APPLICATION OF GIS FOR PROPERTY TAX ASSESSMENT: A CASE STUDY OF SHILLONG MUNICIPAL BOARD

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ABSTRACT

This study examines the application of Geographic Information Systems (GIS) for property tax assessment within the Shillong Municipal Board (SMB), India, highlighting the transformative potential of geospatial technology in improving urban governance for smaller municipalities. A total of 26,611 built-up plots across 27 wards were digitized and categorized into six zones based on economic value. The study employed the Unit Area Value (UAV) method, integrated with GIS, incorporating factors such as construction type, building age, ownership, usage, and location to calculate property taxes. The results revealed notable variations in tax revenue between wards and zones, with central areas generating significantly higher revenue than peripheral regions. The GIS-based system enhanced accuracy in property identification, standardized valuation methods, and improved data management. However, challenges in maintaining up-to-date data and addressing socio-economic disparities in tax burdens were observed. The study proposes improvements, including refining UAV values, adding new assessment factors, and utilizing machine learning for property classification. This research offers a scalable model for small and medium-sized municipalities, providing insights into more efficient, equitable, and transparent property tax systems. The findings have important implications for urban planning, revenue generation, and policy-making, supporting data-driven approaches to sustainable urban development in India and beyond.

Keyword: GIS, Property tax assessment, Unit Area Value, Urban governance, Spatial analysis

INTRODUCTION

Property tax is a vital source of revenue for urban local bodies, particularly in developing countries like India, where municipalities rely on it to fund essential public services such as infrastructure development, sanitation, healthcare, and education (Mishra *et al.*, 2022; Sridhar & Li, 2021). However, property tax systems in many cities are often inefficient, outdated, and characterized by inaccurate property records, inconsistent valuation methods, and limited administrative capacity (Awasthi *et al.*, 2021a; Bahl, 2009). Traditional approaches to property tax assessment, which rely on manual surveys and outdated cadastral maps, frequently result in under-assessment, revenue leakage, and inequitable tax burdens (Samad, 2011). Moreover, the lack of transparency in tax administration fosters distrust among property owners, further exacerbating compliance issues (Gebrihet *et al*., 2023; Prichard & Van Den Boogaard, 2017). In response to these challenges, there has been a growing demand for modernized, data-driven approaches to property tax assessment that leverage advanced technologies to improve accuracy, efficiency, and accountability in urban governance (McCord *et al.,* 2022; van Ooijen *et al*., 2019).

Geographic Information Systems (GIS) have emerged as transformative tools for urban governance, offering a spatial framework to manage, analyse, and visualize property-related data with a high degree of precision (Droj *et al*., 2024; Khan, 2021; Pfeffer *et al*., 2015). In the context of property tax assessment, GIS facilitates the digitization of built-up plots, the integration of spatial and non-spatial data, and the automation of tax calculation processes, significantly improving both accuracy and efficiency (Krishna Kasyap Vattipalli, 2015; Mokhtar *et al*., 2023). By linking geographic data with relevant property attributes such as land use, building characteristics, and ownership details, GIS enables municipalities to conduct spatial analysis that supports more accurate property valuation (Arcuri *et al*., 2020; Jacoby *et al.,* 2002; Locurcio *et al*., 2020). Additionally, GIS-based systems offer increased transparency by providing stakeholders, including property owners and tax administrators, with access to real-time, georeferenced property information (Abin *et al*., 2021; Muswii, 2015). This shift towards GIS-based property tax administration not only minimizes human error and manipulation but also ensures a more equitable distribution of the tax burden, ultimately enhancing public trust in the system (McCord, 2022; Virkar, 2011). As a result, many cities globally have adopted GIS to modernize their property tax systems, resulting in substantial improvements in revenue generation and administrative efficiency (Oyalowo *et al*., 2021; Pescador & Caelian, 2022).

A substantial body of literature has explored the application of GIS in property tax assessment, demonstrating its potential to enhance accuracy, efficiency, and transparency in municipal tax administration. Studies by Bahl *et al*. (1992) and Bird and Slack (Bird & Slack, 2004) laid the foundation for understanding the limitations of traditional property tax systems and the need for modernization in developing countries. More recently, researchers have emphasized the role of GIS in addressing these challenges. For instance, Khan (2021) highlighted how GIS-based property tax systems significantly reduced tax evasion and improved revenue generation in Pakistan's urban centres. Similarly, Francis (2019) and Mete & Yomralioglu (2023) demonstrated the success of GIS in automating property records and integrating multiple datasets for better assessment accuracy. In India, Pareta (2017) and Mukherjee (2018) applied GIS to streamline property tax collection in urban local bodies, while Awasthi *et al*. (2021) and Mishra *et al*. (2022) demonstrated the potential of GIS in improving the accountability and transparency of tax systems.

Despite these advancements, significant gaps remain in the literature, particularly in the context of smaller municipalities in developing countries. While larger cities such as Delhi and Hyderabad have seen success with GIS implementation (Baski, 2024; Singh *et al*., 2022), limited research has focused on smaller urban areas like Shillong, where challenges such as limited technical expertise, funding constraints, and inadequate infrastructure present additional hurdles. Moreover, much of the existing research has centred on GIS applications in wealthier, urbanized regions, leaving the scalability and replicability of such systems in smaller municipalities underexplored. Studies by Droj *et al*. (2024) and Mokhtar *et al*. (2023) such as have called for more research into GIS-based property tax assessment in underrepresented regions to evaluate the broader applicability of these systems.

This study addresses a critical gap in the modernization of property tax systems in small and medium-sized municipalities in India. In particular, it investigates how GIS can be used to digitize property records and implement a more accurate, efficient, and transparent tax assessment framework for the Shillong Municipal Board (SMB). The absence of systematic GIS-based assessment methods in smaller cities often results in outdated, error-prone, and inequitable tax systems. This research aims to bridge this gap by proposing a scalable GIS-based model for property tax administration. The following research questions guide this study:

1. How can GIS be used to digitize and manage built-up plots data effectively in a smaller municipality like Shillong?
2. How does the integration of field-based attributes (e.g., construction type, usage, building age) into a GIS database enhance property tax assessment accuracy using the Unit Area Value (UAV) method?
3. What are the spatial patterns and socio-economic implications of tax revenue generation across different wards and zones within the SMB?
4. Can the GIS-based tax assessment model developed for Shillong be scaled and replicated in other small and medium-sized municipalities across India?

The primary objective of this study is to develop and implement a GIS-based property tax assessment system for the Shillong Municipal Board (SMB) with the aim of improving the accuracy, efficiency, and transparency of property tax administration. Specific goals include the creation of a comprehensive GIS database of built-up plots, the application of the Unit Area Value method with integrated field data, and the evaluation of tax revenue outcomes. The study also assesses the potential for scaling this approach to other municipalities with similar governance challenges.

