International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Measuring Proximity Strength of Residential Land Use to Urban Recreation Space Using Gravity Model

Pradeep Rajasekharan[1], Dr. Anil Kumar P. P.[2]

[1]Research Scholar, Department of Architecture and Planning, National Institute of Technology Calicut, Kerala, India
Email: *pradeepwrites[at]gmail.com*

[2]Professor Department of Architecture and Planning, National Institute of Technology Calicut, Kerala, India
Email: *ppa[at]nitc.ac.in*

Abstract: ***In 2020 UNCHS recognised spatial sustainability as the fourth dimension of Sustainable development, with spatial equity and spatial density as sub-dimensions. Study focuses on proximity-a prime factor in spatial equity. Proximity strength is a term coined to measure the proximity of scattered resident population at the micro-level. Study assesses the residential zoning in terms of the proximity strength of residential areas to urban recreation space locations. An adaptation of the deterministic Gravity model is employed to measure the residences' proximity to recreation locations at micro-level. Malappuram, a medium town and North Paravur, a small town in Kerala, the Indian state, is selected for field application. The residential zonation of the master plans of these municipalities is evaluated with proximity strength. Study areas are modeled in the GIS platform with a grid pattern as suggested by the Delphi expert survey technique. The clustering of proximity strength of grids representing the resident population to recreation spaces is validated using spatial statistic Anselin Moran's I. Malappuram Municipality's value proximity strength of residential zones to recreation spaces is 0.464868. North Paravoor municipality areas, proximity strength value of residential land use parcels to recreation spaces is 0.365610. Logic is applicable to assess and compare the proximity of different urban land uses. Methodology is scalable to encompass any location specific facility in similar situations globally.***

Keywords: Sustainable Urban Development, Compact Development, Spatial Equity, Proximity strength, Proximity Assessment.

1. Introduction

Among the four dimensions of sustainable development, spatial sustainability is lesser discussed aspect, even at concept levels, in contrast to the other three: societal sustainability, economic sustainability, and environmental sustainability. The spatial dimension of sustainability has been overlooked from the inception stages of the sustainable development concept (UN-Habitat, 2020) . Spatial sustainability is recognised as the fourth dimension of sustainable urbanisation with spatial equity and spatial density sub-dimensions in the New Urban Agenda propounded by UNCHS (Hartley & Habitat-III, 2017) . This research paper focuses on proximity, a prime factor of spatial sustainability. This paper assesses residential zonation in master plans with proximity strength for assessing proximal equity to existing urban recreational locations. The study estimates the proximity strength of the residential population distribution to existing recreational facilities. The research aims to evaluate residential zonation in terms of proximity and further discusses how evaluation helps achieve confined compact residential development.

The existing residential density regulation has a high degree of arbitrariness in India (Lee, 2016) . This study focuses on the urban context in Kerala state in the Indian union. The challenges of rapid and scattered urbanisation in Kerala revealed by the last decadal census of 2011 (District Census Handbook, 2011) have necessitated this study. The study focuses on policy recommendations reported in the State Urbanisation Report 2012 (Department of Town and Country Planning; Government of Kerala, 2012) . In the Indian state of Kerala, rapid urbanisation is revealed in Census 2011. Due to the lack of a rational built density regulation, the urbanisation in Kerala state is very scattered. The fast and dispersed urbanisation makes other sustainable urban development attempts nearly infructuous. It necessitates exploring ways and means to counter the trend of scattered urbanisation.

This rapid and scattered urbanisation trend has ill effects on urban sprawl. It is making the efforts toward sustainable development nearly futile (Kotharkar et al., 2014) . SUR suggests a policy of transforming scattered urbanisation into a compact development form to overcome challenges thrown by rapid scattered urbanisation. This study focuses on evaluating residential zones' proximity to urban recreation locations.

2. The Methodology

This work evaluates residential zones in master plans in terms of the proximity strength of residential built-up to urban recreational spaces. The proximity of residential buildings concerning the urban recreational facilities is assessed in terms of proximity strength defined for the study context. The proximity strength is evaluated at the micro-level by considering the distribution of residential buildings in the study area and the distance to the urban recreation facility locations. For this purpose, the study area is represented by a matrix of square grids of 100m x 100m, as suggested by a Delphi expert panel (Hsu & Stanford, 2007) of academicians and professionals in urban planning working in the local context.

The axioms for defining proximity strength depend on the distance and residential buildings' spatial distribution. The gravity model (Chen & Huang, 2018) is employed to estimate the functional relation of interacting spatial elements in various disciplines to assess the proximity strength. The proximity strength of grids representing the micro-level population to all the urban recreational facilities locations is estimated. The number of occupied residential buildings in a grid resembles the population distribution. The proximity values represent the population size in each grid and their distance from the urban recreational locations. The proximity strength values are derived by normalising the proximity values to arrive at unity as their sum. The spatial statistic Anselin local Moran's I (Luc Anselin, 2018) is used to check the significance of grid proximity strength values spatial clustering. The proximity strength values represent the degree of proximity of each grid population to urban recreational locations.

The residential land use zones from the proposed master/development plans are delineated and overlaid on the grids with proximity strength values. The spatial intersections between residential use parcels from master/development plans and grids with their proximity strength are delineated to derive the proximity strength of residential zone parcels. The cumulative value of proximity strength of each grid conforming to residential land use is taken as the proximity strength of residential zones in the master plan.

The study area for field application selected is Malappuram municipality, conforming to the hilly terrain with the highest urbanisation rate in Kerala. Also, another study area, North Paravoor municipality of Ernakulam district in Kerala, with varying urban characteristics and terrain, is chosen as the second study area.

Though the study focuses on spatial sustainability, propounded as the fourth dimension of sustainable development, its contribution to the other three dimensions of sustainability is promising for realising sustainable development, as discussed further in this paper.

3. Study

This section consists of subsections on literature survey, axioms for proximity strength-a term coined for this study, Delphi experts' survey, a spatial model for assessing proximity strength, a brief comprehension of the study area and subsections on filed application and analysis.

3.1. Literature survey

This section's sub-sections discuss the literature study on sustainability, spatial equity and proximity, the importance of urban parks, models and theories in development sciences, and a brief survey of the Delphi technique.

3.1.1. Sustainability, Spatial Equity, and Proximity

Environment, Economy and Equity are the three 'Es' inevitable aspects of sustainability. Equity indicates a societal and political consensus of fairness and justice regarding the distribution of growth and development benefits (Baxamusa, 2008b) . Spatial sustainability focusing on equity and density is essential for urban development and management, especially in developing economies (Hague et al., 2018) . Spatial equity is fair and just treatment irrespective of spatial locations. The equity aspects get subdued and overlooked in urban planning (Calderón-Argelich et al., 2021) . Urban planning should provide spatial equity of services and amenities in a just and fair manner all along spatial dimensions. The spatial equity is explored mainly on a regional scale (Campbell, 2016) . The studies on equity primarily refer to macro-scale like region states or countries, and micro scale studies are limited (Jalaladdini & Oktay, 2012) . Enhancing the fairness of accessibility of resources, facilities, and prospects, is inevitable in making any city equitable (Rigolon et al., 2018) . Due to urbanisation, inequalities in access to civic facilities have increased (Hillier, 2009) . This study focuses on assessing the spatial equity of urban recreational parks at a micro-scale.

