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Reimagining Pune with urban greenways integration

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Abstract

India's unique geographical, economic, and cultural landscapes present distinct challenges and opportunities for developing greenways. Unlike their counterparts in the United States and Europe, Indian greenways must navigate fragmented and varied green spaces across different regions. This paper delves into the ecological, environmental, and planning advantages of greenways, proposing a methodology tailored for the Indian context. It outlines a comprehensive template for greenway design, drawing upon academic literature, satisfaction surveys, and insights from local ecological experts. The methodology is applied to a case study in Pune, Maharashtra, resulting in a template design for greenways network that seamlessly integrates the existing fragmented network of green paths. This paper further explores the integration of urban infrastructure by defining a non-motorized traffic network that connects metropolitan centers to the region's rich cultural heritage resources. Embark on a journey to discover how greenways can revolutionize sustainable non-motorized transportation in India, transforming urban landscapes and fostering a healthier environment for all.

Highlights for public administration, management and planning:

- The impacts of Urban Greenways in a city are nodal for non-motorized transportation with conservation of ecology.
- Spatial assessment of Greenways is one of the important tasks for preparation of Development plan in Urban and Peri urban region.
- An integrated Greenway design template has been prepared by taking into consideration various factors for the integration of greenway within the development plan with assessment of greenways as future scope

Keywords

Greenways, Sustainable infrastructure, Urban infrastructure integration, Non-motorized transport, Greenway Network

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1 Introduction

The creation of greenways and other Open Spaces is something that local government representatives and residents consistently push for to enhance the community's non-motorized transit options and environmental quality. Many residents, urban planners, environmentalists and ecologists want to learn more about the various ideas behind sustainable greenway development. The suitability of greenways as a non-motorized entry point within the urban precinct has also been extensively researched. Creating a social and cultural environment that encourages the greatest number of people to use greenways while preventing future environmental and social problems is always a challenging design task. Multi-objective greenway planning techniques must be used to address these needs. A precise and targeted study technique is necessary to analyze the prospects and challenges for environmentally sound and day-to-day greenways in metropolitan areas. It is necessary to compile a database on social economics, ecology, urban development and planning, and the environment, and to carefully compare these data bases in a way that makes sense. This data base has a great deal of promise for multi-objective greenway planning, social and ecological interest, and urban planning. This paper will address three objectives:

1. The primary objective of this paper is the establishment of contextual framework in providing a template to create greenways in an identified study area, Charholi, Pune.

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2. The development of a methodology for creating a template to serve as an effective tool for greenway planning that blends socio economic, environmental and urban non-motorized pedestrian movement in the development plan through identification of functions, factors and capabilities of factors.

3. Development of parameters through the above methodology for establishing a participatory approach in Greenway planning

1.1 The Indian greenways perception

The Indian connection of greenways is mostly observed through the pilgrimage routes and trade routes that occurred in ancient India (Mathur et al. 2013). This movement pattern is generally observed along the edge of forest, the mountain ranges and the rivers. Over the ages these routes have stayed in place and still find importance in terms of religion and trade. The Indian greenways have always been multi-functional in nature. Natural trails, hiking trails and Riverside circumambulation (Parikrama) path are some of the typologies that are observed as the Indian perspective of greenways. Using the urban greenway planning theory for the Indian contextual conditions, a template can be formulated which adopts to natural processes and individual community needs of each individual city. The master planning of cities needs to address an inclusive process of inter disciplinary function to involve architects, urban designers, ecological planners, landscape planners, urban planners, biodiversity experts and environmental experts. The current scenario of preparing a development plan is largely engaged in formulating a land use plan with the green reservations as a mandatory obligation. These green reservations are not necessarily the eco sensitive and environmentally suitable area of the city. In the fast-developing Indian cities, the inclusion of urban greenways as an augmented tool for moving within the city will greatly benefit the city dwellers in terms of pleasant walkways and enhancement of ecological and environmental perspective.

2 Literature review on urban greenways

2.1 Definitions and importance

Greenways has been defined as: "network of land containing linear elements that are planned, designed, and managed for multi purposes including ecological, recreational, cultural, aesthetic or other purposes compatible with the concept of sustainable land use" (Ahern 1995). Greenways have long been an integral element of the urban landscape. Even in the twenty-first century, they address the challenges and opportunities inherent in urban agglomerations. The 6th Fabos conference of Landscape and Greenway Planning addressed the topic that Urban Greenways in landscape design may solve issues of both expanding and contracting cities (Fábos et al. 2019). Urban Greenways are frequently viewed as undeveloped passageways in the development of cities. As a result, these corridors provide critical linkages for biotic and abiotic ecological processes (Benedict & McMahon 2002). Thus, Greenways are essential elements of nature's pre-existent super infrastructure (Fabos 1995). The definition for Greenway provided by Oxford English Dictionary is: *"a grassy path or way; a piece of undeveloped land near an urban area, set aside for recreational use or environmental conservation"* (Oxford EnglishDictionary 2019). Greenways are also termed as living network that link rural and urban spaces with access for people (President's Commission of American Outdoors 1987).

