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Research Article

Exploring the Design Practice, Trends, and Gaps of Urban Bridges in Ethiopia towards Sustainability

Leule M. Hailemariam [1] **and Denamo A. Nuramo** [2]

[1]*Chair of Appropriate Building Technology, Ethiopian Institute of Architecture, Building Construction and City Development (EIABC), Addis Ababa University (AAU), Addis Ababa, Ethiopia*
[2]*Chair of Construction Materials and Engineering Design, Ethiopian Institute of Architecture, Building Construction, and City Development (EIABC), Addis Ababa University (AAU), Addis Ababa, Ethiopia*

Correspondence should be addressed to Leule M. Hailemariam; leule.mebratie@eiabc.edu.et

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Bridges carrying railways, roads, and pedestrians in rural and urban regions have tremendous characteristics. The case of urban bridges is quite typical for a visual view of the complexity of the characteristics of urban Ethiopia. The existing urban environment in Ethiopia demands great attention regarding bridge infrastructure. The dynamism of urbanity depends on multiple factors such as institutional capabilities for commissioning, monitoring, and decommissioning; professional competence; and culture. The provision of urban bridges should be viewed holistically, beginning with planning and design and continuing through construction. The approach so far has been single-handed, and this creates an unbalanced delivery of the infrastructure. This article explores the existential trends and practices of urban bridge design and identifies the main challenges of practicing sustainability in the design process in Ethiopia. The research is methodically based on a qualitative approach to identify the expert opinions of professionals and designers who are currently participating in urban infrastructure design. The data were gathered through interviews, and the findings show that the practice of sustainable urban bridge design is still in its infancy, and even the concept is unclear to many professionals in the field. While the study emphasizes the importance of sustainable urban bridge provision, it also highlights challenges such as lack of awareness, weak institutional capacity and culture, and lack of mandatory sustainable codes and standards.

1. Introduction

The concept of design activity, although performed for several centuries, did not, however, have any structure or organization thereto. After the middle of the twentieth century, efforts were made to add some formalities to the design approach [1, 2]. Moreover, several designers, engineers, and researchers have expressed their views on the definition of design or what they believe design to be based on observation and knowledge [1]. Design practice and research are increasingly being driven by the need for more imaginative solutions to suit increasingly complicated consumer expectations [3]. This is accompanied by a requirement for services that are more environmentally, socially, and economically sustainable [4].

Bridge design has been reported as a complicated structure that brings relevant differences into the surrounding landscape, involving several specialist sectors such as hydraulic, geotechnical, landscaping, structural, architectural, economic, and sociopolitical. As a result, before beginning the design of a bridge, a concept should be produced, along with the creation of a scaled model that serves as a simulation of the three-dimensional overview of the construction and all alternatives examined [5]. The lifespan of a bridge spans several decades, necessitating careful planning in each step of its design and construction.

To provide value-added concept design, it is essential to have a complete understanding of construction processes, long-term maintenance concerns, and environmental effects.

The concept of sustainability is becoming a primary concern in infrastructure development, especially when the public demands sustainable development. Sustainable development is a much more inclusive process of change for people, the planet, and wealth [6], and it is beyond social, environmental, and economic issues; it may encompass a broader range of topics than sustainability [7]. Sustainable development may also be defined as the process of achieving the stated aim of sustainability [8]. Infrastructure sustainability, whether in urban or rural regions, has a noteworthy influence on sustainable growth.

The provision of bridges in cities and towns must be approached holistically. The role of designers, contractors, owners, and communities in the realization of a sustainable bridge is essential. Bridges account for the entire design process, from concept to completion. Making our concept correct will move the design in the right direction. The design process of attaining sustainability is framed by factors, parameters, and indicators. Sustainable infrastructure can be achieved through sustainable design practice. The process of designing infrastructure needs to fulfill the key major elements as outlined in [9]: material selection, economic considerations, social considerations, environmental considerations, technical considerations, policy and regulations, design and project management, and design professionals and the design process.

Urban bridges are vital infrastructures for creating smooth connectivity between areas, urban mobility, facilitating accessibility, reducing barriers, and adding value if the spaces beneath are used. A bridge must carry a service such as highway or railway traffic, a footpath, and public utilities over an obstacle. To achieve a responsive and sound structure, the conceptual design process of a bridge infrastructure found in an urban environment requires a collaborative, thoughtful, and integrative approach.

The case of Ethiopian urban bridge provision is like that of others, but its delivery mechanism is by far traditional, particularly in terms of the long-term viability of bridge approaches [10]. Urban complexity will exacerbate the problem unless the problem is properly defined and addressed comprehensively. The concept of a sustainable urban bridge, as a core thought of a mechanism, will view the change factors in their relationship to address the current and future impact of the factors. The design of civil infrastructures such as roads, houses, and bridges differs from the design of industrial, mechanical, architectural, and biomedical instruments, as well as furnishings. Infrastructure design is unique due to its capital intensity, size of each structure, and interaction with the natural environment [11]. Bridges are considered a linear infrastructure that requires guiding models and frameworks for design work to be realized.

The objective of the study is to explore the pattern of existing practices, trends, and challenges in the design process of urban bridges towards achieving sustainability. The practice of the urban bridge design is carried out in consulting firms in Ethiopia by asking the senior designer, who has reputable experience in design consultancy.

The study used a qualitative methodology, and structured interviews were used to get the data. The method of content analysis is particularly powerful since it can handle both textual and audio data [12]. Therefore, important themes and relationships were gathered using the content analysis technique.

2. Methods

Methodologically, the research approach is towards a qualitative synthesis of the subjective opinion of selected samples. The subject is how the designers and planners practice the design work of urban bridges found in Ethiopia and what patterns really exist in the process. The experts' explanations of how and why they comprehend the general sustainable design of urban bridges would be more prevalent in the situational analysis of the current design gaps toward achieving the notion of sustainability. Institutional structures and guiding principles would both play significant roles in attaining sustainability.

