Determining the efficacy of identifying factors of deprivation in informal settlements using the membership function

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Abstract
The proliferation of informal settlements is a worldwide phenomenon confronting many cities in developing countries, known as areas of deprivation. A dilemma in improving the conditions in the informal settlements is the selection and measurement of deprivation factors. This research aimed to explore factors of deprivation in the informal settlements that need to be prioritized for increased livability. For this purpose, the DepthMap software and QGIS 3.32 were utilized. As such, the effectiveness of spatial and space syntax theory indicators in informal settlement mapping was investigated. The study area is Akure in the Southwestern part of Nigeria. Ten neighborhoods were selected. The result reveals the importance of city morphology factors, such as the distance to the city center and connectivity, with 28.2% and 33.1% errors, or, in other words, 67% and 72% correctness, prove to be good indicators of deprivation in the informal settlements. The most prominent factor of deprivation in areas was revealed to be the local integration, with a 13.3% error, a result of poor accessibility. These are therefore the factors Germain in policy formulation for the improvement of the livability in the study area.

Keywords: Informal Settlements, GIS, Space Syntax Theory, connectivity, deprivation

1.0 Introduction

Urbanization has been described as a social process that determines the shape of an urban built environment (UN-Habitat, 2020; United Nations, 2019). In 2018, 55.2% of the global population lived in urban areas (UN-Habitat, 2020). To date, rapid urbanization is still being experienced in most developing countries. In developed countries, urbanization is an attribute of industrialization in addition to economic advancement. But, in the global south countries, particularly in Africa and Latin America, urbanization has been attributed to frequent rural-urban migration and high natural population increase (Akirso, 2021). This results in an urban form in developing countries where amenities and utilities are concentrated at the city centre, which serves as the central business district (CBD). This area is also characterized by horizontal growth and housing shortage, prompting the ever-increasing population of the less affluent migrating to deprived settlements in the peripheral lands (Alabi,2021; Du et al., 2022). Thus, creating new peripheral spaces on the edges of urban territories, named informal settlements.

"Informality" as a term refers to a location where groups of people live on land in which they have no legal claim or settlements, where homes are constructed with land subdivision procedures performed without the consent of the planning authorities, not following

regulations and recommended codes (Wahab,2017). Thus, informal settlements may be termed illegal. Even though it can be argued that not all informal settlements are illegal. For instance, informality can arise when land is occupied or developed before an area is planned, that is, when development precedes the preparation and approval of layout/development plans. Hence, informal settlement can be broadly defined as the incremental, unauthorized, and self-organized production of affordable housing and urban infrastructure as opposed to the misunderstood euphemism for 'slum'. Informal settlement is best understood as a mode of city production, a form of architecture, urban design, and planning. The overwhelming majority of informal settlements are permanent. Even demolition, which displaces people and destroys livelihoods, often stimulates new informal re-settlement rather than more formal, planned settlements. Hence these areas have been found synonymously as area of deprivation.

'Deprivation' is a social concept that infers a quality of life below that of the majority in a particular society, to the level that it involves hardship, inadequate access to amenities, and lack of privileges (UN-Habitat 2020). Professionals in the built environment and other related fields of studies have tried relentlessly and are still in the process of identifying and explaining the fundamental drivers of spatial patterns of deprivation and variations as relates to cities. (Inostroza, 2017; Feitosa et al., 2021; UNESCAP, 2022).

Wahab et al (2017) conducted a study focused on analyzing determinants for the expansion of squatter settlements in Nigeria with a mixed research approach and focused only on age, type of occupation, income, migration, and possession of legal construction permits as the outstanding factors which aggravated to the expansion of squatter settlements in the study area. While, Alabi (2022) in his study of Akure revealed that the amenity distribution affects the structure, form and shape of towns and despite their changing tendencies have a direct relationship with the spatial distribution of wealth.

