International Journal of Bridge Engineering (IJBE), Vol. 11, No. 2, (2023), pp. 01-30

A MULTI-CRITERIA DESIGN FRAMEWORK FOR SUSTAINABLE URBAN BRIDGES IN ETHIOPIA

Leule M. Hailemariam[1], Denamo A. Nuramo [2]

[1,2] Ethiopian Institute of Architecture, Building Construction and City Development (EIABC), Addis Ababa University (AAU), Addis Ababa, Ethiopia,
e-mail: [1]leule.mebratie@eiabc.edu.et, [2]denamo.addissie@eiabc.edu.et

ABSTRACT

The primary aim of delivering bridge infrastructure is to provide a link between two distinct objects that are separated by different obstacles. Bridges, although, are more than just a means of connecting in regard to identifying and solving the problem, and it is not just the physical barrier that is relevant. The urban world is a complicated and complex system that cannot be solved by thinking in terms of problems and solutions linearly but rather as a multifaceted system that needs integration, collaboration, problem formulation, and interpretation. The design process necessitates a collective approach from professionals for urban mobility, accessibility, and aesthetics to be fully integrated into product creation. The current practice of bridge design lacks theoretical multicriteria frameworks for a clear and sound decision. The provision of sustainable bridge infrastructure for improved connectivity and convenient urban mobility for people, goods, and services necessitates comprehensive frameworks in urban infrastructure construction work. Sustainable urban bridge provision cannot be accomplished by focusing solely on a few conceptual parameters; rather, it necessitates an integrated view of multiple concepts. Thus, the research identifies multiple attributes for attaining sustainable urban bridges. Using the principal component analysis, five main parameters were identified as being essential for the development of the multicriteria framework. The design problems and objectives that must be addressed to satisfy critical requirements at various design stages are clearly laid out in the framework.

KEYWORDS: Multi-criteria, Framework, Urban bridge, Design, Sustainability.

1 INTRODUCTION

The process of rapid urbanization has a visible effect on the strain of delivered urban infrastructure, especially on the bridge infrastructures [1]. The effect of unguided rapid urbanization also creates resource depletion in the production of the built environment. The resources consumed during the realization of infrastructure and the rapidly changing technology are critical parameters in development of a multicriteria framework for designing a sustainable urban bridge. Sustainable urban bridge design is both a process and a product-oriented activity that necessitates a consistent assessment and evaluation procedure.

Frameworks can help people grasp and apply ideas that might otherwise be difficult to understand. A food pyramid is a diagram that shows us how to eat a healthy diet. Six Sigma and the Plan-To-Check-Act cycle are frameworks for implementing quality improvement initiatives in enterprises. Frameworks include sustainable building rating systems including LEEDS in the United States and BREEAM in the United Kingdom. They assist practitioners in bringing the concept of sustainable buildings into practical processes and activities [2]. Through the notion of sustainability and its models and frameworks, the overall view of infrastructure design and the frameworks connected to design work will be examined in the context of an urban bridges. In the section's ensuing discourse, common understandings regarding the questions of how and why will also be discussed.

A comparable tool for the design process might be based on the thoroughly defined framework for sustainable entire systems design. This framework for entire system design, like the food pyramid, is supposed to make abstract notions more real. The framework can aid in more effective teaching in this area as well as the more widespread use of whole systems design in practice, both of which will result in more sustainable designs [2]. Even though [2] claim it is a comprehensive system design with all available factors, the consideration of sustainability in terms of five-dimensional sustainability pillars is not well thought out.

The design process, regardless of the approach, must have a specified framework to be recognized in practice, and these frameworks will be a major input to get the best design outcome. The models, as can be seen, have parameters in them, and they are the major pillars of the framework and models on which they are founded. In terms of synthesizing the whole design and construction processes, bridges are not a type of linear infrastructure that requires simple guiding models and frameworks for design work to be achieved. However, models and frameworks must be well articulated to cover all important criteria. Bridges are built using a variety of conceptual stances and theoretical backing.

The parametric considerations that holistically combine practically all relevant features to create a very sustainable and resilient design result have been constrained in the design models and frameworks used so far. As a result, the full range of factors or criteria will be investigated in this study, and frameworks for sustainable design work have been developed. Developing a multicriteria framework for design activities and conceptualizing the decision-making process for addressing sustainable design practice would be the central themes of the research. As a result, the goal of the study would be to find the principal parameters for the design of sustainable urban bridges.

2 METHOD

A quantitative approach is a method that emphasizes objective measurements and statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating preexisting statistical data using computational techniques [3]. Primary data would be collected from practicing professionals and experts who are directly or indirectly got a chance to work on the area of urban bridge design.

