A Framework for Sustainable Urban Street Design

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ABSTRACT

Rapid urbanization worldwide poses sustainability issues. To address these issues, Sustainable Urban Streets (SUS) are being developed to balance social, economic, and environmental factors in street design. The main aim of this paper is to investigate the suitable SUS characteristics for metropolitan environments and to develop a framework for SUS design. This study creates a framework for SUS based on four main aspects: environmental sustainability, social sustainability, economic sustainability, and design sustainability. A rigorous search strategy, focusing on urban street design parameters within sustainability frameworks, has been employed through a Systematic Literature Review (SLR) using PRISMA meta-analysis and considering databases from Scopus and Web of Science (WoS). Subsequently, a comprehensive list has been compiled, encompassing all the parameters or attributes and their respective sub-parameters or indicators identified in the study. In the second part of the paper, three rounds of the Delphi technique were used to extract the Indian experts' opinions and to reach a consensus among the experts on the attributes and indicators identified through SLR. To determine the weightage of indicators, statistical computations were performed using SPSS software, which calculated the mean, Standard Deviation (SD), Interquartile Range (IQR), and Coefficient of Variation (CV). Finally, 19 primary attributes and 46 secondary indicators have eventually emerged, which may contribute towards four aspects of SUS design. These attributes and indicators will provide a framework to develop sustainable urban streets in metropolitan areas and foster sustainable development in the city.

Keywords-framework;urban streets; weightage; systematic literature review; Delphi

I. INTRODUCTION

Urbanization is occurring at an unprecedented rate and sustainability is a key challenge globally. According to a 2018 report by the United Nations Department of Economic and Social Affairs, the urban population in 2018 was about 55.3% of the global population and it is expected that it will increase to 70% by 2050 [1]. Rapid urbanization is thus a feasible trend in the development of forthcoming communities. The fundamental consideration for the sustainable development of urban street corridors revolves around achieving a crucial balance among societal, economic, and environmental possibilities and alternatives [2]. The idea behind the "Sustainable Urban Street" concept is to improve transportation and related facilities with a focus on environmental friendliness and pedestrian-centric design [3]. This involves advocating for energy efficiency, reducing environmental footprints, enhancing rainwater infiltration, improving aesthetics, and boosting the economic value of the region [2, 4, 5].

Streets in cities have grown in size as a result of urbanization. There are four primary aspects to a "Sustainable Urban Street": the environment, the society, the economy, and the design. A range of transit choices are included in sustainable streets, facilitating the effective flow of people and goods while taking the economy, ecology, and environment into account. Sustainable streets can be defined as "multimodal rights of way designed and operated to create benefits relating to movement, ecology, and community that together support a broad sustainability agenda embracing the three E's: environment, equity, and economy" [2]. The adoption of SUS has the potential to enhance the livability of communities [6].

Urbanization has led to the progressive extension of urban streets. Streetscapes comprise physical infrastructure, road traffic, human activity on streets, and natural and manmade landscapes, providing public areas centered on people [7]. The present urban environment and infrastructure development face numerous challenges. Examples of significant risks to human health and the environment in this landscape include the disregard for local culture, the negative impact on a city's reputation caused by street pollution, the ecological damage resulting from urban construction, the insufficient safeguarding of cultural heritage, and the violation of sustainable development principles [8]. The concept of human-centered design is largely disregarded in traditional street design, which places a premium on vehicle traffic and results in a hazardous and unwelcoming streetscape [9]. To address the needs of smart city growth, the increasing focus on urban sustainability, and the desire for livable streets, people-oriented design has emerged as a key component. This approach takes into account people's experiences and emotional sustenance. Sidewalks, tree and landscape strips, rain gardens, planters, street furniture, benches, street furnishing, lighting, signage, bus shelters, medians, curbs, bicycle facilities, crossings, public art, and café spaces are all part of SUS [10].