Apart from the Nigerian context, many empirical studies have been conducted in different parts of the world to explain deprivation as synonymous with informal settlements (Amao, 2012; Mensah, Antwi, and Acheampong, 2013; Suditu and Valceanu, 2013; Meshkini, Mansoor, and Esfaram, 2015; Okyere and Kita, 2015; Heshmati and Zarabadi, 2016; Sakala, 2016; Matamanda, 2019; UN-Habitat, 2020; UNESCAP,2022).

The question is not only which of these deprivation factors characterize informal settlements, but also how to quantify and unify the measurement of the factors and to effectively identify the deprivation factors, to help in policy making at improving the living

conditions in the informal settlements (Feitosa et al., 2021). In many articles, the authors use various factors of deprivation to identify informal settlements, for example, the use of noise pollution, air pollution, lack of access to amenities such as electricity, pipe-borne water supply, the shape of buildings, blocks, streets, lack of formal legal titles, the irregular development of the urban structure, the lack of essential public services, and the occurrence on public lands (Wahab 2017; Alabi, 2019; Akirso,2021; Du et al., 2022). This perspective of selecting measurable factors of deprivation individually could be misleading as frequently occurs. Since the relationship between physical and human decisions is interconnected, and it is now impossible to assert that there exists a difference between objective and subjective factors. There is, therefore, the need to consider the accuracy and usefulness of the selected deprivation factors in the detected informal settlements, determining and identifying the factors with the least error.

This research proposes a methodology for identifying key factors of deprivation in informal settlements to support effective urban planning. It focuses on using indicators that are specific, sensitive, practical, and relevant to the local context. The study aims to assist policymakers in applying these indicators for environmental planning, local development, municipal management, and sustainability strategies. The research explores the factors of deprivation within informal settlements, the distance of neighbourhoods from the city centre, the ease of access to central amenities, the street morphology of these areas, and the relationship between street morphology and deprivation.

2.0: Review of Related Literature

In studies concerned with informal settlements, various characteristics have been identified as indicators of deprivation. For example, John Abbott (2003) and Feitosa et al. (2021) identify the form of settlement and houses with morphological characteristics and consider the social relations of households with each other as characteristics of deprivation in the informal settlements. Lefulebe et al., (2014) identified fire caused by the lack of official electricity as one of the characteristics of deprivation in the informal settlements**,** while Kim Dovey et al (2020) utilized the shape of buildings, blocks, streets, and lines to identify informal neighborhoods and stated that their embodiment in morphologies that benefit from informal rules. Inostroza (2017) sees informal settlements as areas with a lack of formal legal titles, the irregular development of the urban structure, the lack of essential public services, and the occurrence on public lands. Akirso (2021) characterized informal settlements as areas that are dense and unplanned with an irregular pattern, including self-built houses without formal land ownership.

Above all characteristics in works of literature for informal settlement, UN-Habitat (2015) indicators are widely accepted that "Informal settlements are residential areas of deprivation where; a) inhabitants have no security of tenure vis-a-vis the land or dwellings they inhabit, with modalities ranging from squatting to informal rental housing, b) the neighborhoods usually lack, or cut off from, basic services and city infrastructure and c) the housing may not comply with current planning and building regulations, and is often found in geographically city fringes. Since most infrastructure in developing countries is located in the city centres, informal settlements remain areas of deprivation of basic infrastructure and services, public space, and green areas. Various indicators characterize informal settlements, such as lack of official electricity, distance from service centers, inappropriate access, such as narrow alleys, and lack of access to the city centre, leading to isolation from developed areas.

Improving livability in the informal settlements in the urban fringes needs an integrated and comprehensive understanding of the informal settlement process, particularly its driving factors. Previous studies revealed that there are no single factors accounting for the deprivation in informal settlements globally (Abebe et al., 2019; Avis, 2016; Diab, El Shaarawy, Yousry, 2020; Fisher and Singh, 2023). Thus, factors responsible for deprivation in the informal settlements are unique in different geographical locations and spans of life. This is attributed to the variations in the socio-cultural, economic, political, environmental, and demographic characteristics of the areas.

