiences a semi-arid climate with high temperatures throughout the year, and it is estimated to have a population of 4.7 million people, with around (27%) residing in urban areas [2–4].

Nouakchott, the capital of Mauritania, is a city located along the Atlantic coast and adjacent to the Senegal River. Established in 1960, Nouakchott has witnessed rapid growth in recent decades, with an estimated population of 1.7 million in 2022 [2,3,5–7]. However, this growth has brought about various challenges, including increased poverty, unemployment, and social inequality. Additionally, it has exacerbated issues related to access to urban services, particularly electricity and the Internet [1,6,8–19].

The significance of these services cannot be overstated. The Internet has been a catalyst for progress in communication, information exchange, goods and services, and technology since its groundbreaking inception in the late 1960s. It is a cornerstone of the emergence of smart cities, a pivotal development in human history that has ushered in a global wave of innovations, advancing not only in developed nations but also in developing ones [16–18,20,21].

In addition, the Internet is an indispensable element that guarantees access to quality education, optimal health, economic prosperity, and social cohesion. Furthermore, it is also an essential tool in the service of smart cities. It fosters connectivity among citizens, public services, and businesses and facilitates citizen engagement through crowdsourcing [22–25]. Smart cities also rely on the Internet of Things (IoT) to ensure the safety, waste management, mobility, and well-being of their residents [20,21,23–25].

Electricity, essential for modern urban living, powers homes, businesses, and the wider economy [1,12,13,20,21,23,24,26]. However, in Nouakchott, access to such vital services is not only uneven across different regions of the city but is also marred by frequent outages and unreliability [4,6,17,18,26–33].

Access to electricity in Mauritania, particularly in Nouakchott, is marred by a web of interconnected challenges. The city frequently grapples with power outages, even within its central districts, underscoring significant inadequacies within the electricity infrastructure [4,17,18,28–33].

Mauritania is ranked as one of the least-performing countries in terms of access to electricity among the top-performing nations in Africa, according to Regulatory Indicators for Sustainable Energy [17].

From an economic perspective, the high cost of electricity presents a formidable obstacle. Despite not being classified among the countries with the highest electricity costs in the sub-Saharan region, electricity expenses can reach (134) euros per month for modest consumption [1,17,18,31,33]. With an unemployment rate exceeding (13%) [3,6], these costs become financially burdensome for households, especially those with limited incomes [17,18,28–30,33].

In recent years, Mauritania has witnessed a remarkable increase in small and medium-sized enterprises, with a growth rate of (83%) and (16%), respectively, in the industrial structure [18]. These enterprises, primarily located in Nouakchott and Nouadhibou, often lack electricity sources, further increasing the demand for electricity [17,18]. The percentage of firms reporting that electricity is the most significant obstacle facing businesses exceeds (14%) [4,17,28,33].

The high demand for electricity encounters significant challenges within the energy infrastructure [1,18,28–30,33]. With only (27) power plants and a total installed capacity of (236.793 MW), Mauritania's electricity-generating capacity lags behind other West African countries [18,26]. The quality of the electricity supply remains insufficient and of subpar quality [18,26], with a predicted decrease in the growth rate of (−0.10) using the IK1 index of aggregate infrastructure stocks [18]. Additionally, the predominance of oil-based generation technology leads to high operational costs, ultimately affecting the price of electricity for consumers. The absence of high-power plants hinders the capacity to provide significant electricity quantities promptly, leading to potential shortages during peak demand [18,28–30,33]. Moreover, the relatively modest average plant dimension of (8.77) limits operational efficiency and the ability to meet the increasing demand [17,18,26,28–30,33].

This increasing demand for electricity, driven by demographic growth and urbanization, faces issues of inadequacy and high installation costs. Total energy consumption exceeds national energy production by approximately (35%), and electricity demand is increasing at a rate of (10%) per year, primarily due to rising industrial and domestic demand [28–30]. In a high-growth scenario for the electricity sector, grid-connected demand (excluding mining activities) is projected to increase by (450%) between 2010 and 2030 [28–30].

This situation has also contributed to electricity theft, primarily in informally urbanized areas, which poses further challenges to the state-owned Mauritanian Electricity Company (SOMELEC) despite governmental efforts [4,28–30,33].

Briefly, Nouakchott's struggle with electricity access is characterized by a multitude of challenges encompassing economic, technical, and infrastructural issues [4,17,18,28–30,32–35].

Understanding that Nouakchott's challenges are not isolated is crucial, as electricity and Internet access pose a persistent concern across the African continent [1,16–19,26,34–43]. With the world's lowest household electrification rate at just (26%), over (560) million people on the continent lack access to electricity [37], further compounded by the fact that more than (650) million individuals rely on low-quality biomass energy sources. African households and enterprises allocate an annual budget of over (17) billion for lighting systems reliant on traditional fuels, often marked by subpar quality, frequent outages, and safety risks [1,37]. Notably, the demand for electricity in Africa is high, and the cost remains exorbitant, increasing with GDP but with diminishing returns [1]. Key challenges include the reliance on conventional energy technologies, which hinder the resolution of energy poverty, the lack of innovation in the energy sector, limited scalability of solutions, and the need for sustainability assessments in energy access innovations [34,35,37,41]. Comprehensive frameworks are crucial to guide the efforts of energy policymakers, entrepreneurs, and researchers [16]. The underdeveloped electrical grid in Africa, with significant parts of the continent lacking access, exacerbates the issue. Even in countries with relatively extensive grid coverage, disparities in access persist [1,34,35,41]. Research has shown a strong positive correlation between residential electricity consumption and GDP per capita in African countries, highlighting the negative effects of electricity scarcity [1]. Further complicating the issue, some areas in Africa, such as the central region, are predicted to remain excluded from electricity access until 2050 [1,34,35,41].

In Sub-Saharan Africa (SSA), the challenges of electricity access are substantial [17,18,41,44,45]. Nearly (70%) of the population, approximately (621) million people, lives without access to electricity. Despite some ambitious projects, such as the stalled (3.5) to (4.8 GW) power plants, these hurdles impede the development of critical energy infrastructure and contribute to the stagnation of electricity markets, hindering progress in alleviating energy poverty and reducing regional disparities [17,41,45].

Furthermore, many SSA countries struggle to meet previous energy access goals due to several barriers. More than (30) SSA countries grapple with chronic energy generation shortages, and the electricity grid infrastructure is in dire need of renovation. Regional energy plans often prioritize investments in grid extension as the primary means of providing energy [17,18,41,44]. However, in many rural areas, the absence of an electricity grid, low population density, and minimal per capita consumption make grid extension a prohibitively expensive option [17,18,41]. Electricity consumption in these communities is likely to remain low, making it unlikely that the cost of grid extension can be justified. Significant capacity constraints further hinder the substantial expansion of access via grid extension. Another major obstacle in most SSA countries is the weakness in their implementation capacity, which necessitates new or amended legislation, institutional strengthening, planning, and the establishment of technical standards and regulatory procedures [17,41,44,45]. Moreover, a significant portion of installed capacity in SSA remains inoperable due to a lack of maintenance, and transmission and distribution losses, averaging (18%) (excluding South Africa), are more than double the global average, adding significant costs to already high electricity tariffs. Electricity consumption per capita has remained almost unchanged since 2000, remaining (75%) lower than in Asia, with average residential electricity consumption at (317) kWh (only (225) kWh if South Africa is excluded), approximately half that of China and one-fifth of Europe [18]. Access to electricity varies significantly across the continent, ranging from a minimum of (3%) in Chad to a maximum of (85%) in South Africa, with urban tariffs consistently higher than rural tariffs [18]. While overall access in the region increased from (23%) in 2000 to (32%) in 2012, with (145) million people connected to the grid, the growth in population has outpaced electrification rates, leaving an additional (100) million people without electricity access [13,17,18,44].

These challenges of limited access to electricity and the Internet have had a direct negative impact on the development of SSA countries across various aspects of life. High costs associated with electricity access impose a significant financial burden on low-income households, exacerbating economic inequalities by limiting their access to improved income sources, education, and employment opportunities [13,17,18,41,44,45].

Moreover, insufficient access to electricity adversely affects crucial services. Health facilities lacking electricity struggle to provide quality medical services, including medication storage and the operation of essential medical equipment. The absence of electricity in schools and homes impedes students' access to adequate lighting, educational technology, and information, hindering their educational progress [41].

Furthermore, the absence of reliable electricity has hindered industrial development and the growth of small businesses, especially in rural areas, due to high costs and infrastructure limitations. Consequently, this restricts economic growth and job opportunities across the region [18,35,41,44–46].

The substantial impact of energy policies on the economy and environment in SSA is evident [35]. Access to electricity is essential for economic and social development. The combination of high electricity prices, inefficient energy systems, and inadequate infrastructure has collectively contributed to limited access in many African countries [13,18,35,44–46].

In contrast, enhanced access to electricity has had positive effects on household welfare, resulting in a slight increase in total household income and a reduction in poverty incidence [13,18,44–46]. Access to electricity has led to an increased allocation of time for paid work and leisure, thus benefiting households. In terms of business outcomes, the impact of electricity access is mixed, with some improvements in business performance, primarily in the agricultural sector [46]. Additionally, electricity access has positively influenced female empowerment within households, especially in terms of family planning, family care, and economic management [46]. Access to electricity has also demonstrated significant positive effects on health outcomes by promoting the use of contraception, reducing fertility rates, enhancing access to health information, and improving overall health results, such as increased life expectancy and reduced mortality rates [18,35,44–46]. See Figure 1 below.

