Model for Assessing Variation in Property Taxation and Infrastructure in Ibadan Metropolis

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Received: 29/04/2025 **Revised:** 24/05/2025 **Accepted:** 10/10/2025

Property tax is a major source of public income in both developed and developing counties. Consequent upon several researches, the use of empirical models for residential property taxation has been suggested, hence identifying suitable empirical models for residential property taxation has become worrisome over the years. However, the determination of suitable parameters to be used as the dependent variables remains a research problem that is best solved by examination of the prevalent situation of the area concerned as no generalized model can best describe all situations. The study therefore developed a model for assessing variation in property taxation and infrastructure in Ibadan metropolis. The model advances the Gleaser model by integrating property tax with population, Land value, owner's income, other taxes paid on land and financial allocation expended on Infrastructure. Quantitative research design approach was adopted in this study. A structured questionnaire was administered to residents of residential properties using a purposive sampling technique. A cubic model was used, and it yielded suitable R^2 values ranging from 58.1 to 95.4 in all the local governments within the Ibadan metropolis. Gleaser model was then used to integrate the property tax with population, Land value, owner's income, other taxes paid on land and financial allocation expended on Infrastructure within the area. The study found out that the generation of property tax may not automatically lead to an increase in financial allocation. It was therefore concluded that the developed model is robust, efficient and a best fit for the Nigerian scenario.
Keywords: Property tax, mathematical models, functional models, infrastructure, Gleaser model

Introduction

Taxes on land and property remain one of the oldest and most reliable sources of revenue for governments worldwide, providing a stable fiscal base particularly for local government administrations (Cagdas *et al*., 2003; Bird & Slack, 2002). In many developing countries, property taxes account for a significant proportion of sub-national revenue, constituting nearly 40% of all local government taxes (Bahl, 2002). Despite this potential, property taxation remains underutilised in Sub-Saharan Africa due to weak administration, valuation challenges, and widespread evasion (Ahmad *et al*., 2014; McCluskey & Plimmer, 2016).

In Nigeria, property tax represents a potentially sustainable source of internally generated revenue (IGR) for local governments. For example, in Ibadan North-East Local Government Area, property tax contributed as much as 17.39% of IGR in 2000 and rose to 51.46% by 2009 (Ajayi, 2011). However, these figures have not translated into consistent growth, largely because property taxation systems remain inefficient and poorly structured. The situation is compounded by limited administrative capacity, political interference, lack of standardized valuation techniques, and poor linkage between tax revenue and infrastructure provision (Krelove, 2012; Roy, 2002).

Scholars and practitioners have therefore sought to design simple, cost-effective, and comprehensive models, both empirical and graphical to support property valuation and taxation (Bird & Slack, 2002; Roy, 2002; McCluskey & Plimmer, 2016). While such models have been applied in both developed and developing contexts, their effectiveness is often constrained by difficulties in selecting the most appropriate parameters that influence property values, such as land location, income levels, and infrastructure availability (Cagdas *et al*., 2003; Ahmad *et al*., 2014). In the Nigerian context, few empirical models have successfully integrated these multiple variables in a way that does not reflect the spatial realities of urban centres like Ibadan.

This gap is critical, as property tax not only provides revenue but also serves as a fiscal tool that links taxation to infrastructure development. The absence of robust, context-specific models limits the ability of local governments to harness property taxation as a sustainable means of financing urban infrastructure.

Against this background, the present study develops an empirical model that mathematically integrates identified taxation variables, including consumer income, government expenditure on infrastructure, and land value at specific property locations, into a single framework. By doing so, the study addresses the parameter selection problem inherent in existing empirical models and provides spatially explicit outputs that illustrate variations in property taxation across Ibadan metropolis. This approach aims to strengthen the fiscal capacity of local governments and enhance the link between property taxation and infrastructure development.

Review of Empirical Studies

Tax-related variables

Consumer Income

Income is a monetary value received from individuals or organizations for personal expenditures, including wages, business, and rent (Krasko, 2013; Altintas *et al*., 2017). Consumer income refers to the money a consumer receives from investments or work, such as dividends or asset sales. Income directly affects consuming behaviour and life styles, with a higher income level determining a family's or person's level of consumption and life styles (Klopotan *et al*., 2016; Pakistan & Pakistan, 2014). Research has shown that income has a significant effect on customers' loyalty, brand sensitivity, and consumer complaint behaviour (Soba & Aydin, 2012; William, 2002). High income levels also lead to more opportunities to complain about products and services, as they have more personal resources to express dissatisfaction more readily (Mat *et al*.,2016; Tronvoll, 2007).