The space syntax theory is utilized for the morphological analysis of the study. This includes the spatial configuration, where the relationship of the elements with other elements and the whole system is considered (Hillier et al., 1993). The space syntax theory also considers the spatial configuration and the way urban spaces are combined are the main factors in the distribution pattern of socio-economic activities, namely the distribution pattern of commercial uses, different ethnicities, urban crimes, and movement in the city (Hillier & Vaughan, 2007). Among the critical indicators of the space syntax theory, we can mention Connectivity, Integration, and Depth. The concept of Connectivity means spatial connection. This means that the greater the value of connection, the greater the number of connections between the desired space and other spaces. The numerical value of the Connectivity expresses the number of accesses leading to the desired space; in other words, the Connectivity specifies the number of nodes directly connected to every single node in the connection graph (Jiang et al., 2000). The value of the Integration of each line is the average number of midway lines that can reach all areas of the city. This is also the average number of

changes in direction to reach all the spaces of the city. The Integration of an urban space is its conjunction with the whole city. Research shows that the distribution of the value of Integration in the city strongly correlates with the movement of pedestrians in that city (Turner, 2007). Depth: The Depth of space is the smallest turns or steps that are taken to reach a space within the city or from one node to each of the nodes in the graph (Jiang, Claramunt, 2002, Fisher and Singh,2023).

3.0 Methodology.

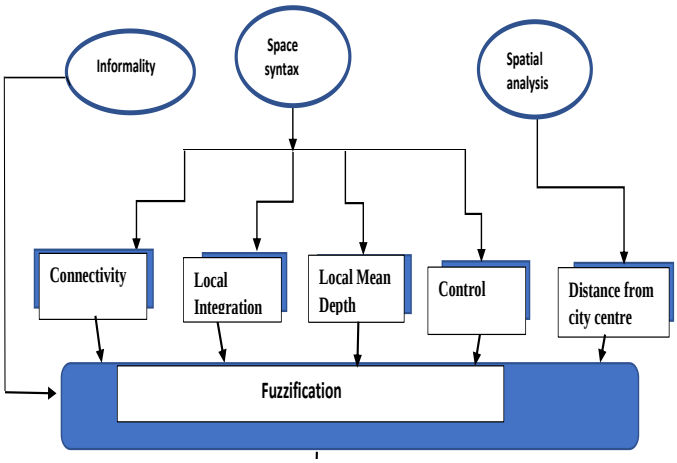


Figure 3. Work steps

The deprivation factors in informal settlements selected for this research were summarized from existing literature. This includes: building approval, distance of neighbourhoods from city centre, distance of amenities and facilities from city centre, street morphology and characteristics (such as street connectivity, street Integration, street control, and street Mean Depth), Wahab, B. (2017); Alabi (2019); Akirso (2021); Du et al., (2022); Fisher and Singh (2023). Ten (10) neighbourhoods were also selected based on the findings of Alabi (2021) as fringe areas of deprivation surrounding the core.

The methodology adopted for the research is in three phases. The first phase is done in several sections, as follows:

(a) Determining the distance of each neighborhood from the city centre using the Network Analyst in ArcGIS software. The ArcGIS software is also used to determine the level of accessibility. The value of each index as an average for each neighborhood in the study area was obtained. In this way, the distance of neighbourhoods from the city centre, where most services are located, is obtained with ArcGIS software (Figure 2). The site of amenities and facilities was buffered at a 1500m radius from the city centre

(b) Open-Street-Map (OSM) and city maps was prepared using ArcGIS software. This will be used for street morphology analysis in the space syntax software. The map of undocumented houses (houses without building approval) was obtained from the Ministry of Lands and Physical Planning, Akure, to prepare a validation map (Figure 4).

(c) Using space syntax theory in DepthMap software the OSM was used determine the street morphology components such as Connectivity, street Integration, street control, and street Mean Depth and the

value of indicators for each of the neighborhoods was interpolated using the fuzzy logic function (Figure 5).