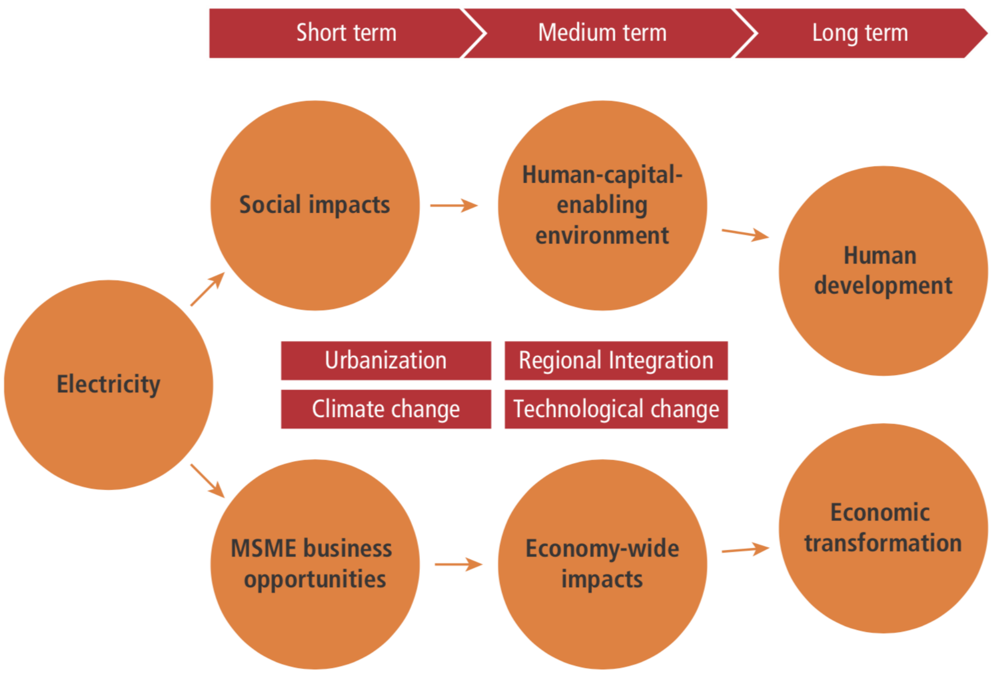

Figure 1. Long, Medium, and Short-Term Positive Impacts of Access to Electricity [17].

Addressing the challenges of limited access to electricity and the Internet is crucial for fostering economic growth and development, improving living standards, and reducing inequalities in SSA countries. To achieve this, numerous studies have been conducted in SSA countries to identify the determinants of access to these essential services.

A study by [13] has demonstrated a significant positive relationship between income levels and access to electricity in Angola, Burkina Faso, Burundi, Cape Verde, the Central

African Republic, Comoros, Ethiopia, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Namibia, Niger, Nigeria, Senegal, Sierra Leone, Sudan, The Gambia, and Zimbabwe. In contrast, there is a significant negative relationship in Benin, Botswana, Cameroon, Chad, Congo, Côte d'Ivoire, Ghana, Mozambique, Rwanda, South Africa, Eswatini, Tanzania, Togo, and Uganda.

Moreover, a study by [40] in South Africa has indicated that household income, larger household sizes, and electricity prices are major determinants of electricity demand and that a policy of providing free basic electricity access is associated with an increased likelihood of households purchasing electricity and reduced total electricity expenses.

In South Africa, a study by [42] has highlighted the importance of electricity access. It has a positive impact on women as it significantly increases female employment. It also contributes to employment by freeing women from domestic production and by promoting microenterprises.

In Nigeria, studies have shown that the level of education is a significant factor in both electricity access and household energy expenditures. Furthermore, the income of the household head, the availability of various energy options, reliability, and affordability are the key determinants of household energy needs [47].

In Mali, the journey to attain reliable electricity access is marked by formidable challenges, underscored by stark figures. The financial landscape of the sector hangs in the balance due to modest tariff adjustments. Over the period from 2004 to 2012, a mere (3%) tariff increment in 2009 failed to keep pace with mounting operational expenses. Consequently, the national utility company finds itself in the throes of a financial predicament. In 2013, the government, in a bid to alleviate the situation, temporarily bolstered subsidies with an infusion of (120) dollars, enabling the company to settle its outstanding debts [33].

In Algeria, Ref. [48] emphasized the significance of household size, housing space, density, room occupancy, and older households in terms of electricity access and the reduction in electricity and gas consumption. On the other hand, an increase in the level of education and ownership of appliances stimulates per capita gas and electricity consumption.

In 2022, as per the findings of [25], it has become evident in West Africa that low household consumption levels and the cost of mobile services stand out as two pivotal obstacles to Internet access. Moreover, factors like gender, age, educational attainment, and geographical location play indispensable roles in shaping the landscape of Internet access.

While many studies have been conducted in African countries to investigate the determinants of electricity and Internet access, each city possesses its own unique challenges.

Nouakchott, shaped by its socio-economic, geographic, and cultural context, exhibits distinctive characteristics. Alarmingly, approximately (85.1%) of households in Nouakchott lack access to the Internet, as revealed by [6]. Furthermore, access to electricity in Mauritania as a whole is limited, with only (33.47%) of the population having access, as reported by [36]. Notably, (14%) of firms consider electricity to be the most significant obstacle to business operations. In addition, the accessibility of electricity and Internet services in Nouakchott is not only unevenly distributed across regions and genders, as noted by [37], but is also marred by frequent outages and unreliability. These statistics underscore the pressing need to devise and implement strategies to enhance household access to electricity and Internet services within the city, as advocated by [37].

The true challenge lies in conducting a thorough, in-depth, and innovative analysis to gather relevant statistics, present clear visual representations, provide an intuitive understanding of the underlying reasons for these disparities, and identify the key factors influencing access to these services. This endeavor is of the utmost importance as it can help inform targeted interventions and policies aimed at bridging the gap and ensuring equitable access to electricity and Internet services in Nouakchott.

This paper endeavors to tackle this challenge through the meticulous application of a logistic regression model, aiming to pinpoint the key determinants influencing access to both electricity and the Internet in Nouakchott. Additionally, it bridges a significant gap in existing research by conducting an extensive analysis of urban services in Mauritania, with a primary focus on Nouakchott. This unique approach delves into the intricate interplay between service access and household economic, social, and geographical backgrounds. By shedding light on the multifaceted service provision landscape in Nouakchott, our research furnishes actionable insights that are invaluable to policymakers and stakeholders dedicated to fostering equitable development within the region.

The manuscript is organized as follows: Section 2 introduces Nouakchott City, elaborates on data sources and data processing techniques, and outlines the proposed model. Section 3 discusses the main findings, including the identification of crucial factors influencing access to essential services and an evaluation of the predictive model's performance. Finally, Section 4 summarizes the study's key takeaways, discusses their implications for urban development, and offers directions for future research.

2. Methodology

In this section, we introduce Nouakchott City, detail our data sources and processing techniques, and outline the proposed model.

2.1. Study Area

Mauritania is a country situated in the Sahel and is considered part of the broader Maghreb region in West Africa. It ranks eleventh in Africa and twenty-ninth globally in terms of land area, covering approximately 1,030,000 square kilometers. Notably, nearly (90%) of this landmass consists of desert regions [2,4,6,11,12,49]. The country is bordered by the Atlantic Ocean to the west, Senegal to the south, Mali to the east and southeast, and Algeria to the north. Holding a strategic position in West Africa with access to the Atlantic Ocean, Mauritania serves as a crucial transit point for trade and is rich in natural resources, including significant reserves of iron, copper, oil, and gas [2,4,6,11,49].

Nouakchott, the capital of Mauritania, holds a central position in the country and plays a crucial role in various aspects. Firstly, it serves as the primary political hub of the nation, hosting government institutions, embassies, and national decision-making bodies [4,6,8,50]. Moreover, it is a significant cultural center where numerous artistic, educational, and cultural events take place. Its strategically advantageous coastal location also makes it economically significant, facilitating maritime trade and connections with other countries [2,4,51].

In 2015, Nouakchott was administratively divided into three regions, locally referred to as "Wilayas" These regions were established with the aim of better managing the population growth and challenges associated with the rapid urbanization of the city [2,6].

The northern region of Nouakchott, also known as "Northern Nouakchott" encompasses the districts of "Teyarett", "Dar Naim", and "Toujounin". The southern region of Nouakchott, or "Southern Nouakchott" includes the districts of "El Mina", "Riadh", and "Arafat", while the western region of Nouakchott, or "Western Nouakchott" comprises the districts of "Tevragh Zeina", "Ksar", and "Sebkha" [2]. See Figure 2 below.

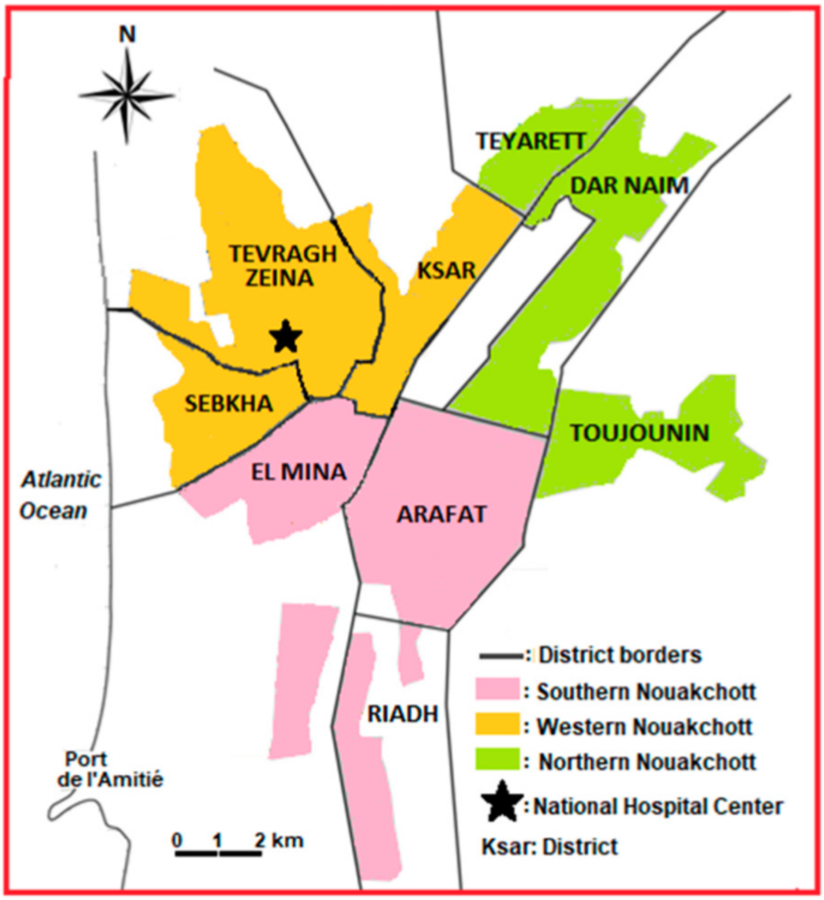

Figure 2. Map of Nouakchott and these regions [2].