Land value and location

Land value is influenced by various factors, including location, amenities, and neighbourhood attributes (Jaeger, 2013; Chen et al., 2017). In New York, land value is related to distance to central business districts and neighbourhood attributes like parks and recreational areas (Gedal & Ellen, 2018). In China, residential land value depends on proximity to CBD, while commercial land value depends on proximity to rail stations (Qin *et al*., 2016). In Singapore, land value depends on proximity to metro stations and good schools (Tu *et al*., 2007). Commercial property buildings have the highest land value, followed by single-family residences, multi-family housing, and condominiums (Cervero, 2006; Rakhmatulloh *et al*., 2018; Peterson, 2013). Infrastructure investments and urban economic growth significantly affect land use change (Munshi, 2020; Nelson, 1999). Accessibility to desired activities and transport infrastructure also affects land value (Dziauddin *et al*., 2015; Liu & Shi, 2017; Atuesta *et al*., 2018). Nearness to green spaces and less air pollution also increases land value. Public service amenities can also improve accessibility and impact land value (Ebertz, 2013; Dziauddin *et al*., 2013).

Forms of property taxation

Taxation is a compulsory levy imposed on property, corporate bodies, and institutions to raise money for social amenities and economic well-being (Okoi & Edame 2013; Ajiteru *et al*., 2018). Property taxes are historically associated with local government due to their immovable nature (Ajayi *et al*., 2014). In the United States, property taxes are considered a benefit tax because they approximate the benefits received from local services (Bird & Slack, 2004; Fischel, 2001). There are three forms of property taxation: annual or rental value, capital value of land and improvement, and site or land value (Stotsky & Yucelik, 1995). Property taxes are levied on all properties, including residential, commercial, industrial, and agricultural (Ajayi et al., 2014). Some countries impose tax on land and buildings separately, while others assess both (Litchfield & Connellan, 2000).

Property taxation and infrastructure

Infrastructure refers to publicly owned facilities like roads, water pipes, and sanitary sewers, essential for societal development (Ray, 2015). It includes physical structures like schools, airports, and schools (Ajiteru *et al*., 2018; Todaro and Smith, 2011). Infrastructural development is made possible by physical, social, and economic infrastructures (Waziri *et al*., 2014; Oisasoje and Ojeifo, 2012; Fidelis, *et al*., 2014). In Nigeria, existing infrastructure faces issues like traffic congestion, poor telecommunication services, and poor drinking water. To address these issues, the federal government needs to mobilize significant revenue through taxation (Adesoye, 2014).

Property taxation and infrastructure

Ajayi *et al*. (2014) found that property tax financing basic infrastructure in Ibadan North local government is crucial. Mabe and Kuusaana (2016) found that property tax contributes to 28% of the Sekondi-Takoradi Metropolitan Assembly's IGF, primarily for waste management, education, social services, street lights, and health facilities. Ajiteru et al. (2018) found that tax revenue is a strong tool for infrastructural development in Osun State, Nigeria. However, inadequate citizen tax payments can lead to low infrastructure levels.

Financial allocation to infrastructure

Infrastructure spending stimulates the US economy and goes beyond basic improvements to power plants, sewers, roads, and highways (Cohen *et al*., 2012). Urban growth in developing countries presents challenges in financing urban infrastructure. Investments are needed for basic services, safer water supply, transportation, and economic productivity (Peterson, 2013). Traditional financing sources for urban infrastructure include local government operating sources, higher government grants, and borrowing (Peterson, 2013). However, local budgets struggle to finance basic services, and higher government may restrict grants for fiscal management (Touche Ross and Co., 1985). Grants from federal or higher government are crucial for state and local capital spending, with highways, sewers, and transit being of greatest importance (Ray, 2015).