Quantitatively, the data collection instruments adopted for this research include survey questionnaires for the primary data that would be collected. The survey questionnaire would be developed based on a substantial review of the literature. The data that would be collected is from practicing professionals, consultants, and planners who are registered in the Ethiopian Ministry of Urban Development and Construction, Construction Industry Development & Regulatory Bureau. And each respondent would be selected based on the bridge infrastructure design involvement in practice. The data collection tool here would be the surveyed questionnaire type. The questionnaire is one of the instruments that help to get first-hand information on the subject matter of the research as it focuses on issues which further serves as a survey to understand the main criteria, mechanisms, concerns, and attitudes of respondents towards the research questions.

In the survey research, structured questionnaires will be administered to the respondents by using a probabilistic sampling technique. Because all registered practicing professionals and consultants in the area have an equal chance of probability to be selected and within probability sampling, the stratified sampling subtype would be sound for the nature of the population for the survey study.

The stratified sampling approach is used to obtain a representative sample when the population from which the sample is to be drawn does not consist of a homogeneous group [4]. Under this technique, the population is divided into various classes or subpopulation, which is individually more homogeneous than the total population. The different subpopulations are called strata, i.e., Architects, Urban planners, Bridge engineers, and Structural engineers. Then certain items are selected from the classes by the random sampling technique. Since each stratum is more homogeneous than the total population, it can get more precise estimates for each stratum. By estimating more accurately each of the parts of the population, with a better estimate of the whole population. In other words, the population will be broken into different strata based on one or more characteristics.

The design practice in Ethiopia is allowed only to practicing professionals who have proven knowledge and experience in the area. Moreover, the sample size will be determined based on the 95% (z-score of 1.96) confidence level and 10% margin of error. Equation 1 is used to determine the sample size since the population is finite:

$$\text{Sample size} = \frac{\left(\frac{\left(z^2 \times p(1-p)\right)}{e^2}\right)}{\left(1+\frac{\left(z^2 \times p(1-p)\right)}{Ne^2}\right)} \quad (1)$$

Where p=50%, percentage picking or population proportion, e=margin of error, and N= population size.

The population size (registered professional practicing architects, urban planners, bridge engineers, and structural engineers) is collected from the ministry of Construction of FDRE (Federal Democratic Republic of Ethiopia). The estimated numbers of registered professionals in 2021 who are practicing in the area are counted as about (N= 2532).

Therefore, the required computed sample size for the questionnaire survey is (n= 92) architects, urban planners, bridge engineers, and structural engineers, and to account the higher response number to questionnaire surveys, a relevant response rate of 20 – 30% is believed to be the norm [5]. Based on this reasoning, it was necessary to adjust the sample size to account for non-response. The ideal sample size to conduct the survey was determined to be 307, assuming a response rate of 30%. However, 204 individuals provided a response, representing a response rate of 67%.

The data collected from respondents were analyzed using a factor analysis technique, so identified parameters based on respondents' level of agreement on many factors were essentially reduced to the main factors. Principal component analysis was utilized to discover the variables using exploratory factor analysis. The measurement model testing was also conducted through a confirmatory factor analysis since such a technique clearly measures the model's fitness.

3 RESULTS

3.1 Data statistics

The demographic data of the respondents is stated below in the cross-tabulation of specialization based on their education and or experience and years of design experience in bridge infrastructure.

Figure 1 demonstrates the cross-tabulation between respondents' specialization and years of experience in bridge infrastructure design. The number of professionals who specialize in bridge engineering with an experience of 6 years is 11. Those who have more than 6 years, but less than 20 years of experience count as 6 in total. Additionally, there is one practicing expert with more than 20 years of experience in the field of bridge engineering.

To assist the practice of sustainable urban bridge design, the research questions were arranged by posing main criterion questions and supporting these with sub-criteria statements that measured each component of the multicriteria framework. A multicriteria framework is one that considers several factors that relate to the widespread application of concepts, ideas, and procedures that are challenging to comprehend.

