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Research Article

Keywords: Spatial Inequality, Peri-Urban Dynamics, Electricity Access, Structural Equation Modeling, Economic Diversification, Shaggar City, Ethiopia

Posted Date: November 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11631841/v1

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Additional Declarations: No competing interests reported.

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November 2026

Abstract

Rapid peri-urban transformation in sub-Saharan Africa creates severe spatial inequalities in physical infrastructure, directly impacting household economic resilience. This study examines the direct and indirect effects of electricity access on household livelihoods through economic diversification and the expansion of income sources in peri-urban Shaggar City, Ethiopia. Using a systematic random sampling design, we collected primary quantitative data from 355 households through structured mobile surveys. We conducted spatial and Structural Equation Modeling (SEM) analyses to evaluate structural path relations. The spatial empirical baseline revealed substantial infrastructural disparities: 58.9% of households had grid connections, while 41.1% lacked access, and non-connected households were spatially concentrated at greater distance decay radii from the main urban center. SEM path coefficients confirmed that electricity access exerts a significant direct positive effect on household economic diversification ($\beta = 0.557, p < 0.001$) and income source expansion ($\beta = 0.457, p < 0.001$). Direct accessibility also significantly enhanced overall livelihood outcomes ($\beta = 0.232, p < 0.001$). Using bias-corrected bootstrapping, it was identified that economic diversification (β=0.122, 95%CI [0.076,0.177]) and increased income (β=0.113, 95%CI [0.074,0.155]) partially mediated the relationship between access to grid electricity and households' livelihood stability. Electrified households leveraged spatial infrastructure to absorb macroeconomic shocks, whereas un-electrified peripheral households remained reliant on subsistence agriculture. Spatial planning frameworks must prioritize decentralized peri-urban grid extensions to bridge regional inequality.

Keywords: *Spatial Inequality; Peri-Urban Dynamics; Electricity Access; Structural Equation Modeling; Economic Diversification; Shaggar City; Ethiopia.*

1. Introduction

Access to household electricity positively impacts households' decisions to diversify their activities and increases their non-farm business income and households' livelihoods. Today, infrastructure is the lifeblood of livelihoods and economic development around the world (Phillips et al., 2019). Providing adequate infrastructure development such as roads, electricity, and water can expand the productive capacity of the economy and achieve sustainable economic diversification (Gisaor, 2020 and Jooji et al., 2017). Electricity development would facilitate economic diversification by creating a conducive environment for residents. Likewise, economic diversification should improve living conditions, sources of income, well-being, and asset ownership while helping to combat hunger and poverty (Kothari, 2013; Alamneh et al., 2023; Tsegay et al., 2021; Adem & Tesafa, 2020; Adao et al., 2019; Moneke, 2020; and Jooji et al., 2017). Having access to electricity has a favourable effect on engaging in off-farm and non-farm activities, which helps diversify sources of income (Alamneh et al., 2023; Tsegay et al., 2021; Adem & Tesafa, 2020; Adao et al., 2019; and Moneke, 2020). Compared to non-users, households with electricity typically have a higher number of home-based economic activities and consume fewer alternative fuels (Kebede et al., 2022b).

Economic diversity in peri-urban farming areas refers to the addition of more elements of high-value crops, vegetables, and animals to traditional crop farming (Wakitole et al., 2022). These elements include livestock such as pork, beef, chicken, goat, and sheep meat; crops such as rice, wheat, soybeans, oil seeds, groundnuts, and barley; and fruits and vegetables such as potatoes, corn, tomatoes, sugarcane, garlic, onions, cabbages, watermelons, mangoes, guavas, oranges, coffee, and chat (Isa et al., 2020). As well as the exercise of off-farm activities like paying employees, selling charcoal and firewood, and engaging in resource-based businesses like selling grass and firewood (Meraner et al., 2018). Similarly, non-farm economic activities include petty trade, service delivery, trade, manufacturing, and handicrafts like weaving, spinning, carpentry, house mudding, and pottery making (Gebiso et al., 2023 and Etea et al., 2019).

Farm households may diversify their economies due to push and pull factors (Reardon & Hopkins, 2006; Ellis, 2000). Pull factors are favorable factors that encourage people to diversify their economic activity and sources of income, such as improved access to electricity (Barrett et al., 2001; Alobo Loison, 2015). Adequate access to electricity services could have promoted

household economic diversification and reduced over-reliance on income from a few sources, such as traditional agriculture.

Researchers who examined the specific impacts of electricity on rural livelihood diversification strategies were (Tsegay et al., 2021; Adem & Tesafa, 2020; Adao et al., 2019; Moneke, 2020; Adao et al., 2019; and Moneke, 2020). Overall, the researchers found that accessibility of electricity services influences the diversification of economic activity from farming and non-farming sources and enhances sources of income and livelihoods in rural areas. Despite these admirable efforts, the exact means by which the availability of electrical power influences economic diversity, revenue streams, and livelihoods has not been well investigated. Existing studies like Emeru et al., (2022) and Alamneh et al., (2023b) have mostly focused on the general benefits of access to electricity services on livelihood diversification without adequately examining how this service directly influences households' enhanced economic diversification, income sources, and livelihoods, particularly in the context of peri-urban areas in Ethiopia. This knowledge gap hinders officials', urban planners', and development authorities' ability to use it effectively for livelihoods and long-term development.

To fill the research gaps, the purpose of this study is to examine the effect of the accessibility of electricity services on farming households' economic diversification and livelihoods in the context of Shaggar City peri-urban areas. It does this by utilizing the pull factors of economic diversification theory as well as the resource-based view of the households' economic diversification, sources of income development, and livelihoods. Because Shaggar City is surrounded by peri-urban villages with varying degrees of agricultural and non-agricultural potential, improving access to electricity services will be essential to boosting the local community's economic diversification, income sources, and livelihoods.

It sought to answer the following research questions:

- How does access to electricity services influence economic diversification of households in Shaggar peri-urban areas?
- How does access to electricity services create favorable conditions for households' income sources and livelihoods in Shaggar Peri-urban areas?
- To what extent do economic diversification and income sources mediate the relationship between accessibility of electricity services and households' income sources and livelihoods?