Gleaser model

The Glaeser model in urban economics highlights the role of property taxes in shaping city growth, density, and land use, particularly in the context of urban sprawl (Glaeser, 2011). According to the model, property taxes can distort housing markets by discouraging improvements and leading to lower-density development, thereby incentivizing outward city expansion (Brueckner & Kim, 2003). However, alternative designs, such as split-rate systems that tax land more heavily than structures, can mitigate sprawl and encourage compact urban forms (Taranu & Verbeeck, 2022). Recent reforms also emphasize the importance of location-based tax zoning to align property tax burdens with socio-economic realities, highlighting that the effectiveness of property taxation depends on careful structural design rather than uniform application (Felis *et al*., 2025).

Study Area

The ancient city of Ibadan town is one of the oldest cities in Africa and a major commercial city in Nigeria. With a population of over 3 million people, Ibadan ranks as the third most populous city in Nigeria. An efficient method of property taxation is therefore a necessity to take full advantage of the high amount of revenue the government could derive from property taxation in such a city. Map of the study area is presented in Figure 1.

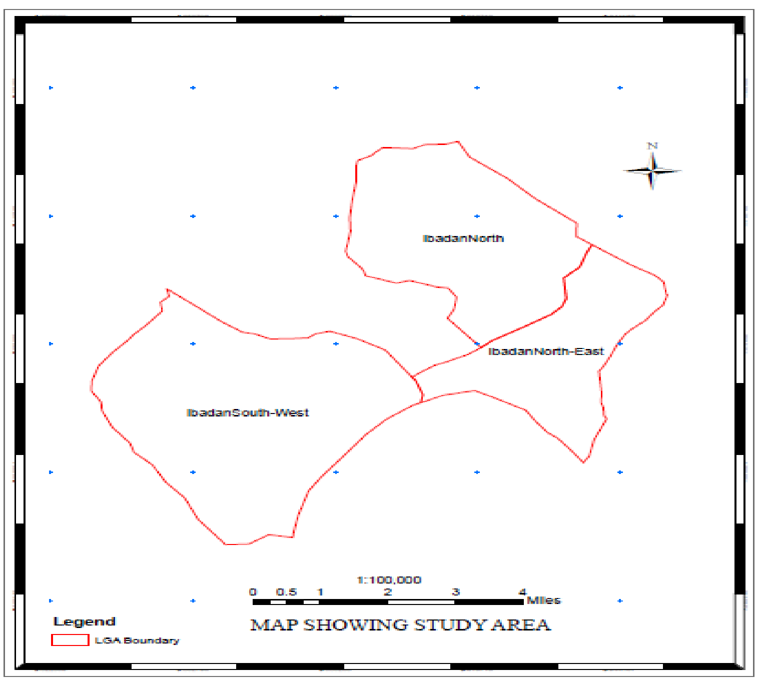


Figure 1: Study Area

Research Methodology

The study was conducted using a quantitative research approach. Data were collected through both primary and secondary sources. The targeted population include residents of the 3 selected locations (Ibadan-north, Ibadan-west and Ibadan-east) and residential buildings in the study area. A structured questionnaire was administered to the respondents using a purposive sampling technique. The data collected also include property tax, income, price of land, infrastructure provided, and land consumption rate. Data collected were sorted and processed using Factor analysis to identify the significant variables which had the maximum effect on the developed taxation model. Based on the obtained field data, a tax generation model was derived.

Model derivation

Sequel upon the high R^2 values (signifying optimum performance) of the cubic models over the quadratic model in all three tested local government areas, the

cubic model was chosen for the determination of the empirical model for property taxation within the study area.
Consider equation 1

$$F = AP_J + BP_J^2 + CP_J + D \qquad (1)$$

Where F = Allocation to Financial Infrastructure
P_J = Property tax paid at location J
A, B and C are coefficients of variables
D is the constant

A mathematical analysis of (2) yields (3) by differentiating the given function

$$\frac{dF}{dP} = 3AP^2 + 2BP + C \qquad (2)$$

But Property tax had earlier been defined as a function of Population of residents and Population of residential buildings i.e.

$$P = f(Pop, PopR) \qquad (3)$$

Where Pop = Population of residents
PopR = Population of residential buildings

Substituting (3) into (2) gives

$$\Delta F = 3A(Pop + PopR)^2 + 2B\,(Pop + PopR) + C \qquad (4)$$

From Gleaser model:

$$U(X, L, A_J)\, subject\ to\ I \geq X + P_J\,(i + I_J)L + B_J \qquad (5)$$

Where $U(X, L, A_J)$ is a utility function common across consumers
I = Income
X = composite commodity with price equal to 1
L = consumption rate of land
P_J = Price of land at Location J
A_J = Amenities level at Location J
B_J = Lump sum tax (equivalent of income tax) at location J
L_J = Property tax at location J