MATERIAL AND METHODS

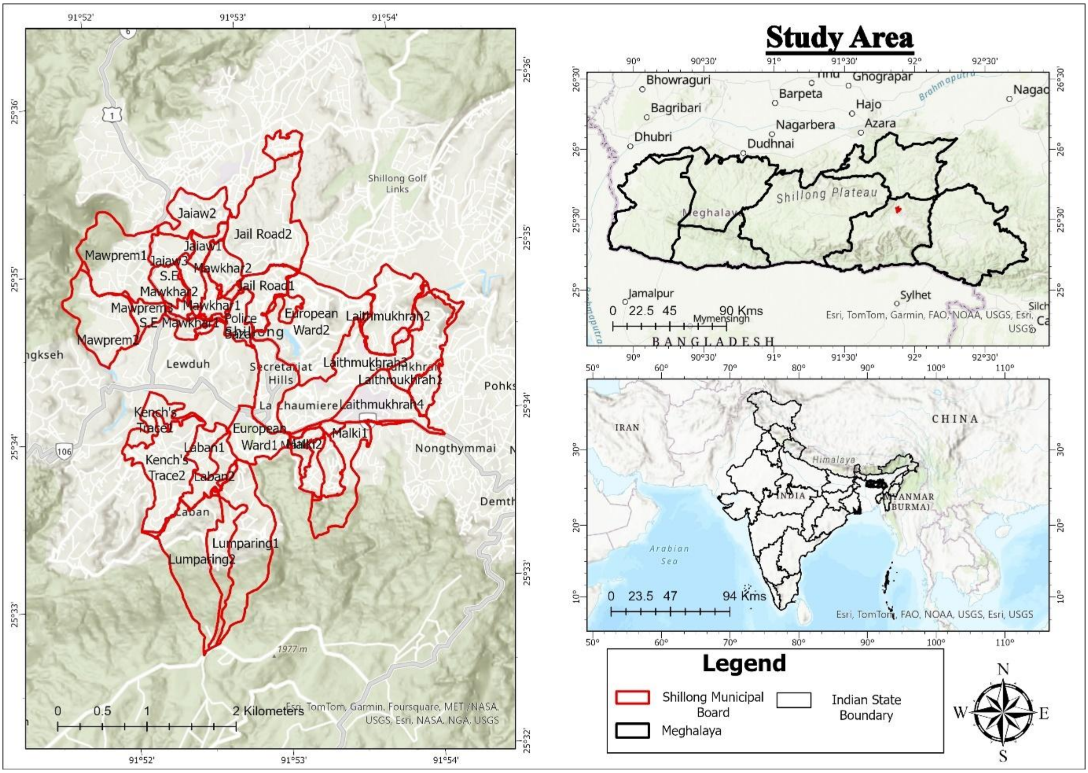
Study Area

The study area encompasses the jurisdiction of the Shillong Municipal Board (SMB), located in Shillong, the capital city of Meghalaya, India (Fig. 1). Nestled in the East Khasi Hills, Shillong is situated at an average elevation of 1,496 meters (4,908 feet) above mean sea level, positioned between the geographic coordinates of 25.5788° N and 91.8933° E. The population within the SMB jurisdiction is estimated to be around 250,000, with a population density of approximately 3,500 people per square kilometre, with most residents concentrated in the central and northern wards. The SMB area is divided into 27 wards, further classified into six zones (A to F) based on proximity to schools, colleges, and hospitals.

Shillong experiences a subtropical highland climate characterized by mild summers and chilly, wet winters. Annual temperatures range from about 4°C (39°F) in January to 24°C (75°F) in August, with substantial rainfall primarily during the Southwest monsoon season, averaging around 2,400 mm annually (Dey & Deka, 2021). The city's moderate temperatures and relatively low humidity are attributed to its high altitude and hilly terrain. The natural landscape of Shillong is marked by rolling hills, dense forests, and numerous streams and waterfalls, reflecting its rich biodiversity. Vegetation primarily comprises temperate broadleaf and mixed forests, including species such as oak, pine, and rhododendron. The East Khasi Hills, including Shillong, are renowned for their diverse flora and fauna, harbouring several endemic and endangered species.

Shillong's urban development has evolved significantly from its origins as a British hill station. The city centre, initially designed with a colonial aesthetic, now features a blend of residential, commercial, and institutional areas, along with peripheral industrial zones. Shillong boasts a well-developed social infrastructure, serving as an educational, healthcare, and governmental hub for the North-East region of India. It hosts numerous educational institutions, including the esteemed Indian Institute of Management Shillong, alongside government and private hospitals, cultural centres, and recreational facilities. However, rapid population growth and urban expansion have posed challenges in service provision, transportation, and housing, necessitating efficient resource management and equitable development strategies. Understanding the unique spatial characteristics and administrative structure of the SMB jurisdiction is crucial for the effective implementation and evaluation of the GIS-based property tax mapping and assessment approach proposed in this study.

Fig. 1: Study area of the Shillong Municipal Board (SMB) within the geographic context of Meghalaya and India



GIS Data Collection and Digitization

The GIS data collection and digitization process involved creating a comprehensive built-up plot map for all properties under the jurisdiction of the Shillong Municipal Board (SMB). This process integrated geospatial technology and field survey data to ensure accurate property representation and assessment for tax purposes.

Built-up Plot Digitization

The initial phase involved using Google Earth Pro for the digitization of built-up plots based on high-resolution satellite imagery. Property boundaries were visually identified by tracing the building footprints and other geographical features visible in the imagery. Each built-up plot was manually digitized by creating polygons around the identified footprints, which were then georeferenced to align with real-world coordinates. These digitized built-up plots were saved in KML/KMZ formats, ensuring compatibility with GIS software for further processing.

Importing Built-up plots

The digitized built-up plots were imported into ArcGIS for advanced spatial analysis. The KML/KMZ files from Google Earth Pro were converted into shapefiles formats using ArcGIS conversion tools. The imported built-up plots were organized into distinct layers within the ArcGIS environment, allowing for further analysis in relation to other spatial datasets such as ward boundaries, road networks, and zoning maps provided by SMB.

Calculation of Property Area

In ArcGIS, the area of each built-up plot was calculated using the "Calculate Geometry" tool. The area was measured in square meters (sqm), the standard unit for property dimensions used in tax assessments. The calculated areas were verified against cadastral records or field measurements, and any discrepancies were corrected by adjusting the built-up plot boundaries. The attribute table of the built-up plot layer was then updated with the area values, along with other relevant property attributes such as built-up plot ID, construction type, age, and usage, which were later utilized in property tax calculations.

Field Survey

The field survey was conducted to verify the accuracy of the digitized built-up plots and collect essential attribute data for properties under the Shillong Municipal Board (SMB). This process was crucial to ensure that the spatial data accurately reflected real-world property characteristics, supporting the assessment of property taxes. The purpose of the field survey had two primary objectives:

1. Verification of Digitized Built-up Plots: The survey team physically inspected each property to ensure that the digitized boundaries matched the actual property boundaries on the ground.
2. Attribute Data Collection: Detailed data on various property characteristics were gathered to populate the attribute table in the GIS database, enabling accurate property tax calculations.

The following property attributes were recorded during the field survey:

1. Construction Type: Categorized into:
   a) RCC (Reinforced Cement Concrete)
   b) Assam Type (traditional structures)
   c) Combined (a mix of RCC and Assam Type)
   d) Other (temporary or unconventional structures)
2. Building Age: Classified into three categories:
   a) Less than 25 years
   b) 25 to 50 years
   c) More than 50 years

3. Ownership Type: Identified as:
    a) Self-occupied
    b) Tenanted
    c) Others (e.g., government or institutionally owned)
4. Property Usage: Categorized as:
    a) Residential
    b) Commercial/Residential (mixed-use)
    c) Commercial
    d) Institutional (e.g., schools, hospitals)
    e) Other (vacant land or temporary structures)
5. Property Location: Classified based on proximity to roads or pathways:
    a) Main Road
    b) Other Roads
    c) Footpaths/Steps
6. Zoning Information: Each property was assigned to a zone based on SMB's ward and zone boundaries, which determined the applicable Unit Area Value (UAV) for tax calculations.

The field survey was conducted by a trained team equipped with GPS-enabled mobile devices for data collection. Attribute data was recorded digitally and later integrated with the digitized built-up plots in the GIS database. Each property's attributes were linked to the corresponding built-up plot in the GIS map, ensuring spatial accuracy and data completeness. To ensure the accuracy of the collected data, surveyors cross-referenced their findings with available municipal records. Any discrepancies in ownership or usage were addressed during this validation process.

Data Integration

The data integration phase involved consolidating spatial data, field survey attributes, and municipal records into a unified GIS environment to support UAV-based property tax assessment. Each digitized built-up plot was assigned a unique Built-up plot ID and linked to field-collected attributes—such as construction type, building age, ownership status, usage, and location—using the Join function in ArcGIS. This created a comprehensive attribute table combining spatial and non-spatial information.

Official ward and zone boundaries from the Shillong Municipal Board (SMB) were integrated to assign zone-wise UAV rates to each plot. Road network data enabled proximity analysis to determine the property's access category (main road, other road, or footpath), which was later used to apply the location factor. While the **multiplicative factor values** were defined by SMB guidelines (detailed in Section - Multiplicative Factor Values (MFV)), their assignment was automated in the GIS database based on property attributes. The final GIS dataset enabled efficient, rule-based computation of property tax. A validation step was conducted to ensure spatial and attribute accuracy through cross-verification with field notes and municipal records, resolving any inconsistencies before final analysis.