This study contributes to the literature on accessibility of electricity services, households' economic diversification, income sources, and livelihoods. First, it fills gaps in understanding the nature of the accessibility of electricity services, households' economic diversification, income sources, and livelihoods in Shaggar City peri-urban areas, which have received limited empirical attention despite their significant economic potential. Second, the study employs structural equation modeling (SEM), which has not been sufficiently utilized in exploring the complex relationship among the accessibility of electricity services, households' economic diversification, income sources, and livelihoods. This statistical method makes it possible to fully comprehend the ways in which these elements interact in the context of Ethiopian households' economic diversification in the city's peripheral areas. Finally, the increased comprehension is anticipated to offer significant insights for decision-makers in the fields of policy, urban planning, and development to decide on the development of suitable electricity services that are utilized for the economic diversification, income growth, and livelihoods of farm households.

2. Literature Review and Hypothesis Development

Access to reliable electricity is instrumental in enhancing the household's livelihood and socio-economic wellbeing, especially in the peri-urban community; besides enabling the provision of essential energy services, electricity facilitates productive activities, promotes small businesses, enhances access to information and markets, and diversifies household sources of income. In Ethiopia, access to electricity has been found to promote the involvement of individuals in off-farm and non-farm activities and diversify income sources (Alamneh et al., 2023; Tsegay et al., 2021; and Adem & Tesafa, 2020; Adao et al., 2019; and Moneke, 2020). Studies have also found that electrified households are more likely to engage in home enterprises and less likely to use traditional energy sources (Kebede et al., 2022b). Similarly, electricity has been found to increase productivity, promote businesses, empower women by facilitating economic participation, and enhance overall socioeconomic wellbeing (Bose et al., 2013 and Ponce et al., 2017).

Electricity access has the potential to enhance the number of income-generating activities at the household level by promoting productive work, promoting enterprises, and facilitating alternative sources of income. Previous studies have established a positive association between electricity access and economic development and diversification of sources of income (Gilberto, 2012; Stern et al., 2019; Adem & Tesafa, 2020; Wang et al., 2021; and Puri et al., 2023). Electricity seems to

be a critical intervention in peri-urban areas as it enables mixed farming and mixed business enterprises.

The reviewed literature provides sufficient evidence on the role of electricity access in promoting livelihoods by enhancing productivity, promoting multiple income-generating activities, improving living conditions, and overall wellbeing. The analysis of earlier research conducted in Ethiopia showed that electrification leads to poverty reduction and better family health outcomes, but the available data show mixed results because of variations in household earnings, how long they have had electricity, and their ability to access additional services (Aragaw, 2012). Research studies from the past have demonstrated that access to electricity leads to higher household earnings and supports business growth, improves living conditions, and strengthens human development (Beyene et al., 2018; Kebede et al., 2022a; and Wakjira & Kefale, 2022). The ability of people to access electricity enables them to create multiple income streams, which helps them build stronger economic stability through their income diversification activities. There is limited literature on the assessment of the mediating role of economic diversification in the relationship between electricity access and household livelihoods in peri-urban Ethiopia. This study sought to assess the effect of electricity access on the livelihoods of the peri-urban community in Shaggar by investigating the direct and indirect effects of electricity access through economic diversification and its determinants.

Hypothesis

Hypothesis 1: The accessibility of electricity services in Shaggar peri-urban areas has a positive and significant direct effect on the economic diversification of households.

Hypothesis 2: The accessibility of electricity services has a favorable and significant direct effect on households' sources of income in Shaggar Peri-urban areas.

Hypothesis 3: The accessibility of electricity services has a favorable and significant direct effect on households' livelihood in Shaggar Peri-urban areas.

Hypothesis 4: The economic diversification of households in Shaggar Peri-urban areas mediates the indirect effect of the availability of electricity services on households' Livelihood.

2.1 Conceptual Framework

As illustrated in Figure 2.1, this approach considers how the accessibility of electricity services has a direct and indirect effect on household livelihoods by facilitating economic diversification and the creation of fresh sources of income. Every element of the framework is intended to answer the primary research questions, specifically how the availability of electrical services effects households' economic diversity, sources of income, and increases their livelihoods.