This research paper is a component of a larger research project that investigates SUS standards in the context of urban areas. While extensive academic study has been conducted on the definitions, concepts, and dimensions of sustainable urban streets, there is currently a dearth of systematic analysis and comprehensive overview concerning the formulation of attributes and indicators for sustainable urban streets within the existing body of literature. The objective of this study is to create a framework for sustainable urban street design. To achieve this study objective, this paper presents a systematic examination of the existing literature review (known as the systematic literature review or SLR), followed by the survey conducted among experts using the Delphi method. The focus of the investigation is the construction of urban streets that are sustainable for urban areas. The main research problem of this study is to identify the attributes and indicators of different aspects of sustainable urban street design in urban areas. To do so, SUS design standards have been created, using SLR and the Delphi procedure, based on SLR and three-round Delphi procedures. To precisely determine the evolution and research trajectory of SUS design, this paper can provide crucial feedback and data for future researchers. Additionally, it can offer useful insights for individuals responsible for sustainable urban street design decisions and inhabitants, enabling them to get a deeper understanding, assess, and actively engage in the development of SUS [11].

II. METHODOLOGY

A two-stage procedure was used in the development of this study. The first stage involved a preliminary literature study, which allowed authors to choose the original set of parameters. The second stage was a Delphi-based third-round expert consultation, conducted in [12]. The purpose of this consultation was to create extensive scientific parameters for SUS by adding, removing, and modifying the preliminary characteristics with the help of experts' expertise (Figure 1).

A. *Initial Stage: Systematic Literature Review*

SLR is a systematic and methodical examination of the research findings of a particular subject [11]. It finds relevant studies using a specified search technique that is well-defined and reproducible. According to the objectives and research questions of the study, any material that does not pertain to the subject will not be considered for inclusion in the review, which presents relevant dada after being meticulously gathered and combined.

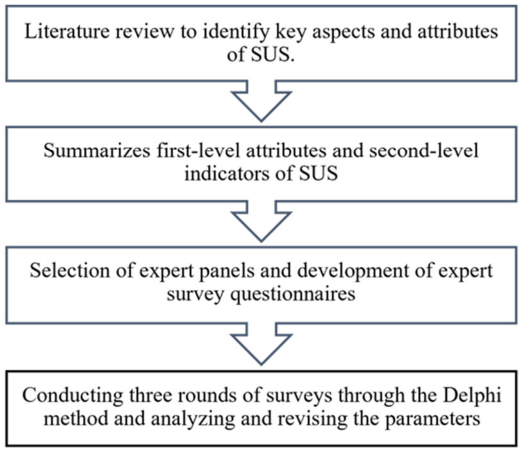

Fig. 1. Methodology for establishing the parameters.

This paper employs the following steps of the systematic literature review proposed in [13] for conducting an SLR, which are:

- Identifying suitable research queries
- Literature research
- Selection of the study
- The extraction of the data
- Research quality evaluations of the selected papers
- Concluding answers to the research questions.

1) *Identification of the Attributes and Indicators of SUS Design*

The attributes and indicators of SUS design are identified through the SLR using PRISMA meta-analyses and considering databases from Scopus and WoS. The following research strategy is adopted for the identification of the attributes and indicators of the SUS design.

TABLE I. SEARCH STRATEGY

Item	Content
Research scope	Urban street design parameters within the framework of sustainability
Database	Scopus and WoS
Time range	1996 to 21/05/2024 for Scopus 2008 to 21/05/2024 for WoS
Keywords	"sustainable street*" or "sustainable" AND "urban street*"
Document type	Article, Conference paper, Book chapter, Conference review, Review, and Book
Language	English

Search strategy: To facilitate the SLR, a comprehensive search strategy was devised to encompass all pertinent materials, as illustrated in Table I.

2) Inclusion and Exclusion Criteria

SLR was conducted utilizing the search methodology. However, several initially identified studies did not meet the criteria for inclusion. Consequently, the literature based on predetermined criteria for inclusion and exclusion was carefully evaluated. This was done to guarantee the excellence of the literature examined and the accuracy of the data obtained. The following steps were taken to ascertain the significance of each examined document:

- On May 21, 2024, data from two databases were downloaded for the current research study. This information was compiled from the WoS and Scopus using the terms "sustainable street*" or "sustainable" AND "urban street*". The search includes journal articles, book chapters, conference papers, conference reviews, reviews, and books that had the terms "sustainable street*" or "sustainable" AND "urban street*" anywhere in their title, abstract, or keywords because these are the most common forms of publication.
- The period considered for Scopus is from 1996 to 2024 (data downloaded on May 21, 2024).
- The period considered for Web of Science is from 2008 to 20024 (data downloaded on May 21, 2024).
- For both sources the "English" language filter was applied. A total of 272 documents were downloaded from Scopus and 127 documents were downloaded from the WoS portal.
- The downloaded documents from both sources were in ".ris" format which was imported to WoS reference manager EndNote for automatically removing any duplicates.
- After removing 53 duplicate documents the final count was 346, which was further analyzed.