2.2 Ecological, environmental and planning benefits

Many scientific studies highlight the notion that incorporating Greenways into urban settings improves social and ecological outcomes. People and the environment stand to benefit from greenway inclusion in planning. Urban greenways enhance both people's mental health and biodiversity for the environment (Cackowski-Campbell & Augustin 2006). Greenways are also used as tool for urban sustainability. Larson et al. (2016) discovered that individuals find urban greenways more beneficial in terms of social interactions than environmental advantages (Larson et al. 2016). Studies have also been conducted to establish links between users' perceptions of urban greenways and the aesthetic value of the area (Kang & Cervero 2009). One study reveals encouraging information about enhanced physical activity levels in the home near Greenways (Wolff & Fitzhugh 2011). Harris

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et al. (2018) discovered that 'The 606' Chicago's Bloomingdale Greenaway had a favorable influence on crime reduction (Harris et al. 2018). Another study examined the phenomenon of rising property values near Greenways (Kang & Cervero 2009). The job density analysis was conducted, and the results demonstrated a positive association with urban Greenway (Jang & Kang 2016). The social benefits of creating Greenways in conjunction with the urban neighborhood's stormwater management system have received widespread recognition (McGuckin & Brown 1995). A constant planting of native plants along a Greenway corridor contributes to the establishment of a healthy ecology in urban settings (Hipparkar & Tholia 2019). Urban greenways give chances for social engagement. Evaluation of health promotion capabilities of Qingshan Lake Greenway Trail in Hangzhou, China was found to have positive impacts of the greenway (Bin et al. 2022). The city's economic growth is also boosted by higher real estate values and job prospects. The Urban Greenways' ecological and sustainability benefits give the city a long-term environmental advantage.

2.3 Notable case examples in developing countries

Urban greenways in developing nations are critical for long-term development, delivering benefits such as improved air quality, increased biodiversity, expanded recreational spaces, and increased overall urban resilience. Significant urban greenways from various regions in developing countries are discussed below to develop a comparative understanding.

(a) (a) Latin America: Medellín Green Corridors (Colombia): A project to transform roadways and urban spaces into green corridors. These corridors improve air quality, reduce urban heat, and also serve as environmentally sensitive ecological paths for animals. The greenway contains 30 green corridors with bicycle lanes, pedestrian walkways, and green areas.

(b) Paseo La Reforma (Mexico City, Mexico): A major avenue turned into a greenway, connecting urban parks with green pathways and cycling lanes. It extends across many parts of the city, integrating gardens, sculptures, and green spaces along the route.

(c) Costanera Sur Ecological Reserve (Buenos Aires, Argentina): A restored natural space that serves as a green corridor and reserve along the Rio de la Plata, just outside the city centre. The Greenway contains hiking trails, native flora and fauna, and educational spaces.

(d) Cheonggyecheon Stream Restoration (Seoul, South Korea): A modern greenway project that restored a historic stream into a pedestrian-friendly ecological space in the middle of Seoul. It is an 11 km of restored stream, walking paths, and greenery in a previously concrete-covered urban zone

(e) Dhaka Hatirjheel Lake Greenway (Bangladesh): A multi-use green space in Dhaka, built around the Hatirjheel Lake. The area serves both recreational and transport purposes. It comprises of pedestrian bridges, cycling paths, gardens, and waterside walkways.

(f) Nairobi Arboretum Greenway (Kenya): A large public green space that serves as a vital green corridor for the city's biodiversity. The greenway has tree-lined walking paths, picnic spots, and educational spaces.

(g) Addis Ababa River Greenways Project (Ethiopia): This project is aimed at transforming the rivers and canals of Addis Ababa into green corridors that incorporate walking paths, parks, and water management systems.

(h) Amman Green Network (Jordan): It is network of green spaces and corridors aimed at connecting parks and open spaces across the city. The projects focus is on enhancing air quality, providing recreational spaces, and promoting biodiversity.

(i) Bangkok Green Bridge (Thailand): It is a green pedestrian bridge connecting two parks in the city, emphasizing the need for walkable and green-friendly infrastructure.

3 Methodology

Intent of this paper is to provide insights in the Urban Greenways through drawing upon academic literature for formulating a Greenway design template in the Indian context and further to develop parameters for establishing a participatory approach. The methodology involves multiple stages of systematic approach as represented in Fig. 1.

The methodology initiates through interviews with experts across various domains in the field of Urban greenways. The interviews provided insights on arriving at the basic Function identification of the greenway template. The functions further