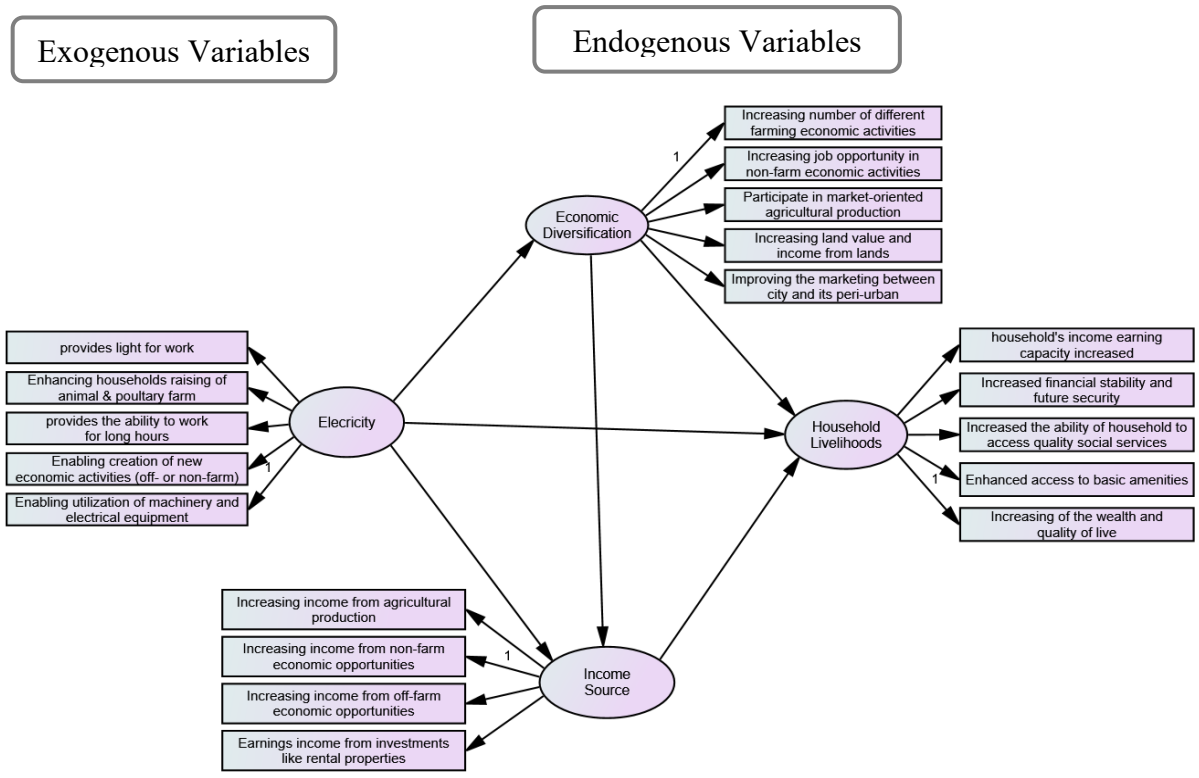


Figure 2.1: The proposed model of the relationship between exogenous and endogenous variables with their observed variables

Source: Adapted by the author from a survey of several literature reviews, 2024

3. Research Methodology

The study was conducted in selected peri-urban areas of Shaggar City, which was established under Regulation No. 233/2015 E.C. in 2023/24. Shaggar City has a total population of 2,111,769, 12 sub-cities, and 36 woredas, from which Sabata, Gelan, and L/Tafo sub-cities were purposively selected because of their economic importance, rapid growth, and strong interaction between urban and peri-urban activities (Figure 3.1).

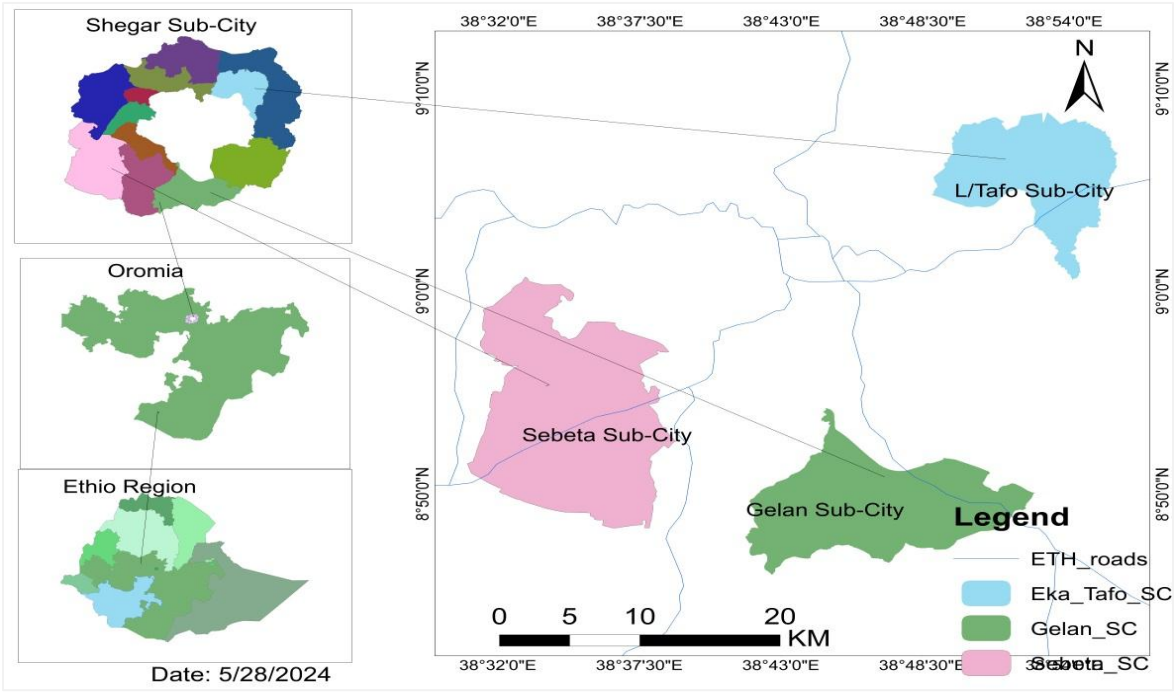


Figure 3.1 Location Map and Administrative Boundary of the Study Area
Source: Developed by the researcher, 2024

A mixed-methods approach with a cross-sectional research design was employed to examine the effects of electricity accessibility on household economic diversification, income sources, and household livelihoods. The study targeted 4,083 households within nine peri-urban zones, representing a population of 16,135 people. Using Yamane's (1967) formula at a 95% confidence level and 5% margin of error, a minimum sample of 364 households was determined and proportionally allocated across the selected villages. Systematic sampling was then used to select household respondents.

The formula $\mathbf{n = \frac{N}{1+N(e2)}}$ $\mathbf{n = \frac{4{,}083}{1+4{,}083(0.05^2)}}$ $\mathbf{n = 364.31 \approx 364}$

Where n is the sample size, N is the population with a confidence level of 95 percent, a P-value of 0.5 and e is the tolerable errors.

Data were collected using structured questionnaires, interview guides, and observation checklists. The main explanatory construct, electricity accessibility, was measured using indicators covering household lighting, poultry and livestock production, creation of non-farm businesses, use of electrical machinery, environmental benefits, and extended working hours. The outcome constructs included economic diversification, income sources, and household livelihoods,

measured through indicators related to farming and non-farm activities, employment, market-oriented production, agricultural and non-agricultural income, savings, financial stability, access to basic services, housing, wealth, and investment. Responses were measured using a five-point Likert scale.