The population for qualitative research through interview techniques would be professionals and scholars who are practicing or doing research in urban bridge design. The research frame for this technique is finite, but it is difficult to list all experts in the field of study. The research frame for the study is a list of AEC consultants who are registered to design and supervise bridge structures. The consultants who participate in the bridge design work would be considered as a population of the study.

The case to explore the design practice and its trend and identify the major challenges of the process is studied using an interview data collection instrument. In-depth interviews are ideal for gathering information about people's personal histories, perspectives, and experiences, especially when dealing with delicate themes [13]. The interview has been conducted through a face-to-face and phone interview. The initial questions were asked to the respondents who were purposively selected based on their urban bridge design experience in the industry. Until the saturation of concepts is reached, the discussion would continue. The number of samples for those with active design duties was determined.

Although sampling is not essential in qualitative research, how many interviews a researcher conducts is influenced by a variety of factors. The researcher will continue sampling until he or she feels that saturation has been reached. Saturation is a difficult concept to grasp [14, 15]. As a result, it would be either theoretical knowledge or code saturation, but in this study, knowledge saturation is considered at the level of determining sample size, and to begin, the recommendation given in [15] of 12 interviews of a homogeneous group is all that is required to reach saturation. However, because the groups under consideration are heterogeneous (architects and engineers), the sample size should be raised beyond twelve depending on the saturation level, as this is the desired endpoint of data collection. Operationally, the decision to discontinue interviews is influenced by a mix of all or some of the following variables.

Group heterogeneity [15]: the more heterogeneous the group is, the more interviews are needed. Satisfying all researcher's purposeful sample criteria that are required for the study and resourcing would be the other variable to consider [16].

Samples were chosen in accordance with the following criteria: willingness to engage in the interview; experience designing urban bridges or doing relevant research; and participants' professional background in either urban design/architecture or engineering design of urban bridges. As a result, the study's participants were chosen based on the characteristics of the samples ($n = 15$). Engineers who design bridges, architects, and structural engineers were the target respondents. The main queries centred on the investigation of urban bridge design practice trends and challenges as well as urban bridge design practice towards sustainability.

To identify the major themes and behaviours, content analysis was chosen as the analysis method. It is necessary to distinguish between manifest and latent content. It is also contended that theory-based coding schemes and standards established by experts are not necessary for content analysis [17]. Researchers are in a better position to choose the most suitable procedures for proving validity and reliability when they are clear about the type of content they want to investigate and the function of theory in their investigations [18].

3. Results

The study primarily assesses the demographic data of the participants, and the description of the background of the respondents is stated in the succeeding point of discussion. Secondly, the study collects the responses of participant questions classified into two main themes. The first portion is dedicated to assessing the current urban bridge design trends, practices, methodologies, and procedures, whereas the second part will discuss how to incorporate sustainability parameters into the design of an urban bridge.

Content data analysis is conducted using a qualitative data analysis program, which has an open-source capability to textual content analysis of qualitative data. The structured interview questions were organized into two central questions, and follow-up questions have been asked to the respondents. The questions are stated in Table 1.

The supportive questions were asked, and follow-up questions were asked in the process to elaborate and to get more theme responses. The responses collected from professionals and experts who have plenty of years in urban bridge design experiences were transcribed and then coded to the themes. The respondent's demographic data and the analysis result are depicted in the following successive facts along with the relationships of the variables mentioned. The sample size ($n = 16$) was purposively taken to explore the existing design trends, practices, and challenges of urban bridge design in Ethiopia towards attaining sustainability. The respondents are professionals who are practicing the design of urban infrastructure in Ethiopia with a professional registration license from the Ethiopian Construction Works Authority.

The data analysis has been conducted through a method of textual analysis of the contents of themes. The themes were developed by coding with text, and then categorization would occur. The use of meaningful labels of contents to draw patterns of concepts towards the exploration of the practice would be done. The results outlined below are systematically organized to synthesize the underpinning meanings. The participant's background details, the state of the current urban bridge design, and the sustainability perceptions of design professionals during the process of designing an urban bridge would be provided.

3.1. Demographic Data. The distribution of the sample's participants is shown by the demographic information in Table 2. The required level of design expertise for practicing design professionals is six years or more in the specific infrastructure. These experts are fully qualified to carry out design consultancy work in the sector.

The participant's host organization falls into one of two categories: consulting engineers (CE) or consulting architects and engineers (CAE). According to the project's expected budget level, the major urban bridge infrastructure design has been used in these two categories at levels ranging from category one to category three. Therefore, the participant from CAE represents around 50% of the total sample. Both structural engineers and architects are among these experts ($n = 4$). The gender distribution ratio of males to females, on the other hand, is 1 : 8, indicating that women are less involved in the design of urban bridge infrastructure.

Although it is thought that professionals with many years of experience in the architectural and engineering design of urban bridges have been given precedence for selection, the choice of these experts was made at random. The distribution of the experts' demographics must take education levels into account as well. The level of education, current job positions, and level of design experience of the specialists in each design area are cross tabulated in Table 2.

According to Table 2, out of the total sample, four participants had a BSc degree, and the remaining twelve had an MSc degree. Architects ($n = 4$), bridge engineers ($n = 7$), and structural Engineers ($n = 4$) make up the distribution of respondents' present jobs. Additionally, the participant's years of design experience ranged from 6 to 10 ($n = 3$), 11 to 15 ($n = 3$), 16 to 20 ($n = 7$), and 21 to 25 ($n = 2$).

All participant's audio recordings were transcribed into text, and the content analysis of the documents was done using ATLAS.ti 7.5's qualitative data analysis (QDA) program. Even though other forms of QDA applications are not preferred technically, only the researchers' familiarity with the program is taken into consideration. The following statements explain the range of expert opinions on the two goals listed in Sections 3.1.1 and 3.1.2.

3.1.1. Existing Urban Bridge Design Practices, Trends, and Challenges. The design practice, as it can be explained by the pattern of trends and challenges that exist in the opinions of

Table 1: Interview themes.