B. Final Stage: Delphi Procedure

This stage involves further analyzing the data collected earlier. The findings produced from the prior literature research are utilized to carry out the Delphi technique for evaluating indicators. The Delphi methodology was first created by the Rand Corporation in 1950 and further enhanced as a method for achieving consensus among experts in 1970 [14]. It involves using a series of questionnaires to gather input from experts on a certain topic to reach a consensus. After each round concludes, a fresh set of survey questions is generated, taking into account the outcomes of the preceding round. The procedure continues iterating until a unanimous agreement is achieved [15].

The questionnaire in this study was developed by SLR and includes two main sections: (1) basic information from experts and (2) topic description, which encompasses SUS and other related concepts. Scientific principles and quality control procedures served as the questionnaire's guides during development. Tables that align with the recommendations for each level, along with new supplementary explanations, were provided by experts. A score of 1–5 on the Likert scale is conducted based on the significance of recommendations. Each indicator is evaluated and assigned scores, which are then used to establish the weightage. Also the questionnaire provides an assessment of experts' acquaintance with guidelines and rationale for evaluation.

1) Selection of Experts

According to authors in [16], experts must fulfill four criteria to guarantee the legitimacy, inclusiveness, and dependability of study findings: (1) gain information and experience through research, (2) willingness to take part, (3) exhibit ample time for involvement, and (4) demonstrate good communication abilities. Furthermore, there are more sets of criteria for choosing an expert for the review process: a minimum of 10 years of expertise in the related field of architecture, possessing a master's degree or more, and willingness to dedicate time to this research. Authors in [17] proposed that the ideal reviewing committee should consist from a minimum of 5 to a maximum of 20 experts. Consequently, the study involves 13 experts for the first Delphi round, namely government officials, professors at the college level, trainee architects, and planners. Out of the total 13 experts of the first round, 6 experts (46%) have a work experience of over 10 years, 5 experts (38%) have a work experience of over 20 years, and 2 experts (15%) have a work experience of over 30 years. Out of the 13 specialists, 8 possess master's degrees (62%), and 5 hold doctoral degrees (38%). The details of the experts with distributions for all three rounds for Delphi procedure are shown in the Table II.

TABLE II. DISTRIBUTION OF EXPERTS

Discipline	First Round	Second Round	Third Round
Government officials	2	1	1
Professors at the college level	5	4	3
Practicing architects	3	3	4
Planners	3	5	2
Total	13	13	10

2) Distribution and Retrieval of the Survey Questionnaire

Survey questions are distributed and gathered from personal interviews. The initial phase involved gathering statistical feedback data from the questionnaire, which were then used to refine and enhance the indicators based on the recommendations of the experts. The initial adjustments/ results were incorporated in the next round of the survey questions. Experts were then queried about their adoption of these revisions and requested to assess the signs on a numerical scale ranging from one to five, where five signifies high importance and one signifies low importance. The final weighting of the indicators was calculated in the third round of Delphi after three rounds of deliberation.

3) Establishment of Filtering Criteria

Even though the primary objective of the Delphi method is to establish consensus among experts, there is no standardized measurement methodology. Consequently, some studies employ a frequency distribution to assess the data, while others employ standard deviation and interquartile range. In the case of a Likert scale with 5 points, it is claimed that the consensus is reached by combining the metrics listed below [18].

- If 51% or more of the experts answered "strongly agreed" on a 5-point Likert scale, which corresponds to values between 4 to 5.
- The range of interquartile values is between 0 to 1.
- The range of standard deviation is between 0 to 1.5 [19].