The indicators that are appropriate for the research question were carefully chosen according to the study's goals, data availability, importance, and policy program context for cross-sectional data in 2014. Electricity accessibility, economic diversification, income-source development, and household livelihoods were measured using multi-item five-point Likert scales. The initial 25 observed indicators were subjected to factor analysis, resulting in 19 retained indicators after six items with low loadings were removed. The table below displays the indicators used in this study (see Table 3.1 in Annex).

For data analysis, Structural Equation Modeling (SEM) using AMOS was employed to assess the relationships among electricity accessibility, economic diversification, income sources, and household livelihoods. SEM was selected because it enables simultaneous assessment of direct and indirect relationships among latent constructs and provides model-fit assessment (Byrne & Van de Vijver, 2010 and Hair et al., 2010). Bootstrapping mediation analysis was further applied to examine whether household economic diversification mediates the relationship between electricity accessibility and household income sources and livelihoods. As illustrated in the following model the direct effect was represented by a_1, b_1, and c_1; that show the direct path connecting exogenous variables (access to electricity) and endogenous variables (ED, ID, and HL). To test the mediation effect, the researchers defined the new stimand functions in AMOS software syntax as shown below:

- ✓ $Electricity \rightarrow ED \rightarrow HL = a_1 * a_2$ ……. (1)
- ✓ $Electricity \rightarrow ID \rightarrow HL = b_1 * b_2$ ……. (2)
- ✓ $Electricity \rightarrow ED \rightarrow ID \rightarrow HL = a_1 * a_3 * b_2$ ……. (3)

The study evaluated the measurement model of the constructs through Confirmatory Factor Analysis (CFA) to test the reliability and validity of the observed variables using factor loading, Average Variance Extracted (AVE), and related analyses. The study relied on the Kaiser-Meyer-Olkin test and Bartlett's test of sphericity to evaluate the suitability of the data for the study (Williams et al., 2010). The fitness of the model was evaluated using goodness of fit indices such

as goodness of fit index (GFI), normed fit index (NFI), Tucker-Lewis index (TLI), adjusted goodness of fit index (AGFI), root mean squared error of approximation (RMSEA), and squared error of approximation (RMSEA), relative Chi-square ($\chi 2/df$) (Hair et al., 2010).

The study followed ethical principles to ensure the well-being of the participants. The study obtained the necessary approvals to conduct the study, explained the objectives to the participants, and ensured confidentiality, anonymity, and informed consent (Kivunja & Kuyini, 2017 and Creswell, 2021). The study analyzed data using Statistical Package for Social Sciences (SPSS) version 27 and AMOS 25 software. The study reported the results of the study using statistical finding tables and figures, SEM Analysis, and qualitative findings.

4. Results and Discussions

4.1 Accessibility of Electric Supply and Distance from the City

The household survey points to considerable inequality in electricity access throughout the peri-urban study area. Among the sampled households ($N = 355$) around 209 (58.9%) of the sampled households have access to electricity services, while about 146 (41.1%) of the sample households have no access to electricity services. Concerning relation between access to electricity and distance from the nearby sub-city center, out of 209 sampled households which have access to electricity services, about 62.7% have access to electricity services at 1-5 km and about 34% at 6-10 km from the city. The spatial pattern difference for households lacking electricity within 6-10 km and 11-15 km from the city was 45.9% and 47.9% of households, respectively. The association between distance from the city and electricity access was statistically significant ($x^2 = 151.6$, df = 2, and $p < 0.001$).

Table 4.1 Percentage of households' access to infrastructural services and distance from the city

Access to	Responses	Crosstab Distance from the city			Total	X^2-value /FFHE/	P-Value
		1 - 5 km	6 - 10 km	11 - 15km			
Electricity	Yes	98/66.2%	44/29.7%	6/4.1%	148/41.7%	88.01	<.001
	No	9/6.2%	67/45.9%	70/47.9%	146		
Education level	Yes	131/62.7%	71/34.0%	7/3.3%	209/58.9%	151.6	<.001
	Illiterate	26/1 3.1%	99/49.7%	74/37.2%	199		
	Read & write	114/73.1%	39/25.0%	3/1.9%	156/44%	160.34	<.001

Source: Researcher survey results, 2024

As complementary documentary reviews and qualitative interviews were conducted, electricity access also differed across the selected sub-cities. The reported connection rates stood at approximately 72.4% in Sabata, 69.7% in Gelan, and 62.5% in L/Tafo. Field observations and key-informant interviews further revealed that access by itself did not ensure reliable service, since households faced interruptions and inconsistent supply. The results highlight the main problems of the residents of Shaggar city and its peri-urban areas, including the spatial inequality of grid connection and the unreliable quality of electricity. The spatial distribution shows that distance from the urban center continues to be a significant constraint on connectivity. While electrical power is an essential component for extended working hours, machinery operation, refrigeration, and the creation of modern centers of off-farm production, its current unreliability undermines local economic activities.

The results highlight the main problems of the residents of Shaggar city and its peri-urban areas, including the spatial inequality of grid connection and the unreliable quality of electricity. While electrical power is an essential component for extended working hours, machinery operation, refrigeration, and the creation of modern centers of off-farm production, its current unreliability undermines local economic activities.

The results align with the findings of Nuru, (2019), who identified energy poverty and infrastructural deficit as significant factors challenging the urban and peri-urban development of various populations within the developing countries. Similarly, the current economic risks uncovered by the respondents correspond with the observation of Igwe, (2013) in Nigeria, whose research established the dependence of agricultural processing and micro-enterprises on the reliability of electricity. Ultimately, it is evident that the expansion of the lines into the peri-urban area of Shaggar city will not resolve the current issues, as addressing them requires looking at electricity generation and distribution processes. The findings necessitate an alternative approach to urban electricity planning capable of incorporating an adequate amount of physical and grid-connected distributed renewable energy sources into the system to secure sufficient power for the local economy.

