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# Sustainability Assessment of a Neighbourhood: An Approach to Sustainable Urban Development - Case of Kochi

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## ABSTRACT

Rapid urbanization is responsible for the alteration of a range of environmental, social, and economic factors. Urban growth has exacerbated environmental problems, which are linked to unsustainable practices with respect to site management, transportation, waste management, water management, housing, and land use management. Global warming is a major issue that the world is encountering without preparation. Urban heat islands caused by rapid urbanization intensify global warming which in turn results in climate change. Cities are becoming warmer and warmer and undesirable. Sustainable planning in urban areas promotes the management of natural resources to improve the quality of life. Cities and towns are formed by clustering of small units called neighborhoods. Thus, it is considered the building block of cities where most developments occur. Therefore, the sustainability of a city depends on the sustainability of neighborhoods. Achieving sustainability in existing urban areas is essential. To improve sustainability in existing urban areas, a sustainability assessment should be done. However, past studies on sustainability assessment have focused on either the city level or building level, whereas the assessment of neighborhood sustainability, an intermediate level, has received very little attention. This study focuses on the sustainability assessment of existing neighborhoods using the Neighborhood Sustainability Assessment (NSA) tool. This paper focuses on - some design strategies and proposals by assessing the existing sustainability profile of the study area which focuses on the improvement of sustainability and quality of life of residents in the study area, located at Kochi.

**KEYWORDS**: Neighborhood Sustainability Assessment (NSA) tool, LEED for Neighborhood Development, Sustainable Neighborhood

# 1 INTRODUCTION

The rapid transformation of rural or semi-rural areas into towns and cities causes changes in the place's characteristics, resulting in population growth and an increase in other infrastructures. This process is referred to as urbanization. It is not only about increasing the number of urban residents or expanding the area of cities, but also about a complete change from rural to urban style in all aspects. Rapid urban growth results in unsustainable practices such as inefficient housing, water management, waste management, and land-use management. It will also reduce vegetation cover, which will lower the rate of carbon sequestration [1].

Several studies show that rapid urban growth results in various environmental problems ranging from local to the global scale, including global warming. As per the studies, urban residents experience more heat stress than rural residents [2]. Urban areas always tend to increase the surface temperature, due to the low albedo materials and reduced green spaces, and this results in the generation of heat islands. These heat islands alter the microclimate and increase the energy demand. Urbanization not only alters the microclimate but also causes the deterioration of the environment.

Global warming is a major issue that is faced all over the world. The generation of urban heat islands by urbanization intensifies global warming which makes cities warmer and results in climate change. Climate change causes extreme weather conditions and climate-related events such as floods, droughts, etc. To reduce the effects of urbanization, sustainable urban planning should be carried out. It will also help to improve the quality of life of residents. The performance of a city is greatly influenced by its neighbourhoods. Effective sustainable planning at the city level can be achieved by improving the sustainability of existing neighbourhoods.

Neighbourhood sustainability assessment (NSA) tools are defined as a set of criteria and themes; and are used to: (a) Evaluate and rate the performance of a given neighbourhood; (b) Assess the neighbourhoods' position on the way towards sustainability, and (c) Specify the extent of neighbourhoods' success in approaching sustainability goals [3,4]. NSA tools help to identify the existing sustainability performance of a neighbourhood and give an insight into the parameters that need to be improved to enhance the performance of the neighbourhood. Several NSA tools are currently in use on a global scale. The following are only a few of the well-known ones: HQE2R, CASBEE-UD, GSAS, IGBC Green Townships, LEED-ND, BCA Green Mark for Districts, BREEAM- Communities, Peral Community Rating System, GBI Township, DGNB for Districts, etc. From this, LEED for Neighbourhod Development (LEED-ND) tool is used to carry out this study, which is a pioneering method in building and neighbourhood sustainability assessment [3].

The main objective of this study is to assess the sustainability performance of an existing neighbourhood by using NSA tools and to study the major issues and quality of life of the residents in the study area. Based on this, the study identifies the major issues and deficiencies of the existing neighbourhood, and sustainable strategies are integrated to improve the sustainability performance of the existing neighbourhood.

