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Framework for measuring sustainability of neighbourhoods in Nagpur, India

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ABSTRACT

Sustainable development tries to provide suitable physical and economical base to human environment with minimal adverse effect on environment. In an urban context measuring sustainability becomes crucial due to its varying and vast dimensions. This study tries to develop a framework to measure sustainability at the neighbourhood level in an urban context Nagpur, India. The framework is developed based on composite indicators. Twenty sub-indicators are selected under different domains as demography, environmental and transport (accessibility, infrastructure, speed and safety).

The theoretical base is studied and experimented for twelve neighbourhoods with varying commercial and residential land-use mix. The indicators' values are computed. A performance benchmarking is determined through literature study. Weights are assigned through expert opinion survey. Linear aggregation facilitated sustainability performance based index for the neighbourhood. This framework can facilitate the policy maker and stakeholders for effective decision making and raising awareness concerning the need to develop and maintain sustainability of urban area.

1. Introduction

Sustainable urban development mainly deals with the improvement and enhancement of the city's economic, social and environmental conditions. It can be achieved through multidimensional approaches like mixed land-use, compact development, transit oriented development, regenerating brownfields, redeveloping core areas, etc. There is a need to have intelligent and efficient land-use planning for reducing energy consumption [1]. There aren't enough studies that measure sustainability at neighbourhood level in the context of India. Green rating systems like Leadership in Energy and Environmental Design rating system and Green Rating for Integrated Habitat Assessment majorly deals with sustainability at building to cluster level. Though some new housing schemes and townships are planned and designed with sustainable approach but, not much effort has been taken to assess the sustainability of the existing neighbourhoods or large urban areas.

This study attempts to understand the sustainability of the neighbourhoods with mixed land-use. The sustainability of these neighbourhoods are studied with the help of different indicator domains-demography, environmental and transport (accessibility, infrastructure, speed and safety).

Mixed land-use is one of the approach to achieve sustainability [2]. Prior studies mention that areas with mixed land-use are more sustainable than segregated areas [3]; however, the proportion of the mix of compatible land uses for sustainable development need investigation. To investigate the change in the land-use mix, leading to (un)sustainability in a city, the neighbourhood scale is appropriate as it provides both residential and non-residential functions through a built environment and connects communities and dwellings to the wider urban context. This study tries to identify the relationship between sustainability and neighbourhoods with varying mixed land-use. It provides a framework to assess the sustainability at neighbourhood level.

1.1. Sustainable neighbourhood

Sustainable neighbourhood focuses on achieving the wellbeing of the community by improving built and unbuilt environment [4]. Some features of sustainable neighbourhood are: i) Satisfaction (neighbourhood and housing); ii) Safety (traffic or accidents and crime); iii) Aesthetics (acceptable appearance); iv) Walkability and Accessibility to amenities and transit; v) Social Interaction (pleasant, friendly social relations and participation); vi) Economic Aspects (manageable cost of residence and provide opportunities); vii) Mix (activities, tenure and housing choices); viii) Environmental (low noise disturbance, less pollution and conservation); ix) Density (Population and Built). While assessing the sustainability of the neighbourhood, following issues need special attention: i) Congestion; ii) Lack of infrastructure; iii) Social issues (health, poverty, crime, affordability, equity); iv) Environmental

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issues (energy, greenhouse gases, pollution and industrial hazards); and v) Transport facility (mode, transit facility and ownership) [5,6,7,8].

Most of the existing sustainability assessment systems are for buildings. Though the sustainability assessment at the neighbourhood level contributes to the city's sustainability, but only few urban areas have integrated the same in improving the decision-making for sustainable development [9,10]. Neighbourhood assessment tools address many challenges and are successful in raising the sustainability consciousness. The methodology of evaluating or achieving neighbourhood sustainability varies [11]. There is a need to improve and evolve these tools over time. The tool can be customized according to the context as the issues selected for one neighbourhood might not be applicable to all neighbourhoods [10]. A Global Survey of Urban Sustainability Rating Tools mentions, amongst 59 urban sustainability rating tools, 24 are for planned neighbourhoods only 2 are for existing neighbourhoods [12]. Thus, there is a need to develop a sustainability framework for existing neighbourhood in specific context.