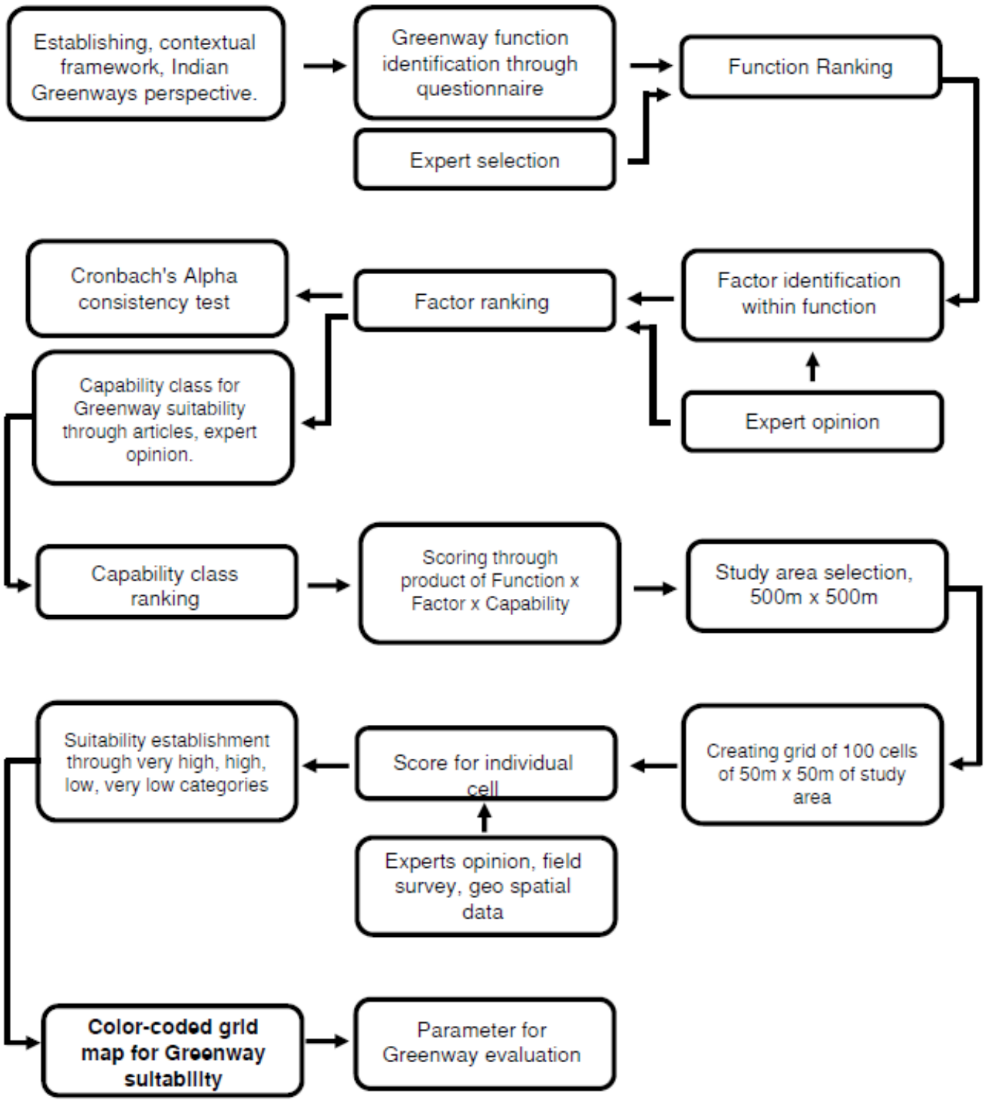

Fig. 1 Flow chart of Research Methodology.

were prioritized through ranking process. Each function was then further interpreted into various factors and priority was established through ranking the factors. The ranking was statistically tested through Chronbach's Alpha test. Further the capability class was established through interviews, articles and case examples. Ranking was established for the capability class. Thus, a template was established where score is generated for a typical cell size of a given area through product of function to factor to capability class. Using this template, a comparative score now can be generated over a selected study area, for deriving a suitable parcel of land for conversion to greenway. Further, the template was tested on a selected study area to generate a suitability map for insertion of the Greenway. Experts provided their opinion on selecting a study area with reference to walkability. Further, an optimized number of 100 cells were indicated by experts for study of individual unit parcel of land to generate score. Therefore, study area of 500m x 500m was selected and it was further divided in 100 cells of 50m x 50m each. A physical inspection was conducted for each cell and scoring was allocated to each cell based on factor and capability class.

Finally, we establish the suitability diagram through empirical results generated out of the theoretical framework. The empirical results accord with theoretical framework for the greenway suitability map, mitigating the basic functions, factors and capability class of the greenway.

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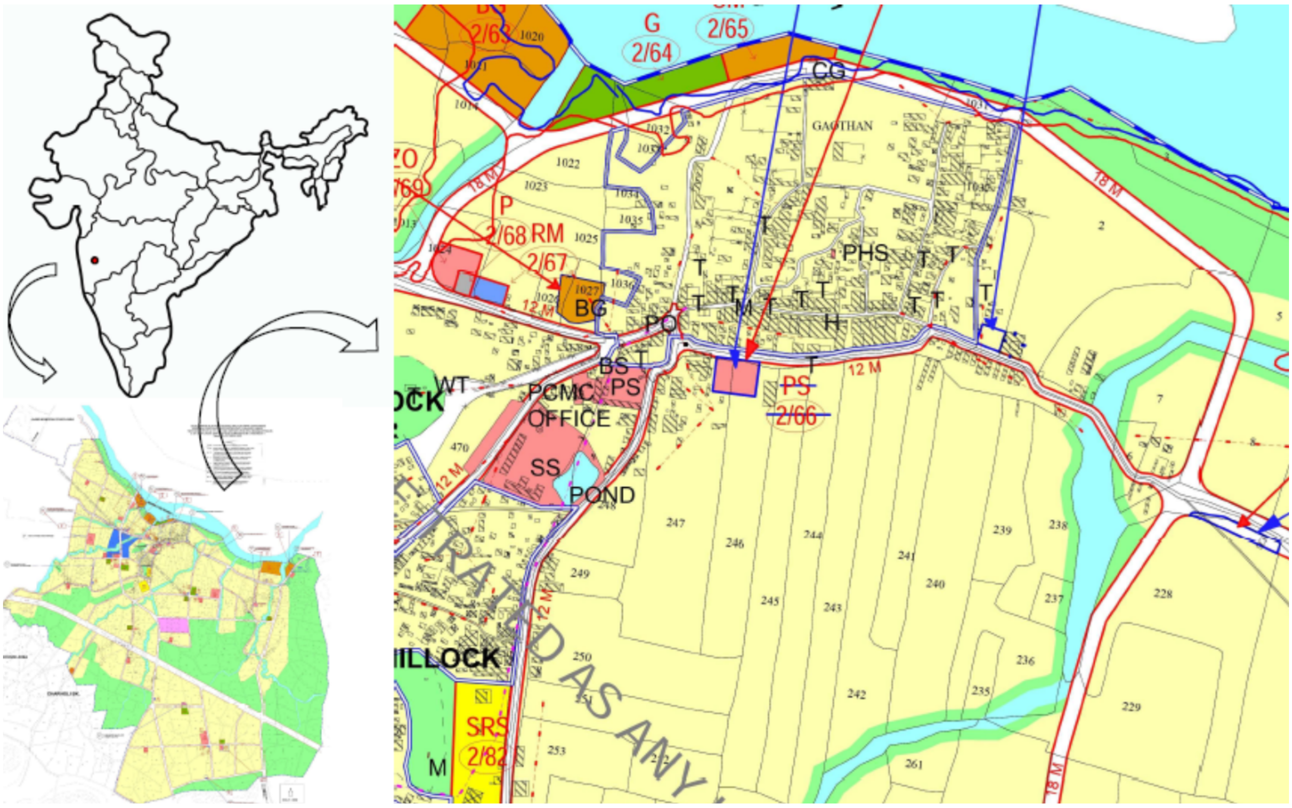

Fig. 2 Location Plan of Charholi, Pune, Maharashtra, India.