Central themes	Supporting themes
Demographic data of the respondent	(i) Gender (ii) Level of education (iii) Current position (iv) Design experience (v) Company category
Existing urban bridge design practice, trend, and challenges	(i) Concept development process (ii) Responsible for concept development (iii) Potential sources of inspiration for bridge aesthetics (iv) Level of relevance of parameters (aesthetic, functionality, and technicality) (v) Level of collaboration of designers (vi) Challenges of urban bridge design
Urban bridge design practice towards sustainability	(i) Evaluation of the design process through the defined values (aesthetic, economic, environmental, social, technological, and technical) (ii) Required criteria to attain sustainability (iii) State of sustainable urban bridge design practice (iv) Challenges to practice sustainability

Table 2: Demographic distribution of participants.

	Level of education		Current job position			Design experience (years)				Total	$N = 15$
	BSc	MSc	Architect	Bridge engineer	Structural engineer	6 to 10	11 to 15	16 to 20	21 to 25		
Level of education											
BSc	4	—	1	2	1	—	2	1	1	4	15
MSc	—	11	3	5	3	3	1	6	1	11	
Current job position											
Architect	1	3	4	—	—	2	1	1	—	4	
Bridge engineer	2	5	—	7	—	—	2	3	2	7	15
Structural engineer	1	3	—	—	4	1	—	3	—	4	
Design experience (year)											
6 to 10	—	3	2	—	1	3	—	—	—	3	
11 to 15	2	1	1	2	—	—	3	—	—	3	15
16 to 20	1	6	1	4	3	—	—	7	—	7	
21 to 25	1	1	—	2	—	—	—	—	2	2	
Total	4	11	4	7	4	3	3	7	2	—	—
Sample ($N = 15$)	15			15			15			—	—

the participant, is framed with the understanding of addressing the central and supportive themes of the interview questions. These themes are related to responding to the research questions: (1) how do design professionals perceive the current practices and trends in urban bridge design and (2) what are the challenges faced in the design of urban bridges? The concepts that directly address the research objectives would be coded and then grouped into families, and then category or theme labelling is done along with networking of the labels to create meaningful patterns.

3.1.2. Urban Bridge Design Practice towards Sustainability. The goal of assessing sustainability practice is critical to the design practice. Identifying the areas that need to be filled to achieve sustainability in the design of urban bridges is essential. The suggested steps are helpful, and Table 3 displays the enhanced codes, their categories, and their labels. Theresearch focuses on how a professional designer achieves sustainability whendesigning urban bridges.

Operationally,sustainability is defined as the responsible design, construction, andmanagement of a healthy built environment (infrastructure) based onresources (water, energy, and materials), efficiency, technologicaladaptability, technically sound, minimal environmental impact, optimal economy,and social equity for the present and future generations. The research focuses on how a professional designer achieves sustainability when designing urban bridges.

The steps for the qualitative data analysis are based on the suggestions made in [19, 20].

Step 1. Transcribing the audio recordings and providing participant ID.

Step 2. Coding or indexing of concepts from the transcribed document or file. This step shall explain the aim of conceptualization of the underlying patterns of urban bridge design practice and its challenges that exist in design process.

Step 3. Decide which code is important and then prepare a list of families. Categories or themes that objectively outline process practice differences and similarity of concepts shall be prepared.

Step 4. Label the categories and create any meaningful connections or networks between them. The categories and connections are the main results of the study. It would be new knowledge about the world from the perspective of the participants in the study.

Step 5. Decide if there is a hierarchy among the categories. Decide if one category is more important than the other and draw a representative figure or an illustrative sketch to summarize the result.

Step 6. Describe the categories found in the study and explain how they are connected or networked without interpreting.

Step 7. Write out the result interpretations and discuss the results found in Step 6. Interpret the results considering the results from previous similar studies and from existing theories or concepts from the perspective of urban bridge design.

Therefore, the analysis of coding is conducted on many concepts, but only the relevant and most important ones are categorized to reach the labels presented in Table 3.

Table 3 shows the detailed code compilation from the participant and the categories that have been prepared. Based on the concept's similarity, the grouped categories were labelled with meaningful concepts aligned to the research question. This question addresses the central theme of the current design practice of urban bridges in Ethiopia. The set of labels identified in the categories of responses would be linked to the variables through a latent content explanation, representing the list of themes.

Table 3: Qualitative data analysis matrix for central theme one.

Interview questions for central theme one	Labelling of categories
(i) How is the design process of urban bridges in Ethiopia?	Dominated by technicality and functionality Fragmented and noncomprehensive design teams Lack of bridge aesthetics Bridge design manuals Contract system is linked with the road system The design parameters are not comprehensive, and safety and durability are the main considerations
(ii) What are the key concept development processes of urban bridge design?	Aesthetic considerations through design competition Structural theories Include holistic parameters Street design concept considerations Functional considerations Landscape considerations Concept implementation
(iii) Whom do you think is responsible for concept development?	Architects/landscape architects Bridge engineer/structural engineer Urban designers Public
(iv) What are the potential sources of inspiration for bridge aesthetics	Nature Built environment Theories
(v) What is the level of relevance of parameters (aesthetic, functionality, and technicality)?	Aesthetics Functionality Technicality
(vi) How is the level of collaboration of designers?	Existing collaboration is little Collaboration is needed between architects, engineers, and stakeholders Collaboration creates an integral design output
(vii) What are the challenges of urban bridge design in Ethiopia?	Lack of integration, coordination, and comprehensiveness of parameters Lack of aesthetical design considerations Approach is too theoretical and technical Client lacks proactive commitment Design lacks concepts of complete street section Lack of public participation and design competition Time and budget constraints

The current design practice has been explained as a more conventional approach, which is dominated by functional and technical provisions. Key concepts in the development process of urban bridge design, such as aesthetics and structural theory, were forwarded. Additionally, different stakeholders are involved in the concept development process. The level of collaboration of professionals was reported as low, even though the understanding of its benefit to producing integral design output is inevitable.