The Sustainable City definition by the United Nations Centre of Human Settlements emphasises social, economic, and physical development (UN-Habitat, 1991) . It overlooks the environmental factors in the definition itself. This definition is questioned for not considering the ecological aspects and the necessity of reducing the city's footprint (P. P. Anilkumar, 2019) . This lacuna is rectified in the NUA programme, which is more inclusive (UN-Habitat, 2020) . NUA handbook released in 2020 explicitly recognises spatial sustainability dimension apart from the much-discussed triads of sustainability (Allen et al., 2016) . Apart from the environment, economy, and society, the NUA propounds spatial sustainability as the fourth dimension of sustainable development (Hague et al., 2018) . NUA Spatial equity and spatial density are the two main sub-dimensions (Hartley & Habitat-III, 2017) . This paper deliberates on assessing spatial equity in terms of proximity.

Urbanisation's equity aspects were overlooked from its inception stages and implementation for achieving sustainable development (Baxamusa, 2008a) . Proximity is the prime and decisive factor in achieving spatial equity (Jalaladdini & Oktay, 2012) . Proximity is the unique aspect of accessibility with distance, mobility, and location to ensure spatial sustainability (Jiao et al., 2017) . Proximal equity refers to the fairness in the nearness of the elements under the subject matter of interest (Jenks & Jones, 2008) . The distance is the main criterion that decides proximity (Jiao et al., 2017) . More the distance lesser will be the proximity and vice versa. Enhancing proximal equity means reducing the distance between a set of elements in space, simultaneously reducing the difference in nearness (Dempsey et al., 2008) . This paper analyses the proximity of residences, the prime factor decisive for spatial equity of urban parks.

3.1.2. The vitality of urban parks:

The urban parks provide a green and refreshing atmosphere, directly contributing to public health by decreasing individual mental stress (Wolch et al., 2014) . Urban recreation centres with serenity have an additive effect on physical health by nurturing better mental attitudes (Annerstedt et al., 2012) . The parks provide safe and clean environments for physical activities that negate problems with obesity in urban living environments (Nielsen & Hansen, 2007) . Urban parks provide different modes of physical and leisure activities for the families to come together and relax and develop cherish able and memorable times of togetherness (Weber & Anderson, 2010) . City parks provide a milieu for better social interactions and societal exchanges (Peters et al., 2010) . Urban recreation centres and parks offer a public space for the heterogeneous community in urban areas to come together, interact and build social cohesion (Peters, 2010) . Though the greenery is cultured, it attracts the local tourists to urban parks, thus giving a refreshing feeling to city dwellers (Chaudhry& Tewari, 2010) . Promoting urban green parks as local tourist destinations can generate finance for the local government and provide a livelihood to people by allowing vending zones of handicrafts, local food and beverages (Majumdar et al., 2011) . The parks and other open recreation facilities are vital for sustainable urban living. This study focuses on assessing the proximity of urban parks and recreation facilities with respect to urban-dwelling units.

3.1.3. Gravity model

Isaac Newton's law for gravitational force between two bodies having mass is Gravity model's fundamental principle. Newton's equation for gravitational force is

$$F = G.\frac{M_1.M_2}{d_{ij}^2} \qquad (1)$$

Where G is a constant, M1 and M2 are the masses and d_{ij}^2, the square of the distance between the centroids of the mass.

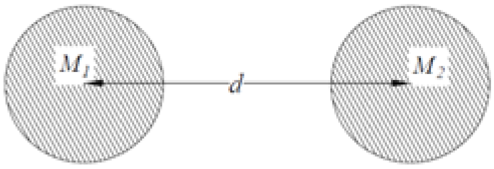

Figure 1: Gravity model Source: Compiled by the author (2021)

Gravity model see **Figure 1**is applied in estimating the relation of two interacting elements in space. Newtonian gravity model is propounded to assess the relative proximity strength between two elements. Gravity model is based on the analogy of Newton's law of gravitation (Stefanouli & Polyzos, 2017) (Chen & Huang, 2018) (Wilson, 1969) . Gravity model is concerned with the interaction of elements between different points in a spatial system, which varies directly with the size or concentration or density of elements in two locations and inversely with the distance between them (Morley et al., 2014) (Nijkamp, 1978) . Gravity model is used to assess and explain spatial relations because of more accurate outcomes (Anderson, James & Anderson E., 2011) . The spatial interaction models built on Gravity model have helped build a better understanding of housing markets behaviour, provision of public facilities, commerce, trade, transport, land use, demography, and migration (Silveira & Dentinho, 2017) . Gravity model, which is a deterministic model, is used widely in many studies to measure the relational strength between entities under consideration. This study employs Gravity model to assess the residential population's relative proximity strength to the urban recreation facilities

3.1.4. Delphi technique

For decision-making, mainly when the data available in the local study context is deficient, the Delphi expert survey helps derive logical decisions based on consensus among domain experts (Hsu & Stanford, 2007) . The Delphi survey technique developed by RAND Corporation in the 1950s is widely used in planning, forecasting, and decision-making as a powerful tool in data deficiency or uncertainty (Suzanne & Okoli, 2004) . The Delphi technique can identify and screen the critical parameters, which is helpful in modelling (Vidal et al., 2011) . The Delphi technique is employed in this study to arrive at a logical consensus on different parameters for micro-level analysis.

3.2. Proximal strength-Axioms

In this study, the term proximal strengthmust be comprehended with all the aspects of population and distance. The two axioms clearly define the proximal equity for population and location in simple mathematical terms.

1) The proximity strength of any location is directly proportional to the size of the resident population.
2) The proximity strength of any two locations is inversely proportional to their distance.

Based on these two axioms, three parameters are considered for assessing proximity.

- The population of any location ($Population_{location}$)
- The population in the catchment area (here walkable distance) for urban recreational facilities ($Population_{urf}$)
- The distance between any location and urban recreation location (d)

Based on the above deterministic geography principles, proximity strength is directly proportional to the population in and around an urban recreation location and inversely proportional to distance.

$$\text{Proximity strength} \propto \frac{Population_{location} \ . \ Population_{urf}}{d}$$

3.3. The Delphi workshop

Delphi expert survey technique is employed to tide over the unavailability of data in decision making. Deficiency of information on parameters for modelling micro-level local context led to choosing the Delphi expert survey methodology. Consequently, the planning and development experts were invited to a Delphi workshop. An expert panel of 25 members was formed to screen the critical parameters obtained through literature and opinion survey

3.3.1. The Delphi Expert Panel:

The details of the participants in the expert panel are given in

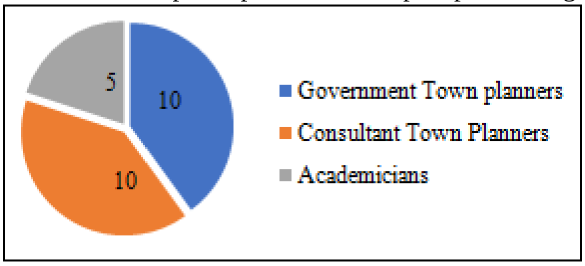

Figure 2. The professional experience of experts is shown in **Table 1**. Absolute anonymity is maintained throughout the Delphi process for screening critical parameters.

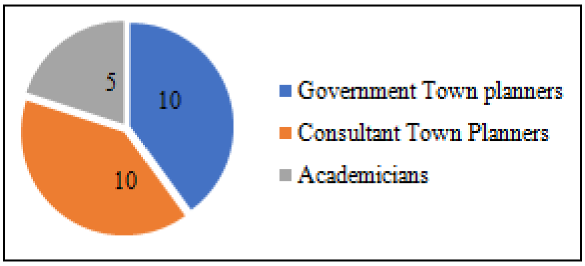

Figure 2: Delphi Expert survey – participants (Source: Compiled by Author)

The 25-member expert panel had ten urban planning practitioners from government offices, ten private urban planning consultants and five academicians. The number of experts with years of experience in the planning profession is given in **Table 1**.