This division is intended to facilitate administrative management and the balanced development of each part of the city, taking into account the specific needs of each region. However, despite this administrative division, challenges related to population growth, informal urbanization, inadequate safeguarding of property rights, limited enforcement of legal frameworks which amplify transaction expenses in frequently inefficient markets, diminished governmental responsibility, and access to urban services remain a significant concern throughout Nouakchott [13,18,51].

Access to electricity and the Internet is influenced by a range of determinants, including geographical location [13], age, educational attainment, income level [13,47], employment sector, gender [13,37,42], employment status, household expenditures [40,47], housing type [40], property ownership [40], and the number of rooms [40]. It is also evident that access to electricity significantly impacts Internet access [12,13,20,38,39,52–54].

In this study, two logistic regression models were applied. The first model aims to identify the key factors influencing access to electricity and predict its access within Nouakchott. The second model focuses on pinpointing the primary determinants of Internet access and forecasting its access in Nouakchott. To construct these models, we conducted a comprehensive analysis of the data obtained from the social survey conducted in Nouakchott by the Japan International Cooperation Agency (JICA) (JICA operates as an executive body responsible for administering Japanese official development assistance (ODA) with the aim of promoting the socio-economic advancement, recovery, or economic stability of developing regions. JICA has transformed into a holistic official organization, equipped with three primary tools for development assistance: technical support, concessional loans (Japanese ODA loans), and grant assistance [49,55,56]). The next part is dedicated to this task.

2.2. Data Sources, and Exploratory Analysis

In this part, we will introduce the readers to the data by discussing its sources, presenting the survey instrument, providing variable definitions, and offering some summary statistics of this data.

2.2.1. Data Sources

The data used in this study were obtained from the social survey conducted in Nouakchott by JICA from 2016 to 2018, with data collection completed in October 2018 [6]. A key strength of this survey was its adoption of a random sampling methodology [6]. This approach ensures a representative sample, minimizing biases and allowing for generalizable findings, which is paramount in understanding broad societal patterns and behaviors. The four main objectives of this social survey were as follows [6]:

1. To apprehend the demographic and socio-economic structure of households;
2. To understand households' access to urban services and their expectations for improvement;
3. To comprehend current, expected, and ideal living conditions;
4. To evaluate the social and ecological sustainability of Nouakchott City.

To achieve the set objectives, JICA Teams carried out a comprehensive household survey that consisted of (126) questions. These questions were directed at (1032) household heads, resulting in a total of (280) distinct variables. The questions were broadly divided into three main categories: (1) those pertaining to the demographic and socio-economic structure of the households; (2) those focused on residents' perceptions and their satisfaction levels concerning living conditions and urban services; and (3) those centered on mobility, transportation, and accessibility [6].

2.2.2. Exploratory Data Analysis

As mentioned in Section 2.1, access to electricity and the Internet is influenced by various factors, including geographical location, age, educational attainment, income level, employment sector, gender, employment status, household expenditures, housing type, property ownership, the number of rooms, and dwelling size. To apply a model for determining the key determinants of electricity and Internet access and to predict access to these services, we need to analyze the data provided by the social survey in Section 2.2.1. This part provides a comprehensive description of these variables in this dataset.

1. Data Cleaning: To ensure the integrity and accuracy of the analysis, we conducted preliminary data cleaning that involved addressing missing data, outliers, and inconsistencies. Specialized software libraries in Python and R were employed for this purpose. A careful assessment confirmed that the data cleaning process did not introduce bias into the analysis and that the final dataset is representative of the population under study. Moreover, we conducted an assessment to evaluate the potential impact of the excluded missing data, ensuring that its removal did not introduce any bias into the analysis. Additionally, any outliers or inconsistent data points were identified and subsequently removed from the dataset to maintain data accuracy and reliability.
2. Summary statistics of key variables:

   (a) Household heads' age:
   Figure 3 shows that the age distribution among household heads in Nouakchott shows three distinct groups. The majority (62.7%) fall within the 22–50 age range, followed by those in the 50–65 age bracket (30%). A smaller proportion (7.2%) are aged 65 and above. This distribution suggests that access to essential services like electricity and the Internet may differ significantly across age groups, warranting further investigation.

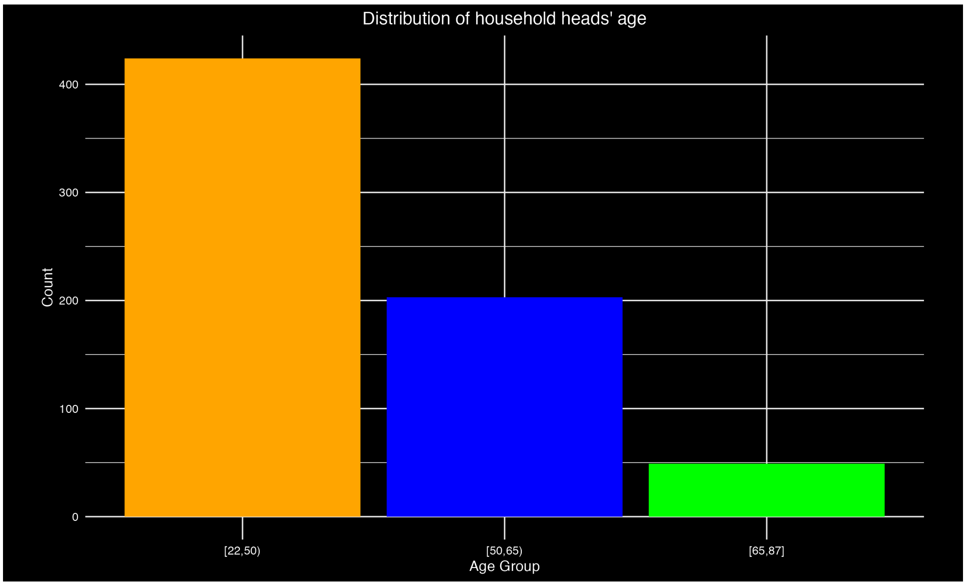

Figure 3. Distribution of household heads' age.

(b) Distribution of households across the different regions in Nouakchott: Figure 4 illustrates the distribution of households across the different regions in Nouakchott. The data show that a significant portion of households (47.3%) are located in the Southern Nouakchott region, followed by (35.5%) in Northern Nouakchott and (17.2%) in Western Nouakchott. This geographical distribution is crucial for understanding access to essential services such as electricity and the Internet. The regional disparities could be indicative of variations in service availability and quality. Therefore, predicting access to these services based on the regions could offer valuable insights for targeted infrastructure development and policy-making.

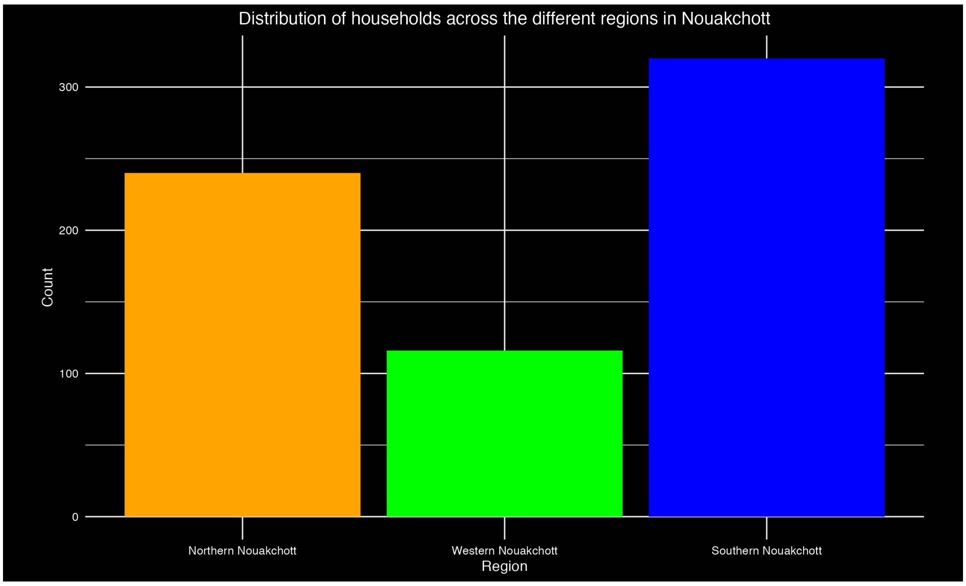

Figure 4. Distribution of households across the different regions in Nouakchott.

(c) Household head Income: To simplify, we have divided household income into three levels: Low (124 euros), medium (224 euros), and high (373 euros). Figure 5 presents the distribution of income groups among households in Nouakchott. Three income groups—low, medium, and high—are observed in the dataset. Specifically, (28.7%) of the households fall under the 'Low' income group, (28.1%) under 'Medium', and (43.2%) under 'High'. The income level of a household can be a crucial factor in determining their access to essential urban services like electricity and the Internet.