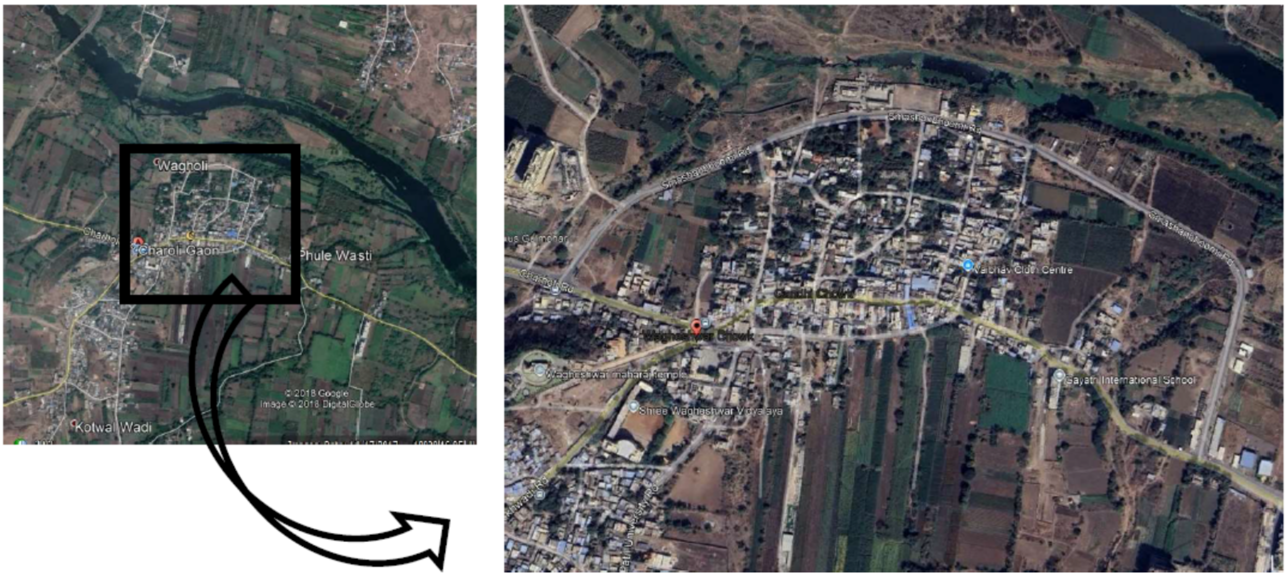

Fig. 3 Google earth Satellite Image of Charholi, Pune. Source: https://earth.google.com

3.1 Structure and layout. The Study area.

The study area selected for the present research is Charholi, Pune (India). It is located approximately 20 km Northwest to Pune urban area (refer Fig. 2). It incorporates approximately 20 square kilometers of land. It is naturally beautiful, semi urban area which is adjacent to a popular religious town Alandi. The town is set along the banks of Indrayani River, thus enjoying the religious stature due to its land water interface (Hipparkar & Varma 2021). Within the last 5 years the area has experienced rapid growth and significant land use pattern. The study area has seen the urban hybridization process in terms of land use dynamics and spatial organization (Keskar & Patkar 2007). Fig. 3 shows the real time setting of the study area through Google earth imagery.

3.2 Biophysical characteristics

The study area has a mean elevation of 560 m. It enjoys a tri seasonal climatic region of summer winter, precipitation. The annual rainfall is about 760 mm. The average minimum and maximum temperature ranges from 12 degree Celsius to 38 degrees Celsius respectively. Geologically the area is a part of Deccan Plateau. The Terrain is characterized by small streams, hillocks and adjoining river. The slope is less than 5% throughout the study area with more than 15% near the hillock's and adjoining hilly area. The soil is characterized by Black cotton agriculture soil while having certain areas of laterite soil and Sandy soils. The drainage pattern is dominated by the adjoining Indrayani River and smaller streams flowing into the river from the South side to the North side. The water of the Indrayani River, located on the Northern side of the study area, flows from the Western side to the Eastern side (Mundhe & Jaybhaye 2017).

The study area is predominantly characterized by native tree pockets and farmlands. The native trees include Umbar (*Ficus racemosa*); Amaba (*Magniferraa Indica*); Kadunimba (*Azadirachta Indica*); Chinch (*Tamrindus Indica*); Erand (*Ricnus communis*); Shevaga (*Molinga olefera*); Subhabhul (*Leucaena leucocephala*); Wad (*Ficus fenghalensis*); Pimpal (*Ficus religiosa*); Jambhul (*Syzygium cumuni*); Sitaphal (*Annona squamosa*); Ashok (*Polyalthia Longifolia*); Naral (*Cocos nucifera*); Awala (*Emblica Oficinalis*) (Hipparkar & Tholia 2019). The study area has a lack of wildlife due to heavy development growth. The study area has an abundant number of birds, insects, and microorganisms which are determinants of a sensitive ecology due to the presence of the adjoining Indrayani River. The study area is bound on the Northern side by the river, and it experiences an increasing development pressure from the southern side of the metropolitan Pune urban area.

3.3 Demographic characteristic

In the study area, agriculture was and is still the primary land use. Subdivision of specific lots have initiated development in the study area. As of the 2011 census, the population was 15,600 and is expected to reach 500,000 by 2030 (Census India 2009). Single-family homes are the primary zones for the study area. Year 2010 saw the adoption of a vigorous annexation program of specific land appropriate for commercial and industrial uses, which led to a significant increase in development in the surrounding areas. The interior streets of the research area cover approximately 50 km in length, and are bounded, respectively, to the north and south by urban highways and the river. Within the study area, the majority of the narrower streets form a network and offer direct access to properties. The study area has grown quickly, in terms of Urban Housing, which has led to a lot of traffic in both the interior and the surrounding areas (Keskar et al. 2018). The planned growth calls for greater infrastructure expansion for transportation and some degree of traffic volume management.