Also, based on the validation map, the percentage of the houses in the neighbourhoods without building approval was determined (Table 1).

Table 1: Building Plan Approval and percentage deprivation

Neighbourhoods	Number of buildings	Buildings without approval	Deprivation
Imuagun	25	19	76%
Olufoam area	25	18	72%
Igoba	25	10	40%
Apatapiti	25	17	68%
Oke-ogba	25	14	56%
Oke-aro	25	13	52%
Ijoka	25	10	40%
Oshinle	25	7	28%
Alagbaka	25	14	36%
Oda Road area	25	14	56%

Source: *Author, 2025*

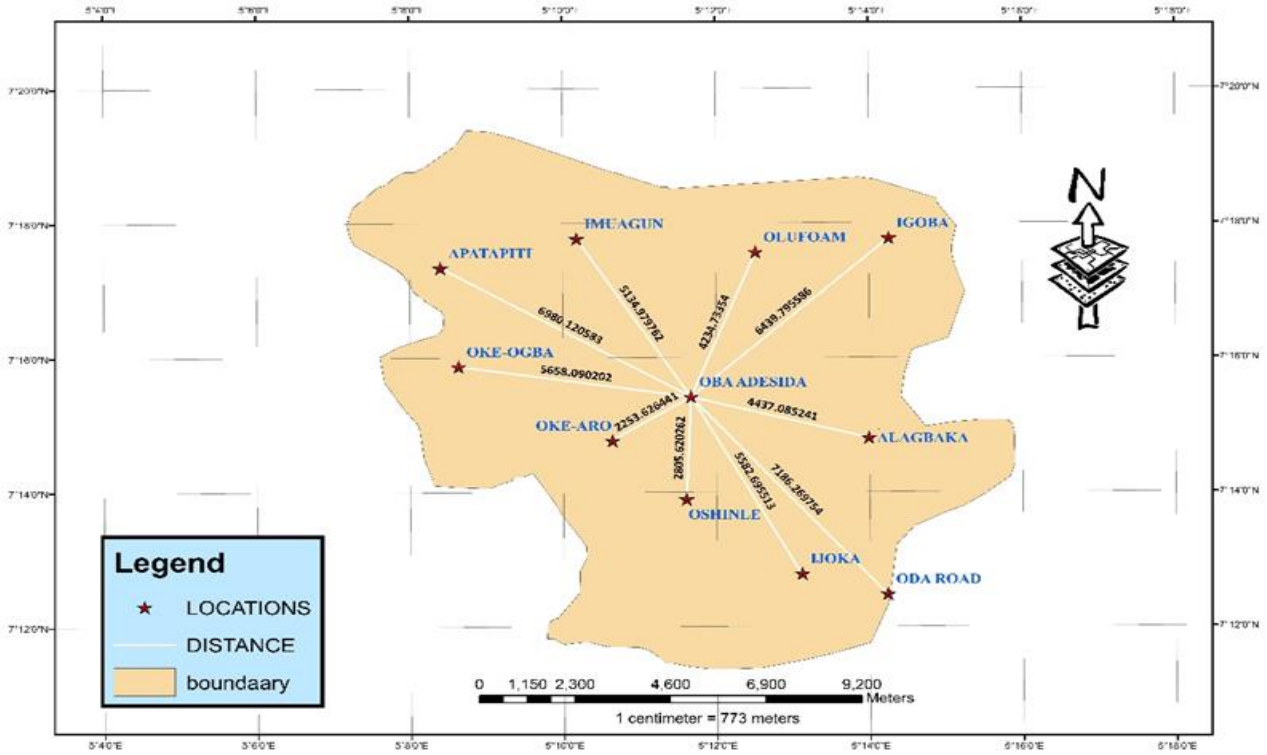


Figure 4. Distance from the city centre
Source: Author, 2025