Parameters such as aesthetics, functionality, and technicality were explained to be relevant in the urban bridge design process. The potential sources of inspiration for the aesthetics of urban bridges were nature, the built environment, and theories, whereas current design practice is confronted with the following challenges: lack of comprehensive inclusion of relevant parameters; lack of aesthetic guidelines; lack of resources (such as finance and time) to create an appealing structure; and lack of inclusion of the concept of complete street design.

The second central theme, with detailed questions addressing the sustainability issues in urban bridge design, has been able to capture meaning. The codes were properly compiled from the responses of the participants. The categories have been prepared based on the concept's possible similarity, and then the grouped categories were labelled (Table 4) with meaningful constructs aligned to the research questions. The labelled themes indicate a list of key parameters of sustainability and the challenges of applying the principles.

In general terms, the practice of sustainable urban bridge design in Ethiopia is not practiced, and it was also noted that there was no sufficient awareness of sustainability. It is also perceived that the concept of sustainability demands high competency to execute. The guiding manuals and standards must also be implemented. The current practice also missed to include sustainability parameters in terms of reference of the project.

The criteria to attain sustainability as mentioned by the participants were aesthetics, functionality, technicality, economy, environmental considerations, technological adaptability, institutional culture, street design concept, social, and appropriate materials. In addition, the use of standards and manuals in incorporating the criteria was also crucial to the practice of sustainable urban bridge design. The evaluation and assessment systems of sustainable bridge design are not currently available.

The main challenges to attaining sustainability in the design process were lack of aesthetic considerations; institutional and professional incompetency; lack of complete economic consideration; and lack of technological adaptability. Furthermore, there are less sustainability awareness, methodical process constraints, lack of comprehensive standards and guidelines, and lack of a sustainability framework. The practice of sustainable design would demand a holistic view of the urban bridge structure and the design process.

The labelled concepts, along with the core variables forwarded to the respondents, are networked in Figure 1. The findings showed that there were about seven key variables to be answered by the participant and that new variables emerged to express the design process. The design work of urban bridges in Ethiopia is completely traditional, and part of the design parameters and design professionals were overlooked by the trend.

The perceptions of professionals towards current practices in urban bridge design in Ethiopia have key indications of not evolving towards making the infrastructure efficient. The process demands a paradigm shift in addressing all design objectives. The path depicted in Figure 1 should be carefully noted to change perceptions through the possible articulation of demand for current and future generations.

On the other hand, the investigation into the practice of sustainable urban bridge design in Ethiopia showed that the systems do not have any practice beyond the level of information. The key ways of the conventional practice were creating awareness about addressing the challenges, designing evaluation mechanisms, and proper induction of sustainability parameters (Figure 2).

The shift from conventional design to sustainable design could be realized by incorporating the comprehensive criteria of sustainability such as social, economic, environmental, technical, technological, and institutional culture. The issue of sustainability in the provision of urban bridges needs to be enhanced through performance assessment and evaluation of the designed infrastructure. Understanding the design context and challenges of Ethiopian urban bridges in addressing the issue of sustainability could be another consideration.

Therefore, the pattern of the existing urban bridge can be explained by raising the key issues mentioned in Figure 3, and, of course, the pattern requires the sustainability concepts to be included in the design process to achieve a sustainable design process that can address the critical design requirements and challenges of evaluation and assessment of the design product.

The pattern presented in Figure 3 is the main finding that indicates the relationship between the concepts that emerged from the existing design practice and the shift to the comprehensive design delivery approach which is sustainable design. The pattern of the existing trend of design is explained by the key themes. The design process of urban bridges in Ethiopia consists of key concept development processes for urban bridge design; potential sources of inspiration for bridge aesthetics; the level of relevance of parameters such as aesthetics, functionality, and technicality; the level of collaboration among designers; and the existing challenges of urban bridge design in Ethiopia. The current urban bridge design necessitates the use of sustainability to provide equal benefit to society.

Sustainable urban bridge design would be achieved through sustainability considerations from the conceptual stage to the final design process. It is also important to recognize the importance of identifying critical attributes and locating reliable rating tools and protocols to assess and evaluate design practice. The practice by itself would, in the process, be improved to reach a holistic understanding and implementation of the paradigm of sustainable urban bridge design.

Table 4: Qualitative data analysis matrix for central theme two.

Interview questions for central theme two	Labelling of categories
(i) How is the practice of sustainable urban bridge design in Ethiopia?	Exclusion of sustainability parameters in the TOR Little design practice Demanding high competency Include sustainable guidelines and manuals
(ii) What are the required key criteria to attain sustainability?	Aesthetic provision Appropriate design standard Street design concept Selecting appropriate material Suitable technology Social consideration Institutional competency Economic consideration Functionality consideration Environmental consideration
(iii) How do you evaluate the sustainable design process through the values of aesthetics, economics, environmental, social, institutional, technological, and technical parameters?	No evaluation and assessment systems Functional value Economic value Environmental value Multiple values through multiple attributes Innovativeness of material usage
(iv) What are the challenges to attain sustainability in the design practice of urban bridges?	Methodical process constraints Lacks aesthetic consideration Lack of comprehensive standards and guidelines Institution and professional incompetency Lack of complete economic consideration Lack of sustainability framework Lack of technological adaptability Sustainability awareness

4. Discussion

The discussion section explains and interprets the findings regarding current, traditionally based urban bridge design practices in Ethiopia. The possibility of attaining sustainability through the design would also be discussed based on the existing state of the art in sustainable urban bridges.

4.1. Exploring Urban Bridge Design in Ethiopia. Design is a critical aspect impacting the contemporary world's products, services, processes, and activities, and it is inextricably related to our social well-being. As a result, every design should at the very least meet the user's requirements [21]. The design practice, which is dominantly functional and technical, could not meet the users' demand. The urban bridge design trend in Ethiopia is traditional and should be integral in the consideration of parameters which are key in the infrastructure provision. The process of producing something previously unknown or unseen: a new product, is also known as conceptualization. It is the design's primary synthesis activity [21] evolved in the process.