3.4 Interviews with experts

This stage of study included conducting interviews with experts in ecology, planning and environment, with special focus on various aspects of Urban Greenways in the Indian context. A careful understanding was developed into the selection of experts for conducting the interviews. Through study of scholarly articles important features of the greenways were listed. These features mainly included non-motorized corridors and paths, environmental implications and ecological characteristics.

Non structured pilot interviews were conducted with some experts. The pilot interviews provided perceptions to conduct structured interviews with all the experts. The structured interviews were conducted to highlight the various aspects of urban Greenways in the Indian context, with respect to the importance of each specific aspect. During the process of interviews, each expert contributed to aspects related to their expertise and thus its overall setting in the Urban greenways. With contributions from all experts, a list of 20 factors were generated that represent the key factors in any given Urban Greenway. Each expert then provided a score varying from "Most Important" to "Least Important" in the five-point Likert Scale for the 20 key factors of Urban Greenways. This stage provided insights to generate a weighted overlay for creation of template design towards greenway planning in the Indian context.

3.5 Greenway function identification

It is vital to identify the many biophysical urban and human community elements present in the research region in order to comprehend the purpose and context of the greenway. The essential and land-

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Fig. 4 Study area photographs of Charholi, Pune.

use-related processes are the functions of the suitability approach. A set of attributes, including topology and so forth, are referred to as factors. Suitability analysis is a well-established practice in landscape planning (Banai-Kashani 1989).

It takes a wide variety of data sets to determine whether greenways are appropriate for insertion. Except for experts in the specified locality, this study incorporates data from the study area and the local population (Miller et al. 1998). The experts' opinions become the cornerstone of the greenway project's planning. A vast amount of data about biological, urban, physical, and socioeconomic aspects was gathered.

Based on the input data and expert interviews, three main Greenway functions were identified:

1. Provision of non-motorized pedestrian corridor within the development plan
2. Protection of natural riparian corridor and their associated function
3. Placement of Greenway such that it provides easy access to roads and important urban centers.

Several information sources were used to define the variable functional factors and capability levels for the study area in order to execute the greenway analysis. The identification of greenway function in relation to the goal established for the insertion of a corridor for non-motorized pedestrian mobility served as the main source. Additional supporting materials for this goal came from local authorities, experts, and members of the public. Scholarly literature and professional judgment were used to identify factors within each function. Expert opinion, field surveys, and academic literature were used to determine the characteristics linked to each element and its data.

3.6 Spatial data collection

This paper addresses the suitability for greenways in the context of a developing town. The components nature determined the data that had to be col-

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lected to reflect function, factor, and capability (Miller et al. 1998). Data of the biophysical nature was derived largely from various sources including the topography data from Survey of India, the development plan prepared by Pimpri Chinchwad Municipal Corporation, Google Earth data, Expert Opinion and extensive field survey.

3.7 Weightage values

Weighting values were divided into three levels; (1) weighting value between functions; (2) weighting value between factors within functions, and (3) capability values between traits within factors. Weighting in suitability analysis refers to assigning weight to each factor in order to recognize its relative importance. Two tiers were created from the values. Values between factors within the functions made up the first level, and capability values between characteristics within the factors made up the second level. In a suitability study, weighting is the process of giving each element a numerical value to indicate its relative importance (Baris et al. 2010). A total of twenty-five experts were interviewed for each greenway function in order to rate each of the criteria that were found. These experts were selected for a multi-objective greenway function based on their experience in their field and their affiliation with the local precinct. Their capacity to supply precise information concerning their area of expertise was determined. Each expert was asked to rank the relevance of the greenway functions. The multipurpose feature of the greenway makes community involvement an effective component of the development process. Initially, a group of experts participated in non-structured interviews to determine and validate the overall parameters and their ranking methodology. After conducting unstructured interviews, a shortlist of twenty factors was created for greenway planning. Twenty-five experts from a variety of sectors, including urban planning, ecology, biodiversity, botany, transportation, architecture, landscape design, and administration, were interviewed in a structured manner. The final results of factor questions were then totaled and the average for each particular factor was derived. The weighted values for each of the factors were converted to a percentage and the procedure was designed such that the sum of the percentage of all factors equals 100. Multiple models were applied to assess the relative weights (Rahmat & Sen 2021). After presenting all of the calculations to experts, the criterions were further refined in order to identify the truly significant greenway factors that contribute to an effective greenway strategy. The initial set of 20 factors for greenway planning was shortlisted to the top 10 factors that would be most helpful in creating an effective greenway design.

The analysis of numerous academic articles and multiple conversations with regional experts in a variety of sectors served as the foundation for the values assigned to the capabilities inside the factor attributes (Miller et al. 1998). The elements of a successful greenway were discussed in terms of their individual variable capacities. Based on each factor's appropriateness support for that particular factor, the appropriate criteria for interpreting its value were generated. Based on very high, high, low, and very low assessments for comparable evaluations across all capability representations across each of the factors, standard categories of suitability were developed. The factor characteristics of very high, was given a capacity value of 4 for high it was 3, for low it was 2, and for very low it was 1. These values were normalized to 0.9, 0.8, 0.6 and 0.1 respectively based on their suitability class for greenway plan (Banai-Kashani 1989). In terms of their own varying capabilities, the components of an effective greenway were discussed. Based on how well each component supported the provided factor, the appropriate criteria for understanding each element's capability value were developed. Standard categories of suitability were developed based on very high, high, low, and very low ratings for comparable evaluations across all capability representations through each of the elements.