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## 2 LITERATURE REVIEW

Since earlier periods human settlements have been split into districts and neighbourhoods geographically, demonstrating the significance of neighbourhoods to the structure of a city. Neighbourhood plays a significant role in the formation of the overall city.
A sustainable neighborhood provides a socially, environmentally, economically healthy, safe, and resilient place to live, work, and play. It acts as a social interactive place that provides all amenities within the neighborhood. It consists of a socially cohesive and diverse mix of housing typologies and amenities for walking, cycling, and proper transit facilities. These neighborhoods promote energy efficiency and conserve the environment from major impacts of urban development by efficient use of resources. It provides residential areas and recreational facilities in closer proximity which enables the residents to use alternative transportation facilities such as cycling.

### 2.1 Criteria and indicators of the sustainable neighborhood

Social aspect:

- Education Facilities
- Health facilities
- Identity and vitality of neighbourhood
- Individual and social security
- Recreation and leisure
- People participation / Public relation
- Food security

Environmental aspect:

- Green and open space Pollution
- Natural landscape
- Population density
- Building density

Economic aspect:

- Employment
- Diverse housing
- Transport and communication facilities
- Facilities and infrastructure services

### 2.2 Neighborhood Sustainability Assessment tools

Sustainability assessment is the assessment done to assess the sustainability performance of neighbourhood. There are several tools that enable to do the assessment of neighbourhood called neighbourhood sustainability assessment (NSA) tools. These tools have great potential for the transition of neighbourhoods towards sustainable development. It provides context-based sensitive results by reviewing the existing condition of the neighbourhood. There are several NSA tools available such as LEED-ND, BREEAM communities, CASBEE city, DGNB urban districts, IGBC green townships, etc [6].

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List of NSA tools:

Table 1 List of Neighbourhood sustainability assessment tools [6]

| Tool | Main developer | Origin | Year |
|---|---|---|---|
| HQE2R | Scientific and Technical Centre for Building (CSTB) | France | 2001 |
| CASBEE-UD | The Institute for Building Environment and Energy Conservation (IBEC) | Japan | 2007 |
| Global Sustainability Assessment System (GSAS) | Gulf Organisation for Research and Development | Qatar | 2007 |
| IGBC Green Townships | Indian Green Building Council | India | 2008 |
| LEED-ND | US Green Building Council (USGBC) | US | 2009 |
| BCA Green Mark for districts | Building and Construction Authority (BCA) | Singapore | 2009 |
| BREEAM-Communities | Building Research Establishment (BRE Global) | UK | 2009 |
| Pearl Community Rating System | Abu Dhabi Urban Planning Council | UAE | 2010 |
| GBI Township | Green Building Index Sdn Bhd (GSB) | Malaysia | 2011 |
| DGNB for Districts | German Sustainable Building Council | Germany | 2012 |
| Green Star Communities | Green Building Council Australia (GBCA) | Australia | 2012 |

## 2.3 NSA TOOL - LEED for Neighbourhood Development (LEED-ND)

Leadership in Energy and Environmental Design for Neighbourhood Development is a rating system that is dedicated to neighbourhood scale assessment. This is a major tool that is used to assess the performance of a neighbourhood. LEED-ND comprises a set of categories such as smart location and linkage, neighborhood pattern and design, green infrastructure and buildings, innovation, and regional priority credits. This is a credit-based rating system. Depending upon the credit-scored, the project can be rated as silver, gold, and platinum.
The main intent of this rating system is to promote healthy, durable, affordable, and environmentally friendly practices in design and construction. This rating system can be used to evaluate the performance level of the neighbourhood and finding out remedies to enhance the performance level. This enables us to achieve a compact, mixed-use neighbourhood with all amenities that can be accessed easily [5].
LEED ND 2009 has five main categories: Smart location and linkage (SLL), Neighbourhood pattern and design (NPD), Green infrastructure and buildings (GIB) , Innovation and design process (IDP), and Regional Priority credits (RP).

### 2.3.1 Smart Location and Linkage (SLL)

This category mainly focuses on site selection and where to build or how to choose a site for neighbourhood development. It encourages development near the existing transit facilities by conserving and protecting the ecological communities and species. It also promotes wetland and water body conservation along with agricultural land conservation to avoid the formation of flood plains. Reuse of land by brownfield redevelopment is also considered thus helping to reduce pressure on undeveloped land. Larger credit in this category includes the promotion of alternative transportation facilities to reduce automobile dependence, thereby reducing pollution and greenhouse gas emissions [5].