But PopR = I – $(L_v + t + FinIn) + P$ (6)

Where I = Income of prospective resident
L_v = Land Value at location J
t = Property tax paid in the same area
FinInfr = amount of money spent on the provision of infrastructure in the same area
P = Population of residents

Consequently (6) therefore becomes

$$3A(PopR + C)^2 + 2B(PopR + C) + C = 0 \qquad (7)$$

Let I – $(L_v + t + FinIn)$ = M
Then

$$3A(M + P + C)^2 + 2B(M + P + C) + C = 0 \qquad (8)$$

Let M + P = P_r (9)

Substituting (9) into (8) and expanding yields (10)

$$3A(P_r^2) + 6AP_rC + 3AC^2 + 2BP_r + 2BC + C = 0 \qquad (10)$$

Recall (10) and let C be 0. Then (11) becomes (12)

$$3A(I - (L_v + t + FinIn) + P)^2 + 2B((I - (L_v + t + FinI \qquad (11)$$

After the expansion of (11) and differentiating the result for the property owner's income we get (12)
For simplicity, let $FinIn$ be written as F

$$6AI - 6AL_v - 6At - 6AF + 6AP + 2B \qquad (12)$$

$$\therefore I = L_v - t - F + P + {}^{B}/_{3A} \qquad (13a)$$

$$t = L_v - F + P + {}^{B}/_{3A} - I \qquad (13b)$$

where
I = Income of prospective resident
L_v = Land Value at location J
t = Property tax paid in the same area
F = amount of money spent on the provision of infrastructure in the same area
P = Population of residents
B = Other income tax from other sources on the property.
A = Factor of priority of payment
3 = multiplier effect for division of other income.

Results and Discussion

The quadratic and cubic models were experimented for all the three local governments being studied in this work. A summary of the results obtained from both models for all three local governments as well as the computed goodness of fit for each model is presented in Table 1.

Table 1: Applicable Models of the Relationship between Financial Allocation to Provision of Infrastructure and Amount of Property tax generated

Local Government	Applicable Model	Equation	R2	Multiplier Variable
Ibadan North Local Government	Quadratic	$FinInfraN = 0.00AptN3 - 1111Apt - 8E + 008$	93.2	
	Cubic	$FinInfraN = 1.85E - 010\ AptN3 - 0.001Apt2 + 2983.578Apt - 2E + 009$	95.4	PopR, Pop
Ibadan North East Local Government	Quadratic	$FinInfraNE = 0.00AptNE\hat{}3 - 1111Apt - 8E + 008$	48.3	
	Cubic	$FinInfraNE = 2E - 009\ AptN\hat{}3 - 0.009Apt\hat{}2 + 133355.59Apt - 6E + 009$	58.1	PopR ,Pop
Ibadan South West Local Government	Quadratic	$FinInfraNsw = -8.7Aptsw\hat{}2 + 164.4Apt - 1E + 008$	68.0	
	Cubic	$FinInfraNsw = -6.76Aptsw\hat{}3 + 8.6Aptsw\hat{}2 - 1.2Aptsw + 3E + 008$	72.1	PopR, Pop

Figure 2 gives a graphical plot of the projected income as expected within the three local governments under study from 1999 to 2015, while Figure 4 shows the relationship between the projected tax values and the land value, expenditure on infrastructure and owners' income.