As stated in [20], the Coefficient of Variation (CV) is an alternative approach for assessing agreements. If the CV is within the range of 0 to 0.5, it indicates a high degree of consensus and there is no need for another round of the Delphi process. If the CV falls within the range of 0.5 to 0.8, it suggests a less desirable level of consensus and a second round may be necessary. However, if the CV is more than 0.8, it indicates a low level of consensus [21].

III. RESULTS

This part presents and elucidates the findings of the examined research and provides a concise overview of sustainable indicators for urban streets within the framework of urban areas. The indicators are mapped for every attribute, explaining how urban streets might attain urban sustainability. The streets must progressively be transformed into a more compassionate, livable, and circular development to adhere to the ideals of sustainable development.

A. Results of Literature Review

1) PRISMA: Method of Study Selection and Quality Evaluation

Publications that fulfilled the study questions were chosen according to the predetermined criteria for inclusion and exclusion. The SLR for the literature search, using the PRISMA 2020 model is depicted in Figure 2, demonstrating the processes of article identification, inclusion, and exclusion along with the quantification of research studies and the rationale for their exclusion. Following the completion of this rigorous screening process, a total of 27 papers were ultimately selected for the subject analysis.

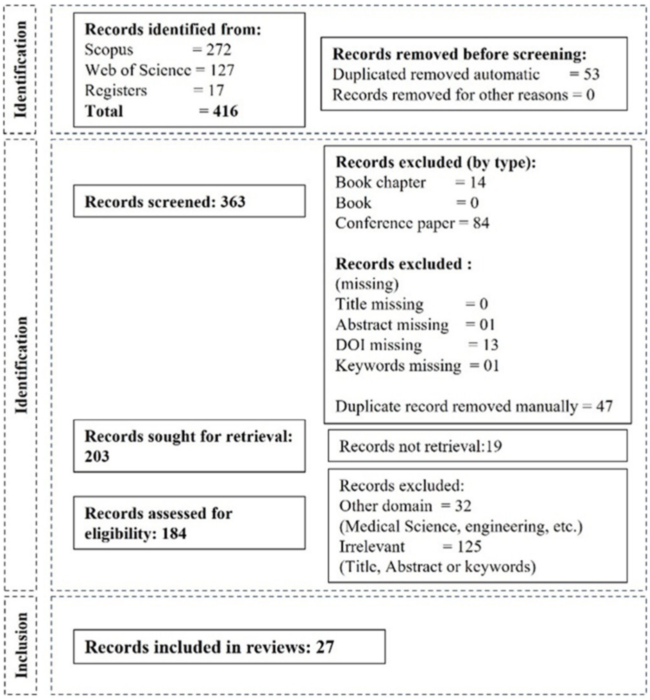

Fig. 2. Screening process.

2) Data Extraction and Analysis

The data derived from the analysis of 27 studies, which emphasized the design parameters of SUS, were documented on an Excel spreadsheet. These data were then categorized into various attributes to demonstrate the primary considerations of SUS design and how to meet the indicators of the four aspects of SUS to enhance urban sustainability. After the data extraction process was finalized, the data were organized in tables for the four aspect layers, namely environmental sustainability, social sustainability, economic sustainability, and design sustainability along with their sources, mean, standard deviation, interquartile range, and coefficient of variation (Table III).