4.2 Assessment of the Suitability of Data used for Measurement Models

4.2.1 Confirmatory Factor Analysis

To create the suggested measurement models, factor rotation was performed using principal component analysis with oblique promax rotation to allow for the correlation of the elements of

latent variables. The measurement model demonstrated acceptable reliability and validity after the removal of six low-loading indicators: Elec6, ED4, ID4, ID5, HL5, and HL7. The final model consisted of 19 observed indicators representing electricity accessibility, economic diversification, income-source development, and household livelihoods (Table 4.2). In this study, the factor rotation of KMO results shows values of 0.96, which indicates that the sampling adequacy criterion was satisfied. The factor analysis revealed that rotation converged into four factors that account for 81.7% of the variance in the data set as a whole.

Table 4.2: Pattern Matrix Component

	Elec	ED	HP	ID
Elec1	.919			
Elec2	.905			
Elec3	.843			
Elec4	.946			
Elec5	.930			
ED1		.882		
ED2		.832		
ED3		.856		
ED5		.922		
ED6		.836		
HL1			.829	
HL2			.902	
HL3			.859	
HL6			.904	
HL4			.848	
ID1				.893
ID2				.860
ID3				.917
ID6				.892

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.

4.2.2. Measurement Model Fit

The AMOS pattern matrix model builder was used to develop the measurement model (MM) with 19 items, converging in four iterations. Initial goodness-of-fit criteria were not met, so error terms with high values were correlated to improve the model fit. Four error terms exceeding 15 within the same construct were selected from the AMOS modification index and correlated. The final model showed a good fit for electricity access, economic diversification, income sources, and household livelihoods (P-value = .073, $\chi 2/df = 1.177$, GFI = .9952, AGFI = .937, CFI = .996, TLI = .988, IFI = .995, NFI = .948, SRMR = .0268, RMSEA = .022, Hair et al., 2010; Preacher et al., 2007; and Diamantopoulos et al., 2000) (Table 4.3 and Figure 4.1).

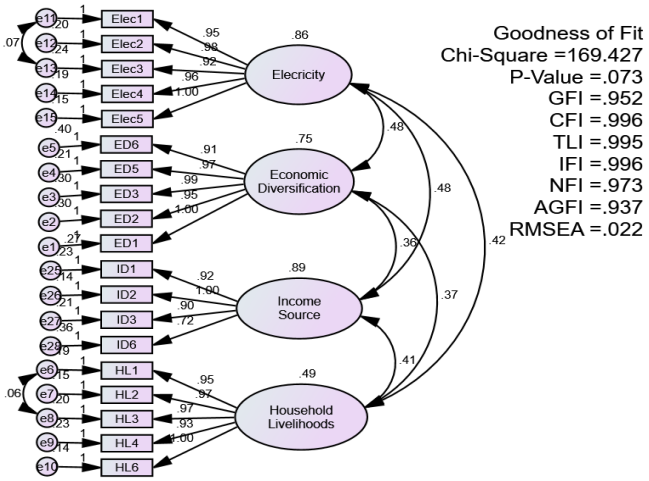


Figure 4.1 The measurement model built by AMOS pattern matrix
Source: Developed by the Researcher using AMOS, 2024

Table 4.3 Goodness-of-fit indices of the measurement model

Indices	x^{2}/df	GFI	AGFI	RMSEA	SRMR	CFI	TLI	IFI	NFI
Recommended value	<3	>0.9	>0.8	<0.05	<0.05	>0.9	>0.9	>0.9	>0.9
Scholars	Hair et al. (2010)	Hair et al. (2010)		Diamantopoulos et al., (2000)		Preacher et al., (2007)			
Observed value	1.177	.937	.937	.022	.0268	.952	.996	.995	.996

Source: Developed by the researcher, 2024

4.2.3 Normality of Data Used to Create Measurement Model

The current data's skewness and kurtosis ranged from -0.38 to .035 and -1.134 to -0.609, respectively (see Table 4.3 in Annex). According to Byrne & Van de Vijver, (2010) proposal for normality, the data in this study were normally distributed because their skewness and kurtosis fell within the permitted range for being classified as normal.

4.2.4 Construct Reliability, Convergent Validity, and Discriminant Validity

As illustrated in Table 4.4, the composite values of the construct in this study exceeded the 0.7 benchmark, ranging from 0.96 to 0.98. Further, as shown in Table 4.4, all AVE values were above the required threshold value of 0.5 for convergent validity; and each construct's AVE was greater than any squared correlation between constructs that shows discriminant validity criteria. Therefore, the constructs used in this study have the required construct reliability, convergent validity, and discriminant validity. Overall, the model demonstrated a good fit, making it suitable for further structural model analysis.

Table 4.4 Correlation Coefficients, Average Variance Extracted (AVE), and Construct Reliability

Latent Variables	Electric	Household Livelihoods	Economic Diversification	Income Source	Composite Reliability (CR) CR > 0.7
Electric	0.89				0.98
Household Livelihoods	0.65	0.85			0.96
Economic Diversification	0.60	0.60	0.84		0.96
Income Source	0.55	0.62	0.44	0.86	0.96

Source: Developed by the author, 2024

4.3 Structural Equation Model Fit

The structural model's output fits the goodness-of-fit indices between the gathered data and the hypothetical model well, as evidenced by multiple fit indices: Chi-square = 167.812, DF = 143, P-value =.077, relative chi-square = 1.17, GFI = .953, AGFI =.938, CFI =.996, IFI =.996, NFI =.973, TLI =.989, and RMSEA =.022 (Figure 4.2). The results of the goodness-of-fit indices of SEM are in line with (Demissie et al., 2024). Thus, the results of the structural model were used to retest the hypotheses in the section that follows.