3.8 Statistical analysis

Chronbach's Alpha (α) Internal Consistency Test was used to analyze the internal consistency and reliability of the factors (Tavakol & Dennick 2011). The underline construct was to check whether the closeness of factors as a group was same or not. Intent and purpose of the reliability measures for the selected criteria of the factors were checked for this research. The Alpha score ranges between 0 to 1 and the higher Alpha value indicates higher reliability as interpreted. Alpha value of more than 0.90 indicates excellent internal consistency, more than 0.80 indicates good internal consistency, between 0.60 to 0.80 indicates acceptable internal consistency, less than 0.60 indicates poor consistency and less than 0.5 indicates not acceptable consistency. The Chronbach's Alpha was calculated as indicated by the Experts opinion for factor ranking. The following equation was used

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for calculation.

$$\alpha = (\frac{k}{k-1})(1 - \frac{\sum V_c}{V_t}) \quad (1)$$

Where $\alpha$is the coefficient Alpha, k is the total number of criteria, V_c Vc is the variance of individual criteria, V_t is the variance of total of all criteria.
As per Chronbach's Alpha formula given, the final evaluated value Alpha was found to be 0.899. This value ranges between 0.8 to 0.9, which indicates a good range of internal consistency among the opinions given by the experts making the reliability.

3.9 Evaluation

The completion of the final suitability greenway plan was submitted for review and feedback to the original experts. The experts looked for adjacency conflicts and other inconsistencies. Validation was provided by the experts for individual cells with respect to their class capacity for the respective factors which eventually had generated the suitable greenway plan in the selected study area.

4 Results

4.1 Weighting across function factors and capabilities

Following are the weighting results which are normalized from the evaluation of expert opinion for the greenway functions:

Non-motorized corridor:	0.63
Access and Integration:	0.52
Riparian Corridor Protection:	0.18

The results of the first function, which concerned the provision of non-motorized corridors, revealed that the most important appropriateness factor was linkage to important destinations. It was followed by the access point factor. For the second function, Access and Integration, the Network Integration factor received the highest score, followed by the Topography factor. The third function is riparian corridor protection, and the results highlight the relevance of appropriateness through elements such as vegetation, native planting, hydrology, soil conditions, ecological restoration, and water management.
Following are the findings of between-factor evaluations using public data, expert opinion, and broader expert questions. These findings showed that Topography and Connect to Destinations was the most critical aspect connected with Greenway Planning, followed by Hydrology and Network connections. These same findings indicate that water management and ecological restoration activities were less relevant factors.

Topography:	10.57
Connect to Destinations:	10.48
Hydrology:	10.39
Network Integration:	10.29
Native Planting:	10.29
Vegetation:	10.20
Access Points:	10.02
Soil Conditions:	9.74
Ecological Restoration:	9.19
Water Management:	8.82

Table 1 shows the capability class evaluation and class description for the features included in each non-motorized function factor. According to these data, public transportation and important public spaces within 25m receive the highest capability ranking, while those with public transportation and important public spaces beyond 100m receive the lowest capability ranking.
Table 2 shows the capability evaluation with class description and description of the attributes present in each Access and Integration function factor. The areas with the greatest capacity score have a water stream within 10 meters, a slope of less than 5%, and a road network within 25 meters. While the lowest capability rating places included streams beyond 50m, slopes greater than 15%, and road networks beyond 100m.
Riparian corridor preservation received the lowest greenway function value at 0.18 (Table 1). The expert opinion indicate that six factors influence riparian corridor characteristics: Vegetation, native planting, hydrology, soil conditions, ecological restoration and water management. The between factor evaluation of these characteristics is reported in Table 2. Hydrology, Native planting and vegetation characteristics received the highest weighting values at 10.39, 10.29 and 10.20, respectively. The general consensus of the survey data was that soil conditions, ecological restoration and water management had the least impact on greenway suitability, with weighting values of 9.74, 9.19 and 8.82 respectively.
Table 3 shows the capability values and class description for riparian corridor preservation. Areas with the best capabilities in this function were identified by increased vegetation density, a high concentration of native plants, closeness to a water stream, the presence of black cotton soil, and proximity to vegetation and storm water drain.

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Table 1 Description of within factor capability classes, of the non-motorized corridor function, used in a greenway suitability analysis for Charholi, Punes

Function	Function Score	Factor	Relative Percent	Class Description	Capability Score
Non-motorized corridor	0.63	Connect to Destinations	10.48		
		CD1		Public transport: 100m	0.10
		CD2		Public transport: 50 to 100	0.60
		CD3		Public transport: 25 to 50	0.80
		CD4		Public transport: 25m	0.90
Non-motorized corridor	0.63	Access Points	10.02		
		AP1		Public spaces of Importance: 100m	0.10
		AP2		Public spaces of Importance: 50 to 100	0.60
		AP3		Public spaces of Importance: 25 to 50m	0.80
		AP4		Public spaces of Importance: 25m	0.90

Table 2 Description of within factor capability classes, of the Access and Integration function, used in a greenway suitability analysis for Charholi, Pune

Function	Function Score	Factor	Relative Percent	Class Description	Capability Score
Access and Integration	0.52	Topography	10.57		
		TP1		Water stream >50m Slope >15%	0.10
		TP2		Water stream 20- 50m Slope 10 to 15%	0.60
		TP3		Water stream 0 - 20m Slope 5 to 10%	0.80
		TP4		Water stream 0 - 10m Slope <5%	0.90
Access and Integration	0.52	Network Integration	10.29		
		NI1		State/ city/ town Roads: >100m	0.10
		NI2		State/ city/ town Roads: 50 to 100	0.60
		NI3		State/ city/ town Roads: 25 to 50m	0.80
		NI4		State/ city/ town Roads: <25m	0.90