Property Tax Assessment

The property tax assessment for properties under the Shillong Municipal Board (SMB) is calculated using the Unit Area Value (UAV) method. This method provides a standardized and transparent approach to assessing property taxes based on the covered area of each property and a set of multiplicative factors that account for various property characteristics.

Unit Area Value (UAV) Method

The UAV method assigns a base unit area value per square meter of covered area for each property, based on the zone in which it is located. These zones reflect the economic value of the land and its development density. The annual property tax is calculated using the following formula:

$$Annual\ Tax\ Payable\ (Rs) = Zone-wise\ UAV \times Covered\ Area\ (sqm) \times Multiplicative\ Factor\ Values\ (MFV) \times Tax\ Rate$$

Where:

- Zone-wise UAV: The base unit area value for a specific zone.
- Covered Area: The total built-up area of the property in square meters.
- Multiplicative Factor Values (MFV): A combination of factors that adjust the tax based on structure type, age, occupancy status, usage, and location.
- Tax Rate: A percentage applied to the computed rateable value. The tax rate for SMB is set at 4.5 %.

Zone-wise Unit Area Value (UAV)

The UAV differs across zones within SMB's jurisdiction, reflecting the property's location and its associated land value (Table 1). These zones were predefined by the Shillong Municipal Board (SMB) under the official Unit Area-Based Self-Assessment Method (UASAM) for property taxation ("Unit Area-Based Self-Assessment Method," 2015). Higher-value zones, such as commercial areas, have higher UAVs, while residential and peripheral zones have lower UAVs. The UAVs are as follows:

Table 1: Zone-wise unit area value (UAV) for property tax assessment in SMB

Zone	A	B	C	D	E	F
UAV (Rs/sqm)	500	264	210	158	128	86

For example, properties in Zone A have a UAV of Rs. 500 per square meter, while properties in Zone F have a UAV of Rs. 86 per square meter. The covered area is the total built-up area of the property, measured in square meters (sqm). It includes the total floor area of the building or structure. The tax payable increases proportionally with the covered area.

Multiplicative Factor Values (MFV)

The UAV method incorporates multiplicative factors to account for specific property characteristics. These factors ensure that the tax assessment reflects the property's unique attributes, such as its construction type, age, occupancy, use, and location. The multiplicative factor values were adopted directly from the official guidelines issued by the Shillong Municipal Board (SMB) as part of its Unit Area-Based Self-Assessment Method (UASAM) for municipal holding tax ("Unit Area-Based Self-Assessment Method," 2015). The factors are as follows:

a) Structure Factor (SF): Based on the building's construction material, reflecting durability and market value:
    a) RCC (Reinforced Cement Concrete): 1.0
    b) Assam Type: 0.9
    c) Other Structures: 0.7
b) Age Factor (AF): Accounts for depreciation due to the building's age:
    a) Less than 25 years: 1.0
    b) 25 to 50 years: 0.8
    c) More than 50 years: 0.6
c) Occupancy Factor (OF): Reflects the occupancy status:
    a) Self-occupied: 1.0
    b) Tenanted: 1.5
d) Use Factor (UF): Based on the property's primary function:
    a) Residential: 1.0
    b) Institutional: 1.5
    c) Commercial/Industrial: 2.0
    d) Public Sector (Central/State): 3.0
e) Location Factor (LF): Based on the property's proximity to roads:
    a) Main Road: 1.0
    b) Other Roads: 0.8
    c) Footpaths/Steps: 0.6

Computation of Annual Property Tax

The final element of the formula is the tax rate, which is applied to the computed rateable value. For SMB, the tax rate is set at 4.5 %. Once all the factors have been determined, the following steps are used to compute the annual property tax are as follows:

1. Determine the zone-wise UAV based on the property's location.
2. Measure the covered area of the property in square meters.
3. Apply the multiplicative factor values (SF, AF, OF, UF, LF) based on property characteristics.
4. Apply the tax rate (4.5 %) to calculate the final tax payable.

Illustrative Example

Consider a property in Zone B, located on a main road. The property is an RCC structure, less than 25 years old, tenanted, and used for commercial purposes. The covered area is 200 square meters.

$$Annual\ Tax\ Payable = 264 \times 200 \times (1.0 \times 1.0 \times 1.5 \times 2.0 \times 1.0) \times 0.045 = 7{,}128\ Rs.$$

Thus, the annual property tax for this property would be Rs. 7,128.

RESULTS

Digitization of Built-up Plots

The digitization of built-up plots within the Shillong Municipal Board (SMB) involved mapping and categorizing a total of 26,611 properties across the city, divided into various wards and zones. This section presents the results of the digitization process through ward-wise and zone-wise distributions, as illustrated in Figures 2 and 3.

Built-up plots were digitized across 27 wards within SMB, with significant variation in the number of properties per ward (Table 2). Some wards exhibited a higher property density compared to others. Kench's Trace 2 recorded the highest number of properties (1,886), followed by Mawprem 3 (1,566) and Laithmukhrah 3 (1,389). Conversely, Police Bazar had the lowest number of properties, with only 480, which may reflect the ward's smaller geographic area or lower property density. The distribution of properties across wards is depicted in Fig. 2, where each ward is color-coded to indicate its boundary, and the red points represent the digitized properties. The map highlights a higher concentration of properties in central, more developed wards such as Laithmukhrah and Malki, while the outskirts, including Kench's Trace and Lumparing, also have considerable property densities.