Table 1: Experience in years of members of Delphi expert panel (Source: Compiled by Author)

Professional experience in years.	23	24	25	26	27	28	30
Government Town Planners (Nos)	3	2	4	0	0	0	1
Private Consultant Town Planners (Nos)	3	0	2	2	2	1	0
Academicians (Nos)	1	2	0	0	0	1	1

3.3.2. Delphi Expert Survey for selecting the area and shape of grids for GIS modelling:

The consensus on the opinion on the size and shape of grids employed for micro-level analysis of proximity with respect to the urban recreation facility is done in two stages. In the first stage, the Delphi rounds were done to evolve a consensus on the shape of grids, and in the second stage, for agreement on the area of grids.

3.3.3. Delphi Expert Survey for consensus on Grid's Shape:

For study and analysis, the 25-member expert panel was requested to suggest the best shape for micro-level grid analysis to develop consensus on the shape of grids to estimate the proximity of micro-level locations with respect to urban recreation locations. These values were taken as the base opinion to arrive at a consensus relevant to the local context. No data from other contexts were shared as it may cause bias among experts. In the second and third trials, the experts were requested to give suggestions after the previous suggestions were shared among the expert panel, keeping the anonymity of suggestions.

Table 2: Delphi Expert Survey-Grid's Shape – Selection (Source: Compiled by Author)

S no	Shape	Number of experts favouring Trial 1	Number of experts favouring Trial 2	Number of experts favouring Trial 3
1	Hexagon	8	7	5
2	Square	10	14	16
3	Triangle	7	4	4

Table 2clearly shows experts' opinions in three trials to arrive at a consensus on the shape of grids to be employed for micro-level analysis. The three trials show an explicit agreement on the shape of the grids for micro-level analysis for proximity strength with respect to critical urban recreation location facilities. The square shape was chosen for the shape of grids to be used in the micro-level analysis.

3.3.4. Delphi Expert Survey for consensus on Area of Grids:

To have a consensus on the area of grids to estimate the proximity at the micro-level with respect to urban recreation location, the 25-member expert panel was requested to suggest the best grid area in their own opinion. In the first trial, the choice was open to each expert to express their opinion, and in subsequent attempts, the options suggested in the first trial were used to develop a consensus. No data from other contexts were shared as it may cause bias among experts.

The outcome of all the trials of the Delphi survey is shown in **Table 3**. In the first trial, 12 different suggestions were made by a 25-member expert panel, and a consensus has arrived upon these alternatives in the subsequent trials. A total of three trials were required to reach an explicit agreement. The expert panel suggested a grid size of 100 m2 through the Delphi technique.

Table 3: Delphi Expert Survey-Grid's Area – Selection (Source: Compiled by Author)

S. no	The suggested side length of the square grid (m)	Number of experts Trial 1	Number of experts Trial 2	Number of experts Trial 3
1	500	2	0	0
2	100	7	13	18
3	150	2	2	2
4	200	2	2	2
5	300	2	2	2
6	400	1	0	0
7	500	2	3	1
8	600	2	1	0
9	750	1	1	0
10	800	2	1	0
11	900	1	0	0
12	1000	1	0	0

A clear consensus was evolved on the size and shape of the grids to be employed for micro-level analysis to estimate the proximity of recreational facilities. A square grid of 100 side lengths is used for micro-level analysis to estimate proximity.

3.3.5. Delphi for selecting maximum walking distance for measuring proximity strength

To decide on the optimum walking distance suitable in the local context of Kerala state for Gravity modelling for the analyses part of this study. The experts were requested to recommend an optimum walking distance for proximity analysis for compact residential development in the Kerala context.

In the first trial, open suggestions from the experts were invited. In the first trial, 15 different values were suggested by a 25-member expert panel. These values were taken as the base opinion to develop a consensus relevant to local contexts. No data from other contexts were shared as it may cause bias. In the second and third trials, the experts were requested to give suggestions after the suggestions from previous trials were shared among the expert panel, keeping the anonymity of suggestions.

Table 4: Delphi Expert Survey-Optimum walking distance (Source: Compiled by Author)

S. no	Walking distance for proximity analysis (m)	Number of experts Trial 1	Number of experts Trial 2	Number of experts Trial 3
1	200	2	1	0
2	250	2	0	0
3	300	1	2	0
4	400	2	3	4
5	450	1	2	1
6	500	1	0	1
7	550	1	0	1
8	600	4	9	13
9	650	1	1	1
10	750	1	0	0
11	800	4	3	2
12	900	2	2	2
13	1000	1	0	0
14	1200	1	0	0
15	2000	1	2	0

Table 4shows the expert panel's suggestions in all the three trials conducted to arrive at a consensus on maximum distance criteria to be taken in the proximity analysis in the urban areas in the Kerala context. A maximum walking distance of 600 metres was chosen as the optimum walking distance to estimate the proximity strength of grids with respect to urban recreation locations.

3.4. A spatial model for assessing proximity strength

The gravity model is found suitable from the literature review for modelling the Proximity strength based on the axioms.

3.4.1. Modelling proximal strength for the study area:

Dwelling units (D. U. s) in a 100 X 100-metre grid pattern represent the study area's population. The D. U. s in each grid also represents the population per one-hectare grid. It also describes the density per hectare at the micro-level. The number of dwelling units represents the population, and the distance between grids centroid and urban recreation locations represents proximity. This equivalence is analogous to Gravity model. The exponent component of distance in the denominator can be considered unity as the linear distance is inversely proportional to proximity.

3.4.2. Gravity model for Proximal strength assessment:

The gravity model with unity distance exponent factor is employed to assess proximity strength. **Figure 2** represents Gravity model for proximity strength.

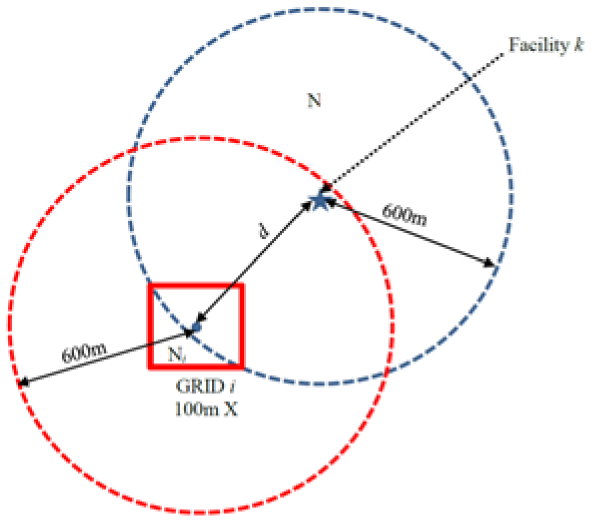

Figure 3: Gravity Model for assessing Proximity strength (Source: Compiled by Author)

In **Figure 3**above, ***i*** represents the ***i***th grid, and ***k*** represents one of the urban recreation facilities within 600m from the centroid of grid ***i***. $\mathbf{N_i}$is the population represented by the number of dwelling units in the ***i***th grid, and **N** is the population within 600m of the facility ***k***. d is the distance between grid ***i*** and urban recreation location is **K**.

Proximity strength of Grid i = $(N_i X\ N) / d$ **(2)**

As the distance is inversely proportional to proximity, the above formula can be approximated as the gravity model with the distance exponent factor as unity.

3.5. The study area for field application of proximity strength

A brief study demographic study of the area is inevitable for better comprehension. A quick survey of demographic patterns from relevant census data for Malappuram municipality and North Paravur Municipality is done.

3.5.1. Study area Malappuram municipality:

The state of Kerala witnessed rapid scattered urbanisation during the past decade, which was promptly revealed in the 2011 census. As per the census, the state-level urbanisation has leapfrogged from 25.96% to 47.72% from 2001 to 2011. The urban area that showed the most considerable urbanisation growth rate (16.47%) was Malappuram. Malappuram urban agglomeration (U. A.) was found to have the most urbanisation rate (16.87%) in Kerala.