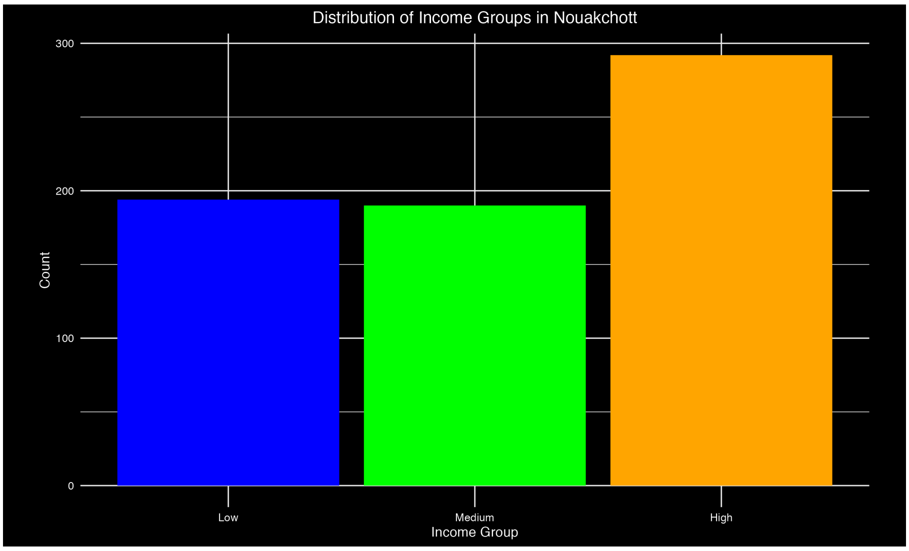

Figure 5. Distribution of household head Income.

(d) Gender of household heads:
Figure 6 showcases the number of household heads by gender in Nouakchott. With male (63%) and female (37%) household heads, the data reveals a skewed distribution favoring men. This gender imbalance may not only reflect the social and cultural dynamics at play but also have important implications. For example, households led by women might face more challenges in accessing essential services such as the Internet and electricity due to various social or economic factors. Thus, it is crucial for policymakers to understand these gender-based disparities in order to formulate more effective programs aimed at reducing them. In addition, understanding the gender dynamics within households can offer additional insights, especially considering that gender may influence the type of employment and educational opportunities available.

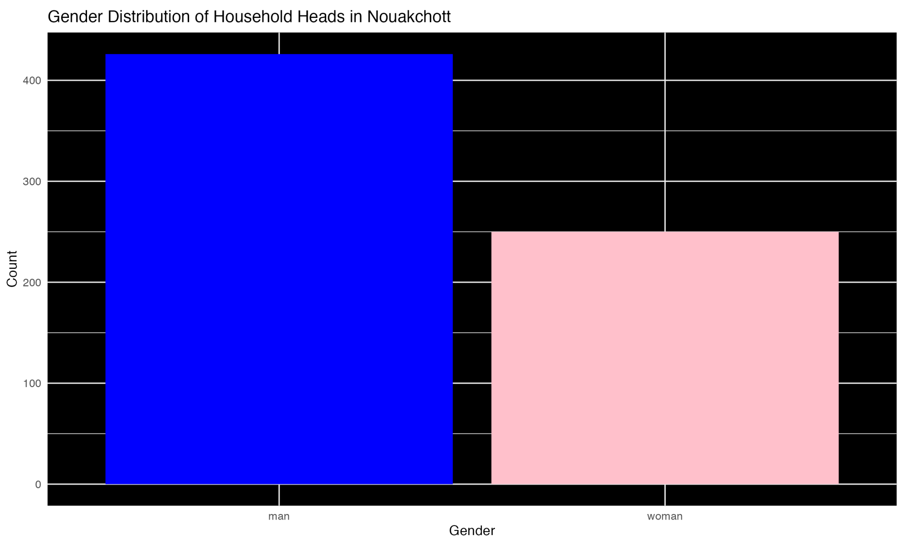

Figure 6. Gender Distribution of Household Heads in Nouakchott.

(e) Employment status of household heads:
Figure 7 illustrates the distribution of employment categories among household heads in Nouakchott. Notably, (49.4%) are in full-time employment, (37.7%) are part-time employed, and the remaining (12.9%) are unemployed. The relatively high rate of full-time employment suggests economic stability for the majority of households, which may subsequently translate into easier access to essential services like electricity and the Internet. However, the (12.9%) unemployment rate is a concern and could indicate barriers to accessing these services due to financial constraints. Policymakers must focus on this vulnerable group to ensure the equitable distribution of essential resources.

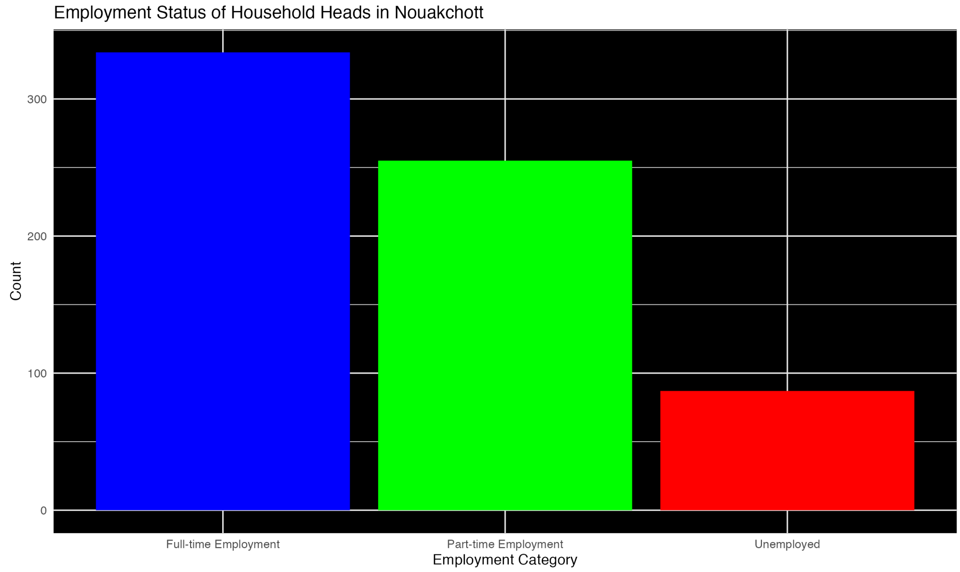

Figure 7. Distribution of the employment status of Household Heads in Nouakchott.

(f) Education level of Household Heads in Nouakchott:
Figure 8 displays the education level distribution among household heads in Nouakchott. The data show significant variation, with the largest group (31.1%) having completed school but not obtaining the Baccalaureate. Those with lower than primary school education make up (21.3%), and those who attended Mahadras (Islamic Mahadra education is a non-formal education system that has existed in Mauritania for centuries. It is based on the memorization of the Quran and hadiths. It is free and open to all. It plays an important role in Mauritian society) constitute (17.8%). Those with Baccalaureate, Bachelor's, and Master's or Doctoral degrees are comparatively fewer, constituting (10.4%), (11.1%), and (8.4%), respectively. This diverse educational landscape could have direct implications for household access to essential services like electricity and the Internet. Higher educational levels are generally correlated with better employment opportunities, which in turn could affect the ability to afford such services. Policymakers should consider these disparities when designing programs aimed at increasing access to essential services.

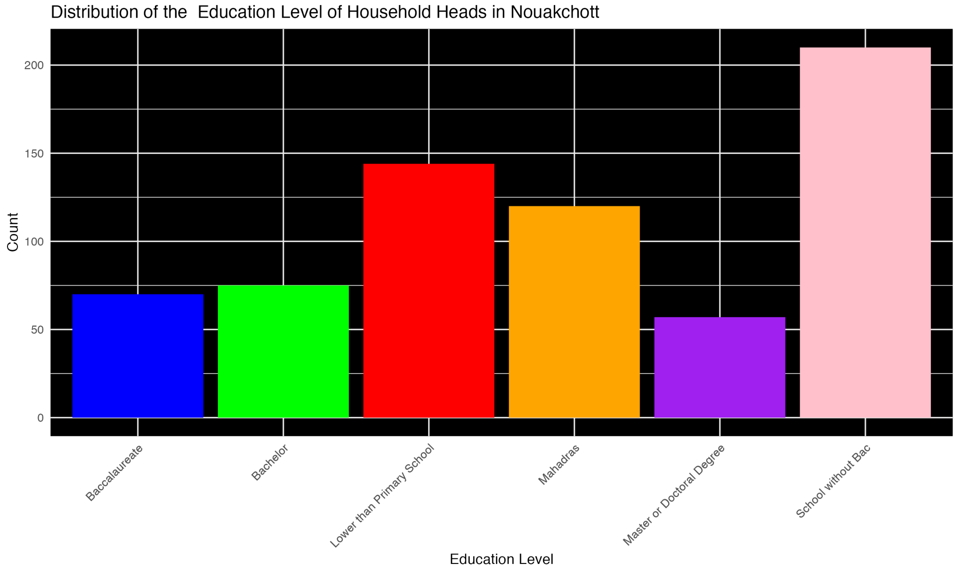

Figure 8. Distribution of the education level of Household Heads in Nouakchott.

(g) Property Ownership Among Household Heads in Nouakchott:
Figure 9 illustrates the property ownership status of household heads in Nouakchott. Most notably, the vast majority of household heads (62.4%) own their property, while (32.2%) reside in privately owned rental units. A very small percentage (2.2%) lives in government-owned rental units, and (3.1%) is categorized as "uncertain". Property ownership could be a significant variable when examining access to essential services like electricity and the Internet. Homeownership often represents a form of stability that might make access to such services more straightforward, both in terms of infrastructure and the ability to afford the costs. In contrast, those in rental units—particularly government-owned units—may face additional challenges, from a lack of control over the property to possible restrictions or conditions set by landlords or the government.