Fig. 2: Spatial distribution of properties across various wards in the SMB

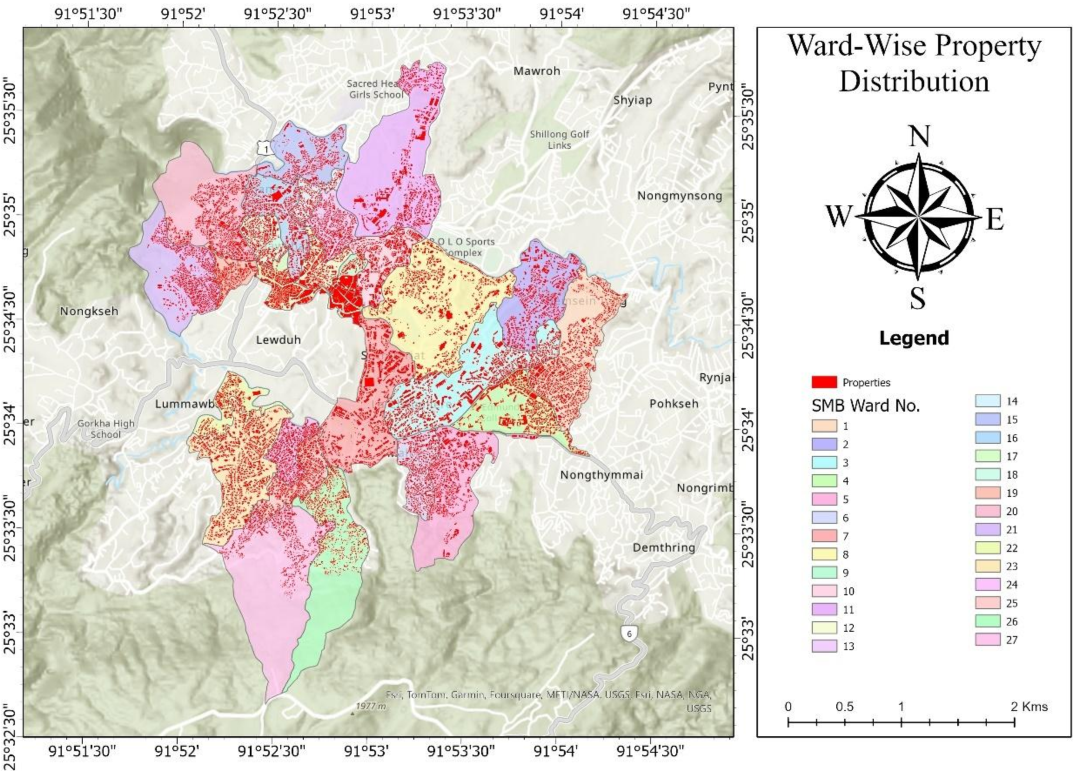


Fig. 3: Spatial distribution of properties across various zones in the SMB

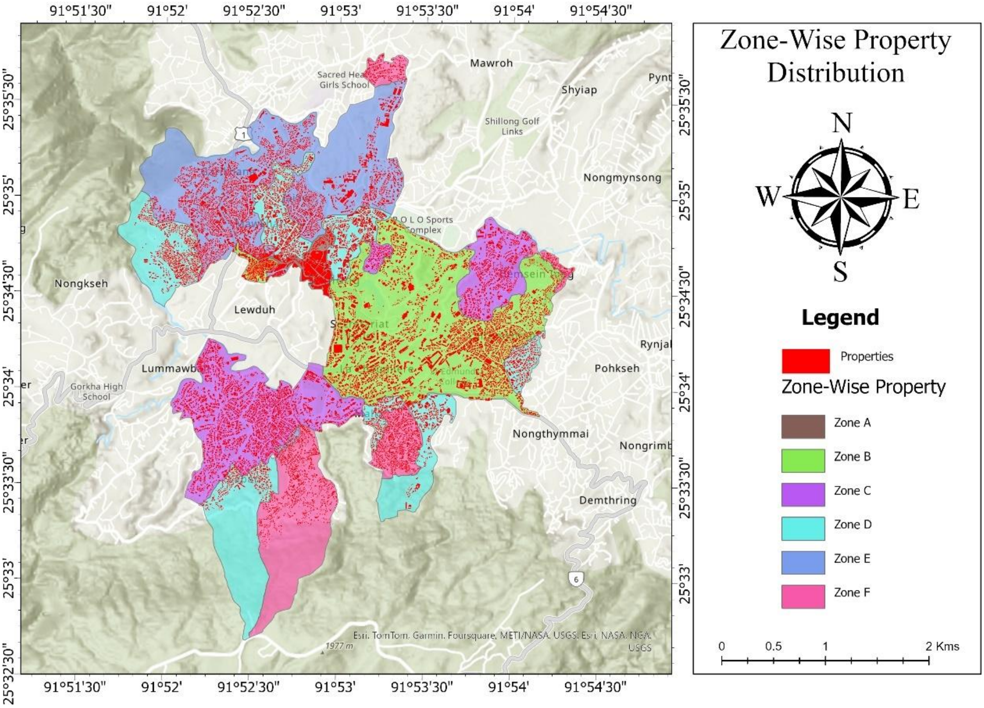


Table 2: Ward-wise distribution of properties in SMB

Wards	Ward Name	No. of Properties	Wards	Ward Name	No. of Properties
1	Laithmukhrah1	1302	15	Jaiaw2	1040
2	Laithmukhrah2	781	16	Jaiaw3	1043
3	Laithmukhrah3	1389	17	S.E Mawkhar1	709
4	Laithmukhrah4	1026	18	S.E Mawkhar2	673
5	Malki1	1138	19	Mawprem1	548
6	Malki2	1068	20	Mawprem2	1090
7	European Ward1	1273	21	Mawprem3	1566
8	European Ward2	993	22	Kench's Trace1	432
9	Police Bazar	480	23	Kench's Trace2	1886
10	Jail Road1	798	24	Laban1	840
11	Jail Road2	1146	25	Laban2	899
12	Mawkhar1	766	26	Lumparing1	996
13	Mawkhar2	1185	27	Lumparing2	1020
14	Jaiaw1	524	**Total Properties**		**26611**

To further differentiate property valuation, the built-up plots were categorized into six zones (A to F) based on geographic location and economic factors. Each zone corresponds to a specific property tax slab, with Zone A representing the highest value properties and Zone F the lowest. Zone E contained the largest number of properties (6,504), followed by Zone D (5,541) and Zone C (5,519). In contrast, Zone A, representing premium properties, had the fewest properties (653). Fig. 3 illustrates the spatial distribution of properties across these zones. Zones B and C, located in the central parts of Shillong, dominate the property landscape, while Zone F, comprising peripheral and less developed areas, shows a lower concentration of properties (Table 3).

Table 3: Zone-wise distribution of properties in SMB

Zone	**No. of Properties**
A	653
B	5120
C	5519
D	5541
E	6504
F	3274
Total Properties	**26611**

Multiplicative Factor Analysis

In this study, the property tax assessment is primarily influenced by five key multiplicative factors that are Construction Type, Building Age, Ownership Type, Property Usage, and Property Location. These factors, derived from field survey data, were integrated into the GIS database to ensure a comprehensive and accurate property tax calculation.

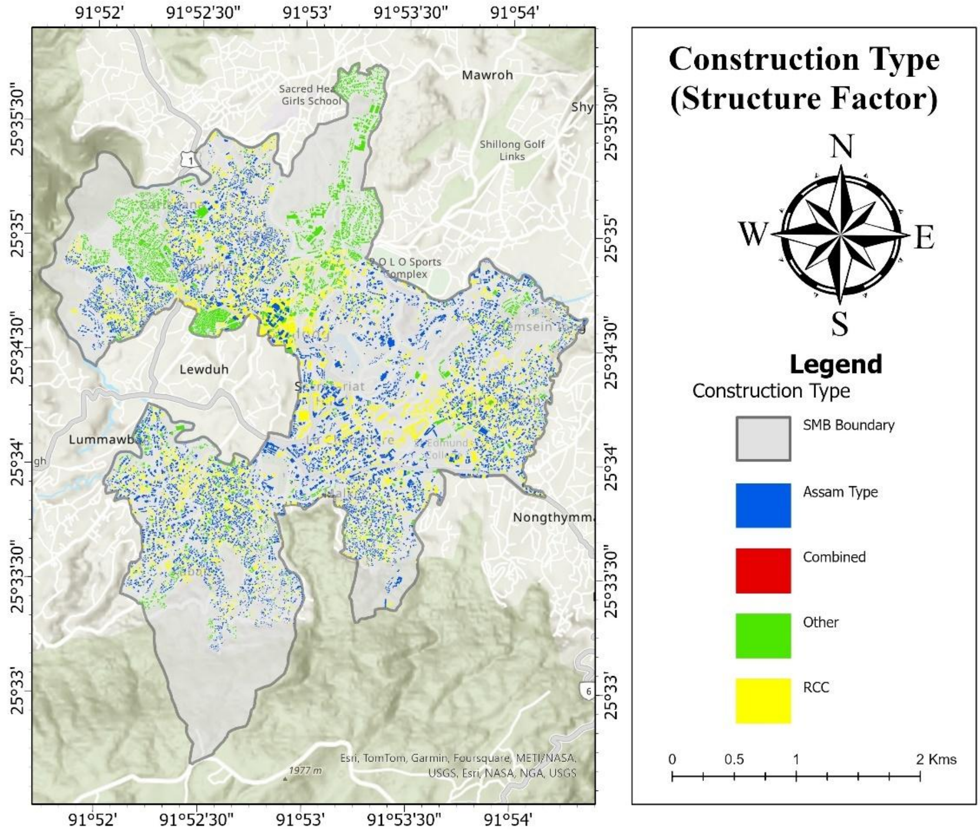
Construction Type (Structure Factor)

The type of construction across the Shillong Municipal Board (SMB) significantly affects the property's structural value and corresponding tax rate. The Structure Factor (SF) assigned to each construction type reflects its durability and market value. Among the 26,611 properties surveyed, Reinforced Cement Concrete (RCC) structures were the most common, accounting for 10,903 properties (Table 4). These RCC structures were predominantly located in Zones B and C, as shown in Figure 4 (Structure Factor Map). Traditional Assam Type constructions, characteristic of the region, made up 10,007 properties and were more prevalent in the peripheral zones, particularly in Zones E and F. Combined construction types accounted for 1,082 properties, while other structures (temporary or unconventional) contributed 4,619 properties. Given their modern construction, RCC structures are assigned the highest structure factor (SF = 1.0), resulting in higher tax liabilities compared to Assam Type (SF = 0.9) and Other structures (SF = 0.7). This distribution reflects the urban development trends in Shillong, where newer areas adopt modern construction methods, while traditional Assam Type buildings remain prevalent in certain regions.