Based on these features, Malappuram (see **Figure 4)** was selected as the study area for the field application of the proposed framework. Malappuram district headquarters is within the municipality. The Malappuram municipality has an area of 33.61 sq. Km, with a population of 68, 127 and a population density of 2027 per sq. Km. Malappuram municipality is embedded in the rolling terrain of midlands

ISSN: 2319-7064
SJIF (2022): 7.942

between the coastal plain along the Arabian sea and the highlands of Western Ghats. The word 'Malappuram' literally means hilltop.

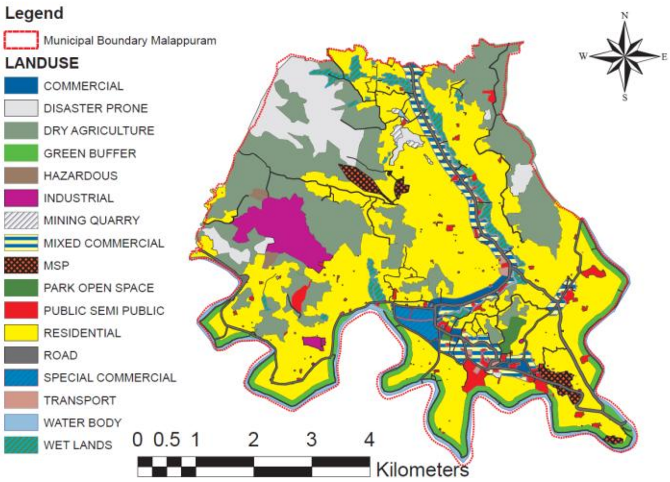

Figure 4: Malappuram Municipality-Proposed Land-use Map (Source: Development Plan for Malappuram Municipality TCPD, Govt. Kerala)

3.5.2. Study area North Paravur municipality

An urban area with diverse characteristics is selected for generalisation and field verification of the proximity assessment model. North Paravur municipality is a specific study area with different urban features.

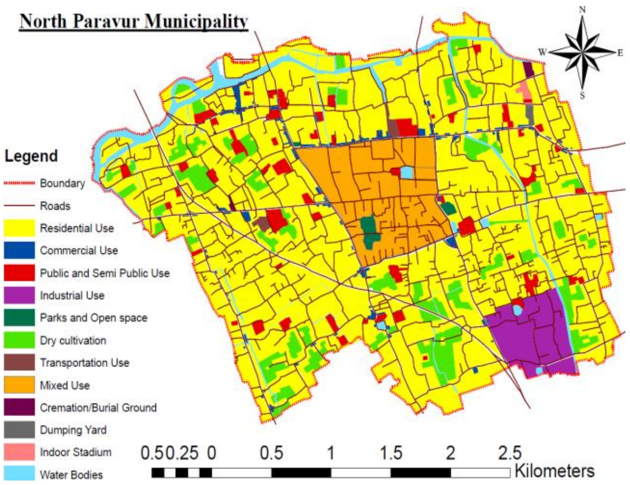

Figure 5: Paravur Municipality-Proposed Land-use Map (Source: Master Plan for Paravur Municipality TCP Wing, LSGD, Govt. Kerala)

Figure 5shows the land use map of the North Paravur municipal area. The town has an area of 9.04 sq. Km and population size of 31503 as per the 2011 census. Accordingly, the population density of North Paravur municipality is 3493 per sq. Km.

4. Analysis

For relevant micro-level analysis, a grid overlay is placed over the entire study area. The grids are 100 m x100 m in size with an area of one hectare. These grids represent the micro-level unit for further research. The number of dwelling units per grid multiplied by the settlement average household size represents the residential density. The number of dwelling units per grid multiplied by the average household size of the settlement within a walkable distance of 600 metres from the urban recreation locations is treated as the population weightage to that particular facility. Euclidean distance between the location of the urban recreation facility and the centroid of the grid is taken for the Gravity model's distance parameter.

4.1. Analysis for assessing proximity strength of urban recreation locations for Malappuram Municipality:

The residential building's location is marked in**Figure 6.** The north-western portion of the municipal area has highly sloping and rolling terrain and is not inhabited. Granite quarries and plantation land is situated in this portion.

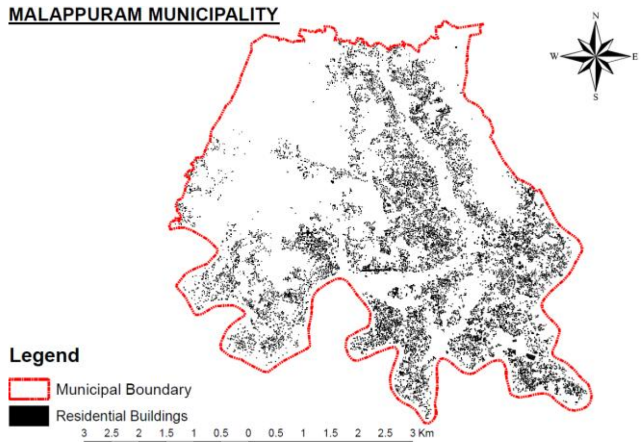

Figure 6: Location of Residential buildings-Malappuram (Source: Compiled by Author)

Also, the northeast portion along the municipal area boundary is not populated because of difficult terrain. The rugged rolling landscape is a constraint in urban development. The dwelling units are scattered along the places where the terrain slope is friendly.

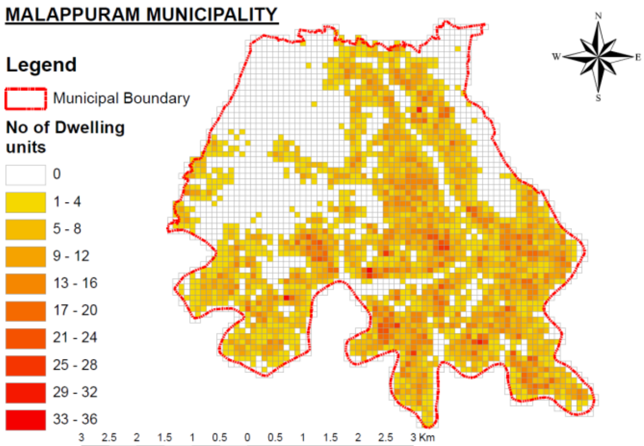

Figure 7: Dwelling unit density per one-hectare grid-Malappuram (Source: Compiled by Author)

The dwelling unit grid density is shown in**Figure 7.** The grids with no dwelling units are marked white and represent uninhabited land. These areas have a higher slope and rolling terrain.

There are five recreational spaces open to the public in the municipal area. They are Kottappadi Football stadium, Kottakunnu Park, Kottakunnu children's park, Indira Priyadarshini indoor stadium and Grand Masjid maidan.

The locations of the five parks in Malappuram municipal area are shown in **Figure 8**. The proximity strength of grids to recreational park locations is calculated using Gravity model for each grid.

The normalised proximity strength with respect to Recreational spaces calculated using Gravity model is mapped in GIS, as shown in **Figure 9**. The largest contiguous area of proximity strength is towards the southeast portion of the municipality where the town centre is located.

The AMI identifies grids with high-value clusters, low-value clusters, and outliers, i. e. high among low-value clusters and low among high-value clusters. **Figure 10** depicts significant clustering of high proximity strength values with respect to recreation parks derived by the spatial statistic; AMI. The grids mapped in red are high-value clusters. The high proximity strength values are clustering in two non-contiguous areas. The municipal area's southeast portion is the largest contiguous area with significantly high-value clustering for recreational proximity strength.