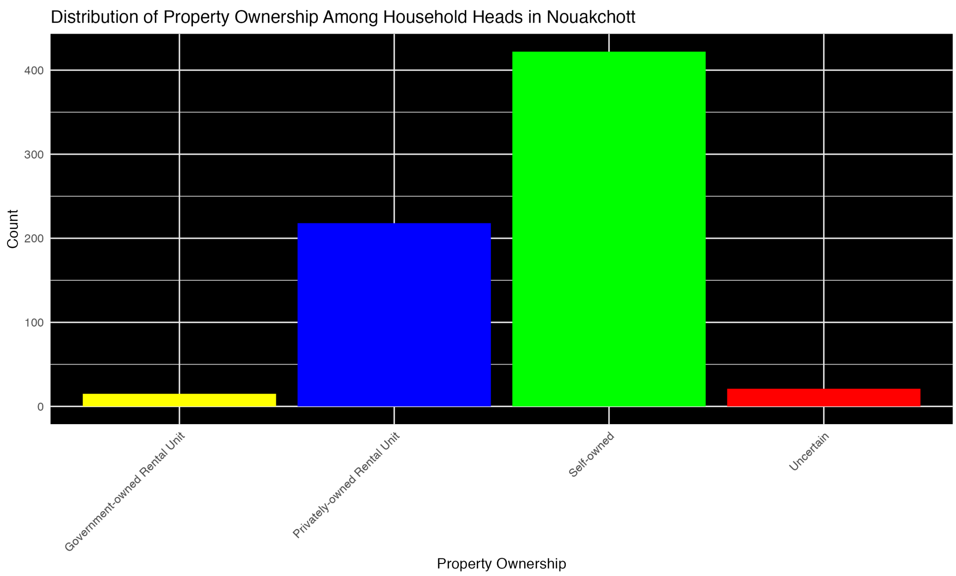

Figure 9. Distribution of Property Ownership Among Household Heads in Nouakchott.

(h) Number of Rooms per household in Nouakchott:
Figure 10 illustrates the distribution of the number of rooms per household in Nouakchott. The number of rooms ranges from 0 to 15, with the median at 3 rooms. A majority of households have between 2 and 4 rooms. The number of rooms in a household may have implications for access to electricity, as larger households may require more extensive electrical infrastructure or may experience different challenges in securing a reliable electricity supply.

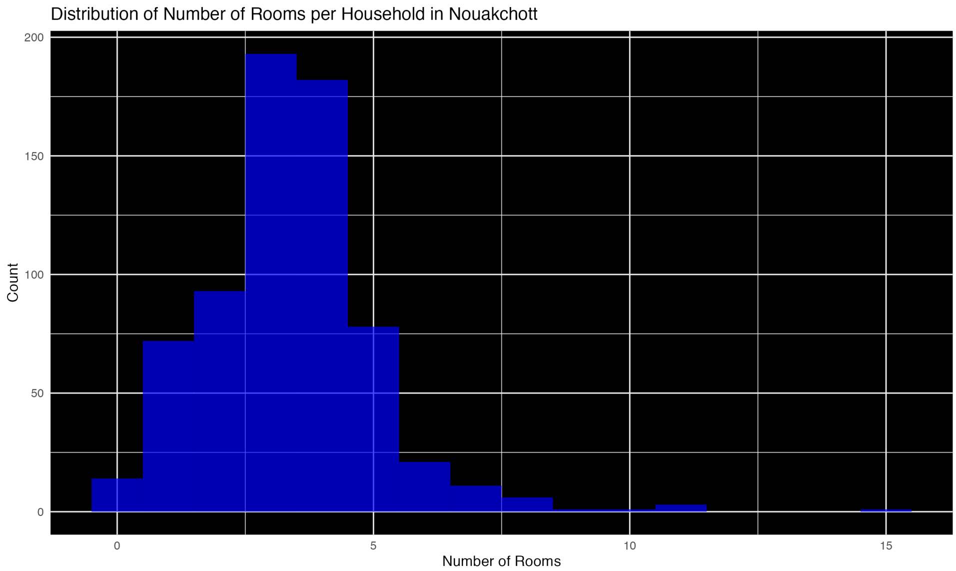

Figure 10. Distribution of Number of Rooms per Household in Nouakchott.

(i) Highest Monthly Expenditures by Household Heads in Nouakchott:
Figure 11 displays the distribution of the highest monthly expenditures among household heads in Nouakchott. A significant majority (62.1%), reported food as their highest monthly expense, followed by rent at (35.1%). Utilities such as electricity and water supply constitute a smaller proportion. This distribution is crucial for understanding the economic constraints that household heads face, which in turn can affect their ability to access essential services like electricity and the Internet.

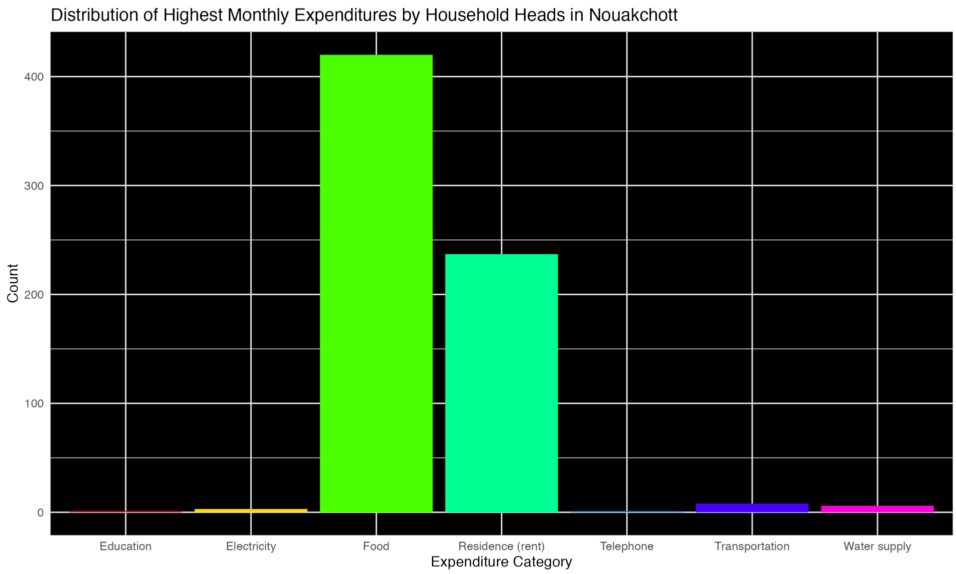

Figure 11. Distribution of Highest Monthly Expenditures by Household Heads in Nouakchott.

(j) Electricity access for household heads in Nouakchott:
Figure 12 displays that (94.1%) of households in Nouakchott have access to electricity, leaving (5.9%) without. While this high percentage might suggest that electricity is widely available, it is essential to explore why the remaining households are left without access. Understanding this can influence the availability of other essential services that depend on electricity, such as healthcare devices, educational tools, or home businesses. The absence of electricity in these households could be due to various factors, like location and affordability. Addressing these factors can significantly improve the quality of life for these residents.

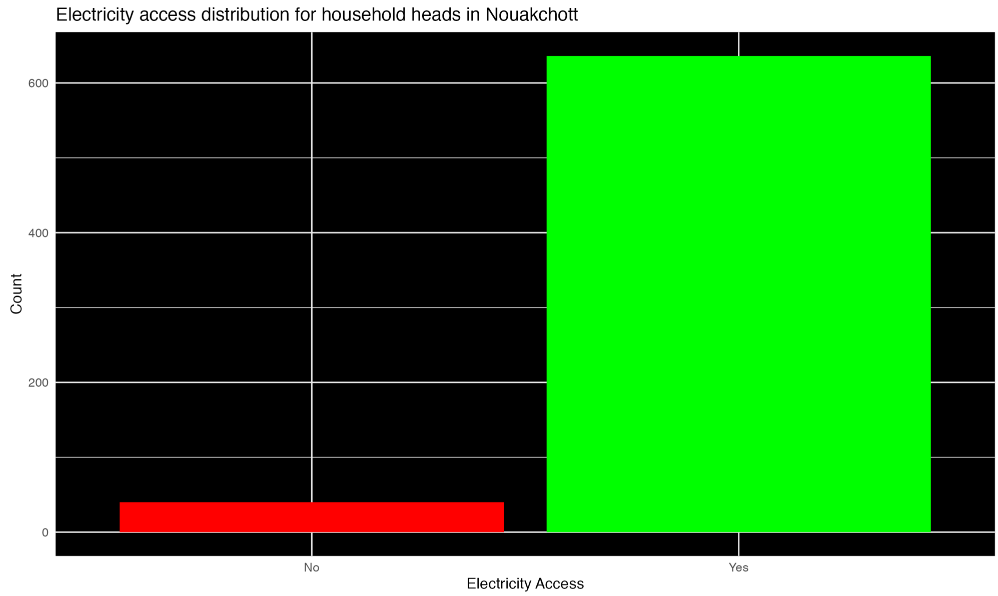

Figure 12. Electricity access distribution for household heads in Nouakchott.

(k) Internet access for household heads in Nouakchott:
Figure 13 presents the distribution of Internet access among households in Nouakchott. A striking (85.1%) of households do not have Internet access, compared to only (14.9%) with access. This significant gap suggests that Internet accessibility is a pressing issue that may be influenced by multiple factors such as affordability, a lack of infrastructure, or digital literacy. The absence of Internet access can impede educational and economic opportunities, making it critical to understand the underlying factors of this digital divide and address them accordingly.
After exploring the distributions and characteristics of each variable individually, we will now enter the crucial phase of bivariate analysis. This step is essential to study the relationships between the different variables and thus develop a robust predictive model. It is at this stage that we will begin to identify the key factors that influence access to essential services (electricity and Internet).