Table 4: Distribution of properties by construction type

Construction Type	RCC	Assam Type	Other Structures	Others
No. of Properties	10903	10007	1082	4619

Fig. 4: Spatial distribution of property construction types (structure factor) in SMB



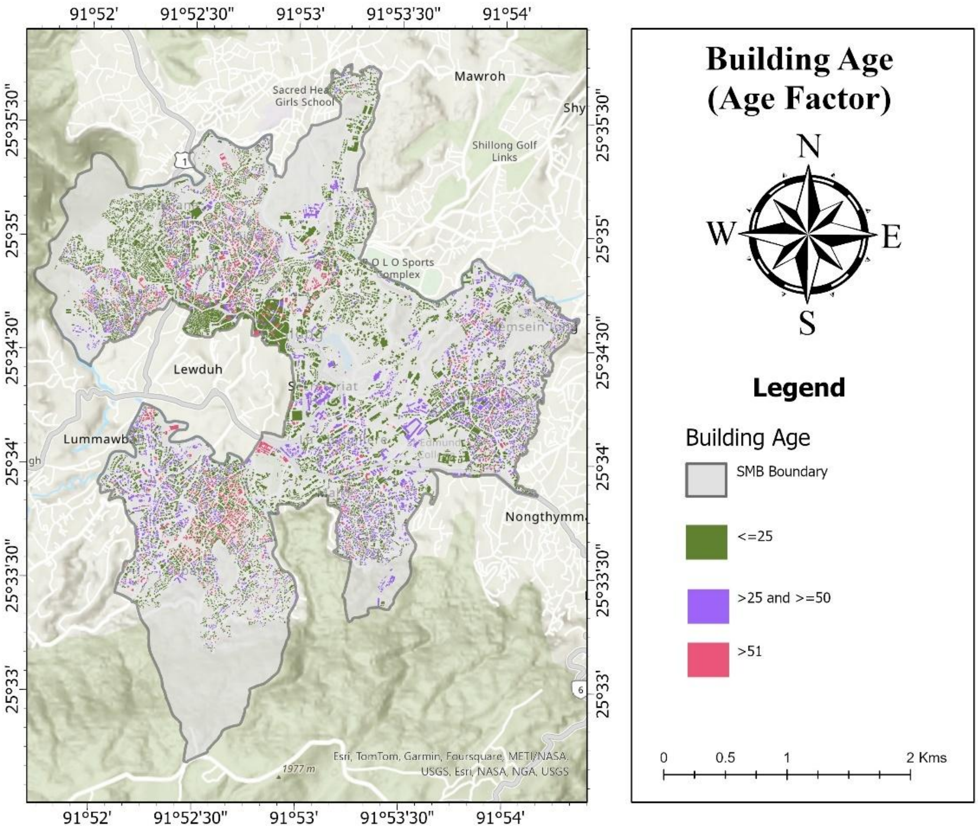
Building Age (Age Factor)

Building age is another critical determinant in property tax calculations, as older properties typically depreciate in value and are therefore assigned lower Age Factors (AF). As shown in Fig. 5, the majority of properties (21,986) are relatively new, being less than 25 years old (Table 5). These newer properties are concentrated in Zones B, C, and parts of Zone D. In contrast, 3,983 properties fall into the 25-50 years age category, while only 642 properties are over 50 years old, with these older structures primarily located in Zones E and F. Properties that are less than 25 years old are assigned the highest age factor (AF = 1.0), reflecting their higher market value and thus a higher tax rate. On the other hand, properties older than 50 years have a reduced age factor (AF = 0.6), acknowledging the depreciation of the building over time and leading to lower tax liabilities.

Table 5: Distribution of properties by building age

Building Age	Less than 25 years	25 to 50 years	More than 50 years
No. of Properties	21986	3983	642

Fig. 5: Spatial distribution of building age (age factor) in SMB



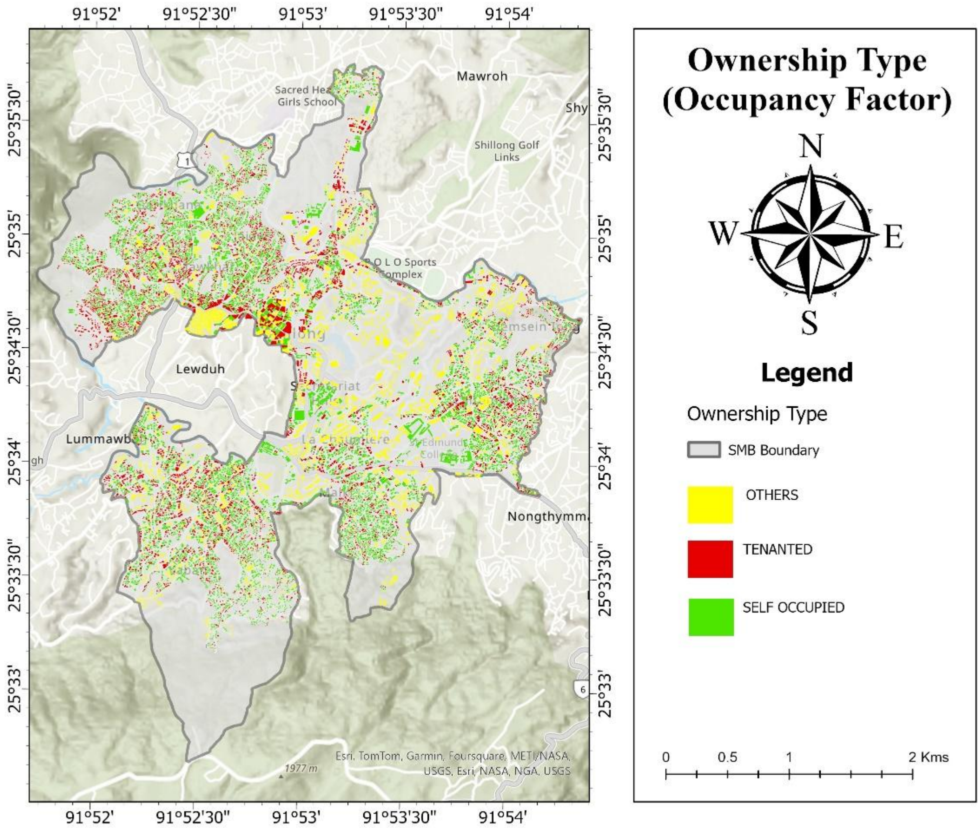
Ownership Type (Occupancy Factor)

Ownership status plays a significant role in determining the Occupancy Factor (OF), with tenanted properties generally subjected to higher taxes due to their potential for rental income. As shown in Fig. 6, self-occupied properties dominate the SMB area, comprising 12,707 properties (Table 6), and are distributed relatively evenly across all zones. Tenanted properties account for 9,451 properties, mainly located in commercial zones and along main roads in Zones A and B, indicating higher rental activity in these areas. Other ownership types, such as government or institutional properties, constitute 4,453 properties. Tenanted properties are assigned a higher occupancy factor (OF = 1.5) compared to self-occupied properties (OF = 1.0), resulting in higher tax obligations. This underscores the economic importance of rental properties, particularly in Zones B and C, where commercial and mixed-use properties are prevalent.