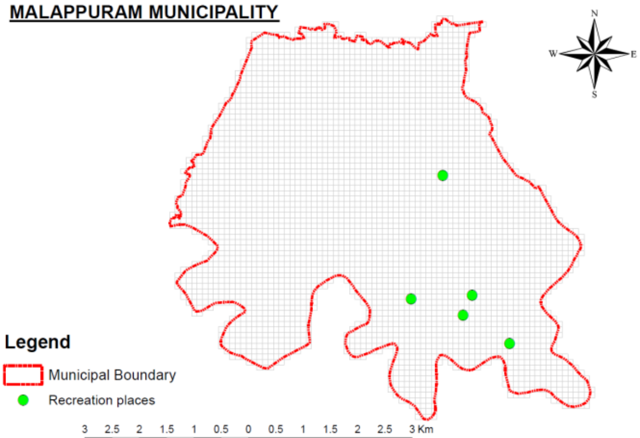

Figure 8: Recreational areas' Location-Malappuram (Source: Compiled by Author)

4.2. Analysis for assessing proximity strength of urban recreation locations for North Paravur Municipality

To comprehend the scattered nature of residential development, the existing pattern of dwelling units is analysed. All the dwelling units in the municipal area are mapped on the GIS platform. The spatial data used for preparing the North Paravur Master Plan is used for the study.

The scattered development pattern of dwelling units all over the municipal area is shown in **Figure 11**. The scattered pattern is the general development trend typical to the Kerala state.

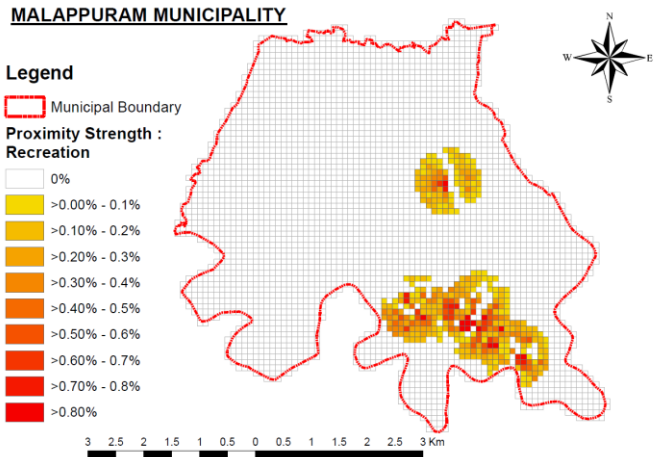

Figure 9: Proximity Strength-Recreational areas-Malappuram (Source: Compiled by Author)

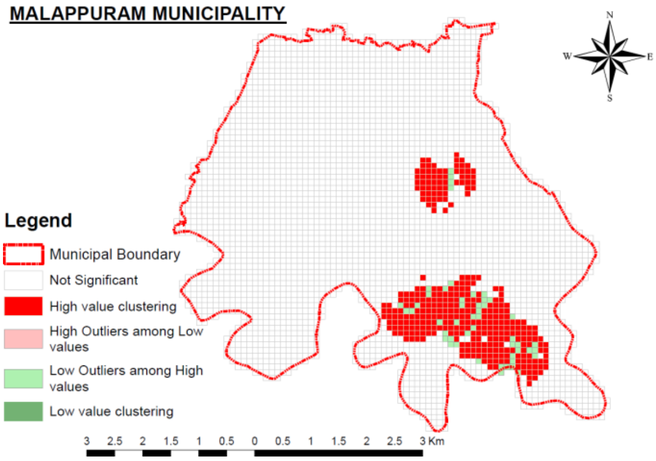

Figure 10: Clustering-Proximity Strength-Recreational areas-Malappuram (Source: Compiled by Author)

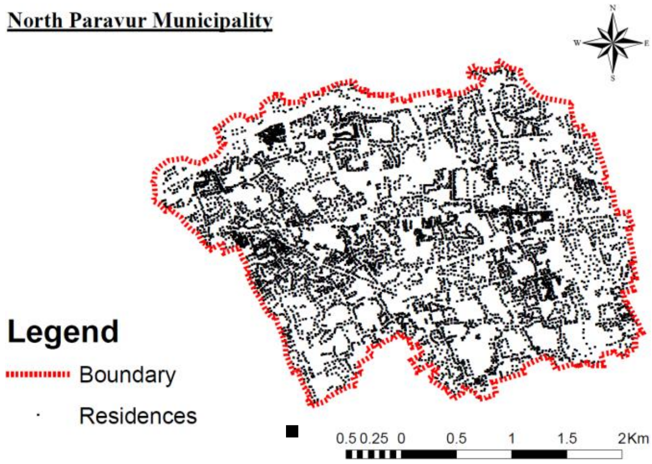

Figure 11: Dwelling Units Locations-North Paravur (Source: Compiled by Author)

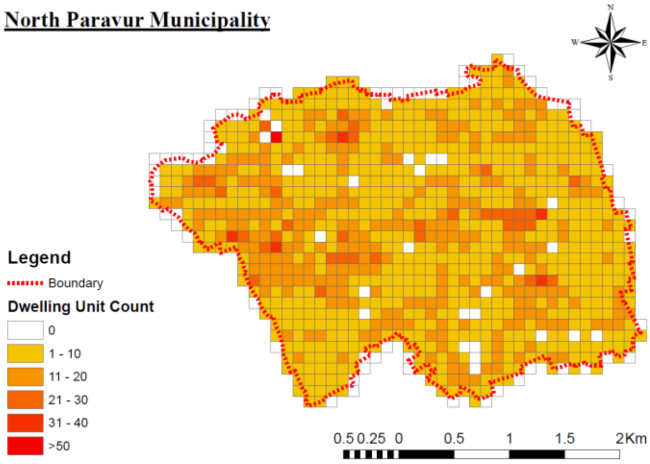

Figure 12: Dwelling Units per 100m x 100m Square Grid-North Paravur (Source: Compiled by Author)

The residential density pattern within the municipal area is shown in **Figure 12**. It reflects the scattered pattern seen in Kerala state. The highest count of D. U. s in a one-hectare size grid is 55. There are 989 grids. Total D. U. s are 8235. The mean of D. U. s per grid is 8.326593, the Standard Deviation is 6.533534, and the gross average density in the municipal area is 9.11 DUs per hectare. The scattered residential development pattern evolved from the Desakota development style is an example of general scattered development traits seen all over Kerala.

There are two recreational open space locations, the Municipal Stadium and Ambedkar municipal parks in Paravur, mapped in the GIS platform.

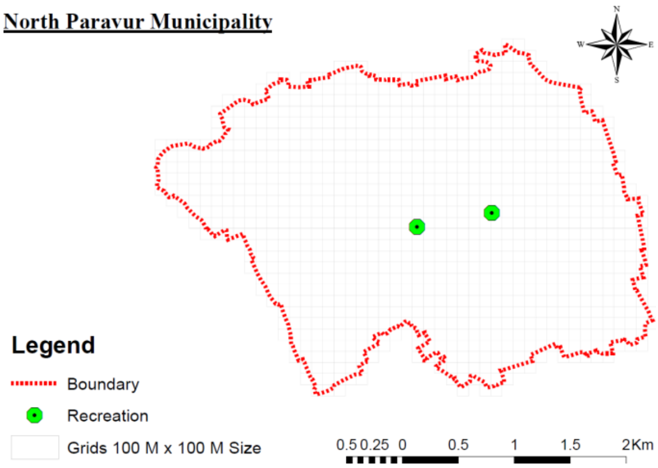

Figure 13: Location-Recreation space-North Paravur (Source: Compiled by Author)

There are two urban recreation spaces in North Paravoor, a municipal stadium and a municipal park. The recreation space of the North Paravur municipal area is shown in **Figure 13**. The central area of the town offers high proximity strength to recreation spaces. The proximity strength values are concentrated between and around the two recreation spaces.