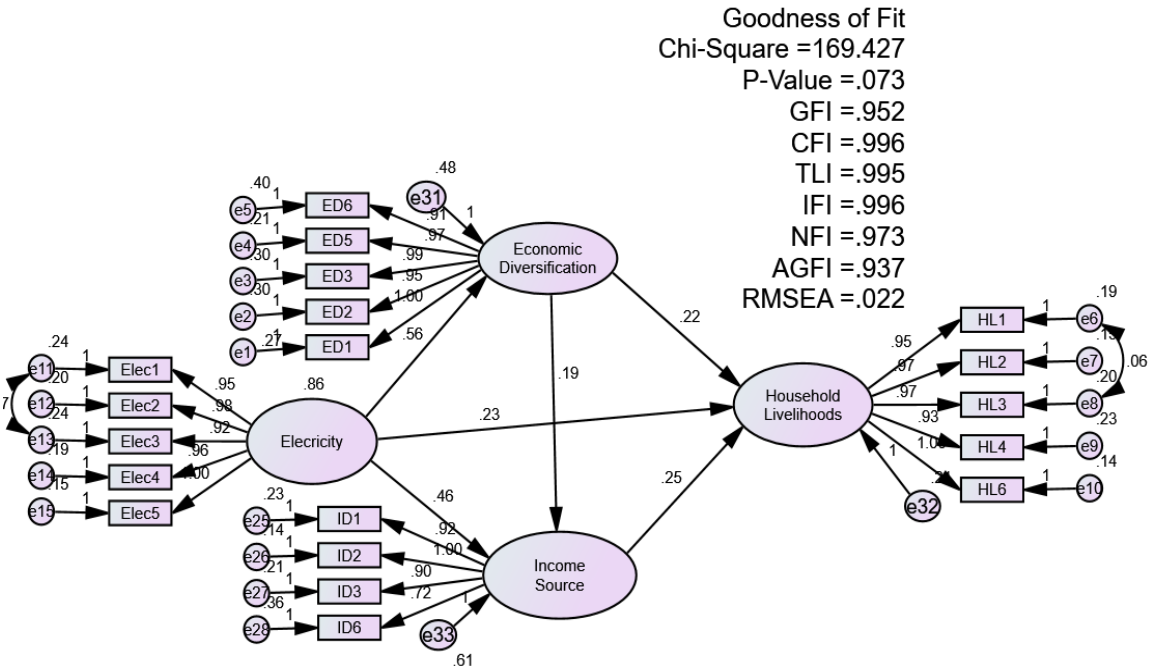


Figure 4.2 Unstandardized regression weights of direct and indirect effects and goodness-of-fit of structural model of the study

Source: Developed by the Researcher using AMOS, 2024

4.3 The Findings of Hypothesized Direct Effects

Now that the structural model's output matches the goodness-of-fit indices of the gathered data and the hypothetical model well, it is time to test the hypothesis. Thus, the path coefficients of the

structural equation model developed by AMOS software were used to test the hypothesized direct effects.

4.2.1 Direct Effects of Accessibility of Electricity on Households' Economic Diversification

Hypothesis 1: The accessibility of electricity service has a positive and significant effect on households' economic diversification in the Peri-urban areas of Shaggar City.

Table 4.5 Description of regression weight, Standardized error, Critical rate, and P-Value of the direct effects results

	Direct Effects	Regression weight (β)	Standardized error	Critical rate	P-Value	Remark
H1	Economic Diversification <--- Electricity Service	.557	.048	11.537	***	Accepted
H2	Income Development <--- Electricity Service	.457	.064	7.155	***	Accepted
H3	Income Development <--- Economic Diversification	.189	.068	2.776	.006	Accepted
H4	Household Livelihoods <--- Electricity Service	.232	.043	5.329	***	Accepted

Source: Developed by the researcher, 2024

As illustrated in AMOS SEM Figure 4.2 and in Table 4.5 results, the accessibility of electricity service has a positive and statistically significant effect on the economic diversification of households (β = .557, C.R. = 11.537, p =***). The result implies that a one-unit increase in access to electricity service is associated with a 0.56-unit increase in the expected value of households' economic diversification in Peri-urban areas of Shaggar City. Thus, H1 is supported by statistical evidence from the findings.

The positive beta coefficient (β = 0.56) indicates that as the availability of electricity in the village increases by one, the possibility of the residents in the village diversifying their economic activities increases by 0.56 compared to those without electricity. This indicates that there is a positive linear association between the availability of the electricity service and residents economic diversification by providing a stable supply of electricity, enhancing households raising of poultry farming, livestock rearing, engaging in non-farm businesses like food processing and other microbusinesses, enabling to utilize electric machineries like refrigeration to store and move perishable agricultural products, and water pumps enabling them to cultivate seasonal market-oriented crops and vegetables. As the result of KII and field observation taken image in Figure 4.3 shows the households that have electric supply accessibility use electricity for lighting, television, and refrigerators in the peri-urban areas as well as the use of solar energy for irrigation in Gelan periphery (Figure 4.4).

In general, the availability of electric power in the village can give residents in the areas the ability to diversify their economic activities in farming, off-farming, and non-farming. Similar to this study's findings, Bose et al., (2013); Gilberto (2012); and Ponce et al., (2017) investigated that the villages which had electric supply have positive results in expanding agricultural activity, production, advancement of business, enhancing the standard of living, and human capital development.



Figure 4.3 The image shows the use of electricity for lighting, television, and refrigerators in the peri-urban areas
Source: Image taken by the researchers during field observation, 2024



Figure 4.4 The images show the use of solar energy for irrigation in Gelan periphery
Source: Image taken by the researchers during field observation, 2024

4.2.2 Effects of Accessibility of Electricity Service on Households' Income Sources

Hypothesis 2: accessibility of electricity service in peri-urban areas has positive and significant direct effects on households' source of income development.

As illustrated in the findings of the SEM results in Table 4.5, the accessibility of electricity service to households has a positive and significant direct effect on their source of income development (β =.457, C.R. = 7.155, p =***). Hence, the H_2 hypothesis was supported by statistical data, which implies the accessibility of electricity service has a significant effect on the households' source of

income development at the 0.05 level of significance. This implies that access to electricity creates favorable conditions for households to increase their income from agricultural production, as well as non-farm and off-farm economic opportunities. This result was in line with Stern et al., (2019) and Puri et al., (2023); Adem & Tesafa, (2020); Xu et al., (2023) and Wang et al., (2021) those find that there is significant relationship exists between income source advancement and access of electricity.