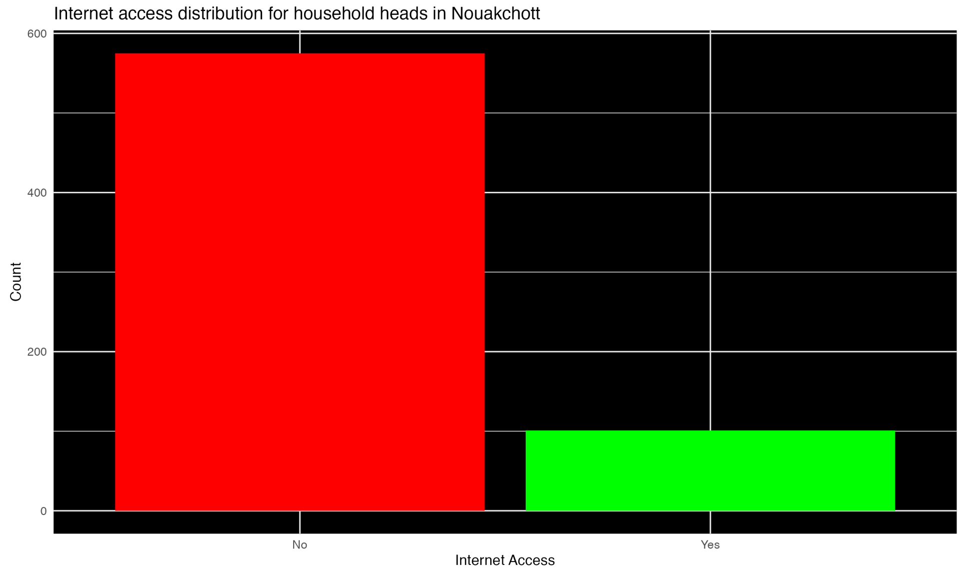

Figure 13. Internet access distribution for household heads in Nouakchott.

3. Bivariate Analysis of Electricity and Internet Access Versus Their Determinants: We conducted bivariate analyses on two binary response variables, namely, electricity access and Internet access, and their various determinants as outlined in Section 2.1. Two types of tests are conducted:
   (a) Chi-Squared Test for Categorical Variables: The Chi-Squared Test is commonly used to examine the association between two categorical variables. It often tests hypotheses about the independence or dependence of these variables [57–59]. It examines whether there is a significant association between the categorical independent variable and the binary dependent variables.
   (b) *T*-Test for Continuous Variables: The *T*-Test is used to assess the association between a binary and a continuous variable [58,59].

   Tables 1 and 2 provide the *p*-values for these tests.

Table 1. Chi-Squared Test Results for different variables affecting electricity access.

Variable	*p*-Value
Household heads' age	0.2624218
Different regions in Nouakchott	0.01996972
Household head Income	0.5211015
Gender of household heads	0.03359537
Employment status of household heads	0.8287739
Education level of household heads	0.05647001
Property ownership among household heads	0.001705311
Number of rooms per household	0.01283053
Highest monthly expenditures by household heads	0.004870824

Table 2. Chi-Squared Test Results for different variables affecting Internet access.

Variable	*p*-Value
Household heads' age	0.2760777
Different regions in Nouakchott	0.04042241
Household head Income	0.000004
Gender of household heads	0.6789384
Employment Status of household heads	0.8288
Education level of household heads	0.00000028
Property ownership among household heads	0.1858189
Number of rooms per household	0.0001952235
Highest monthly expenditures by household heads	0.0000641065
Electricity access	0.04067138

In the bivariate analyses presented in Tables 1 and 2, *p*-values below (0.05) for variables like Gender and Property Ownership suggest they are potential predictors for Electricity and Internet Access. Conversely, Age, Employment Status, and Income may not be strong influencers, based on their higher *p*-values. It is important to emphasize that these findings serve as preliminary indicators and may be clarified by multivariable analyses like logistic regression, which we will explore in Section 2.3.

2.3. Logistic Regression Models

In this subsection, we will construct and discuss logistic regression models aimed at predicting access to two essential services: electricity and the Internet. These models will integrate various explanatory variables, as identified through our previous bivariate analyses, to offer an in-depth understanding of the key determinants affecting access to these services.

According to the bivariate analysis presented in Section 2.2.2, along with methodologies and findings from the existing literature, logistic regression is identified as the most appropriate model for exploring the determinants of both electricity and Internet access.

The logistic regression model is a powerful tool for predicting the probability of a binary outcome given one or more independent variables. Due to its simplicity, ease of interpretation, and wide applicability, it is a popular choice for various research applications [60–63]. The general form of the logistic regression model can be expressed as follows [59,64,65]:

$$\text{logit}(\mathbb{P}[\mathbf{Y}=1]) = \text{logit}(p) = \log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 \times x_1 + \beta_2 \times x_2 + \ldots + \beta_\text{p} \times x_\text{p}$$

where:

- $\text{logit}(p) = \log(odds)$ is a transformation that converts a probability value, which lies between 0 and 1, to a value ranging between $-\infty$ and $+\infty$.
- The odds ratio (*odds* or OR) quantifies the relationship between exposure and an outcome. It compares the odds of the outcome occurring in exposed vs. unexposed groups. An odds ratio over 1 suggests increased risk, less than 1 indicates decreased risk, and 1 implies no association.
- $\mathbf{Y}$ is the binary outcome variable.
- β_0 is the intercept coefficient (the intercept coefficient represents the log-odds of having electricity or Internet access when all predictor variables are zero [64]).
- $\beta_1, \beta_2, \ldots, \beta_\text{p}$ are the coefficients, representing the effects of the independent variables on the outcome variable.

- $x_1, x_2, \ldots, x_\mathrm{p}$ are the independent variables (predictors).
- p is the number of independent variables.

The coefficients $\beta_1, \beta_2, \ldots, \beta_\mathrm{p}$ are estimated using maximum likelihood estimation methods [65]. The likelihood function serves as a measure to evaluate how well the model's predicted probabilities align with the observed outcomes. The aim is to maximize this function to find the optimal values of the coefficients that yield the highest probability of observing the given data. Optimization algorithms such as *Newton–Raphson* and *BFGS* [66] are commonly employed to find these maximum likelihood estimates efficiently [64]. Once these coefficients are estimated, the probability $p = \mathbb{P}[\mathbf{Y} = 1]$ can be calculated using the logistic function as follows [60,64]:

$$p = \frac{1}{1 + e^{-(\beta_0 + \sum_{i=1}^{\mathrm{p}} \beta_\mathrm{i} x_\mathrm{i})}}$$

Having discussed the general structure and estimation procedures of logistic regression, we now present the tailored models designed to understand access to electricity and the Internet, which are:

- Model for Electricity Access:

$$\begin{aligned}\log\left(\frac{p}{1-p}\right) &= \beta_0 + \beta_1 \times \text{Household heads' Age} + \beta_2 \times \text{Regions} \\ &+ \beta_3 \times \text{Income} + \beta_4 \times \text{Gender} + \beta_5 \times \text{Employment Status} \\ &+ \beta_6 \times \text{Education Level} + \beta_7 \times \text{Property Ownership} \\ &+ \beta_8 \times \text{Number of Rooms} + \beta_9 \times \text{Monthly Expenditures}\end{aligned}$$

  where $p = \mathbb{P}[\mathbf{Y} = \text{'Yes'}]$ represents the likelihood that a given household head has access to electricity, based on the predictors included in this model.

- Model for Internet Access:

$$\begin{aligned}\log\left(\frac{p}{1-p}\right) &= \beta_0 + \beta_1 \times \text{Household heads' Age} + \beta_2 \times \text{Regions} \\ &+ \beta_3 \times \text{Income} + \beta_4 \times \text{Gender} + \beta_5 \times \text{Employment Status} \\ &+ \beta_6 \times \text{Education Level} + \beta_7 \times \text{Property Ownership} \\ &+ \beta_8 \times \text{Monthly Expenditures} + \beta_9 \times \text{Electricity access}\end{aligned}$$

  where $p = \mathbb{P}[\mathbf{Y} = \text{'Yes'}]$ represents the likelihood that a given household head has access to the Internet, based on the predictors included in this model.

After establishing the tailored logistic regression models to examine access to electricity and the Internet, we will use the `glm()` function in R to estimate these models. The following section, Section 3, will present a detailed analysis of the results obtained from estimating these models.

3. Results and Findings

3.1. Models Performance

In this part, we aim to validate and assess the predictive performance of our models, as defined in Section 2.3. We compute the following four metrics for both models:

1. The Likelihood Ratio Test (LRT) is a statistical test used to test whether the more complex model fits the data significantly better than the simpler model. If the LRT statistic is greater than the critical value from the chi-squared distribution, then we reject the null hypothesis and conclude that the full model fits the data significantly better than the null model. This means that the inclusion of the predictor in the full model is statistically significant [64].

2. Nagelkerke's R^2 (It is crucial to note that Nagelkerke's R^2 values in logistic regression are generally lower and less close to 1 compared to those in linear regression models. This is because the pseudo R^2 values in logistic regression do not represent the proportion of explained variance but are instead measures of how well the model fits compared to a null model [64]) [64] is a modified version of the Cox and Snell R^2 and is commonly used in logistic regression to evaluate the goodness-of-fit of the model. It is calculated using the log-likelihood of the null model and the log-likelihood of the full model. Nagelkerke's R^2 adjusts the scale of the Cox and Snell R^2 to range between 0 and 1, making it easier to interpret.
3. Area Under the Curve (AUC) [64]: AUC is a widely used metric to assess the performance of binary classification models such as logistic regression. It quantifies this capability, with a value closer to 1 indicating excellent discriminatory power, and a value closer to 0.5 suggesting no better accuracy than random guessing.
4. Model Prediction Evaluation: Evaluating the predictive performance of a logistic regression model is a crucial step in the modeling process. To assess how well the model generalizes to unseen data, we can employ several metrics calculated from the model's predictions on both the training and test data sets [64]. For a given observation i, let y_i be the actual outcome and $\hat{y}_i$ be the predicted outcome. The predicted outcome can be calculated from the predicted probabilities, $\hat{p}_i$, as follows:

$$\hat{y}_i = \begin{cases} \text{“Yes”} & \text{if } \hat{p}_i > 0.5 \\ \text{“No”} & \text{otherwise} \end{cases}$$

The *confusion matrix* is a fundamental tool for this assessment. The matrix comprises four components: True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN).