The current project delivery system, for example, in Germany, is distinguished by its conventional nature, in which the design and construction phases are carried out in sequential order [22]. It has been stated that because the contract with the client is separate, this delivery system is problematic for the smooth collaboration and communication required between the designer and the builder [22]. It should also be emphasized that the delivery of the design and construction work will result in time and cost overruns. However, if the design process followed a design competition for urban bridges, this traditional method of delivery approach has a positive side because bridges are elegant structures that stand in front of nature and humankind. Integrated project delivery (IPD) is a method of project delivery that includes early involvement of project participants; risk/reward sharing; a buy-out stage instead of traditional bidding; and deferring profit paid out until all project tasks are finished [23]. IPD is worth considering in the context of urban bridge design practice in Ethiopia. The collaboration, integration, and communicative delivery process would help to sustain the project.

The researchers believed that the delivery of urban bridges should be reconsidered by conducting a design competition before awarding any contract. For any project scenario, these existing delivery approaches can be swapped out. Therefore, aesthetic consideration through design competition [24] is the key parameter to produce sound concept development.

It is also noted that there is no consensus among scientists as to what to callbridge architecture or bridge aesthetics. Cruz [25] defined architecture and aesthetics as "Architecture is the art and science of designing and building structures, or large groups of structures, in keeping

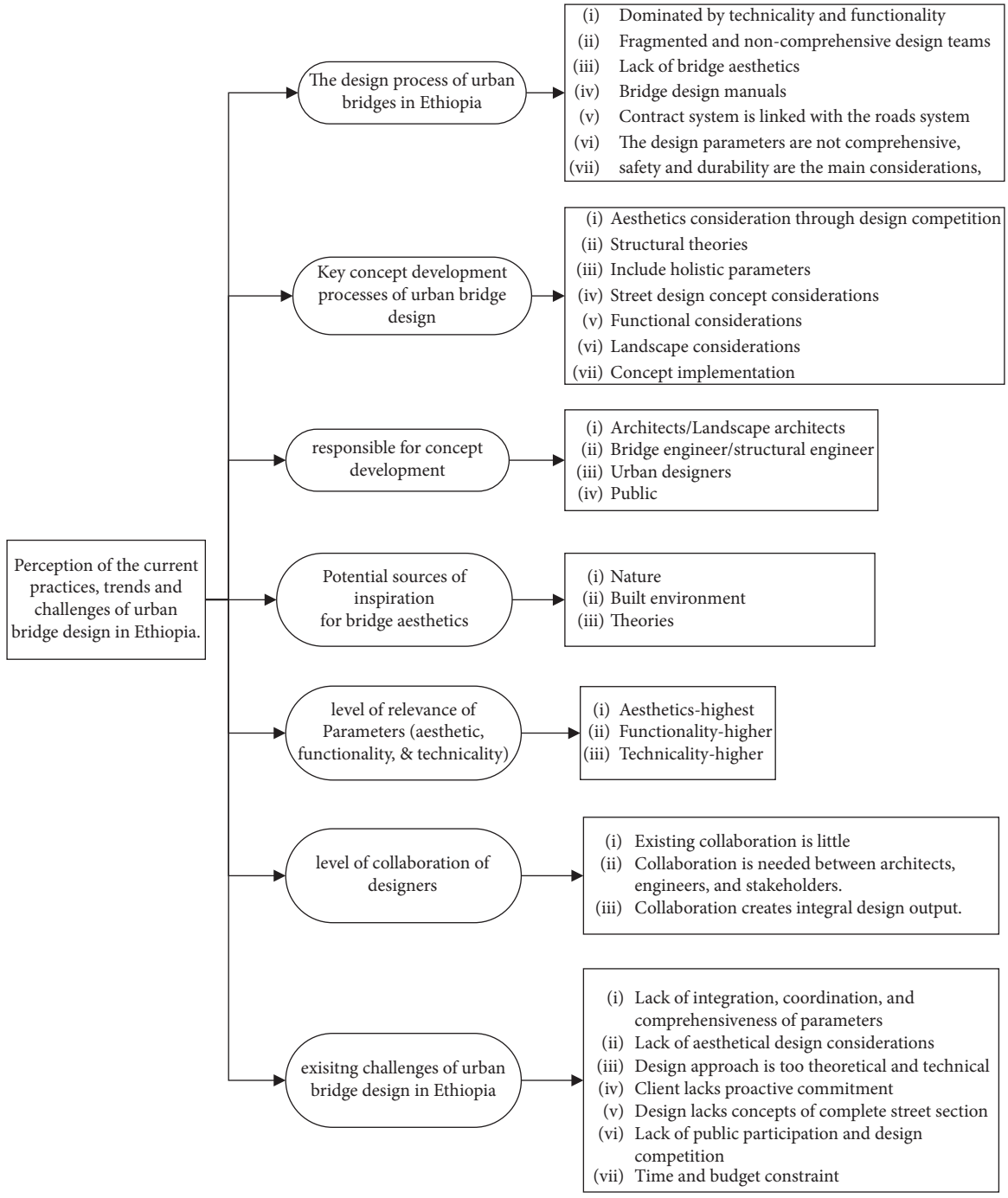

Figure 1: Trends of urban bridge design in Ethiopia.

with aesthetic and functional criteria, or structures built following such principles. Aesthetics, on the other hand, is the science of studying thequalities of an object's beauty and their perception through our senses." The engineering design process addresses the practical aspects of the design, but the aesthetic aspect of bridge design is sometimes overlooked.