4.2.3 Effects of Accessibility of Electricity Service on Households' Livelihoods

Hypothesis 3: Accessibility of electricity service in peri-urban areas has positive and significant direct effects on households' livelihoods in Shaggar City peri-urban areas.

As illustrated in the findings of the SEM results in Table 4.5, the accessibility of electricity service to households has a positive and significant direct effect on the households' livelihoods development in Shaggar City peri-urban areas (β =.232, C.R. = 5.33, p =***). Hence, the H_3 hypothesis was supported by statistical data, which implies that the accessibility of electricity service has a significant effect on the households' livelihoods enhancement at the 0.05 level of significance.

According to the field survey, KII, and observation results, households living on the peripheries of urban areas that have access to electricity services have a variety of opportunities to participate in a wide range of economic development activities, through increasing the quantity and variety of crops they cultivate, raising a larger variety of livestock (dairy, poultry, and animal fattening), enhancing the use of local resources (land and water), enhancing market-oriented agricultural production, and creating employment opportunities in the fields of off- and non-farming.

This shows that access to electricity creates opportunities for households to increase income-earning capacity; financial stability and future security; the ability of household members to access basic amenities; increased wealth and quality of life; and household asset development that reflects household livelihoods. The results are confirmed with Beyene et al., (2018); Kebede et al., (2022a); Wakjira & Kefale, (2022); and Aragaw, (2012), those found that access to electricity services has positive results in the areas of production, profit margin, development and business modernization, quality of life, and human capital development, that lead to households' livelihoods.

4.2.4 Mediating Effect

Hypothesis 4: The indirect effect of the accessibility of electricity in the peri-urban villages on the households' livelihoods through the mediators of households' ED and ID in Shaggar City was positive and significant.

Table 4.6: Indirect effect of User-defined Estimands

Parameter	Estimate	Bootstrap 95% Confidence Interval		P-Value
		Lower	Upper	
Indirect Effect Electricity → ED → HP	.122	.076	.177	.013
Indirect Effect Electricity → ID → HP	.113	.074	.155	.007
Indirect Effect Electricity → ED → ID → HP	.026	.004	.053	.050

Source: Developed by the researchers, 2024

As shown in the results of the user-defined estimands of SEM in Table 4.6 in the Shaggar peri-urban areas, the accessibility of electricity service through mediation of households' ED was found to have positive and significant indirect effects on the households' livelihoods (β = 0.122, CI [0.076, 0.177], p = 0.013). Additionally, the accessibility of electricity service through mediation of households' ID was found to have positive and significant indirect effects on the households' livelihoods (β = 0.113, CI [0.074, 0.155], p = 0.007). Further, SEM result provides that the accessibility of electricity had a positive and almost significant indirect effect on the households' livelihoods through the mediation of the households' economic diversification and income source (β = 0.026, CI [0.004, 0.053], p-value = 0.05).

The above result shows that zero was not included in the biased 95% confidence interval of the model for the availability of electricity and drinking water. This implies that the hypothesized indirect effect was supported by statistical evidence, as well as the presence of the mediation effect of households' economic diversification and income source in the relationship between the accessibility of households' electricity services and their livelihoods, with a significance level of p-value less than 0.05. Additionally, the type of mediation was complementary partial mediation in the association between the accessibility of electricity services, the households' source of income, and livelihoods in peri-urban areas of Shaggar City. Through field observations and KIIs, the researcher observed that the households in Sabata sub-peri-urban areas were using modern electric irrigation systems powered by solar energy for agricultural practices, upgraded harvesting and ploughing implements, and electrically powered cold storage facilities.

Accessibility of electricity influences households' sources of income and livelihoods in several ways, including supplying the energy required for production, improving the use of machinery and electrical equipment (including the use of refrigerators to transport and store agricultural goods), lowering environmental pollution, and stimulating the development of new economic activity. Therefore, accessing electricity not only directly improves living conditions but also catalyzes the economic diversification activity of the residents and develops the sources of income among households.

The result of the study is in line with Gao and Yue, (2020) who found that household electrification led to increased income for households as well as the creation of job opportunities in related sectors, and contributes to overall city and periphery area sustainable relation development. Additionally, the study conducted in Myanmar's rural sector by Paudel et al., (2022) highlighted that significant income growth was linked to economic diversification of households, particularly through non-farm activities including small-scale entrepreneurship and off-farm employment. Economic diversification should improve living conditions, sources of income, well-being, and asset ownership while helping to combat hunger and poverty as well as enhance livelihoods (Purwanto, 2020 and Jooji et al., 2017).

5. Conclusions

The study's focus was to examine the direct and indirect effects of the accessibility of electricity services on households' livelihoods through their economic diversification and source of income in Shaggar peri-urban areas, Ethiopia. The study shows that electricity access is spatially uneven, with more than two-fifths of households surveyed lacking electricity, and access was strongly associated with distance from the main urban center of Shaggar City. Additionally, as Structural Equation Modeling results show, electricity access significantly influences household economic diversification by transitioning from purely farm-based livelihoods to a diversified mix of farm, non-farm, and off-farm enterprises to expand household income streams. Moreover, economic diversification and income sources partially mediate the relationship between households' livelihoods and the accessibility of electricity services. Electricity contributes to livelihoods not only through direct household benefits but also by creating conditions under which households can diversify economic activities and expand income sources. This suggests that electrification should be viewed as part of a wider process of peri-urban economic transformation by fostering economic diversification and income sources.

6. Implication of the Study:

Theoretical Implications: Electricity is demonstrated as a pull factor facilitating economic diversification and enhancing sources of income that lead to livelihood enhancement.

Policy Implications: Provision of electricity should be integrated with peri-urban economic development and income sources to improve livelihoods rather than treated only as household infrastructure.

Practitioner Implications: Managers and practitioners in the energy sector should effectively plan and execute electricity infrastructure projects and reliability, particularly in peri-urban regions, to promote income diversification and long-term household livelihoods.

Methodological Implications: Methodologically, this study applies Structural Equation Modeling (SEM) to examine the intricate relationships between electricity access, economic diversification, income sources, and household livelihoods, offering a framework adaptable to other similar studies of infrastructure and household economic outcomes.