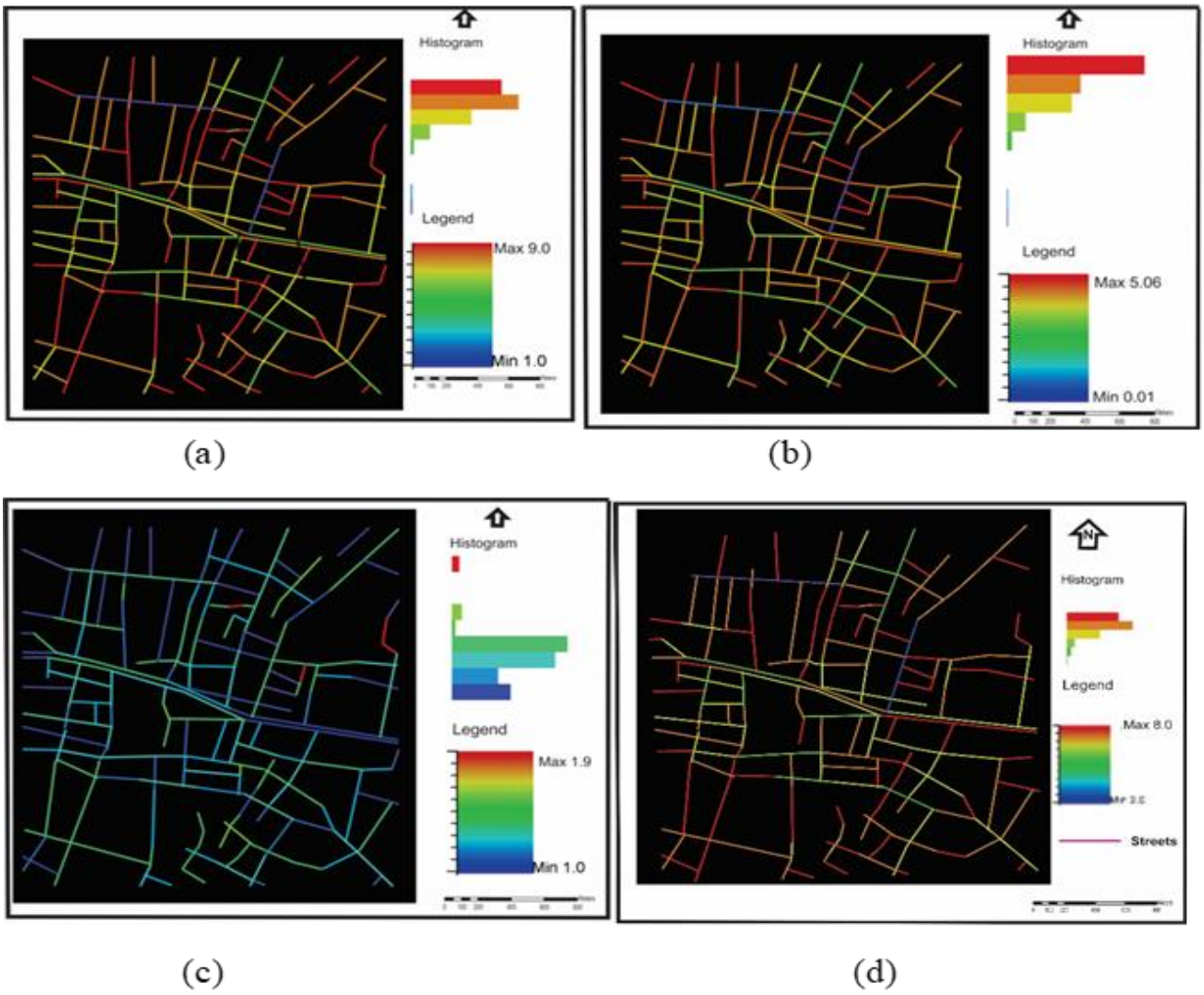


Figure 5: *Streets accessibility of the study area: (a) Connectivity (b) local Integration, (c) local mean depth, (d) control*

The Figure 5 is the result of the DepthMap analysis of street morphology, axial maps showing the result of connectivity, local integration, local mean depth and control, where the red colour line represents a high road connectivity, which indicates an area of high integration, therefore high propensity for movement and easy accessibility. While the blue colour line indicates areas of moderate accessibility with less integration.