"Aesthetic characteristics are expressed not only by the form, colour, light, and shadow of the object but also by the object's immediate surroundings: they are thus also dependent on object environment" [26]. Because the bridge and its surroundings are three-dimensional in space, depending on the angle of view, the vision and impression generated are different. This is not exactly a ground-breaking observation. However, in discussion of structural aesthetics, the effect of a fourth dimension, time, is frequently disregarded. Because the object and the observer exist in the same four dimensions, the observer normally overlooks the impact of time, yet time plays a significant part in the viewer's perception and assessment [27].

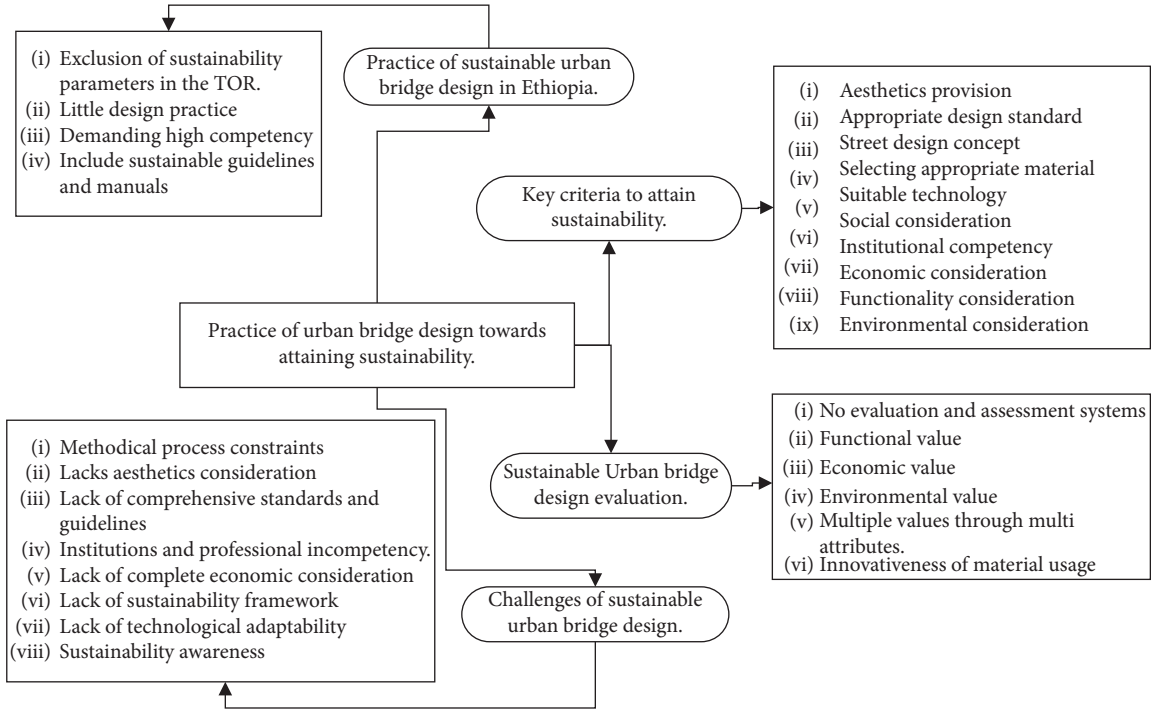

Figure 2: The state of sustainable urban bridge design in Ethiopia.

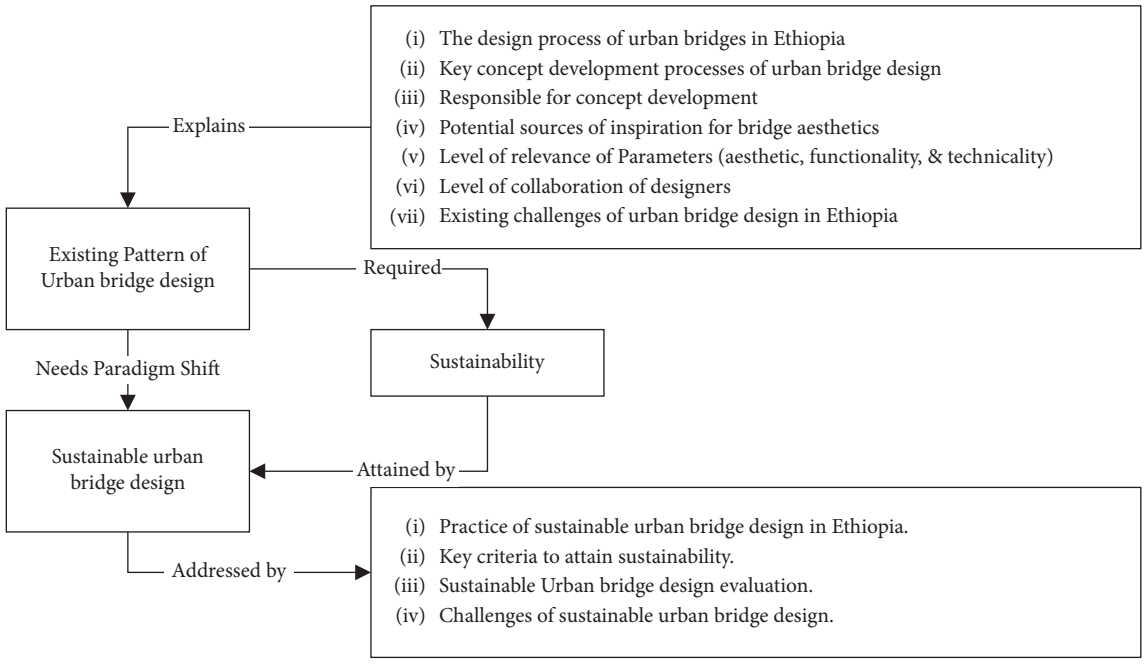

Figure 3: A mechanism of sustainable urban bridge design.