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### 2.3.2 Neighborhood Pattern and Design (NPD)

This category focuses on internal connectivity and compact development to protect the existing undeveloped land. This gives insight into what to build. It encourages walkable streets, diverse communities, improvement of transit facilities, etc. The main intent is to reduce the usage of private vehicles and to increase the usage of public transit facilities thus reducing the parking footprint and traffic congestion. This also focuses on the improvement of access to civic facilities and recreational facilities. Facilities such as schools and local food production facilities are also included in this category [5].

### 2.3.3 Green Infrastructure and Buildings (GIB)

This category focuses on the mitigation of environmental impacts and strategies that can be adopted to improve building performance in terms of building energy efficiency, building water efficiency, water-efficient landscaping, retrofitting of old buildings, and reuse of existing abandoned buildings. This category also gives more importance to waste management, light pollution reduction, mitigation of urban heat islands, on-site renewable energy production, etc [5].

### 2.3.4 Innovation and design process (IDP)

This category encourages innovative design ideas that will enhance the smart growth of the neighbourhood. It also provides credit to the inclusion of LEED-accredited professionals [5].

### 2.3.5 2.4.5 Regional priority credits (RP)

This credit aims to incorporate regional variations into the evaluation system [5].

## 3 STUDY AREA

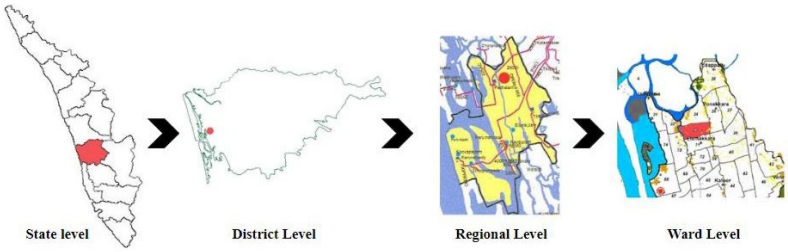


Figure 1: Location Map

The proposed site is Elamakkara, situated in the western portion of Kochi in the Ernakulam district of Kerala. The total site area is about 0.98 Km Sq (242.2 Acres). It is one of the prime residential localities of Kochi, Kerala. The settlement pattern of the neighbourhood is a compact low-rise settlement with 80% residential and 20% of commercial buildings. The eastern and western side of the neighbourhood is bordered by waterbodies.

### 3.1 Population density

The population of this neighborhood is 8939 in 2001, 10274 in 2021, and the projected population for 2041 is 10490. Population density is 63 person/hectare as of the 2001 survey

[Kerala census data 2001]. The projected population density for 2021 is 67.45 people/hectare. Building density ranges from 6.5 - 11 Du/Acre. [7]

## 3.2 Topography

The site is bordered by water canals in the East and the West. Therefore, the elevation of the site ranges from 11 meters to 2 meters above mean sea level (MSL). Land near the water bodies is low-lying areas with an elevation of 2 meters to 4 meters above MSL. And this area is mostly waterlogged and prone to flooding.

### 3.2.1 Elevation profile

According to the study done by Sowmya K and C M John on the elevation profile of cochin city, the major portion of the proposed site comes under 6-10 meters above mean sea level. Some of the regions are above 10 - 19 meters and a small portion comes under 0-3 meters above mean sea level. Thus, the portion under 0-3 meters above mean sea level is not habitable [7].

### 3.2.2 Coastal Regulation Zone [CRZ]

A small portion of the site near to the canal falls under CRZ II, it constitutes the developed areas up to the shoreline, which fall within the existing municipal limits.

## 3.3 Water bodies

Kochi is one of the major seaports in India and the safest harbor in the Indian Ocean. Kochi is rich in its Inland water networks and waterway system which consists of lagoons, backwaters, canals, and estuaries. Major water transportation network, such as the National waterway connecting Kollam and Kottappuram also passes through this region. Major water bodies passing through Kochi are canals, and later join the river and flow into the sea. The main canals in Kochi city are Edappally Canal, Thevara - Perandoor Canal, and Chilavanoor Canal [8].

### 3.3.1 Micro-level water bodies

The canals passing through the site are Thevara - Perandoor canal and the Chilavanoor canal. Thevara - Perandoor canal is located on the western side of the site and the Chilavanoor canal in the eastern side of the site. These two canals make the ward boundary.

## 3.4 Physiography

The district consists of well-defined units, High-lands, Mid-lands, and Low-lands. Highlands are mostly located in the eastern and northern portions of the district, where the midlands occupy the center portion and the lowlands in the eastern part of the district. The lowlands in the district lie between the backwater and the sea. As per the natural resources data bank of Ernakulam, the study area lies on low land.