4.2 Integration of Data and Analysis

A smaller area within the study area was selected to perform the testing of the above factors and their class capability. The selected area was carefully chosen through a diverse group of experts such that it represents most of the physical features considered for greenway planning. The area taken up was 500 m by 500 m having an area of 0.25 square kilometers. The area was further divided into smaller cells of 50 m by 50 m each. Thus, the pilot area now consisted of 100 equal cells for checking the values of factors and class capability. The study was then carried out to associate a value for each of the cells in the pilot area for the shortlisted factors. Each cell was subjected to an understanding of its own class capability associated with its factor for providing the ranking from very high suitability to very low suitability with scores of 4 to 1 respectively. The score was generated as a product of: the normalized function value x factor relative important percentage x its capability ranking for each of the cells. The final score of the cell was the sum of all the 10 factors with its associated factor ranking based on the suitability of that respective factor. Thus, the score was generated for all the 100 cells within the selected study area. This final score led to a suitability map for the identified area representing the final greenway. Color coding was designated for the scores as green for very high suitability, yellow for high suitability, orange for low suitability and red for very low suitability (Fig. 5). The elements within functions were integrated using an overlay approach. This process resulted in an appropriateness evaluation for each function (see Table 1-2-3).

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Table 3 Description of within factor capability classes, of the Riparian Corridor Protection function, used in a greenway suitability analysis for Charholi, Pune.

Function	Function Score	Factor	Relative Percent	Class Description	Capability Score
Riparian corridor protection	0.18	Vegetation	10.20		
		VG2		Vegetation density of trees foliage 1 to 5	0.60
		VG3		Vegetation density of trees foliage 5 to 10	0.80
		VG4		Vegetation density of trees foliage >10	0.90
Riparian corridor protection	0.18	Native Planting	10.29		
		NP1		Native Plants <1	0.10
		NP2		Native Plants 1 to 5	0.60
		NP3		Native Plants 5 to 10	0.80
		NP4		Native Plants >10	0.90
Riparian corridor protection	0.18	Hydrology	10.39		
		HD1		Surface or Underground Water stream >50m.	0.10
		HD2		Surface or Underground Water stream 20- 50m.	0.60
		HD3		Surface or Underground Water stream 0 - 20m.	0.80
		HD4		Surface or Underground Water stream 0 - 10m.	0.90
Riparian corridor protection	0.18	Soil Conditions	9.74		
		SC1		Sandy soil	0.10
		SC2		Laterite Soil	0.60
		SC3		Loamy Soil	0.80
		SC4		Black Cotton soil	0.90
Riparian corridor protection	0.18	Ecological Restoration	9.19		
		ER1		Nearness to vegetation >50m.	0.10
		ER2		Nearness to vegetation 20- 50m.	0.60
		ER3		Nearness to vegetation 10 - 20m.	0.80
		ER4		Nearness to vegetation 0 - 10m.	0.90
Riparian corridor protection	0.18	Water Management	8.82		
		WM1		Distance from Storm drain >50m.	0.10
		WM2		Distance from Storm drain 20- 50m.	0.60
		WM3		Distance from Storm drain 0 - 20m.	0.80
		WM4		Distance from Storm drain 0 - 10m.	0.90

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A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
22.28	29.97	21.64	21.43	16.35	15.03	12.28	13.1	12.55	12.55
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
23.76	29.91	29.99	28.92	28.92	21.31	15.25	15.85	14.98	14.75
C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
23.33	27.88	22.02	16.42	17.74	28.1	28.27	19.79	18.97	14.71
D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
29.23	24.37	18.38	18.38	17.28	17.53	15.53	27.79	28.76	22.13
E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
21.71	19.92	9.22	8.4	8.4	8.35	9.66	20.8	29.02	29.17
F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
21.71	14.5	8.3	7.48	7.48	7.43	8.22	20.1	29.21	22.66
G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
18.68	5.19	5.19	4.37	5.24	5.98	16.02	29.37	29.36	12.05
H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
17.15	6.06	5.19	4.37	4.37	6.06	14.84	29.69	27.83	15.37
I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
17.47	10.73	6.11	6.11	6.98	6.16	13.98	29.36	20.86	9.86
J1	J2	J3	J4	J5	J6	J7	J8	J9	J10
18.6	12.94	8.32	8.32	8.32	7.77	21.68	29.36	13.56	8.14

LEGEND FOR SUITABILITY

- Very High
- High
- Low
- Very Low

Fig. 5 Cell wise suitability data score for suitability.

Fig. 6 Study area overlaid on Topographic sheet, Google earth Image and Development plan respectively.

These three function coverages were then merged to create an overall greenway suitability study (Fig. 6). The evaluation of this output revealed that 20% of the area had very high capability, 13% had high capability, 36% had low capability, and 31% had very low capability. This final coverage was then applied during the output evaluation phase of the procedure. It is observed that the high suitability areas follow the nearness to road network and access points located along with the water stream pattern in the study area.

4.3 Assessment of the output

After creating the final suitability map, experts were asked to examine the results and provide input. Development of a suitability evaluation system for urban greenway alignment selection creates a workable solution (Xiaohuai 2022). The experts looked for adjacency conflicts and other inconsistencies that would not have been seen until the final composite site map was created. Individual function coverages were also made available to these professionals to validate earlier capacity categories. The experts agreed that the approach appeared to produce a valid and trustworthy greenway suitability result.

5 Discussion

5.1 Contribution of research

We have tried to accomplish the set objectives for this research. A contextual framework establishment mostly recognizes the local characteristics. We understand the challenges in framing the aspects concerning the context in which the greenways are to be planned. We diagnose that the factors formulated are interrelated with each other and do not act as self-regulating entities. Preferably each component would be associated with a specific

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concept or element while remaining completely independent of the others. However, the interaction of factors and functions offers a significant opportunity to design and analyses new factor ranking algorithms, such as the one utilized in this study. We recognize difficulties of allocating the capability class values based on the judgement of the expert's opinion (Hopkins 1977). The capability class for ranking the suitability value from very high suitability to very low suitability creates challenges in specific factors such as topography, ecological restoration and vegetation, for a selected study area of 500m x 500m. This is further challenged for ranking in a smaller grid of 50m x 50m of grid cell to allocate specific attribute through experts and on field survey. The draft greenway suitability map was post-processed to remove ambiguity in giving capability scores for each 50m x 50m grid. This post processing helped to significantly reduce the generalization for a particular factor and its capability class related to its grid. This post-processing is always recommended due to its unique ability to help clarify data and make final maps clearer and easier to read.