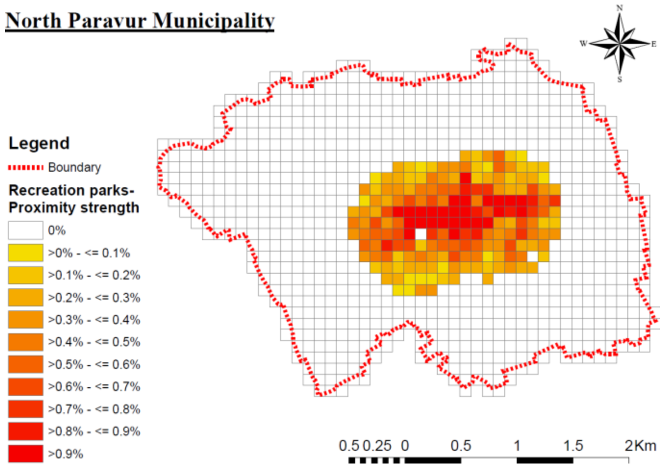

Figure 14: Proximity Strength-Recreation space-North Paravur (Source: Compiled by Author)

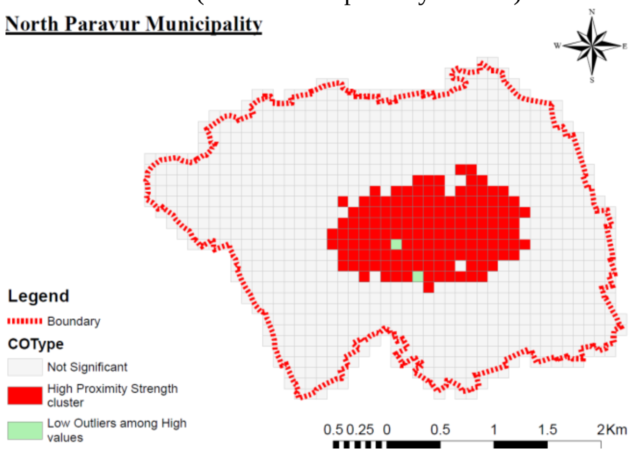

Figure 15: Clustering-Proximity Strength – Recreation facilities-North Paravur (Source: Compiled by Author)

The AMI identifies grids with high-value clusters, low-value clusters, and outliers. The AMI clustering of high proximity strength grids with respect to Recreation space locations is shown in **Figure 15**. The high-proximity strength value clusters are marked in red. The central area of the town has a high proximity cluster to recreation spaces. In the master plan, the central area marked as the Town centre zone is mixed-use. This study considers the residential use zone in assessing the proximity primarily. The cluster of high proximity strength values does not conform to the residential use parcels of the proposed land use map of the Paravoor Master Plan.

5. Results

The grids with proximity strength values are over layed on the land use zone map for the study area. The spatial intersection of residential zones and grids with proximity strength is done. Some grids partially intersect, whereas some fully intersect with the residential zone. The proximity strength values are cumulated in the ratio of grid area that spatially intersects the residential zone. The cumulative value of proximity strength calculated from the intersection of residential zones and grids with proximity strength indicates the level to which residential zones could include the areas with proximity strength.

5.1. Results for Malappuram:

The residential land use zones are delineated from the proposed land use map of the Development Plan for Malappuram, as shown in **Figure 16**.

The Residential land use zones delineated from the Malappuram master plan are overlaid on the grids with proximity values shown in **Figure 9**. The intersection of these two layers is shown in **Figure 17.**

The proximity strength values of grids are cumulated by the ratio of area each grid intersects the residential land use is derived as 0.464868. The deal represents how the residential land use zone accommodates the proximity strength of existing residential distribution with respect to urban recreation facilities.

5.2. Results for North Paravoor:

The proposed residential land use parcels of the Master Plan of North Paravur are delineated, as shown in **Figure 18**. The residential land use is almost uniformly spread over the plan area except for the central mixed-use zone and industrial use zone towards the southeastern periphery.

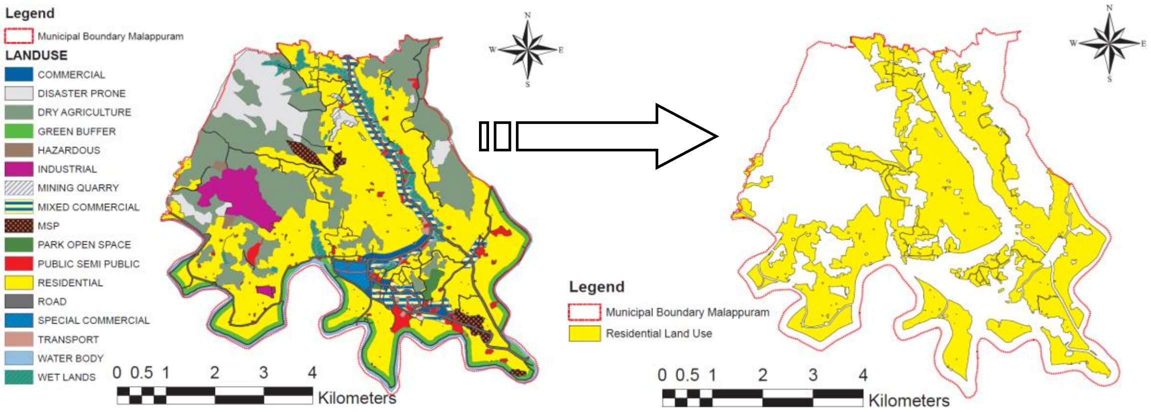

Figure 16: Delineation of Residential Land Use from Development Plan of Malappuram (Source: Compiled by Author)

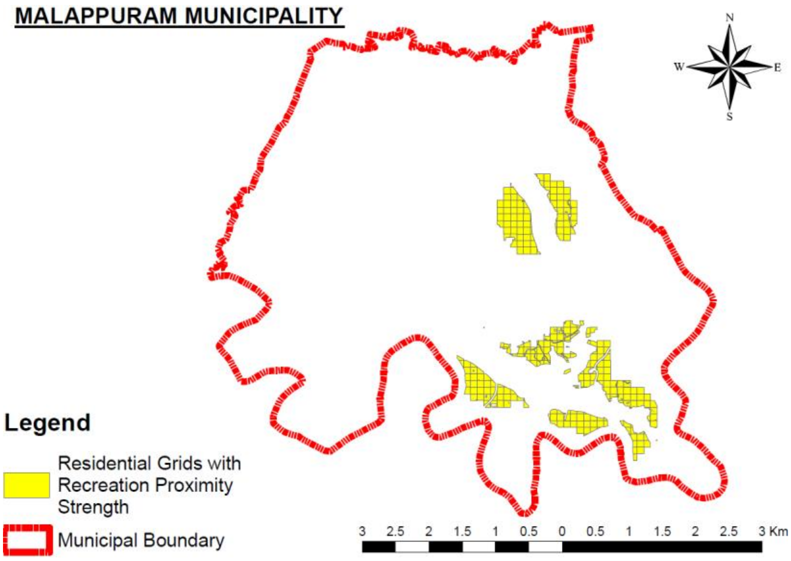

Figure 17: Grids with Proximity Strength to Urban Recreation facilities intersecting Residential land use zones, Malappuram. (Source: Compiled by Author)