## 3.5 Geology

As per the Natural Resources Data bank study report, a major part of the district consists of Charnockite and migmatite groups of rocks of Precambrian age. The study area mainly

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consists of sand and silt which are Palaeo beach ridge deposits (sand) and flood plain deposits (silt, sand, clay).

### 3.6 Geomorphology

As per the Natural Resources Data bank study report, the study area lies in the coastal plain. The coastal plain is a low-lying area, with a maximum elevation of around 10 meters, which is characterised by backwater bodies, marshy lands, sandy flats, and alluvial plains.

### 3.7 Soils

The soil typology in the study area is found to be a K0, which is deep moderately well-drained soil. It consists of sandy soils, with a moderately shallow water table on gentle slopes [Natural resources data bank – Ernakulam].

### 3.8 Land use change

As per the study conducted by Sajith K.S [9], the land use map of the site during 1967 was having mixed land use. And the banks of the canals are in seasonally flooded areas. In 2019, the land use of the site changed from Mixed land use to a Highly habited area.
From this change in land use, will be able to understand the changes that had happened over the years. This land use change has exerted pressure on the environment which results in climate change.

### 3.9 Climate of Kochi

Kochi has a tropical climate with abundant rainfall and sunlight. As per the Kappen climate classification, Kochi comes under Tropical Monsoon Climate (Am). The annual temperature of Kochi ranges between 22° C and 32° C and an annual rainfall of around 3000mm since it lies on the windward side of the Western Ghats. Since it is a coastal region and the presence of a large area of backwaters, humidity in this region is high throughout the year.

#### 3.9.1 Temperature

March-May is the hottest month in Kochi. Maximum temperatures occur during March and April with more than 95°F (35°C).

#### 3.9.2 Cloud cover

Most sunny days are experienced during the months of January and February. The regions in Kochi experience partly cloudy during April, May, September, and October. Sky overcast is during the months of June, July and August.

#### 3.9.3 Wind

The wind is blowing from the Southwest to the Northeast direction. This also contributes to gaining more rain in this region. More windy days are experienced during April, May, and June. Less windy days are during November, December, and January.

#### 3.9.4 Precipitation

Kochi receives abundant rainfall. The Wettest months are experienced during June, July, and August. Dry days are experienced during the period from December to March.

#### 3.9.5 Humidity

Kochi experiences high humidity throughout the year due to the presence of sea and backwaters. High humidity is experienced from April to June. Less humidity is during December and January. But most of the days are muggy that lasts for 11 months and 92% of the time it is oppressive and miserable.

### 3.10 Site survey

A site study was conducted to study the settlement pattern, existing land use, livelihood of residents, and quality of life of residents in the study area. To analyze these parameters, a survey was conducted among the residents in the study area. From the survey, I was able to find the current issues that are faced by the residents in the neighbourhood and the existing facilities that are available in the neighborhood. This helped me to sort out the needs of the residents and arrive at strategies for the neighbourhood by referring to the LEED-ND guidelines.

## 4 MATERIALS AND METHODS

After understanding the different neighborhood assessment tools, LEED for Neighborhood development is chosen for the assessment of neighbourhood. Prior to the assessments, a study is done along with the site survey. The site survey was conducted among the residents of the neighbourhood. This helped to identify the typology of residents, existing conditions, and amenities that are available in the neighbourhood.
The neighbourhood sustainability assessment is carried out in two stages using the LEED-ND checklist. At the primary stage, the existing neighborhood is assessed, and the credit points acquired are noted. Several design solutions and strategies are suggested to improve the sustainability performance of the neighborhood.
A secondary assessment is carried out by considering the proposed design strategies to the existing neighbourhood and the total credit points acquired are noted and compared with the initial credit points. Thus, the sustainability performance of the neighborhood is assessed.
To prove the compatibility of the suggested design proposals, outdoor simulations are carried out using ENVI -met software, and results are analyzed.

## 5 RESULTS AND DISCUSSION

This section presents neighbourhood assessments, results, and observations.

### 5.1 Neighborhood Sustainability Assessment – Existing case

#### 5.1.1 Smart Location and Linkage (SLL)

Sustainability assessment of neighbourhood is done using the LEED for Neighbourhood Development checklist and scoring is done. The first category of this rating system is smart location and linkage, which discusses location, ecosystems and open spaces, contaminated sites, transit-oriented locations, cycling facilities, and job and housing proximity.