TABLE III. ATTRIBUTES AND INDICATORS OF SUSTAINABLE URBAN STREETS DESIGN

Attributes	Indicators	Source	First Round				Second Round				Third Round			
			Mean	SD	IQR	CV	Mean	SD	IQR	CV	Mean	SD	IQR	CV
Aspect Layer- Environmental Sustainability														
Adaptability	Resorting mobility after a storm/ hurricane	[22]	4.31	0.8	1	0.2								
	% of flood risk area	[23, 24]	2.46	0.7	1	0.3	3.00	1.1	2	0.4	4.00	0.5	0	0.1
	Adaptability capacity to local climate	[1, 25-27]	2.31	0.8	1	0.3	2.00	0.6	0	0.3	2.20	0.4	0	0.2
	Adaptability capacity to extreme weather conditions	[1, 25-27]	4.25	0.6	1	0.1								
Urban heat island mitigation	Cool pavement	[28]	2.38	0.7	1	0.3	4.00	0.7	0	0.2				
	Street greenery	[22]	2.31	0.8	1	0.3	2.15	0.8	1	0.4	2.30	0.7	1	0.3
	% Street tree shading	[1, 25-27]	4.46	0.5	1	0.1								
	Air temperature difference	[1, 25-27]	4.00	0.7	0.5	0.2								
Comfort	Outdoor thermal comfort	[29, 30]	4.46	0.7	1	0.1								
Pollution reduction	Average Annual emission of NO_2	[31]	2.46	0.9	1	0.4	2.31	0.6	1	0.3	2.30	0.5	0.75	0.2
	Average noise emission	[31]	4.38	0.7	1	0.1								
	Air Quality Index	[32]	4.54	0.5	1	0.1								