Table 6: Distribution of properties by ownership type

Ownership Type	Self-Occupied	Tenanted	Others
No. of Properties	12707	9451	4453

Fig. 6: Spatial distribution of properties ownership (occupancy factor) in SMB



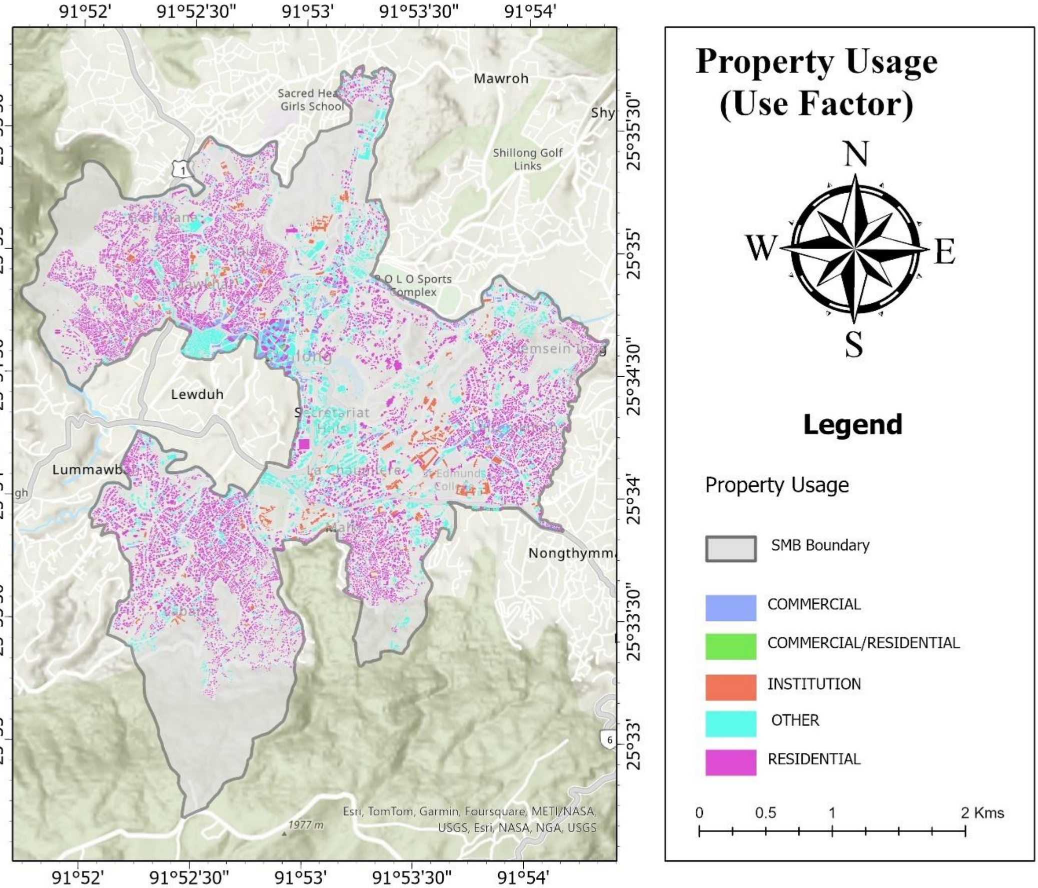
Property Usage (Use Factor)

The primary usage of a property is another critical factor in determining its tax rate. Different categories of property use attract varying Use Factors (UF), with commercial and institutional properties generally subjected to higher taxes. As visualized in Fig. 7, residential properties are the most common, making up 19,786 of the total properties (Table 7). These are distributed across all zones, with significant concentrations in Zones C and D. Commercial properties, totalling 1,814, are primarily located in Zones A and B, which serve as Shillong's commercial hubs. Institutional properties account for 575 properties, while Commercial-Residential and Other categories represent 26 and 4,410 properties, respectively. Commercial properties, with a UF of 2.0, and institutional properties, with a UF of 1.5, are taxed more heavily than residential properties (UF = 1.0), reflecting their greater income-generating potential, particularly in the central urban zones.

Table 7: Distribution of properties by usage

Property Usage	Residential	Commercial	Commercial-Residential	Institutional	Other
No. of Properties	19786	1814	26	575	4410

Fig. 7: Spatial distribution of properties usage (use factor) in SMB



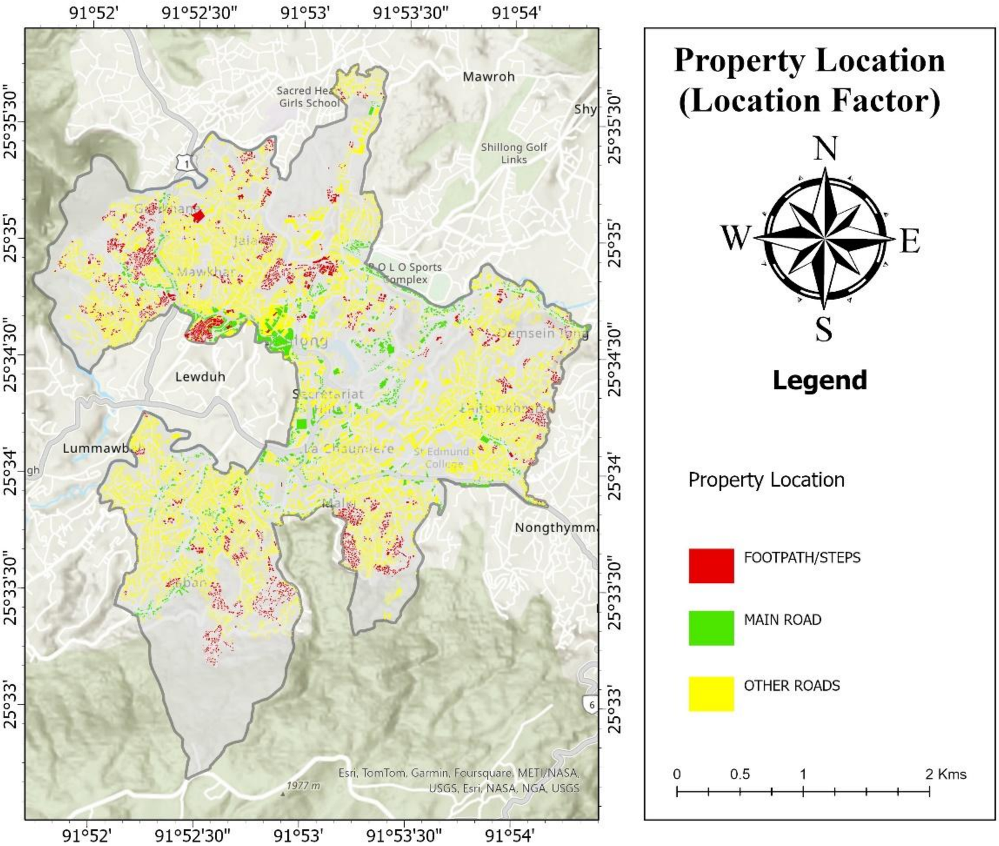
Property Location (Location Factor)

The location and accessibility of a property have a significant impact on its valuation, with properties located on main roads attracting higher taxes than those on internal roads or footpaths. As depicted in Fig. 8, properties situated on main roads account for 2,309 properties (Table 8), predominantly found in Zones A and B, which have higher commercial density. Other roads contain 19,885 properties, while properties accessible by footpaths or steps account for 4,417 properties, mostly located in peripheral areas like Zones E and F. Properties on main roads are assigned a Location Factor (LF) of 1.0, while those on other roads or footpaths have lower factors (LF = 0.8 and LF = 0.6, respectively). This highlights the impact of infrastructure and accessibility on property valuation, with properties on main roads incurring higher taxes due to their prime location and greater commercial potential.

Table 8: Distribution of properties by locations

Property Location	Main Road	Other Roads	Footpaths/Steps
No. of Properties	2309	19885	4417

Fig. 8: Spatial distribution of properties location (location factor) in SMB



Property Tax Assessment

The property tax assessment for the Shillong Municipal Board (SMB) was calculated using the Unit Area Value (UAV) method, which incorporates multiple multiplicative factors such as construction type, building age, ownership type, property usage, and property location. The total property tax revenue collected across the SMB area amounted to Rs. 53,195,183. This section provides a detailed analysis of property tax distribution by ward and zone.

Ward-Wise Property Tax Revenue

The distribution of property tax revenue across 27 wards within the SMB jurisdiction exhibits significant variation due to differences in property characteristics, economic value, and location factors. As shown in Table 9 ward-wise property tax, the highest revenue-generating wards are concentrated in commercial and densely populated areas. Ward 9 (Police Bazar) generated the highest property tax revenue, amounting to Rs. 7,053,247, largely due to its prime location in the central business district with high commercial activity. Ward 3 (Laithmukhrah3) followed closely, contributing Rs. 6,704,402 in revenue. Laithmukhrah, being a mixed-use area with residential, commercial, and institutional properties, has a high property valuation. Ward 7 (European Ward1) also showed substantial revenue generation of Rs. 6,532,018 due to its high number of RCC structures and its central location. Ward 26 (Lumparing1) and Ward 19 (Mawprem1) had the lowest property tax revenue, contributing Rs. 292,583 and Rs. 422,657, respectively. These wards are located on the periphery, with lower property values and fewer commercial properties.