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

The accuracy rate gives us an immediate idea of how often the model correctly classifies an observation. An accuracy rate close to 1 indicates excellent model performance, while a rate close to 0 suggests poor performance.

The following tables, Tables 3 and 4, present the values obtained for these metrics for the two models.

Table 3. The metric values for the electricity access model.

Metric	Value
LRT	***p*-Value** = 0.00003702677
Nagelkerke's R^2	0.62
AUC	0.96
Accuracy	0.94

Table 4. The metric values for the Internet access model.

Metric	Value
LRT	***p*-Value** = 0.000000000187
Nagelkerke's R^2	0.60
AUC	0.92
Accuracy	0.91

Both Tables 3 and 4 suggest robust models for predicting electricity and Internet access. With low LRT p-values and high values for Nagelkerke's R^2, AUC, and Accuracy, the models appear to be both statistically significant and highly predictive. This bodes well for the reliability of our study.

After showcasing the performance and precision of our models, we now turn to interpreting the results of these two models in the following part.

3.2. Interpretation of Estimated Coefficients and Discussion

In this part, we delve into the interpretation of estimated coefficients, followed by a detailed discussion of their implications.

3.2.1. Interpretation of Estimated Coefficients

1. When interpreting the logistic regression odds ratios for the electricity access model: Table 5 shows that several factors significantly influence access to electricity. The number of rooms in the house is significantly associated with electricity access (OR = 0.59, $p < 0.000012$). Similarly, living in Western Nouakchott increases the odds of having electricity access compared to the North (OR = 1.89, $p = 0.02$). Gender are less likely than men to have access to electricity (OR = 0.33, $p = 0.012$). Moreover, owning a house substantially increases these odds (OR for self-owned = 6.77, $p = 0.015$). In addition, household expenditures, particularly among those with elevated monthly electricity usage, demonstrate a noteworthy inverse link with electricity access (OR = 0.62, $p = 0.003$). Most other variables, such as education level and employment status, do not show a significant association with electricity access.

Table 5. Odds Ratios, and *p*-values from the electricity access model.

Variable	Modalities	OR	*p*-Value
Household head Income	Low (Reference)	—	—
	Medium	0.68	0.4
	High	0.80	0.6
Number of rooms		0.59 *	<0.000012
Education level	School without Bac (Reference)	—	—
	Baccalaureate	1.68	0.5
	Bachelor	1.05	0.9
	Lower than primary school	1.40	0.56
	Mahadras	2.51	0.057
	Master or Doctoral degree	0.90	0.9
Regions in Nouakchott	Northern Nouakchott (Reference)	—	—
	Western Nouakchott	1.89	0.02
	Southern Nouakchott	1.19	0.9
Household heads' age	[22, 50) (Reference)	—	—
	[50, 65)	1.36	0.4
	[65, 87]	0.88	0.8
Gender	Man (Reference)	—	—
	Woman	0.33	0.012

Table 5. *Cont.*

Variable	Modalities	OR	*p*-Value
Expenditures by household heads	Food (Reference)	—	—
	Education	0.99	0.9
	Electricity	0.62	0.03
	Residence (rent)	2.85	0.9
	Telephone	0.00	0.91
	Transportation	0.98	>0.7
	Water supply	0.99	>0.8
Employment status	Full-time employment (Reference)	—	—
	Part-time employed	1.21	0.6
	Unemployed	1.33	0.6
Property ownership	Privately-owned rental unit (reference)	—	—
	Government-owned rental unit (social, etc.)	2.89	0.4
	Self-owned	6.77	0.015
	Uncertain	10.5	0.008

2. Interpreting the logistic regression odds ratios for Internet access model:
Table 6 shows that household heads with high income are (3.14) times more likely to have Internet access than those with low income, and this is statistically significant ($p = 0.003$). Lack of electricity access significantly decreases the odds of having Internet by (81%) (OR = 0.19, p-value = 0.011). Those with a Bachelor's degree have more than twice the odds of having Internet compared to those without a Baccalaureate, and this is also significant (p-value = 0.018). Living in Western Nouakchott significantly increases the odds by (132%) (OR = 2.32, $p = 0.012$). Spending on transportation and water supply are highly significant variables, with ORs of (13.2) and (30.1) respectively, and p-values less than 0.005. No significant effect was observed for gender, age, or other expenditure categories on Internet access.

Table 6. Odds Ratios, and *p*-values from the Internet access model.

Variable	Modalities	OR	*p*-Value
Household head Income	Low (reference)	—	—
	Medium	1.74	0.2
	High	3.14	0.003
Electricity access	Yes (reference)	—	—
	No	0.19	0.011
Education level	school without Bac (reference)	—	—
	Baccalaureate	1.52	0.3
	Bachelor	2.38	0.018
	Lower than primary school	0.56	0.2
	Mahadras	0.64	0.3
	Master or Doctoral degree	1.61	0.3

Table 6. *Cont.*

Variable	Modalities	OR	*p*-Value
Regions in Nouakchott	Northern Nouakchott (Reference)	—	—
	Western Nouakchott	2.32	0.012
	Southern Nouakchott	0.97	0.9
Household heads' Age	[22, 50) (Reference)	—	—
	[50, 65)	0.95	0.9
	[65, 87]	0.37	0.13
Gender	man (Reference)	—	—
	woman	1.21	0.5
Expenditures by household Heads	Food (Reference)	—	—
	Education	1	>0.9
	Electricity	1.55	0.8
	Residence (rent)	2.65	0.15
	Telephone	0.00	>0.9
	Transportation	13.2	0.003
	Water supply	30.1	0.001
Employment status	Full-time employment (Reference)	—	—
	Part-time employed	0.55	0.056
	Unemployed	1.89	0.15
Property Ownership	Privately-owned rental unit (Reference)	—	—
	Government-owned rental unit (social, etc.)	0.99	>0.9
	Self-owned	2.37	0.2
	Uncertain	0.36	0.4

3.2.2. Discussion

Our analysis illuminates key determinants significantly affecting access to electricity and the Internet within Nouakchott.

Firstly, our examination of the electricity access model has unveiled a striking revelation: the significant negative impact of the number of rooms in a household on access to electricity (OR = 0.59), indicating a noteworthy economic relationship. This observation can be rationalized by the tendency for dwellings with a greater number of rooms to be more spacious, potentially incurring higher construction and maintenance costs. In Nouakchott, it is commonplace for houses to feature considerable floor space, partially in response to the region's warm climate, which necessitates extensive electricity use for air conditioning. Elevated construction and maintenance costs could reduce households' ability to cover electricity access fees, especially given the notably high electricity tariffs in Nouakchott. Consequently, households residing in more spacious accommodations are likely to encounter more pronounced economic challenges in obtaining electricity access. This revelation serves as a testament to the impact of construction costs, housing size, construction methods, and the availability of affordable services on electricity access within the city. It is important to note that this finding differs from that reported in a South African study by [40], which indicates a positive association between the number of rooms in a household and electricity access and availability. This divergence is logical due to Nouakchott's unique economic, urban, and construction mindset, infrastructure disparities, service availability, and pricing dynamics.

Secondly, the substantial positive impact of geographic location within the city on electricity access is evident. Residents in Western Nouakchott have significantly higher odds (OR = 1.89) of accessing electricity compared to their counterparts in Northern and Southern Nouakchott. These regional disparities likely have historical and economic origins. Historically, certain areas of the city have received more substantial investments in electrical infrastructure, resulting in improved electricity access. Concurrently, disparities in the distribution of essential services, such as healthcare and education, are a common issue within the city. Specific regions, particularly in the north and south, often lack access to these critical amenities. Furthermore, informal settlements or shantytowns in particular areas exacerbate the issue as they encounter infrastructure development challenges, which subsequently affect their access to electricity. The absence of formal urbanization planning often leads to inadequate electricity distribution in these regions. Economic disparities also play a role in this scenario. Western Nouakchott may have a higher concentration of affluent households capable of affording private electricity generators or maintaining a reliable electricity supply. Conversely, the northern and southern areas may host more economically disadvantaged households, which contributes to varying levels of electricity access. In summary, disparities in electricity access within Nouakchott are a result of a complex interplay of historical infrastructure development, unequal essential service distribution, informal urbanization, and economic disparities affecting different city regions. This finding is in alignment with results from related studies in SSA countries [13,40].

Thirdly, household expenditures, especially those with higher monthly electricity consumption, show a significant negative association with access to electricity. This finding suggests that households with elevated electricity consumption, likely due to commercial activities or subscription issues, face greater challenges in securing access to electricity. These financial burdens could stem from increased electricity consumption and may be linked to business operations or subscription difficulties. Conversely, it is also notable that property ownership has a substantial positive impact on electricity access. Owning a home significantly increases the odds of having electricity access. This outcome may be attributed to the fact that homeowners are both incentivized and financially equipped to invest in better utilities, including reliable electricity services. These findings align with those of related studies such as [40,47] in South Africa and Nigeria.