3.0 Result

As mentioned, the steps of this research were carried out in three phases. In the first phase, the value of each index as an average for each neighborhood in the study area was obtained. Thus, the distance from the city centre and the number of access roads leading to the neighbourhoods (used as a surrogate for rate accessibility) were calculated in ArcGIS software. The mean depth, connectivity, and integration were calculated in the space layout software (DepthMap) and then averaged for each neighborhood to obtain these values. Also,

based on the validation map, the percentage of each neighborhood deprived was determined (Table 1). In the second relationship between deprivation and street morphology was determined (Table 2). Then, using fuzzy functions specific to each index, the value of the fuzzy membership degree of each index for each neighborhood was calculated. The values of the degree of membership of each index are between zero and one. The value closer to zero indicates low deprivation, and the value closer to one high deprivation (Table 3). In the third and final phase, the percentage error (%) of the relation between street morphology and distance to the city centre was calculated (Table 4).

Table 2. Relationship between street morphology and **deprivation**

s/no	Neighbourhoods	Connectivity	Local integration	Local mean depth	control	Distance from the city centre (m)	Deprivation
1	Imuagun	4.0	4.5	1.2	4.0	5134.980	76%
2	Olufoam area	2.5	2.6	1.3	2.6	4234.734	72%
3	Igoba	4.3	4.0	1.4	4.2	6439.796	40%
4	Apatapiti	4.2	4.0	1.4	3.9	6980.121	68%
5	Oke-ogba	3.6	3.5	1.5	3.6	5658.090	56%
6	Oke-aro	3.8	3.6	1.2	3.6	2253.626	52%
7	Ijoka	4.0	4.1	1.7	3.8	5582.696	56%
8	Oshinle	4.0	4.0	1.6	3.8	2805.620	40%
9	Oda Road area	1.3	3.8	1.8	4.2	7186.270	36%
10	Alagbaka	2.5	2.6	1.2	2.8	4437.085	28%

Source: *Author, 2025*

In this phase, the effects of these indicators were also compared, and their values were standardized using Equation (1) (fuzzy function). This is to determine the membership level of each of the indicators for each neighborhood (Table 3). Therefore, according to the range of values for each index, the membership in the fuzzy function is expressed as follows, as in Zadeh (1965):

$$a = \{(x, \mu a(x)) \mid x \in X\} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

$\mu a(x)$: $X \rightarrow [0, 1]$

Where $\mu a(x) = 1$ if x is totally in a

$\mu a(x) = 0$ if x is not in a

$0 < \mu a(x) < 1$ if x is partly in a

a= Fuzzy set

$\mu a(x)$ = Membership function

X = Universe of discourse

Table 3. The Fuzzy function result of the relation between street morphology and deprivation

s/no	Neighbourhoods	Connectivity	Local integration	Local mean depth	control	Distance from city center (m)	Deprivation
1	Imuagun	0.5	0.9	0.2	0.75	0.10	0.76
2	Olufoam area	0.25	0.52	0.3	0.52	0.08	0.72
3	Igoba	0.8	0.6	0.4	0.7	0.13	0.40
4	Apatapiti	0.75	0.6	0.4	0.65	0.14	0.68
5	Oke-ogba	0+.4	0.3	0.5	0.4	0.11	0.56
6	Oke-aro	0.6	0.36	0.2	0.4	0.04	0.52
7	Ijoka	5	0.64	0.7	0.55	0.11	0.56
8	Oshinle	0.5	0.64	0.7	0.55	0.06	0.40
9	Oda Road area	0. 06	0.58	0.8	0.7	0.14	0.36
10	Alagbaka	0.25	0.52	0.2	0.6	0.09	0.28