Theessential philosophical question: What is beauty in a bridge? is thestarting point for aesthetics, important rules, or conceptual entities. Functionality, environmental harmony, proportion, order, line, surface, colour, time, context, fashion, and taste have all been mentioned [28]. Aesthetic consideration designing urban bridges is inevitable since the built element is open to public judgment and open to natural integration into the existing urban infrastructure. It is wise to consider the form of the urban bridge in the conceptual stage; otherwise, it would be debatable in the sense of do we practice architectural concepts or not, and if not, why? Is it not our responsibility to be involved in the realization of such an infrastructure in front of our gate? Why are bridge engineers becoming architects in fact, with little practice and

knowledge in aesthetical provision? Why do urban designers become silent in the production of urban bridges in cities and towns?

Taste, which is a function of time, determines public approbation. A new piece of art should represent current tastes, and its creative impact should be in line with modern artistic standards. However, as time passes, artistic expectations and ideas shift. This indicates that until an object achieves a mature degree of appreciation, some variation in appreciation is to be expected, assuming it has the fundamental qualities deserving of such a position and its surroundings are not radically altered [27].

The design approach in general looks for a paradigm that fulfills the current and future requirements which include humanity and the environment. The newly emerging thought of design approach concerning architectural science is nature-based. The nature-guided paradigm signifies that architecture/aesthetics may play a new role in fulfilling the needs of an ever-changing planet by serving as a leading example of thought and action [29]. The previous efforts may have influenced the intellectual framework of modern computer advances, supporting architectural thinking as a holistic model of cross-scientific activity akin to nature's synergistic processes [29]. In the case of urban infrastructure design, the existing built environment must also be considered throughout the design process. Nature is a lesson book for engineering design principles.

The set of tasks that begins with the formulation and modeling of the product design utilizing precise and neutral concepts is derived from needs or ideas. The production of design concepts, which consider the various phases of the physical life cycle, is then followed by the evaluation of the suggested design concepts. These activities are completed by evaluating the design concepts' suitability for the specified needs. A design idea is a set of concepts and technical features that define and explain a system, machine, or component that is practical and capable of meeting all the design criteria [30]. The term chosen here is widely used in engineering design and differs from the perspective of industrial designers [31].

Common bridge design consists of four steps: conceptual, preliminary, detailed design, and shop drawing. The goal of the conceptual design is to provide several possible solutions and choose one or more promising concepts for further consideration. With the use of simple, rough calculations and detailed, large-scale sketches, the dimensions of the cross section and the most critical structural elements are subsequently determined. At this stage, the most essential elements to examine are cost and elegance, as well as the required span length owing to the surroundings effect [32].

According to the classic dissection found in numerous engineering design textbooks, conceptual design is the first step in the engineering design process [33]. The conceptual design process includes tasks such as refining the design problem, evaluating and comparing the concepts developed to solve the design problem, and selecting the concepts created to solve the design problem. Concept development or synthesis, conceptevaluation and comparison, which is adequacy, performance analysis, engineeringrequirements of the environment, and problem analysis are the subprocessesthat make up a conceptual design.

Because the decisions taken during conceptual design govern the whole engineering design process, this activity is regarded as the most important in engineering design. As a result, the process described above should not be viewed as a linear process but rather as a complex activity involving several contributors from various fields. The cost of the product being developed is merely one of the performance criteria [31].

The cost, performance, dependability, safety, and environmental effects of a product are all influenced by the decisions made during the conceptual design. Design decisions are thought to account for more than 75% of final product prices [34]. Researchers noticed the impact of design decisions on downstream activities in the early 1980s. As a result, various methodologies have been proposed, including design for assembly, design for manufacturing, and concurrent engineering. These approaches have also been implemented using software tools. Most of these tools, however, are only useful during the detailed design process. Even the finest level of detailed design, however, cannot make up for a bad design concept created during the conceptual design process [34].

Due to the nature of linking separated items, designing bridges has been a tremendous chance and privilege for designers since then. While the process may appear repetitious, it also involves the capacity to identify problems and formulate them into solvable situations. In Ethiopia, the customary practice is to focus solely on the functional fulfillment of the product with the addressed problems, with the problem being approached in a unidirectional manner. The challenge of bridge design requires a holistic or systemic approach. Even though urban bridges are intended to deal with the effect or consideration, a realistic articulation of the problem of the dynamicity and complexity of the urban area is required.

In today's bridge design, appearance is significantly more essential than it was a few years ago. To incorporate the neighbouring built fabric, conceptual development is becoming increasingly important. Urban bridges are considered a critical infrastructure for seamless connectivity between places, urban mobility, improving accessibility, reducing barriers, and adding value if spaces underneath them are used [35]. This affirms that concept inspiration would emerge from natural environment, built environment, landscape considerations, and different theories.

A bridge must transmit a service (such as highway or railway traffic, a footpath, or public utility) across an obstacle (such as another road or railway, a river, or a valley) and convey weight from the service to the foundations at the ground level. The functional aspects that have the most impact on a bridge's conceptual design noted [35, 36] are "aesthetic and environmental aspects, the topography and geology of the site, the clearance requirements for impact avoidance of the type and magnitude of the loading to be carried out, local constructional skills and materials, methods of erection, and future inspection and maintenance." These factors cannot be ranked in any specific order

of significance; their relative value will change from project to project, and each must be evaluated on its own merits [35].

Lack of integration, coordination, and comprehensiveness of parameters; absence of aesthetic design considerations; design approach that is too theoretical and technical; lack of proactive commitment on the part of the client; lack of concepts for a complete street section; absence of public participation and design competition; and time and budget restraints are some of the gaps identified in the study. The list of challenges may be longer because the design was fragmented and conventional in its execution. It is true that a higher amount of change would occur if tradition were to give way to sustainability.

4.2. Urban Bridge Design in Ethiopia towards Sustainability. The second theme was how to include sustainability into the design process. There are three major stages or processes involved in the design of any infrastructure [37]. These are input (knowledge and experience about the object), a process which deals about design activities and procedures (design code requirement, time, economy, construction method, design objectives, design culture, design technology public requirement, client requirement,environmental requirements, social requirement, and institutional culture), and output (description and justification of the object).