Furthermore, gender disparity is a salient issue when considering electricity access in the context of Nouakchott. Our research reveals that women face a distinct disadvantage in terms of accessing electricity. This gender-based inequality extends beyond the boundaries of electricity access and can have far-reaching consequences for the well-being and development prospects of women in the region. The gender gap in electricity access is indicative of broader gender inequalities and challenges that women face in accessing essential services. This issue is not isolated to Nouakchott but resonates across various African countries. Studies like [1,13,37,40,42] have consistently reported gender disparities and the unique challenges women encounter when trying to access essential services. These disparities include unequal access to education, healthcare, and economic opportunities, often stemming from societal norms and traditional roles assigned to women. The alignment of our findings with those of other studies across Africa underscores the systemic nature of gender disparities and the pressing need to address these inequalities. It serves as a reminder that gender inequality is a multifaceted issue with profound social, economic, and developmental implications for women in the region.

On the other hand, the Internet access model similarly reveals regional disparities, particularly in favor of Western Nouakchott, mirroring the pattern observed in the electricity model. These findings point to the presence of regional inequalities in Internet access, with the western part of Nouakchott appearing to possess a more advanced status. This divergence is potentially attributed to several factors, including heightened economic activity, increased infrastructure investments, or proximity to telecommunication hubs. The concentration of Internet access in the western region has significant implications for socio-economic development disparities within Nouakchott, as Internet access is increasingly recognized as an essential tool for education, communication, and economic opportunities. This observed pattern aligns with commonly observed trends in cities across emerging economies, as supported by studies such as those conducted by [25,43,47].

High income is another pivotal factor influencing Internet access. This finding aligns logically with the fact that high-income households can afford the necessary devices and recurring fees associated with Internet usage. Confirming what was already mentioned, access to electricity is a significant determinant, which makes sense given that a stable power supply is crucial for consistent Internet access. Moreover, education level significantly contributes to Internet access. This may be because higher levels of education often demand and facilitate the use of Internet resources for academic and professional development. With increasing educational attainment, households may have greater needs for Internet access to support education, work, business, and various other aspects of daily life [25].

In addition, our findings indicate that expenditures on transportation and water supply are significantly associated with Internet access. These expenses can reflect a household's overall financial stability and their engagement with modern services. While these trends are common among West African cities [25], their significance varies and depends on city-specific factors. However, it is crucial to acknowledge that the impact of these factors can vary between cities. Each city has its own unique dynamics and challenges influencing the relationship between transportation, water supply expenditures, and Internet access. Factors like infrastructure development, geographical location, and government policies can shape how these expenditures affect Internet access in a particular city. Therefore, while the influence of transportation and water supply expenses on Internet access is a recurring trend in West African cities, it is essential to consider each city's distinct context when developing policies and interventions to improve Internet access. Understanding local dynamics and identifying other influential factors will aid in crafting targeted strategies to bridge the digital divide and ensure equitable Internet access for all residents.

In summary, both models identify crucial factors influencing the access to electricity and the Internet in Nouakchott, including regional location, expenditures, education level, number of rooms, gender, property ownership, and household income.

These findings serve as vital signposts for policymakers dedicated to achieving equitable development and ensuring widespread access to fundamental utilities in Nouakchott. Our analysis underscores the multifaceted impact of these factors on various aspects of the city's development, including economic growth, educational opportunities, gender equity, infrastructure development, environment, security, health information dissemination, and sustainability. By addressing these disparities through targeted interventions, policymakers can actively contribute to nurturing a more inclusive and equitable environment that prioritizes the well-being, progress, and prosperity of Nouakchott's residents.

4. Conclusions and Perspectives

In this final section, we first summarize the key findings of our study and then discuss potential future perspectives and directions.

4.1. Summary of Key Findings

Our research has revealed striking disparities in access to essential urban services, namely electricity and the Internet. Geographic location significantly influences access, with Western Nouakchott standing out as the most privileged region. Gender-based inequalities are evident, particularly in electricity access, presenting a concern for women's socio-economic prospects. Socioeconomic factors such as home ownership, income, and education play crucial roles, intertwining access with socio-economic status. Moreover, the interplay between electricity and Internet access underlines the intricate dynamics of urban service provision. Infrastructure disparities, historical development, and economic inequalities contribute to variations in utility access across the city. High educational attainment bolsters Internet access, emphasizing the Internet's role in education. Furthermore, income levels influence Internet access, ensuring affordability. Households with higher electricity consumption face hurdles in access. Expenditures on transportation and water supply can reflect financial stability and engagement with modern services, a trend observed in various West African cities.

These findings serve as signposts for policymakers committed to promoting equitable development, affecting socio-economic growth, education, gender equity, infrastructure development, and various other aspects of Nouakchott's development. Bridging these disparities should be a priority, fostering a more inclusive and equitable environment for all residents.

4.2. Contribution to Urban Development and Recommendation

The analysis conducted in this study provides actionable insights that can guide equitable development and service provision in Nouakchott. For instance, addressing geographic disparities in utility access is a significant challenge. Our research has unveiled substantial disparities in essential urban service access, with Western Nouakchott standing out as the most privileged region. To tackle this issue, policymakers should focus on targeted infrastructure investments. It is imperative to prioritize electrification projects in the northern parts of Nouakchott, where disparities are most pronounced. To bridge these regional disparities in electricity and Internet access, policymakers should allocate resources to extend the electrical grid, improve grid reliability, and explore renewable energy solutions in underserved areas. These focused infrastructural investments will not only enhance utility access but also foster socio-economic development in these areas.

Empowering women through gender-sensitive approaches is another crucial aspect. Gender-based inequalities in electricity access are concerning for women's socio-economic prospects. Policymakers can take steps to empower women and rectify these disparities. Gender-sensitive initiatives should be introduced, including offering subsidized electricity rates for women-headed households and launching education programs. These initiatives will enhance women's understanding of how to access and manage electricity, contributing to their empowerment and promoting gender equity in utility access. This empowerment can lead to positive societal changes, enabling women to take on more active roles in the community and contribute to a broader socio-economic development.

Promoting home ownership and affordable housing is a key consideration. The role of property ownership in utility access underscores the need for housing policies that facilitate home ownership. To tackle this challenge, policymakers should focus on affordable housing development, and encourage public–private partnerships. These partnerships can provide affordable housing options equipped with essential utilities, thus indirectly increasing access to basic amenities, including electricity and the Internet. Such measures will not only enhance utility access but also contribute to better living conditions and community development.

Fostering inclusive community development is essential. The interplay between electricity and Internet access reveals the complex dynamics of urban service provision. Infrastructure disparities, historical development, and economic inequalities contribute to variations in utility access across the city. To foster inclusive community development, it is essential to empower citizens. This can be achieved by promoting transparency in data sharing and communication. Such transparency enables residents to advocate for equal service provision and take an active role in their community's development.

By implementing these recommendations, Nouakchott can take key steps toward transforming into a smarter, more equitable city. This not only benefits the city but also offers a valuable roadmap that other African cities may choose to follow in their pursuit of more inclusive and equitable urban development.

4.3. Limitations and Future Research Directions

The data used in this study were sourced from the social survey conducted in Nouakchott by JICA from 2016 to 2018. This survey encompassed 1032 household heads. While statistically significant, this sample does not represent all households in Nouakchott, which introduces potential biases. Additionally, the study's focus on Nouakchott alone is a limitation. Other cities in Mauritania have their own unique challenges and issues related to access to essential services. Therefore, while our findings provide a comprehensive understanding of Nouakchott, their generalizability to other Mauritanian cities might be limited.

Furthermore, the methodology employed in this study, specifically the logistic regression analysis, has its own set of limitations. Logistic regression is effective for studying associations between variables, but it may not capture intangible factors or variables not included in the analysis. This study primarily deals with observable and measurable factors, and it might overlook latent variables that play a crucial role in understanding utility access disparities.

To address these limitations and enhance the study's scope, current future research considers employing more advanced statistical methods. Techniques like latent growth modeling, structural equation modeling, time series analysis, and robust research designs can provide a more comprehensive view of long-term trends and effects. This could involve studying the long-term impact of electricity access on the environment and modeling these effects while considering the demographic growth of the population.

We are currently integrating logistic regression with the Path Analysis model [67] to offer a more holistic model for urban services in Nouakchott.

Additionally, plans are underway to employ a confirmatory factor analysis model [68] to assess residents' satisfaction and urban livability in Nouakchott City.

A significant initiative in progress is a study on waste management (both solid and liquid) in Nouakchott. This research, building upon our current study, aims to provide a detailed analysis and propose solutions to address waste management challenges in the city.

Furthermore, another study in the pipeline aims to address the abstract aspects of access to urban services, focusing on key latent variables: social norms, satisfaction, motivation, expectation, and participation. By incorporating these latent variables into the analysis, we can better understand the psychological and social factors that shape the perception and utilization of urban services.

Finally, a platform is in development to engage residents actively in the city's growth and to showcase the ranking of Mauritanian cities based on electricity and Internet services.

Author Contributions: Conceptualization, S.A.E.A., J.C., E.B.D., R.A., M.A. and C.S.T.K.; methodology, S.A.E.A.; software, S.A.E.A.; validation, S.A.E.A., E.B.D., J.C., R.A., M.A. and C.S.T.K.; formal analysis, S.A.E.A. and E.B.D.; data curation, S.A.E.A.; writing—original draft preparation, S.A.E.A.; writing—review and editing, S.A.E.A., E.B.D., R.A., M.A. and C.S.T.K.; supervision, J.C.; project administration, J.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors would like to express their gratitude to the Japan International Cooperation Agency (JICA) for their invaluable support. The data used in this study were obtained from the social survey conducted in Nouakchott by JICA, which has significantly contributed to the depth and validity of our research.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

Internet of Things	IoT
SOMELEC	Mauritanian Electricity Company
SSA	Sub-Saharan Africa
JICA	Japan International Cooperation Agency
Odds Ratio	OR
Likelihood Ratio Test	LRT
Area Under the Curve	AUC

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