	Green asphalt usage	[22]	2.08	0.8	1	0.4	2.00	0.7	0	0.4	1.90	0.7	0.75	0.4
	Annual energy saving-conversion to LEDs	[22]	2.15	0.8	1	0.4	2.31	0.8	1	0.3	2.50	0.5	1	0.2
	Road transport CO_2 emission	[23]	2.46	1.0	1	0.4	2.31	0.8	1	0.3	2.30	0.7	1	0.3
	% of pavement reuse	[28]	2.15	0.9	1	0.4	2.08	0.8	1	0.4	2.40	0.5	1	0.2
	Recycled materials	[28, 33]	2.23	1.1	0	0.5	2.23	1.0	1	0.5	2.50	1.0	1	0.4
	Regional materials	[28]	2.38	1.0	0	0.4	2.23	0.7	0	0.3	2.40	0.8	1	0.4
	Sustainable materials	[28, 34]	1.62	0.7	1	0.4	1.62	0.5	1	0.3	1.90	0.6	0	0.3
	Quiet pavement	[30]	2.38	0.5	1	0.2	2.31	0.6	1	0.3	2.20	0.6	0.75	0.3
	Waste management	[30]	2.31	0.5	1	0.2	2.38	0.5	1	0.2	2.50	0.5	1	0.2
	Lifecycle pollution reduction	[30]	1.54	0.5	1	0.3	1.92	0.6	0	0.3	2.10	0.6	0	0.3
Ecological balance	Permeable pavement and bioswales	[28]	4.00	0.8	2	0.2	4.00	0.7	0	0.2				
	Runoff flow control	[28]	2.38	0.5	1	0.2	2.46	0.7	1	0.3	2.50	0.7	1	0.3
	Runoff quality	[28]	2.23	0.7	0	0.3	2.00	0.6	0	0.3	2.20	0.4	0	0.2
	Site vegetation	[28]	4.23	0.7	1	0.2								
	Ecological planting	[28]	2.46	0.5	1	0.2	2.38	0.7	1	0.3	2.20	0.6	0.75	0.3
	Number of planting types	[1, 25-27]	2.38	0.8	1	0.3	2.31	0.9	1	0.4	2.30	0.5	0.75	0.2
	Rainwater management	[1, 25-27]	4.23	0.7	1	0.2								
Green life promotion	Public conversation events for street safety	[22]	2.15	0.6	0	0.3	2.23	0.4	0	0.2	2.30	0.5	0.75	0.2
	Public campaigns for traffic safety	[22]	4.00	0.8	0	0.2								
	Green lifestyle promotion	[1, 25-27]	2.38	0.8	1	0.3	2.38	0.8	1	0.3	4.00	0.7	0	0.2
	Green travel support	[1, 25-27]	4.08	0.8	1	0.2								
Aspect Layer- Social Sustainability														
Equality	Tactile pavement for the blind	[1, 25-27]	4.15	0.7	1	0.2								
	Barrier-free facilities	[1, 25-27]	4.08	0.8	1.0	0.2								
	Transparency of the party wall	[1, 25-27]	2.38	0.8	1	0.3	2.38	0.9	1	0.4	2.50	0.7	1	0.3
Safety	Crashes and injuries for motorists, pedestrians, and cyclists	[32]	2.31	0.8	1	0.3	2.31	0.6	0	0.3	2.40	0.7	0.75	0.3
	Traffic fatality	[22]	4.38	0.5	1	0.1								
	Designed traffic speeds	[32, 35]	2.31	0.9	1	0.4	2.15	0.9	1	0.4	2.30	0.8	0.75	0.4
	Coverage proportion of street cameras	[22]	4.08	0.5	0	0.1								
	Number of street crimes	[30]	2.46	1.1	1	0.4	2.31	0.9	1	0.4	2.50	0.7	1	0.3
	Coverage safety equipment	[1, 25-27]	2.31	1.3	0	0.5	2.00	0.6	0	0.3	2.10	0.6	0	0.3
	Street lights	[1, 25-27]	4.77	0.4	0	0.1								
	Bollards	[25, 36]	2.31	0.6	0	0.3	2.15	0.4	0	0.2	2.20	0.4	0	0.2
Accessibility	Quality of service in public transport	[31]	2.38	0.8	1	0.3	2.38	0.5	1	0.2	2.50	0.5	1	0.2
	Number of parking lots	[31]	2.23	0.7	1	0.3	2.31	0.6	1	0.3	2.20	0.4	0	0.2
	Volume of vehicles, bus passengers, bicycle riders, and users of public space	[32]	2.46	0.5	1	0.2	2.46	0.5	1	0.2	2.50	0.5	1	0.2
	Bus system service quality	[22]	2.46	0.8	1	0.3	2.46	0.7	1	0.3	2.50	0.7	1	0.3
	Ridership on bus	[22]	2.46	0.7	1	0.3	2.46	0.5	1	0.2	2.30	0.5	0.75	0.2
	Bus Lane network	[22]	2.46	0.5	1	0.2	2.31	0.5	1	0.2	1.90	0.6	0	0.3
	Cycling lane network	[22]	2.46	0.7	1	0.3	2.31	0.6	1	0.3	2.20	0.6	0.75	0.3
	Coverage of sharing bike	[22]	2.46	0.7	1	0.3	2.46	0.5	1	0.2	2.10	0.6	0	0.3
	Pedestrian access	[28]	4.38	0.5	1	0.1								
	Bicycle access	[28]	2.46	0.5	1	0.2	2.38	0.5	1	0.2	2.40	0.5	1	0.2
	Transit access	[28]	2.46	0.7	1	0.3	2.38	0.7	1	0.3	2.40	0.7	1	0.3
	The variety of arrival ways	[1, 25-27]	4.00	0.8	2.0	0.2	4.00	0.7	0.0	0.2				
	Clear sign and guidance system	[1, 25-27]	4.08	1.1	1	0.3								
	Bus Shelters	[25]	2.46	0.9	1	0.4	2.31	0.6	1	0.3	2.40	0.7	1	0.3
Diversity	Diversity of street activities	[32]	4.00	0.8	2.0	0.2	4.00	0.7	0.0	0.2				
	Number of Street events per year	[22]	2.46	0.7	1	0.3	2.23	0.7	1	0.3	2.10	0.7	0.75	0.4
	Number of public seats	[22]	2.38	0.5	1	0.2	2.23	0.4	0	0.2	2.30	0.5	0.75	0.2
	Diversity of street functions	[22]	4.15	0.8	1.0	0.2								
Cultural inheritance	Number of urban arts	[10, 22]	2.46	0.7	1	0.3	2.46	0.5	1	0.2	2.20	0.6	0.75	0.3
	Aesthetic quality of urban art	[22]	4.00	0.8	2.0	0.2	4.00	0.7	0.0	0.2				