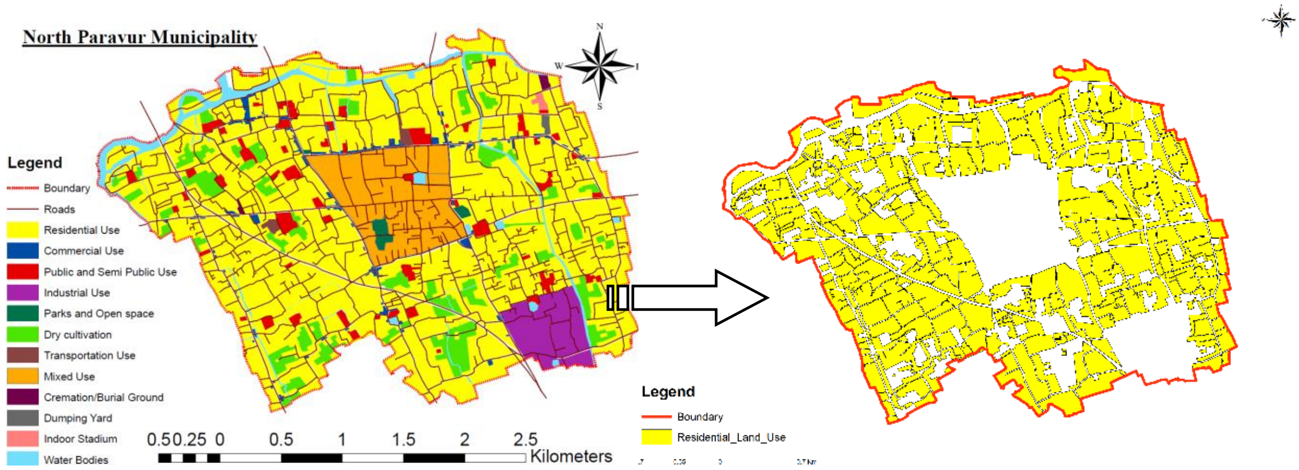

Figure 18: Delineation of Residential Land Use from Development Plan of North Paravoor (Source: Master Plan for Paravoor Municipality TCP Wing, LSGD, Govt. Kerala)

The residential land use delineated is overlaid on the grids with proximity strength values. The spatial intersection of the two layers is shown in **Figure 19**.

The cumulative value of ratios of proximity grid according to the proportion of the area of grids intersecting the residential area is 0.3556. This value represents how the residential land use zonation accommodates the proximity strength of existing residential distribution with respect to urban recreation facilities in the North Paravoor Master Plan.

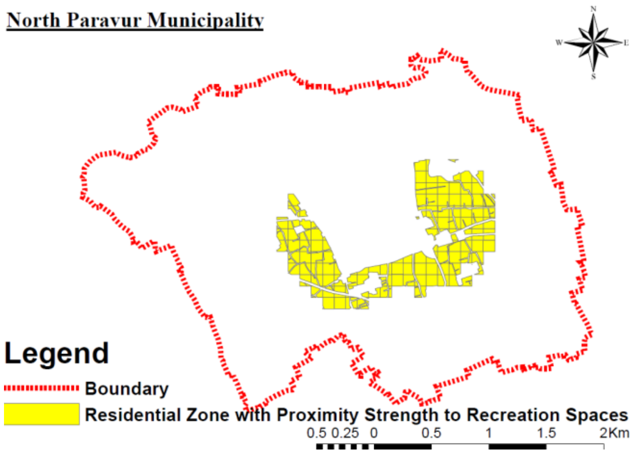

Figure 19: Grids with Proximity Strength to Urban Recreation facilities intersecting Residential land use zones, North Paravoor. (Source: Compiled by Author)

6. Discussion

The results derived as cumulative proximity strength show the degree of proximity captured in the residential zone land parcels. The degree of proximity strength conforming to residential zone parcels is 0.464868 for Malappuram and 0.365610 for North Paravoor. It also means, for Malappuram, 0.535132 (=1-0.464868) or 53.51% of proximity strength with respect to urban recreational facilities is not included in the present residential zone areas of the Development Plan for Malappuram. For North Paravoor, the degree of proximity strength conforming to residential land parcels is 0.365610. It implies that 0.63439 (= 1-0.365610) or 63.43% of proximity strength with respect to urban recreation locations are not included in the current residential zone parcels of the Paravoor Master Plan. The spatial assessment shows which areas are significant and which are not according to proximity strength to urban recreation locations.

The study accounts for the existing density of residential buildings and the existing locations of urban facilities. The proximity strength to locations that provide urban services can also be assessed, and the study can be scaled at the town level.

By improving the spatial equity, and thus spatial sustainability, the footprint of the residential built environment can be reduced, which will negate the adverse effect of the existing scattered pattern of development. It reduces dependability on motorised transport to reduce fossil fuel consumption and pollution. Also, it preserves arable land, thus reducing the conflicts with nature and land per capita andhousing costs. It checks the chances of global warming.

Confining residential development with better proximity to urban facilities will lead to economic sustainability. It reduces per capita land costs for residential development. Also, the confinement of residential development in a settlement triggers a demand for other supporting land uses like a retail commercial uses to be spatially confined. Furthermore, it reduces the cost of providing linear infrastructure to residential use areas, reduces the cost of social infrastructure by enhancing better sharing of facilities, and saves commuting costs.

The enhancement of spatial sustainability can also improve social sustainability. Improving proximity to facilities in urban settlements will lead to confined, compact urban residential development and more social interaction and cohesion. It will reduce commuting, thus enabling more quality time, promoting social equity of accessibility, enabling more organisation and self-help groups and more civic involvement in governance.

Paper ID: SR22811060707 DOI: 10.21275/SR22811060707

7. Conclusion

This research aims to build a rational theoretical background for evaluating the proximity strength of residential zones with objectivity. Focusing on proximity, a prime factor in spatial equity and sustainability, the study considers micro-level variations in the real world by accounting for individual residential building locations to estimate residential density. This study provides a deterministic methodology to assess the proximity of any urban facilities. Though this learning effort focuses only on the urban recreation locations, the same method can be usedfor all other urban facilities. This study can be scaled up to enhance the proximity of all social infrastructure locations by redefining the current residential density control regime. The degree of arbitrariness is too high in the existing residential density control regime and is not location-specific. The residential density regulations are more use specific and not location-specific. Though this study focuses only on and putting forth a rationale for improving spatial equity, this can enhance all other three dimensions of sustainability: environmental, economic, and social sustainability by promoting compact development. The findings can lead a long way to Sustainable development and to enhance spatial equity-the fourth dimension of sustainability explicitly identified by the New Urban Agenda by UN-HABITAT

References

[1] Allen, A., Frediani, A. A., & Walnycki, A. (2016). Transforming a 'New Urban Agenda' into a just urban agenda. *International Institute for Environment and Development*.

[2] Anderson, James, E., & Anderson E., J. (2011). The Gravity Model. *Annual Review of Economics*, *3* (2011), 133–160. https: //doi. org/1 0.1 1 46/annurev-economics-l 1 1 809-1 2

[3] Annerstedt, M., Östergren, P. O., Björk, J., Grahn, P., Skärbäck, E., & Währborg, P. (2012). Green qualities in the neighbourhood and mental health-Results from a longitudinal cohort study in Southern Sweden. *BMC Public Health*, *12* (1). https: //doi. org/10.1186/1471-2458-12-337

[4] Baxamusa, M. H. (2008a). Empowering communities through deliberation the model of community benefits agreements. *Journal of Planning Education and Research*, *27* (3), 261–276. https: //doi. org/10.1177/0739456X07308448

[5] Baxamusa, M. H. (2008b). The Third E : Equity as a Condition of Sustainability. *MIT Journal of Planning*, *8* (8), 16–24.