Different criteria and indicators are used to develop the sustainability framework [10,11]. Although, achieving sustainability is the aim of these tools, but there are differences in the process to pursue the aim. They have differences in themes and indicators [13,14]. A comparative study of six exiting tools-i) Indian Green Building Council (IGBC) Green Townships; ii) LEED for Neighbourhood Development (ND); iii) Building Research Establishment Environmental Assessment Methodology (BREEAM) Communities; iv) Comprehensive Assessment System for Built Environment Efficiency for Urban Development (CASBEE-UD); v) Haute Qualité Environnementale et Economique Réhabilitation (HQE2R); and vi) Neighbourhood Sustainability Framework (NSF) expressed different approaches. Amongst different thrust areas, ‘resources and environment’ gets maximum emphasis followed by ‘physical infrastructure’ and ‘transport’ theme. Neighbourhood form (density) shows significant influence on travel behaviour. Other influencing features such as orientation of buildings, mixed use, availability of green spaces also reduce environmental impacts. Except CASBEE-UD mixed land-use as an indicator is included in other five tools. The sustainability issues are inter-related [15] and mixed use development affects other issues such as energy and transportation [10]. Mixed use and density (high, medium and low) is the neighbourhood selection criteria in NSF [4].

2. Study area

Nagpur, with a history of three hundred years, acts as the key administrative, business and institutional center for central India. The city has seen enormous development activities in the last two decades [16]. There are different typologies of neighbourhoods within the Nagpur Municipal Corporation's administrative limit with different land-use mix as high-mix in core, moderate-mix in the intermediate areas and low-mix in the fringe. Mix of commercial and residential land-use was most perceptible here. Twelve neighbourhoods (NH1 to NH12) with varying residential and commercial mix were selected. They were divided under four categories as i) L1- High Commercial; ii) L2- Moderate-High Commercial; iii) L3- Moderate-Low Commercial; and iv) L4-Low Commercial. The study areas, their mix and other characteristics are represented in Table 1 and Fig. 1. Within a category, land-use mix, age and socio-economic characteristics of the neighbourhoods are similar. Household survey is conducted in each neighbourhood to know the residents' socio economic condition, travel behaviour and perception.

3. Indexing base of the model

Indexing method is based on composite indicators which involve following steps - i) indicator selection; ii) data collection; iii) normalization of the indicator score (benchmarking); iv) assigning weights to the indicators using experts' opinion survey; and v) aggregation (linear).

3.1. Indicators-data collection and normalization of the indicator score (benchmarking)

Density, environmental, transport and social aspects influence sustainability and land-use [17]. Thus, selected indicators revolve around these domains. Expert consultation and literature review guided the indicator selection. Indicators' data was extracted either from the monitoring stations (primary data) by the researcher or from the resource agencies or reports (secondary data). The indicator domains are categorized in three distinct groups as - i) demography; ii) environmental; and iii) transport (accessibility, road infrastructure, traffic speed and safety) further, detailed in twenty indicators (Table 2). Each indicator is studied for its contribution to sustainability.

Each indicator has different units. So, the indicators' scores are normalized by representing them in five-point scale (low to high sustainability level). The benchmarking is decided with the help of literature study and expert opinion. The selected indicators are assigned values based on their performance (Table 3). The indicator scores are computed and the results and observations are reported for the neighbourhood.

3.2. Demography indicators

Demography provides an overview of the population size, density and pattern. Humans' population size, distribution, and characteristics are central to sustainability [18]. There are two indicators under demography domain as population density, i.e. number of persons per unit area (including floating population) and percentage of working population.

3.2.1. Population density

To prevent sprawl and promote sustainability, higher urban density is perceived as an effective land-use strategy [8,19]. It tries to concentrate people and their activities. Thus, lower energy is used in travel and reduce resource use [20]. There are multiple opinions about an optimum range of density. A worldwide variation exists in defining the range of density, the high density perceived by developed nations is equivalent to the low density of developing nations [21]. Since the study revolves around commercial and residential mix, floating population contributes to load on infrastructure and congestion. Therefore, while calculating the population density floating population has been added to the residents' population.

3.2.2. Working population

Workforce or working population is a measure of a number of persons working per total population. The working population comprises of working adults in the age ranges from 15 to 64 and non-working population consist of children, elderly, retired persons and non-working adult females [22]. In a neighbourhood, there should be a balance of working and non-working population. An optimum number of working population contributes to an active portion of an area's economy. UDPFI guidelines suggest workforce participation as thirty-three percent [23]. This decides the benchmarking for working population. The study uses population data of 2011 census to compute a population density and working population [24].

3.3. Environmental indicators

Environmental issues play a vital role to understand land-use mix. Six indicators are selected to study environmental aspects as noise pollution, tree density and open land availability.

3.3.1. Road noise

The traffic noise is studied for major and residential roads. Noise is

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