The neighbourhood is located on an infill site. As per LEED-ND, the infill is 75% of the site surrounded by existing development. According to the assessment by site study, the neighbourhood comes under the infill site category since it is surrounded by more than 75% of existing development. The neighbourhood is well connected by street networks and transit amenities. As it is an infill site and a previously developed site, 5 credit points are scored under LEED-ND SLL credit 1 preferred locations.
The neighbourhood has a good and well-connected street network. As per the assessment, the intersections of the neighbourhood are between 135 to 154 intersections per square kilometer, 4 points are scored under SLL credit 1 preferred locations.
Due to urbanization, some of the species are found to be threatened and endangered as per the biodiversity study report [Local Biodiversity Strategy and Action Plan for Kochi Municipal Corporation]. The low-lying land near the Perandoor canal and Chilavanoor canal is developed and there is no buffer of undeveloped land around them. Thus, the SLL prerequisites 2 and 3 cannot be achieved. As per the site study, the neighbourhood was not farmland and thus agricultural land conservation credit is achieved.
Since the site does not conserves pre-existing on-site habitat, and native plants, restores degraded on-site habitats, wetlands, and water bodies, and does not have long-term plans SLL credit 7,8,9 is not scored during the assessment. The neighbourhood was not a contaminated brownfield site, the brownfield redevelopment credit is not applicable to this neighbourhood.
When assessing the transit-oriented location of the neighbourhood, the neighbourhood has a well-connected road network. But the access to water transportation is less even though the neighbourhood has the well potential to connect to a water transportation network. Under the SLL credit-3 locations with reduced auto dependence, 3 points are scored as per the number of transit services. There is no existing cycling facility in the neighbourhood. The neighbourhood provides jobs on an infill site which has an 800 meters distance between the existing transit stop and housing. Thus, SLL credit-5 is achieved.
By assessing the Smart Location and Linkage category, 13 points are scored from 27 possible points.

### 5.1.2 Neighborhood Pattern and Design (NPD)

This category of the LEED-ND discusses walkable streets, compact development, neighbourhood connections, affordable and diverse housing, parking, and transportation demands, parks and recreation, universal design, community participation, local food, school access, and design.
All buildings in the neigbourhood have entries to a public space such as streets or roads. The building-height-to-street width ratio of 1 to 3 is only present on the main roads and streets and lanes are narrow. Sidewalks are present along both sides of the main roads. Most of the building follows a minimal distance between sidewalks. On-street parking is available on main roads. NPD credit 1 walkable street is achieved with a score of 6 out of 12. Available streets are not comfortable for walking during the daytime due to lack of shade. Thus, the shading of walkways helps to improve the usage of sidewalks.
The assessment of NPD prerequisite 2 compact development shows that the density of dwelling units ranges from 7 – 11 dwelling units per acre. Thus, this enables us to score a point in NPD credit 2 compact development as per the criteria. The neighbourhood has access to streets or pathways and intersections which helps to connect all regions of the neighbourhood and access to all commercial or civic uses. The available intersections do not include cul-de-sacs and the neighbourhood has intersections between 116 to 154 per square kilometer.

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After analyzing the affordable and diverse housing, Simpson's diversity index is .51, which is greater than and less than .6. Thus, one point is achieved as per the NPD criteria.
Parking and transportation demand analysis of the neighbourhood shows that there is no enough parking space in the neighbourhood both for vehicles and bicycles. Thus, there is a need for a proper parking facility that allows people to use it at their convenience.
Credit 10 access to recreation facilities in the NPD category analyses the availability of recreation space in the neighbourhood. As per the analysis, there is a common playground in the neighbourhood. Most of the residents have access to this space within 800 meters. But there is no green open space in the neighbourhood such as squares, or parks.
There are three schools in the neighbourhood that can be accessed within 800 meters. People in the neighbourhood do not have space to produce local food. From the survey, the interest of residents in local food production is analyzed. Thus, providing space for local food production will help to improve the production of local food products.
Thus, all together in the NPD category, points scored were 12 out of 44.