[6] Calderón-Argelich, A., Benetti, S., Anguelovski, I., Connolly, J. J. T., Langemeyer, J., & Baró, F. (2021). Tracing and building up environmental justice considerations in the urban ecosystem service literature: A systematic review. *Landscape and Urban Planning*, *214*. https: //doi. org/10.1016/j. landurbplan.2021.104130

[7] Campbell, S. (2016). Green Cities, Growing Cities, Just Cities?: Urban Planning and the Contradictions of Sustainable Development. In *Readings in Planning Theory: Fourth Edition*. https: //doi. org/10.1002/9781119084679. ch11

[8] District census handbook, (2011).

[9] Chaudhry, P., & Tewari, V. P. (2010). Role of public parks/gardens in attracting domestic tourists: An example from city Beautiful of India. *Tourismos*, *5* (1), 101–110.

[10] Chen, Y., & Huang, L. (2018). A scaling approach to evaluating the distance exponent of the urban gravity model. *Chaos, Solitons and Fractals*, *109*, 303–313. https: //doi. org/10.1016/j. chaos.2018.02.037

[11] Dempsey, N., Brown, C., Raman, S., Porta, S., Jenks, M., Jones, C., & Bramley, G. (2008). Dimensions ofthe Sustainable City, Future City 2 Chapter 2 Elements of Urban Form. In *Media* (Vol.2). https: //doi. org/10.1007/978-1-4020-8647-2

[12] Department of Town and Country Planning; Government of Kerala. (2012). *State Urbanisation Report* (Issue March).

[13] Hague, C., Platt, C., & Taylor, P. (2018). *Delivering the New Urban Agenda through Urban and Territorial Planning*. United Nations Human Settlements Programme (UN-Habitat).

[14] Hartley, L., & Habitat-III. (2017). The New Urban Agenda: Ten Things You Need To Know. *Landscape Architecture Australia*, *153* (153), 17–24.

[15] Hillier, B. (2009). Spatial Sustainability in Cities Organic Patterns and Sustainable Forms. In D. Koch, L. Marcus, & J. Steen (Eds.), *7th International Space Syntax Symposium* (Vol. K01, Issue 1, pp.1–20). Elsevier B. V. https: //doi. org/10.1068/c110019

[16] Hsu, C., & Stanford, B. A. (2007). The Delphi Technique : Making Sense of Consensus Chia-Chien. *Practical Assessment, Research & Evaluation*, *12* (10), 1–8.

[17] Jalaladdini, S., & Oktay, D. (2012). Urban Public Spaces and Vitality: A Socio-Spatial Analysis in the Streets of Cypriot Towns. *Procedia-Social and Behavioral Sciences*, *35* (December 2011), 664–674. https: //doi. org/10.1016/j. sbspro.2012.02.135

[18] Jenks, M., & Jones, C. (2008). Dimensions ofthe Sustainable City, Future City 2, Chapter 1 Issues and Concepts. *Media*, *2*, 215-237–237. https: //doi. org/10.1007/978-1-4020-8647-2

[19] Jiao, L., Xu, G., Jin, J., Dong, T., Liu, J., Wu, Y., & Zhang, B. (2017). Remotely sensed urban environmental indices and their economic implications. *Habitat International*, *67*, 22–32. https: //doi. org/10.1016/j. habitatint.2017.06.012

[20] Kotharkar, R., Bahadure, P., & Sarda, N. (2014). Measuring compact urban form: A case of Nagpur city, India. *Sustainability (Switzerland)*, *6* (7), 4246–4272. https: //doi. org/10.3390/su6074246

[21] Lee, J.-S. (2016). Measuring the value of apartment density? *International Journal of Housing Markets and Analysis*, *9* (4), 483–501. https: //doi. org/10.1108/IJHMA-08-2015-0047

[22] Luc Anselin. (2018). A Local Indicator of Multivariate Spatial Association. *Geographical Analysis*, *00*, 1–18. https: //doi. org/10.13140/RG.2.2.18101.58084

[23] Majumdar, S., Deng, J., Zhang, Y., & Pierskalla, C. (2011). Using contingent valuation to estimate the willingness of tourists to pay for urban forests: A study in Savannah, Georgia. *Urban Forestry and Urban Greening*, *10* (4), 275–280. https: //doi. org/10.1016/j.

ufug.2011.07.006

[24] Morley, C., Rosselló, J., & Santana-Gallego, M. (2014). Gravity models for tourism demand: Theory and use. *Annals of Tourism Research*, *48*, 1–10. https: //doi. org/10.1016/j. annals.2014.05.008

[25] Nielsen, T. S., & Hansen, K. B. (2007). Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. *Health and Place*, *13* (4), 839–850. https: //doi. org/10.1016/j. healthplace.2007.02.001

[26] Nijkamp, P. (1978). Gravity and entropy models: the state of the art. *Colloquium Vervoersplanologisch Speurwerk*, *1977*, 281–319.

[27] P. P. Anilkumar. (2019). Urbanisation and Sustainable Cities. In H. Singh & C. Purushothaman (Eds.), *Introduction to Smart Cities* (1st ed., pp.17–27). Pearson India Educaional Services Pvt. Ltd. in. pearson. com

[28] Peters, K. (2010). Being together in urban parks: Connecting public space, leisure, and diversity. *Leisure Sciences*, *32* (5), 418–433. https: //doi. org/10.1080/01490400.2010.510987

[29] Peters, K., Elands, B., & Buijs, A. (2010). Social interactions in urban parks: Stimulating social cohesion? *Urban Forestry and Urban Greening*, *9* (2), 93–100. https: //doi. org/10.1016/j. ufug.2009.11.003

[30] Rigolon, A., Browning, M., & Jennings, V. (2018). Inequities in the quality of urban park systems: An environmental justice investigation of cities in the United States. *Landscape and Urban Planning*, *178* (January), 156–169. https: //doi. org/10.1016/j. landurbplan.2018.05.026

[31] Silveira, P., & Dentinho, T. P. (2017). A spatial interaction model with land use and land value. *Cities*, *August*, 0–1. https: //doi. org/10.1016/j. cities.2017.08.023

[32] Stefanouli, M., & Polyzos, S. (2017). Gravity vs radiation model: two approaches on commuting in Greece. *Transportation Research Procedia*, *24*, 65–72. https: //doi. org/10.1016/j. trpro.2017.05.069

[33] Suzanne, D. P., & Okoli, C. (2004). The Delphi Method as a Research Tool : An Example, Design Considerations and Applications. *Information & Management*, *42* (1), 15–29. https: //doi. org/10.1016/j. im.2003.11.002

[34] UN-Habitat. (1991). *Sustainable Cities Programme*. UNCHS. http: //www.fukuoka. unhabitat. org/programmes/detail04_03_en. html

[35] UN-Habitat. (2020). *The New Urban Agenda*. United Nations Human Settlements Programme (UN-Habitat).

[36] Vidal, L. A., Marle, F., & Bocquet, J. C. (2011). Using a Delphi process and the Analytic Hierarchy Process (AHP) to evaluate the complexity of projects. *Expert Systems with Applications*, *38* (5), 5388–5405. https: //doi. org/10.1016/j. eswa.2010.10.016

[37] Weber, D., & Anderson, D. (2010). Contact with nature: Recreation experience preferences in Australian parks. *Annals of Leisure Research*, *13* (1–2), 46–69. https: //doi. org/10.1080/11745398.2010.9686837

[38] Wilson, A. G. (1969). The Use of Analogies in Geography. *Geographical Analysis*, *1* (3), 225–233. https: //doi. org/https: //doi. org/10.1111/j.1538-4632.1969. tb00620. x

[39] Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities “just green enough. ” *Landscape and Urban Planning*, *125*, 234–244. https: //doi. org/10.1016/j. landurbplan.2014.01.017