5.2 Comparison of results with the current research

The results indicate the public transportation and important public spaces within 25m receive the highest capability ranking. The results also indicate the areas with the greatest capacity score have a water stream within 10 meters, a slope of less than 5%, and a road network within 25 meters. The results also prove that areas with the best capabilities in this function were identified by increased vegetation density, a high concentration of native plants, closeness to a water stream, the presence of black cotton soil, and proximity to vegetation and storm water drain. Current research indicates Urban greenways have denser vegetation instead of grasslands for enhanced mental health and stress relief. This study was carried out using advanced Virtual Reality (VR) equipment (Jiang et al. 2024). Another study proves the interconnectivity of Greenways with road network to provide better physical health benefits. Research carried out through recent advancements in Computer Vision (CV) using social media, Instagram posts, proved the social interactions withing these public spaces to be more enhanced (Song et al. 2022)
The current trends of conducting research include using of latest available technologies such as GIS software platform, VR, CV, social media and such other platforms. This paper verifies that the results achieved through an approach of allocating suitability values in the subdivided cells still indicate similar attributes for the working of Urban Greenways.

5.3 Comparison of the empirical findings with theoretical framework

The empirical finding of the research provided a score for each of the cells through product of the Function to the factor to the capability class. Each cell has been associated with a score through physical inspection on the field attributing the values of various parameters selected through expert opinion and research articles. As seen on the color-coded grid (Fig. 5), vast components of the research area were determined to be unsuitable for greenway construction. This is closely linked to the growing friction between developmental pressures and the natural environment. Areas with high and moderate suitability levels were identified as having a high concentration of existing water streams, native plant species, and proximity to the road network. The theoretical framework of factors attributing to a greenway is justified through the empirical findings.

5.4 General Applicability of this research

This type of greenway suitability assessment can be utilized to safeguard the land's environmental and physical resources while also assisting in guiding future development. It is observed that diverse administrative authorities are involved in the process of land use classification resulting in inconstancies (Faria et al. 2023). The resulting greenway suitability data can be utilized as reliable inputs into the development of additional techniques to determine other land-use or design plans because they are derived mathematically. A study has established that urban growth is significantly attributed to transportation modes within the urban areas (Kharel & Singh 2022). An optimized commuting methodology can be achieved between residence and workplace through shorter pleasant routes (Rahman & Ashik 2020). Regenerating land-use or design concepts can also be accomplished with ease by reevaluating initial assumptions or current knowledge. Careful land use planning of the peri urban regions results in an efficient model of decentralizing from the urban areas (Lad & Petkar 2022). To represent different circumstances without having to recreate the entire process, it is crucial to make sure that the process is explicit.

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5.5 Development of parameters for greenway testing

Establishment of contextual framework, and creation of template for Greenway planning further led to development of generating parameters for testing of Greenways. The post processing of factors and capability class with the experts led to development of determinants to create greenways in a participatory approach. Interviews with experts generated enquiry about the stakeholder's perceptions of evaluating the greenways. Following eighteen parameters have been shortlisted for greenway evaluation: safety measures; cleanliness and maintenance; lighting along the Greenway; accessibility of the Greenway; signage along the Greenway; seating and rest areas; connectivity of the Greenway; facilities provided for cyclists; art installations; serenity and silence; using strollers or wheelchairs; security measures; wayfinding elements; quality of air; response time for addressing maintenance; availability of shaded areas; community engagement initiative; natural cooling.

5.6 Recommendations and future research

The present scope of this research is the establishment of contextual framework through developing the understanding of the study area through its characteristics, socio economic features, bio physical features and extensive field work. The present scope also includes developing a methodology of creating a template through identification of the greenway's functions, contributing factors with relative importance and generating capability class for greenway suitability. The scope of this research ends by generating various parameters for evaluating greenways.

The future scope of research would comprise of a more detailed study of a larger area with a detailed grid of lesser cell size. Further scope would undertake the usage of GIS for the regional study based on the mathematical model derived in this research, for generating the algorithm for greenway suitability. A suitability study using GIS, for water harvesting in Kulsi basin, India, was successfully validated (Thakuriah 2023). It would also be undertaken to generate finer factors for greenway suitability, adding to the present ten factors considered in this research. Many scholarly articles have recognized suitability analysis through usage of GIS (Geographical Information System) software algorithm's (Du et al. 2012). The present scope of this research is to allocate values to a cell to serve as pilot study prior to engaging the entire region for GIS suitability (Keskar & Kumar 2013).

The future scope of research would undertake the testing and validation of the various parameters for evaluating greenways.

6 Conclusions

The approach to this study was a direct method of allocating values to a smaller study area using field observations and expert opinion with published literature. This methodology uses general human wisdom along with proven methodologies for ranking, in allocating the cell values, and therefore has less chance for skewing results. It would be useful to carry out such pilot studies before taking up a large region using advanced software's such as GIS. This study was done to assess the viability of a multifunctional greenway for measuring efficacy using a ranking system. The method involved identifying and assessing greenway appropriateness functions, features, and capabilities. Implementing the recommended method yielded a color-coded grid layout that classified and depicted the various levels of greenway suitability across the study region. This suitability map provides useful information about the interaction of environmental elements and how they relate to the built environment in the study area. Suitability analysis is an effective method for greenway planning. Planners may help local leaders and individuals establish greenways in their areas by continuing to develop and refine suitability analyses.

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