The spatial distribution of average property tax across wards is depicted in Fig. 9 ward-wise average tax map, where the darker shades represent higher average taxes. Wards in central Shillong, particularly Laithmukhrah and Police Bazar, exhibit the highest average taxes due to the concentration of high-value properties and commercial activity.

Fig. 9: Spatial distribution of average property tax across wards

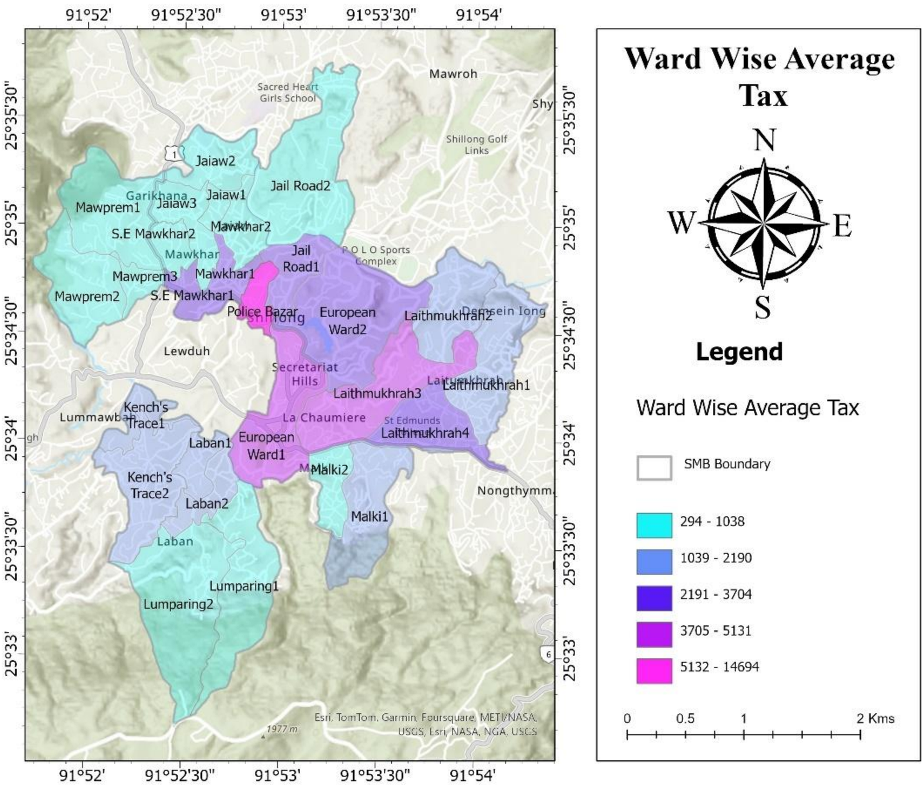


Table 9: Ward-wise property tax revenue

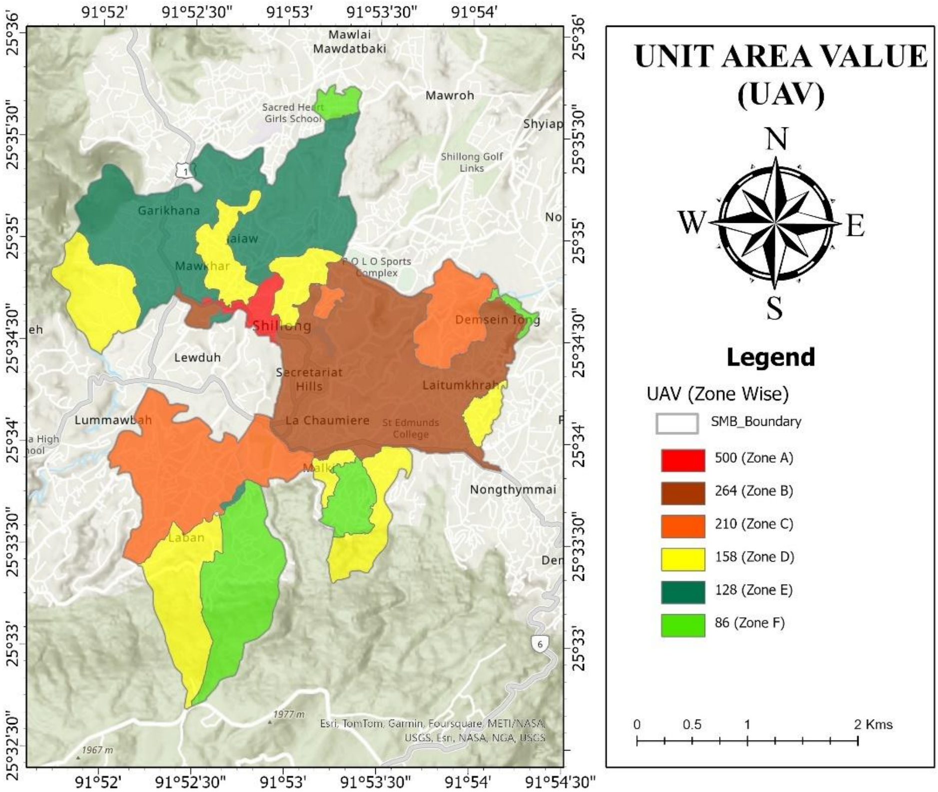
Ward No.	Ward Name	Revenue (in Rs.)	Ward No.	Ward Name	Revenue (in Rs.)
Ward 1	Laithmukhrah1	2007548	Ward 15	Jaiaw2	678785.8
Ward 2	Laithmukhrah2	1710793	Ward 16	Jaiaw3	1082627
Ward 3	Laithmukhrah3	6704402	Ward 17	S.E Mawkhar1	2183418
Ward 4	Laithmukhrah4	3800459	Ward 18	S.E Mawkhar2	632227.2
Ward 5	Malki1	1754802	Ward 19	Mawprem1	422657.4
Ward 6	Malki2	807130.8	Ward 20	Mawprem2	476541.4
Ward 7	European Ward1	6532018	Ward 21	Mawprem3	1291016
Ward 8	European Ward2	2886310	Ward 22	Kench's Trace1	570254.3

Ward 9	Police Bazar	7053247	Ward 23	Kench's Trace2	2979929
Ward 10	Jail Road1	1989969	Ward 24	Laban1	1426112
Ward 11	Jail Road2	1106433	Ward 25	Laban2	1104225
Ward 12	Mawkhar1	2052402	Ward 26	Lumparing1	292583.5
Ward 13	Mawkhar2	704065.3	Ward 27	Lumparing2	594914.6
Ward 14	Jaiaw1	350311.8	**Total Revenue**		**53195183**

Zone-Wise Property Tax Revenue

The property tax revenue is also analysed across six zones, which are designated based on the economic value of the area and the Unit Area Value (UAV) assigned to properties within each zone (Fig. 10 and Table 10). Zone-wise property tax summarizes the revenue distribution, Zone B comprising central commercial areas, generated the highest revenue, contributing Rs. 21,440,168. This is due to the high density of commercial properties and higher UAV values assigned to this zone. Zone C followed, with a total revenue of Rs. 9,606,027, reflecting its mix of residential and commercial properties with moderate UAV values. Zone F, the least developed zone with predominantly residential properties and low property values, contributed the lowest revenue of Rs. 998,905.