### 5.1.3 Green Infrastructure and buildings (GIB)

Green Infrastructure and Buildings category discusses green construction techniques, energy efficiency and conservation, energy production and distribution, water efficiency and distribution, stormwater and wastewater, green buildings process, Historic, and existing building reuse, Heat islands, reuse and recycling, and light pollution.
The sustainability assessment is done in this category, but the existing neighbourhood does not have green infrastructure and other energy conservation practices. Therefore, no points are gained from this category. But from the site study, the possibility and potential of adopting green building techniques have been identified.
Currently, there are no sustainable practices followed in the neighbourhood. Local energy production and other practices such as heat island reduction, and light pollution reduction are also not practiced. Proposing practices that can be adopted in the neighbourhood to improve sustainable practices will help to reduce energy consumption and thus reduce energy demand.

### 5.1.4 Innovation and Design Process (IDP) and Regional Priority Credit (RP)

The IDP credit assesses the innovation and exemplary performance in the neighbourhood and the RP credit assesses the geographical-specific, environmental, and social equity-specific priorities that exist in the neighbourhood.
From the assessment, no credit point was achieved in these two categories. There are no innovative performance and RP priorities that are addressed in the neighbourhood.

Table 2 Neighbourhood sustainability assessment - Existing case

| LEED – ND Categories | Points Achieved | Possible Points |
|---|---|---|
| Smart Location and Linkage | 13 | 27 |
| Neighbourhood Pattern and Design | 12 | 44 |
| Green Infrastructure and Buildings | 0 | 29 |
| Innovation and Design Process | 0 | 6 |
| Regional Priority Credits | 0 | 4 |
| **Total points** | **25** | **110** |

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## 5.2 Neighborhood Sustainability Assessment – Proposed case

### 5.2.1 Smart Location and Linkage (SLL)

A secondary assessment is performed after proposing design solutions and strategies to the existing neighbourhood to improve the sustainability performance of the neighbourhood. In the SLL category, credit 7-site design for habitat/wetland conservation, and credit 8-Restoration of habitat/wetlands are considered. Therefore, existing trees and 20% of undeveloped are conserved and vegetation is restored in the vacant lands to improve the green cover and reduce the urban heat island effect.

The existing neighbourhood is not directly connected with the existing water metro network of Kochi. Thus, proposing a boat jetty at the western portion of the neighbourhood located on the banks of the Perandoor canal enables to connect the neighbourhood with the existing nearest water metro terminal located at Vaduthala, South Chittoor, and Mulavukad north terminals which is 3.5 Km away. By this proposal, SLL credit-3 Locations with reduced auto dependence are improvised and one more point is scored in this credit. A transit stop is also proposed near to the existing school to improve the accessibility to public transportation and thus improve the transit facilities.

And altogether in the SLL category, four more points are scored by implementing design proposals to the existing neighbourhood, and the total points scored in this category becomes 17.

### 5.2.2 Neighborhood Pattern and Design (NPD)

Neighbourhood pattern and design category is assessed. To improve the walkability of the neighbourhood, pedestrian paths are proposed. Lanes and streets are lined with non–invasive trees. This will help to improve the noon-time shading. The low design speed of 20mph for residential areas and 25mph for non-residential areas are proposed as per the LEED-ND guidelines. Which will help to increase the convenience of using bicycles.

Lack of parking space in the neighbourhood is a major issue that is faced by the residents in the neighbourhood. To solve this, a proper parking facility is proposed which reduces the on-street parking and congestion in the lanes and streets. This improves circulation through the streets and lanes. By this, NPD credit-5 is achieved. The transit facility is also improved by providing information displays at existing and new transit stops. This helps to achieve NPD credit-7 transit facilities.

A good neighborhood consists of green open spaces and recreation spaces that can be accessed by all residents in the neighbourhood. In this neighbourhood, outdoor recreational facility (Elamakkara playground) is available. But the neighbourhood lacks open green spaces such as squares or plazas. Thus, an open green recreation space is proposed which can be accessed by all residents within 800 meters by cycling or walking. Thus achieves the NPD credit-9 access to civic/public spaces.

All the proposed open spaces in the neighbourhood are universally accessible. Local food production is improved by providing a dedicated space in the neighbourhood for local food production. This is managed by residential associations in each region. This helps to increase job opportunities and social equity.

Altogether, the NPD credit score increased from 12 to 21 which indicated the improvement in the facilities and sustainability profile of the neighbourhood in the NPD category.