Bridge designers, engineers, and maintenance crews, of course, have been using green, sustainable techniques for decades. These include things like utilizing rapid technology, employing prefabricated components and recycled or reused materials, and designing for a longer lifespan through more deliberate and durable designs. That is, however, simply the beginning. This effort can go a long way if things like designing structures and selecting materials based on a bridge's potential life (centuries versus decades), considering long-term economic and environmental costs rather than immediate benefits, using innovative materials and technologies, being more collaborative during the design and construction processes, and thinking about how a bridge can bring lifestyle benefits—and perhaps even delight—to its community are considered.

Most models of the design process are derived from an individual's own experience or are adapted from models of the decision process developed for other fields. The whole system design framework [38, 39] comprises the design process, design principles, and design methods as an input for the system [39]. These components have played a role in efficient whole-system design practice.

Sustainability does not require a loss in quality of life but does require a change in mindset, a change in value towards less consumptive lifestyles. These reforms must include global interdependence, environmental care, social responsibility, and economic viability. Sustainable design must take a different approach than traditional design to embrace these changes in mindset. The innovative design approach must recognize the impacts of every design choice on the natural and cultural resources of the local, regional, and global environments.

Thus, the definition of sustainable design that guides this research is as follows: sustainable design is an alternative approach to traditional design, which leads toward a less consumptive mindsetthat embraces global interdependence, environmental stewardship, socialresponsibility, economic viability, and technological systematics and considersthe impacts of design choices at local, regional, and global levels.

While traditional design and building prioritize cost, performance, and quality, sustainable design and construction add to these criteria the reduction of resource depletion and environmental degradation as well as the creation of a healthy built environment [40, 41]. This model of the new sustainability paradigm shows the issues that must be considered for design making at all stages of the life cycle of the facility [42].

Sustainable designers and builders will approach each project with the facility's complete life cycle in mind, not just the initial capital expenditure. Instead of viewing the constructed environment as a separate entity from the natural environment, it should be understood as a component of the natural flow and exchange of matter and energy within the biosphere. In addition to the nonliving components that comprise the built environment, sustainable designers and builders must consider the living components of the built environment (flora, fauna, and humans), which operate as a whole system in the context of other ecosystems in the biosphere [43].

A sustainable design practice can help to create sustainable infrastructure. The process of designing infrastructure needs to fulfill the key major elements as outlined in [9] as material selection, economic considerations, social considerations, environmental considerations, technical considerations, policy and regulations, design and project management, and design professionals and the design process.

The design process of attaining sustainability is framed by factors, parameters, and indicators. Material selection is one of the factors for sustainable infrastructure. The fact that resources are limited is not deniable, and thus designers should devise a method for the selection of materials. Everything is interrelated and balanced in the world's design. It was designed with a holistic approach [44].

Bridges have been vital for society from the dawn of time when the connection between and among villages, cities, and communities became possible. Until recently, the sole element considered in the decision-making process for any form of the bridge construction process was the cost. However, currently, the goal should be to build sustainable bridges rather than merely bridges. From design until deconstruction, different sustainable criteria and approaches are employed for decision making at each phase of a bridge's life cycle [45]. The parameters provided, however, are centred on the planning and design stages, even if a holistic perspective of the design process would undoubtedly benefit the other phases.

Since there are no legal restrictions, the existing design practice in Ethiopia does not take sustainability into account in its entirety. This is due to the industry's lack of readiness as well as the fact that it is not currently practiced. To obtain

linked services from the infrastructure, it will be necessary to adopt sustainability concepts given the existing demand for infrastructure facilities in urban areas. It is crucial that all specialists involved in the design of urban bridges share a common perspective.

Challenges have also been noted in the research which can be framed into two issues: the professional's and institution's level of awareness towards the principle of sustainability and the lack of well-established working models or framework. This can be viewed in the form of guidelines, protocols, or even on the level of code of practice in the urban built environment provision. The rating tools, evaluating protocols and assessing guidelines, shall be put in place in the working environment. Professional and institutional competencies will be enhanced through career development and collaboration practices among practitioners.

5. Conclusion

This research has explored the process of designing urban bridges in Ethiopia. It was quite interesting that the practice of design work was inclined towards the delivery of the functional requirements of mobility and safety. The mere understanding of the professionals was as simple as connecting points that were distant in space, while the following issues with the present design practice must be addressed: lack of aesthetic standards; insufficient resources such as money and time to build an attractive structure; and lack of thorough incorporation of the notion of comprehensive street design. Although the design process falls into conventionality, which does not have a clear objective synthesis and problem formulation, there is a potential to understand the existential problems.

The concept of sustainability in urban bridge design has little understanding. The factors, which are key in addressing the design problem, were centred on five dimensions. The dimensions are technological adaptability, technical soundness, minimal environmental impact, optimum economy, and social equity for the present and future generations. The challenges of urban bridge design in attaining sustainability are also essential to be noted here. Lack of aesthetic consideration, institutional and professional incompetence, lack of full economic analysis, and lack of technical adaptation were the key obstacles to achieving sustainability in the design process. Additionally, there is a lack of comprehensive norms and rules, a sustainability framework, rigorous process constraints, and sustainability awareness. A thorough understanding of the urban bridge structure and the design procedure would be necessary for sustainable design practice.

The question of how to manage changes in sustainability in the case of urban bridge design is practically necessary for producing well-informed designers and planners to meet the required design and planning objectives. Whatever the theoretical position, there are performance measurement and rating tools available to indicate the current level of change. The change management study towards sustainability principles and sustainable design practice will be the future topic of study. Exploring current trends and highlighting challenges would be a primary goal for sustainable design practice.

Data Availability

The data used to support the findings of this study are available upon request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors contributed to the study's conception and design. Document preparation, data collection, and analysis were performed by Leule M. Hailemariam. The first draft of the manuscript was also written by Leule M. Hailemariam, and all authors commented on previous versions of the manuscript. All authors have read and approved the final manuscript.

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