7. Limitation of the Research and Future Research Direction:

This study provides valuable insights but is limited to Shaggar City and its peri-urban areas, which are influenced by their proximity to Finfinne (Addis Ababa). To foster sustainable economic development, long-term planning should integrate electricity expansion and socio-economic data analysis across Shaggar, Finfinne, and the surrounding peri-urban region.

Future researchers should expand the study contexts by extending the geographical scope to include a wider range of city regions through longitudinal data that cover significant time spans to capture complex dynamics of electricity accessibility and its implications on city-regional economic diversification, sources of income, and livelihoods.

8. Declarations & Statements

Authors' Contributions

- **Ahmed Mohammed:** Conceptualization, methodology, field survey data collection, statistical modeling (SEM), GIS map, drafting the original manuscript.
- **Kanchan Singh:** Research supervision, conceptual framework refinement, structural equation modeling validation, critical review and editing.
- **Ranavijai B. Singh:** Co-supervision, spatial infrastructure and economic analysis, manuscript revision and editorial structuring. All authors read and approved the final manuscript.

Ethical Approval

This study was conducted in accordance with the ethical standards of the institutional research committee. Formal ethical clearance was obtained from the Ethics Committee of the College of Urban Development and Engineering at Ethiopian Civil Service University under Reference Numbers **RAD/025/2014** and **RAD/028/2014** (see Annex). Administrative gatekeeper approval and field data collection authorization were granted by the Shaggar City Administration Office under Reference Number **106/2015** (see Annex).

Consent to Participate

Informed consent was obtained from all individual household participants involved in the study prior to administering the survey questionnaires. Participation was voluntary, and anonymity was maintained across all spatial and socio-economic data collection workflows.

Consent for Publication

Not applicable (the manuscript contains no individual person's identifiable data or images).

Competing Interests

The authors declare that they have no financial or non-financial competing interests that are relevant to the content of this article.

Funding

The authors declare that no external grant funding was received for the conduct of this research, data collection, or preparation of this manuscript.

Availability of Data and Materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Acknowledgements

The authors express their appreciation to the Shaggar City Administration Office and municipal field coordinators for facilitating access and administrative support during household data collection. We also extend our thanks to the survey enumerators and local community members in the peri-urban study districts for their participation.

Clinical trial number

Not applicable.

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Supplementary Material

Table 3.1: Variables used to measure the effects of electricity accessibility on households' economic diversification and Source of Income development

Exogenous Variables	Latent variables	Unit of measurement
1. The benefits of access to electricity	1. It provides light needed for households' work (Elec1) 2. Enhancing household raising of poultry farming (Elec2) 3. Enhancing household's livestock rearing by the households (Elec3)	Perception of households in

		4. Enabling creation of new economic activities like engaging in non-farm businesses, for example food processing and other microbusinesses (Elec4) 5. Enabling utilization of machinery and electrical equipment (Elec5) 6. Reducing the negative impact on environmental prolusion (Elec6) 7. It provides the ability to work for long hours (Elec7)	lickert scale from 1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; and 5 = strongly agree
		Endogenous Variables and their latent variables	
2.	**Economic Diversification over the past decade**	1) Increasing number of different farming economic activities (ED1) 2) Increasing job opportunity in non-farm economic activities (ED2) 3) Enhancing market-oriented agricultural production (ED3) 4) Increasing efficient usage of local natural resources (ED4) 5) Increasing land value and income from lands (SID5) 6) Improving the marketing between city and its peri-urban (SID6)	
3.	**Source of Income development over the past decade**	1) Increasing income from agricultural production (ID1) 2) Increasing income from non-farm economic opportunities (ID2) 3) Increasing income from off-farm economic opportunities (ID3) 4) Improving money sent by family members working in other areas (ID4) 5) Earnings income from investments like rental properties (ID5) 6) Increasing saving (ID6)	
4.	**Households Livelihoods over the past decade**	1) The household's income earning capacity increased (HP1) 2) Increased financial stability and future security (HP2) 3) Increased the ability of household members to access quality social well-being services (HP3) 4) Enhanced access to basic amenities (HP4) 5) The household owns their residence (HP5) 6) Increasing wealth and quality of life (HP6) 7) Increasing new investment activities (SID7)	

Source: Adapted by the author from survey of several literature reviews, 2024

Table 4.7 Assessment of normality

Variable	min	Max	skew	c.r.	kurtosis	c.r.
ID6	2.000	5.000	-.245	-1.884	-.727	-2.794
ID3	2.000	5.000	-.145	-1.112	-.955	-3.675
ID2	2.000	5.000	-.106	-.816	-1.134	-4.360
ID1	2.000	5.000	-.186	-1.430	-1.038	-3.991
HP6	2.000	5.000	-.380	-2.925	-.780	-2.999
HP4	2.000	5.000	-.342	-2.628	-.609	-2.341

Variable	min	Max	skew	c.r.	kurtosis	c.r.
HP3	2.000	5.000	-.365	-2.811	-.783	-3.010
HP2	2.000	5.000	-.299	-2.301	-.712	-2.740
HP1	2.000	5.000	-.364	-2.801	-.628	-2.416
ED6	2.000	5.000	.035	.270	-1.091	-4.196
ED5	2.000	5.000	.002	.019	-.948	-3.645
ED3	2.000	5.000	-.087	-.670	-1.105	-4.248
ED2	2.000	5.000	-.045	-.344	-1.036	-3.986
ED1	2.000	5.000	.011	.085	-1.092	-4.200
Elec5	2.000	5.000	-.347	-2.672	-.984	-3.785
Elec4	2.000	5.000	-.210	-1.614	-1.004	-3.861
Elec3	2.000	5.000	-.239	-1.838	-.950	-3.653
Elec2	2.000	5.000	-.233	-1.793	-1.037	-3.989
Elec1	2.000	5.000	-.236	-1.813	-1.023	-3.933
Multivariate					7.638	2.547

Source: Developed by the Researcher using AMOS, 2024

Supplementary Files

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