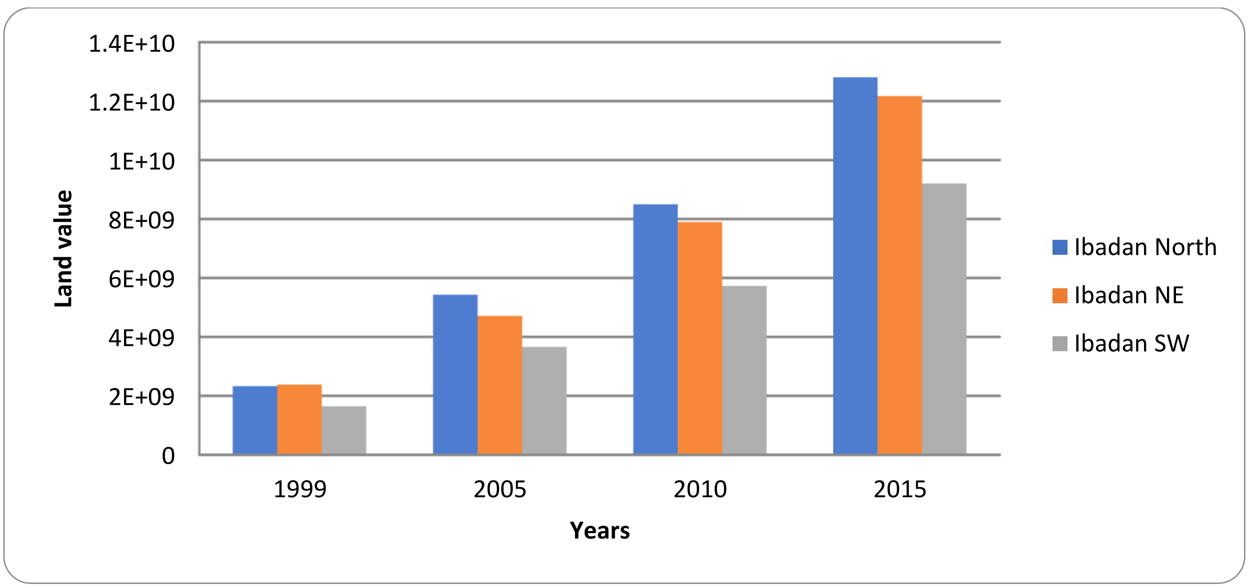


Figure 2: Projected income from property tax within the three LGA's in the year 1999 – 2015 (overlay graph)

The linear trend observed in Figure 3 indicates that an increase in any of the parameters (Expenditure on Infrastructure and owner's income) reflects a corresponding increase in the amount to be paid for property tax. This observed trend validates the model as this is the expected behaviour of such a curve.

The spatial pattern of projected tax rates across the Ibadan metropolis is similarly presented in Figure 4 and it shows Ibadan North consistently having the largest amount of expected tax value throughout the projected years. This is just as expected as Ibadan North is dominated by the high-class personalities in Ibadan therefore the land value and associated amount for land purchase is higher than what is obtainable in other places.

This model therefore supports the general principle of taxation which suggests that people should pay tax that conforms to what they enjoy from the government.

From the generated spatial pattern, we see the highbrow area (Ibadan North) since it receives the highest amount of government attention (i.e. amount spent by the government on infrastructure) and also the residents within the area earn higher than those in other areas, the expected tax generated from the area is more.