Source: Author, 2025

In the third phase the percent error of each index for each neighborhood was calculated (Table 4), followed by the final phase, where comparison was made of the values obtained for each index in each neighborhood with the fuzzy membership value in the validation map also for each neighborhood, (Using Equation -2). After calculating the error rate of each index for each neighborhood, the overall average of each index between the neighborhoods is obtained to determine the error rate of each index in identifying areas of deprivation using the equation -2:

$$£ = \frac{(va - ve)}{ve} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where £ = Percent error

υ_a = Actual value observed

υ_e = Expected value

Table 4. Percentage error (%) of the relation between street morphology and distance to the city centre

s/no	Neighbourhood	Connectivity	Local integration	Local mean depth	control	Distance from the city centre
1	Imuagun	27.5	5	18.4	25	35.40
2	Olufoam area	36	24	15.8	33.75	32.3
3	Igoba	30.1	10	45.7	23.6	38.4
4	Apatapiti	2.67	10	45.7	25.6	39.21
5	Oke-ogba	30	15	10	27.5	36.6
6	Oke-aro	21.6	14	18.4	27.5	16.7
7	Ijoka	27.8	9	11.1	26.3	36.6
8	Oshinle	27.8	10	7.9	26.3	23.3
9	Oda Road area	42.6	12	2.7	23.8	39.6
10	Alagbaka	36.1	24	18.4	32.5	33.1

Source: *Author, 2025*

Table 5 Average percentage error and correctness of deprivation factors

	Connectivity	Local integration	Local mean depth	control	Distance to the city centre
Average percentage error	28.2%	13.3%	19.8%	27.2%	33.1%
Average percentage correctness	72%	87%	80%	73%	67%

Source: Author, 2025

4.0 Conclusion

This research aims to introduce an effective methodology of determining factors of deprivation in informal settlements in cities for effective planning.

After examining various factors of deprivation at the neighborhood scale, displaying them in fuzzy form, and comparing them with validation map values. It was revealed that the factors of street morphology, such as connectivity, local integration, local mean depth, control, and distance to the city centre, had percentage errors of 28.2%, 13.3%, 19.8%, 27.2%, and 33.1%, respectively (Table 5). As a result, it can be expressed that the factor of local integration index with a correct percentage of 87% is the most important and main index in identifying informal settlements. This is followed by the factors of local mean depth index with a correct percentage of 80%, while connectivity and control factors were 72% and 73%, respectively. The factor with the lowest index is the distance from the city centre.

This index shows that local integration is the most important factor, as it shows the conjunction with the whole city; in other words, it is the average number of changes of direction that can be reached from the neighborhoods to the city centre, that is, ease of movement. This value of Integration correlates with the movement of pedestrians in the city, as in Turner (2007). It can be envisaged hypothetically that if a person stands on the street in the informal area, he will have less direct view of other parts of the neighborhoods, which could disrupt movement in the settlements because vehicles will have to constantly change direction of movement. This increase slows movement and may lead to traffic jams. The next important index is the factor of local mean depth. The Depth of space means passing through several other spaces to reach the city centre, where amenities are located. The importance of the effect of this index, as revealed, agrees with Jiang and Claramunt (2002).

The third important index is the connectivity factor, which is low and has a direct

relationship with integration. Therefore, the neighborhoods' lack of access to amenities causes the isolation of these neighborhoods from the city centre, which has increased deprivation and social harm to the residents of these settlements, as in Jiang et al. (2000).

Planners and city managers should, therefore, prioritize the improvement in connecting neighbourhoods to the city centre during planning and urban renewal or reconstruction and create more routes for each neighborhood to the city centre to prevent the isolation of neighborhoods. This will increase access to amenities and facilities enjoyed at the city centre thereby reducing deprivation. It will also open up the informal settlements to more physical development, improve social and economic cohesion.

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