	Aesthetic quality of street furniture	[1, 25-27]	4.00	0.7	0.0	0.2								
	Style consistency with surroundings	[1, 25-27]	2.46	0.5	1	0.2	2.46	0.5	1	0.2	2.10	0.6	0	0.3
	Historical inheritance & cultural display	[1, 25-27]	2.46	0.5	1	0.2	2.31	0.5	1	0.2	2.40	0.5	1	0.2
Aspect Layer- Economic Sustainability														
Intensive land utilization	Intensiveness of street space	[1, 25-27]	2.46	0.7	1	0.3	2.31	0.6	1	0.3	2.30	0.7	1	0.3
	Mixed-use of street land	[1, 25-27]	4.23	0.6	1	0.1								
Efficiency	Efficiency in parking/loading	[32]	2.46	1.0	1	0.4	2.46	0.8	1	0.3	2.40	0.8	1	0.4
	Actual traffic speed	[32, 37]	2.38	0.5	1	0.2	2.23	0.4	0	0.2	2.40	0.5	1	0.2
	Parking smart program	[22]	4.38	0.5	1	0.1								
	Intelligent transportation system	[28]	4.00	0.6	0	0.1								
	Traffic performance index	[30]	2.46	0.7	1	0.3	2.31	0.5	1	0.2	2.30	0.5	0.75	0.2
Business creation	Retail sales	[32]	2.46	0.5	1	0.2	2.46	0.5	1	0.2	2.30	0.5	0.75	0.2
	Retailer visitor spending	[32]	2.46	0.8	1	0.3	2.31	0.6	1	0.3	2.20	0.6	0.75	0.3
	Retail sales tax filings	[32]	1.62	0.7	1	0.4	1.77	0.6	1	0.3	1.90	0.6	1	0.3
	Density of shops	[1, 25-27]	2.38	1.3	1	0.5	2.54	1.1	1	0.4	2.00	0.5	0	0.2
	Types of shop/ business	[1, 25-27]	2.54	0.5	1	0.2	2.46	0.5	1	0.2	4.00	0.7	0	0.2
Job creation	Employment generation	[31]	2.46	0.7	1	0.3	4.00	0.7	0	0.2				
	Number of employment	[32]	2.08	1.0	1	0.5	1.85	0.7	1	0.4	2.00	0.7	0	0.3
	Types of employment	[1, 25-27]	4.15	0.8	1.0	0.2								
Value addition of property	Increase in commercial price/ rent	[32]	4.00	0.7	0.0	0.2								
	Increase in housing price/ rent	[32]	4.00	0.6	0.0	0.1								
Aspect Layer- Design Sustainability														
Design	Street paving	[25, 36, 39]	2.23	0.8	1.0	0.4	2.31	0.8	1	0.3	2.20	0.4	0	0.2
	Sidewalks	[10]	4.54	0.5	1	0.1								
	Street corners	[10]	4.38	0.5	1	0.1								
	Medians	[10]	2.38	0.7	1	0.3	2.23	0.4	0	0.2	2.10	0.3	0	0.2
	Kerbs & kerbs ramps	[36]	4.31	0.5	1	0.1								
	Street Furniture	[26, 36, 39]	4.38	0.7	1	0.1								
	Bicycle facilities	[10]	2.46	0.8	1	0.3	2.46	0.7	1	0.3	2.50	0.7	1	0.3
	crossing	[10]	2.46	0.5	1	0.2	2.31	0.5	1	0.2	2.40	0.5	1	0.2
	Trees, landscape strips, and planters	[10]	4.62	0.5	1	0.1								
	Raingarden	[10]	2.46	0.5	1	0.2	2.38	0.7	1	0.3	2.40	0.7	1	0.3
	Kiosk spaces	[10]	4.08	0.6	0.0	0.2								
	Dustbins	[36]	4.62	0.5	1	0.1								
Urban principles	Legibility	[10]	2.38	0.5	1	0.2	2.38	0.5	1	0.2	2.00	0.7	0	0.3
	Attractiveness	[10]	4.46	0.5	1	0.1								
	Liveliness	[10]	4.46	0.5	1	0.1								
Encroachment	Types of temporary business/ hawkers	[38, 39]	4.00	0.8	2.0	0.2	4.00	0.7	0.0	0.2				
	Electric poles/ Trees on sidewalks	[38, 39]	4.00	0.7	0.0	0.2								

B. Result of the Delphi Procedure

After extracting the data and obtaining the full set of SUS parameters, the screening of each indication against each characteristic began. During the screening process, experts were asked to score the signs on a scale of one to five, with five representing significant relevance and one representing low significance. The indicators were weighted using SPSS software. The final indicators and weightings were determined after three rounds of debate. The adopted technique achieved consensus by combining three established criteria. The indicator's mean value should be between 4 and 5, its interquartile value between 0 and 1, and its standard deviation range from 0 to 1.5. The indication that did not meet the above three criteria was removed from the list of SUS. Table IV contains the final list of attributes and indicators for SUS design, which was determined after thorough consideration of each of the three stages of the Delphi process.