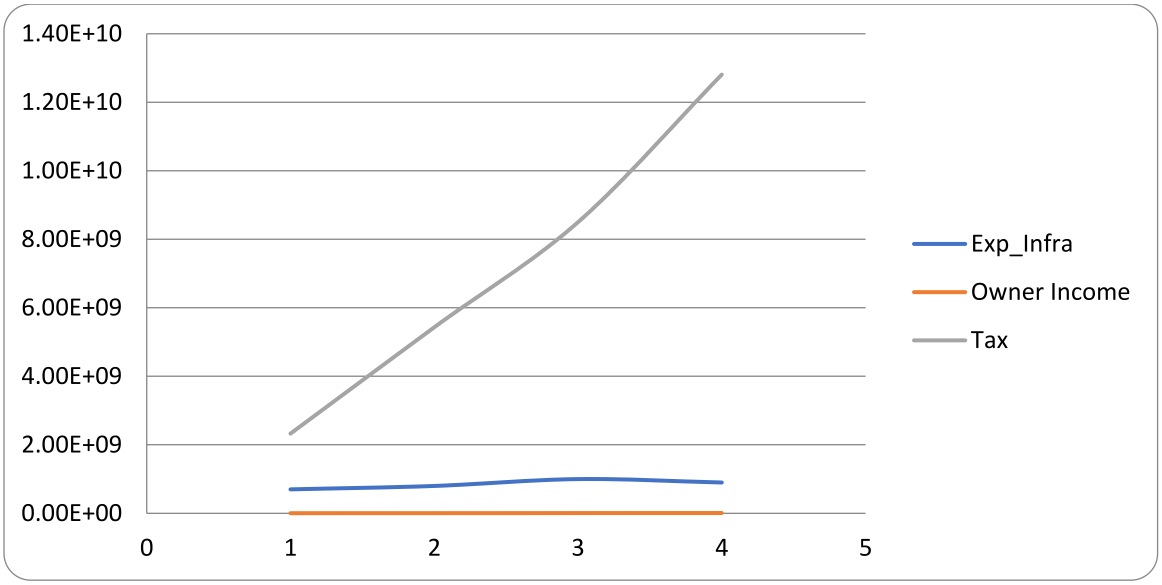
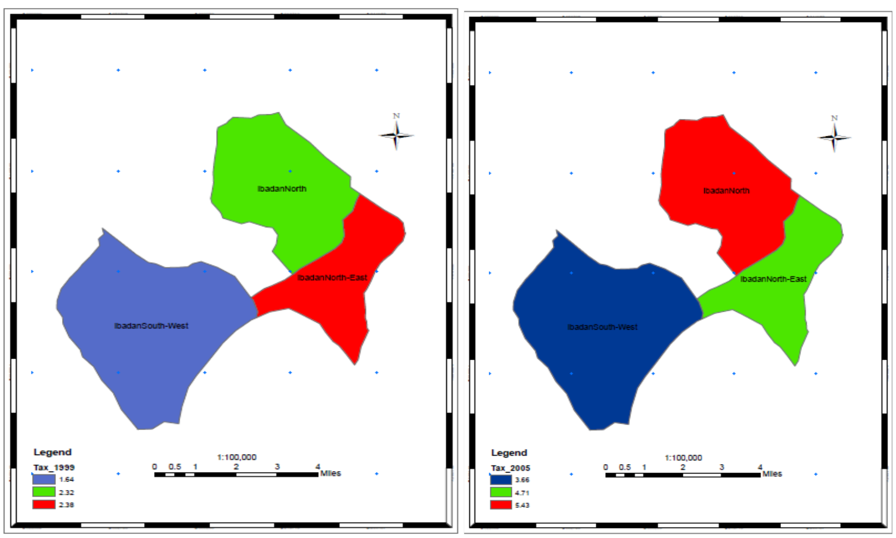
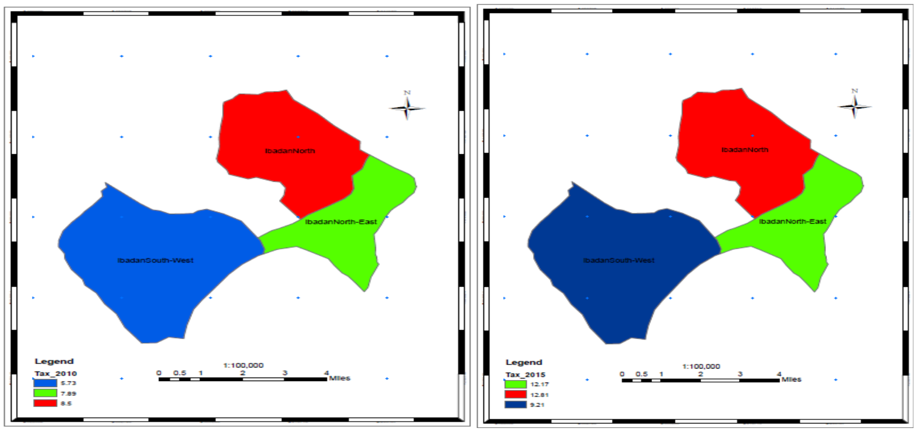


Figure 3: Parameter trend curve



(a)1999 (b) 2005



(c) 2010 (d) 2015

Figure 4: Spatial pattern of projected tax rates across Ibadan Metropolis (a – d)

Conclusion

It was discovered that the generation of property tax within all the sampled local governments is not only dependent on a single variable but a complex mathematical relationship between several variables. The preliminary assessment also reveals that the generation of property tax may not automatically lead to an increase in financial allocation.

The derived model has proven to be a very efficient tool for property taxation within the study area. The utilization of the Gleaser model in the equation derivation has helped to incorporate parameters such as property value, expenditure on infrastructure, property owner's income and other taxes payable within the area into the equation. This therefore makes the equation very flexible as property owners are taxed only based on these essential parameters thereby ensuring that no taxpayer pays more than the exact value of infrastructure he is enjoying from the government. The study recommends this model for assessing variation in property taxation and infrastructure in urban areas of Nigeria.

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