Fig. 10: Spatial distribution of unit area value across zones

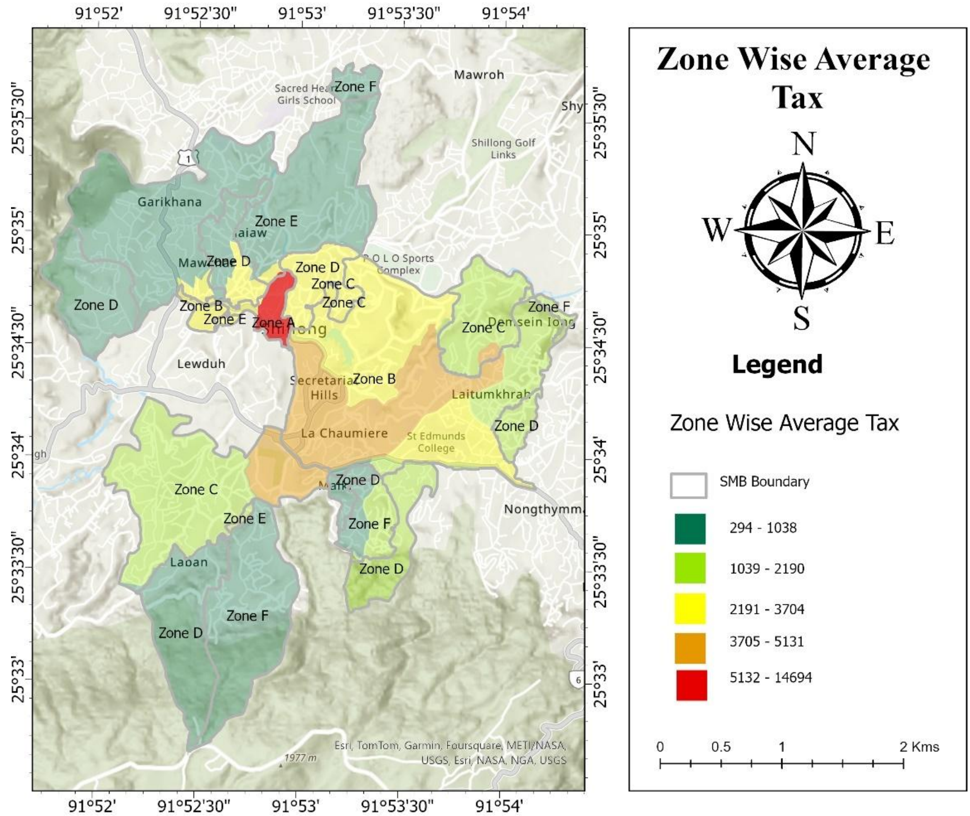


The Fig. 11 zone-wise average tax map illustrates the spatial distribution of average property tax across zones. Zone B, located in the heart of Shillong, shows the highest average tax, while Zone F, located on the outskirts, exhibits the lowest tax values. The overall revenue generated from property tax across all zones and wards is Rs. 53,195,183 (Table 10). This amount reflects the varying economic and property characteristics across different parts of the city, with the majority of the revenue coming from commercial and high-value residential areas concentrated in Zones B and C.

Table 10: Zone-wise property tax revenue

Zone	**Revenue (in Rs.)**
Zone A	9452067
Zone B	21440168
Zone C	9606027
Zone D	6827914
Zone E	4870102
Zone F	998904.8
Total Revenue	**53195183**

Fig. 11: Spatial distribution of average property tax across zones



DISCUSSION

This study highlights the successfully implementation a GIS-based property tax assessment system for the Shillong Municipal Board (SMB), demonstrating the transformative potential of geospatial technology in modernizing urban governance and revenue generation for smaller municipalities. The digitization of 26,611 built-up plots across 27 wards led to several key improvements, including increased accuracy in property identification, streamlined data collection, and enhanced transparency in tax assessments. The integration of field survey data covering factors such as construction type, building age, and property usage into the GIS environment provided a more systematic and equitable framework for property tax calculation. By employing UAV method, the study introduced a standardized, transparent, and easily verifiable approach to property taxation that improves public trust in the system and simplifies property owner compliance. The zone-wise and ward-wise analyses revealed substantial spatial variations in property distribution and tax revenue, offering valuable insights for future urban planning and policy-making in Shillong.

In comparison with previous research, the findings of this study align with global trends in the use of GIS for property tax assessment. For instance, studies by Naghavi *et al*. (2022) and Ahsan *et al*. (2023) have highlighted the ability of GIS to improve data accuracy, tax collection efficiency, and transparency in urban areas, particularly in developed countries. Similarly, research conducted in India by Nath & Madhoo (2022) demonstrated that GIS-based property tax systems in cities like Pune increased municipal revenue by identifying unassessed properties and correcting inaccurate property records. This study extends these findings to smaller municipalities, underscoring the adaptability of GIS-based systems to the unique challenges faced by cities like Shillong. However, it also reveals gaps in current research, particularly regarding the application of GIS in India's northeastern region, thus contributing to the broader literature by exploring the socio-economic complexities of property taxation in this underexplored area.

Unexpected results emerged from the socio-economic disparities observed in the zone-wise analysis, particularly in Zones E and F, where lower-income areas faced disproportionately high tax burdens. This finding was significant as it highlighted the potential unintended consequences of implementing a standardized tax assessment system. The UAV method, while providing transparency, may not fully account for localized socio-economic differences, suggesting that further refinement is needed to ensure that property taxes do not disproportionately impact vulnerable populations. These results suggest that future research should focus on understanding the socio-economic implications of GIS-based tax systems, particularly in developing regions with wide income disparities.

Despite the successes of this study, several limitations must be acknowledged. The high density of buildings and informal settlements in certain areas of Shillong presented challenges in accurately defining property boundaries. This issue, along with field survey constraints, such as inaccessible areas and potential subjectivity in assessing property characteristics like building age and construction type, introduced a degree of uncertainty into the final assessments. Additionally, while the UAV method provides a solid foundation for property valuation, it may not fully capture property-specific attributes, such as recent renovations or infrastructure improvements, that could influence market value. Maintaining an up-to-date GIS database amid rapid urban development is also a significant challenge, particularly for smaller municipalities with limited resources, such as SMB. These limitations point to areas where the GIS-based system can be further refined.

Looking forward, several avenues for future research and improvements to the system are recommended. First, UAV values should be periodically updated to better reflect localized property value changes, ensuring fairness in taxation. Additionally, integrating environmental factors, infrastructure quality, and proximity to amenities into the tax assessment model could provide a more comprehensive evaluation system. Machine learning techniques, as demonstrated in recent study by (Khan & Khan, 2025; Zilli *et al*., 2024), could be employed to automate property classification, further improving the accuracy and efficiency of the assessment process. Developing mechanisms for real-time data updates and integrating this GIS-based system with other municipal databases, such as land use or building permits, could offer a more holistic view of urban development and governance (Khan *et al*., 2024). Future research should also extend this methodology to other municipalities, conducting comparative studies to assess the scalability and effectiveness of GIS-based property tax systems in different contexts. Moreover, examining the socio-economic impacts of these systems could help ensure that the balance between revenue generation and social equity is maintained.

While this study highlights challenges in the implementation of GIS-based property tax systems, the results underscore their potential for transforming urban governance in smaller municipalities like Shillong. By improving transparency, accuracy, and efficiency in tax assessments, GIS technology can help local governments better manage urban development and generate much-needed revenue for public services. The insights gained from this research can guide future urban planning strategies and provide a model for the adoption of GIS-based systems in other regions of India, particularly those facing similar challenges. The continued refinement of these systems, alongside a focus on equity and socio-economic impacts, will be essential for fostering more sustainable, efficient, and inclusive urban development.

CONCLUSION

This study has shown the effective use of Geographic Information Systems (GIS) in transforming property tax assessment for the Shillong Municipal Board (SMB). By integrating spatial data with field survey attributes, the system created a transparent and equitable framework for property valuation and taxation. The digitization of 26,611 properties across 27 wards and their classification into six zones has provided SMB with valuable spatial insights that enhance the accuracy and efficiency of the tax assessment process.

The results revealed notable disparities in tax revenue across different zones, highlighting the economic variations within Shillong. Central areas like Police Bazar and Laithmukhrah generated significantly higher revenues compared to peripheral zones, offering important insights for future urban development planning. This GIS-based system has improved upon traditional property tax methods by enhancing property identification, standardizing valuation, and providing more robust data management. However, challenges such as keeping data updated and addressing socio-economic disparities in tax burden remain critical issues for further improvement.

The success of this GIS-based approach in Shillong sets a foundation for other small to medium-sized municipalities in India to adopt similar systems. Beyond boosting revenue, such systems enable better urban planning, infrastructure development, and service delivery through data-driven decision-making. The findings of this study reinforce the importance of embracing geospatial technologies for more effective and equitable urban management in growing cities.

Ultimately, this research highlights GIS's potential in revolutionizing property tax systems for smaller municipalities. By creating a fair and efficient tax assessment process, GIS fosters greater transparency and public trust while supporting the financial sustainability of municipal operations. As cities like Shillong refine and expand these capabilities, they offer a model for smarter, more responsive urban governance throughout India and beyond.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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