### 5.2.3 Green Infrastructure and buildings (GIB)

Green infrastructure and building credit are assessed after implementing several design proposals and strategies in the existing neighbourhood. Major proposals include the preservation of 10% to 20% of existing undeveloped land and the restoration of vegetation is done in these lands. Onsite energy is produced by means of installing solar panels. Thus, a minimum of 6% of the total energy demand can be produced in the neighbourhood.
The GIB category credit-5 supports the restoration of old buildings in the neighbourhood. One such building is identified which is abandoned and this can be utilized as a public library for the neighbourhood. Apart from this, mitigation of the heat island effect in the neighbourhood is also considered in this category. To mitigate the heat island effect of the neighbourhood, cool roofs/green roofs are proposed for about 60% of the buildings in the neighbourhood. This will help to reduce heat absorption and radiant temperature. Paving in the neighbourhood is also replaced with high albedo permeable pavements that allow infiltration of water and reduce the risk of flooding in the neighbourhood.
Light pollution is reduced by replacing the existing streetlights with motion sensor lights and solar streetlights. All outdoor lights in the neighbourhood are fixed downward which reduces the amount of reflected light to the sky and avoids skyglow. It also reduces energy consumption and improves energy efficiency.

Table 3 Neighbourhood sustainability assessment - Proposed case

| LEED – ND Categories | Points Achieved | Possible Points |
|---|---|---|
| Smart Location and Linkage | 17 | 27 |
| Neighbourhood Pattern and Design | 21 | 44 |
| Green Infrastructure and Buildings | 7 | 29 |
| Innovation and Design Process | 0 | 6 |
| Regional Priority Credits | 0 | 4 |
| **Total points** | **45** | **110** |

### 5.2.4 Analysis

Table 4 Comparison of primary and secondary assessment

| LEED – ND Categories | Primary assessment | Secondary assessment |
|---|---|---|
| Smart Location and Linkage | 13 | 17 |
| Neighbourhood Pattern and Design | 12 | 21 |
| Green Infrastructure and Buildings | 0 | 7 |
| Innovation and Design Process | 0 | 0 |
| Regional Priority Credits | 0 | 0 |
| **Total credit points scored** | **25** | **45** |

The total points scored during the secondary assessment was 45 and the score during the primary assessment was 25. Thus, by implementing the strategies into the existing

neighbourhood, 20 points were achieved. This shows a good improvement in the sustainability profile of the existing neighbourhood. This assessment not only helped to improve the sustainability performance but also helped to improve the basic amenities of the existing neighbourhood.

One of the major proposals includes the replacement of impermeable low albedo paving material with high albedo permeable pavements. To check the compatibility of this proposal, a simulation was performed using ENVI-met lite software to assess the surface temperature difference between the existing case and the proposed case. The surface temperature of the region with asphalt roads is above 42.74 degrees Celsius and concrete pavement with a low albedo value is 35.11 degree Celsius.

After simulating the region by replacing the pavement with permeable pavement having a high albedo value, the surface temperature of the region with reflective pavement decreased from 35.54 degrees Celsius to 27.46 degrees Celsius.

Thus, the result shows a decrease in surface temperature which will help to reduce the heat island effect of neighbourhood if the pavements are replaced with permeable reflective pavements. The permeability of pavements also helps in the draining of water into the soil and reduces the possibility of the formation of floods in the neighbourhood.

## 6 CONCLUSION

Neighbourhoods act as clusters of a city. Thus, achieving sustainability at this clusters helps the city to perform better. Rather than focusing on the new developments, more focus should be given to the existing developments. Improving the sustainability of existing buildings/ neighbourhoods will help to reduce the negative impacts caused due to rapid urbanization. From this study, an assessment of the neighbourhood done using the LEED-ND checklist indicates a low sustainability performance of the existing neighbourhood. The site study and survey indicate the lack of amenities in the neighbourhood such as recreational facilities, green open spaces, cycling paths, shaded pathways, etc. The environmental performance and quality of life were also low. This indicates the weakness in planning and policy making.

Thus, several design proposals and strategies are suggested to improve the neighbourhood quality and thereby in lieu of thus improving sustainability of the neighbourhood. After this, assessment is repeated to analyze the efficiency and sustainability performance of the neighbourhood. Results show an increase in the sustainability performance of the neighbourhood.

The findings from this research show that integrating NSA tools while planning a neighborhood/community will contribute to more sustainable living and will improve the quality of life in the city.

Therefore, this methodology can be adapted to other neighbourhoods in Kochi and other cities to assess the sustainability performance and to analyze the major issues of the neighbourhood. It will help to make good decisions in policy making and tackle unsustainable practices. Thereby leading to sustainable urban development.

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