IV. CONCLUSION

This study examined the attributes and indicators of sustainable urban street design through a comprehensive examination of the existing literature. Additionally, it used the input of experts and design professionals in three rounds of the Delphi method to develop a framework for sustainable urban street design. Creating a foundation for sustainable urban street design is an essential component of urban sustainability. This framework has the potential to be further developed and evaluated for its inclusion in the design decision process to be enhanced. These design considerations will assist urban planners and experts in selecting design choices for new or renovated sustainable urban street designs to improve urban sustainability, performance, and aesthetics.

TABLE IV. LIST OF ATTRIBUTES AND INDICATORS FOR SUS DESIGN AFTER THREE ROUNDS OF DELPHI PROCEDURE

Aspect Layer	Attributes	Indicators	Final Delphi Score
Environmental Sustainability	Adaptability	Resorting mobility after a storm/ hurricane	4.31
		% of flood risk area	4.00
		Adaptability capacity to extreme weather conditions	4.25
	Urban heat island mitigation	Cool Pavement	4.00
		% Street tree shading	4.46
		Air temperature difference	4.00
	Comfort	Outdoor thermal comfort	4.46
	Pollution reduction	Average noise emission	4.38
		Air quality index	4.54
	Ecological balance	Permeable pavement and bioswales	4.00
		Site vegetation	4.23
		Rainwater management	4.23
	Green lifestyle promotion	Public Campaigns for traffic safety	4.00
		Green lifestyle promotion	4.00
		Green travel support	4.08
Social Sustainability	Equality	Tactile pavement for the blind	4.15
		Barrier-free facilities	4.08
	Safety	Traffic fatality	4.38
		Coverage proportion of street cameras	4.08
		Street lights	4.77
	Accessibility	Pedestrian access	4.38
		The variety of arrival ways	4.00
		Clear sign and guidance system	4.08
	Diversity	Diversity of street activities	4.00
		Diversity of street functions	4.15
	Cultural inheritance	Aesthetic quality of urban art	4.00
		Aesthetic quality of street furniture	4.00
Economic Sustainability	Intensive land Utilization	Mixed-use of street land	4.23
	Efficiency	Parking smart program	4.38
		Intelligent transportation system	4.00
	Business creation	Types of shop/ business	4.00
	Job creation	Employment generation	4.00
		Types of employment	4.15
	Value addition of property	Increase in commercial price/ rent	4.00
		Increase in housing price/ rent	4.00
Design Sustainability	Design	Sidewalks	4.54
		Street corners	4.38
		Kerbs & kerbs ramps	4.31
		Street furniture	4.38
		Trees, landscape strips, and planters	4.62
		Kiosk spaces	4.08
		Dustbins	4.62
	Urban principles	Attractiveness	4.46
		Liveliness	4.46
	Encroachment	Types of temporary business/ hawkers	4.00
		Electric poles/ Trees on sidewalks	4.00

In this investigation, a comprehensive set of 19 attributes and 101 indicators of SUS design were initially identified and categorized for the expert's opinion to reach a consensus. After three rounds of the Delphi procedure, 19 attributes and 46 indicators were identified for SUS design in a metropolitan city in India. The significance of this work lies in its research findings, which are essential for comprehending the impact of SUS design on sustainable development. Furthermore, the findings offer researchers and designers a theoretical foundation for SUS design. The main finding of this research is the development of a framework for sustainable urban street design in Indian cities. As a result, it is both feasible and valuable to implement this research's evaluation framework and study methodologies to investigate their potential applications in other practical settings.

This research may be expanded to encompass more dimensions of sustainability and their corresponding attributes and indicators in the design of urban streets, using a more comprehensive database. To implement the Delphi approach more effectively, it is recommended to involve a greater number of experts from diverse sectors on a global scale. In the future, researchers have the potential to create an indicator system for SUS that can be applied to other cities or nations, utilizing the existing SUS assessment framework.

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