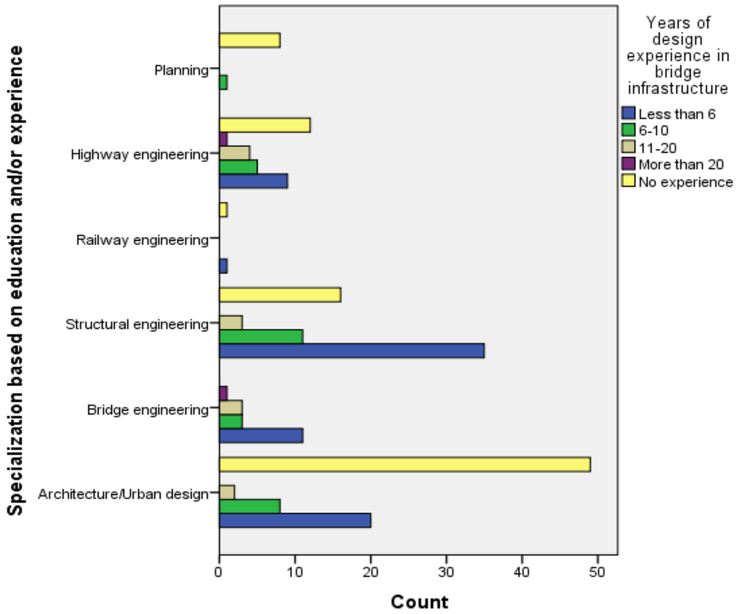

Figure 1. Crosstabs of specialization and years of design experience

The suitable ways of asking questions to the respondent were found to be by collecting their level of agreement or disagreement depending on the level of importance of the criteria forwarded. And the questions were asked to be filled in a Likert scale measurement with a scale of 1 to 5. Rating on a scale of 1 to 5 criteria provided in terms of their importance in the sustainable urban bridge design (1= not important, 2=low importance,3= neutral, 4= important & 5 = essential).

The five main statements have been able to be measured using the subsequent statements to be rated and by transforming the data using statistical mean and the means have also been coded in a different code within a range. The range from 1.00 to 1.79 was coded as '1', from 1.80 to 2.59 coded as '2', from 2.60 to 3.39 coded as '3', from 3.40 to 4.19 coded as '4' and finally from 4.20 to 5.00 was coded as '5'.

The data has been tested for its reliability consistency of the questionnaire and the result was conducted by using Cronbach's Alpha and found it to be 0.970 for 62 items to be included in the survey questionnaire was reliable for further statistical analysis. The data which is collected from 204 samples of respondents shall also be tested for normality whether the data values are sampled from a population that follows a normal distribution or not. The test of normality along with statistical graphs(computations) was conducted for hypothesis testing. The descriptive statistics are listed in Table 1.

Table 1. Descriptive of identifying sustainability criteria

Descriptive				
			Statistic	Std. Error
Social Criteria	Mean		4.2059	.05589
	95% Confidence Interval for Mean	Lower Bound	4.0957	
		Upper Bound	4.3161	
	5% Trimmed Mean		4.2560	
	Median		4.0000	
	Variance		.637	
	Std. Deviation		.79825	
	Minimum		2.00	
	Maximum		5.00	
	Range		3.00	
	Interquartile Range		1.00	
	Skewness		-.681	.170
	Kurtosis		-.269	.339
Environmental Criteria	Mean		4.1275	.06072
	95% Confidence Interval for Mean	Lower Bound	4.0077	
		Upper Bound	4.2472	
	5% Trimmed Mean		4.1906	
	Median		4.0000	
	Variance		.752	
	Std. Deviation		.86727	
	Minimum		2.00	
	Maximum		5.00	
	Range		3.00	
	Interquartile Range		1.00	
	Skewness		-.662	.170
	Kurtosis		-.414	.339
Economic Criteria	Mean		4.2206	.05753
	95% Confidence Interval for Mean	Lower Bound	4.1072	
		Upper Bound	4.3340	
	5% Trimmed Mean		4.2996	
	Median		4.0000	
	Variance		.675	
	Std. Deviation		.82173	
	Minimum		2.00	
	Maximum		5.00	
	Range		3.00	
	Interquartile Range		1.00	
	Skewness		-.967	.170
	Kurtosis		.535	.339
Institutional Criteria	Mean		4.3676	.05802
	95% Confidence Interval for Mean	Lower Bound	4.2532	
		Upper Bound	4.4821	
	5% Trimmed Mean		4.4466	
	Median		5.0000	
	Variance		.687	
	Std. Deviation		.82875	
	Minimum		2.00	
	Maximum		5.00	

	Range		3.00	
	Interquartile Range		1.00	
	Skewness		-1.144	.170
	Kurtosis		.469	.339
Technical and Technological Criteria	Mean		4.3627	.05670
	95% Confidence Interval for Mean	Lower Bound	4.2509	
		Upper Bound	4.4746	
	5% Trimmed Mean		4.4357	
	Median		5.0000	
	Variance		.656	
	Std. Deviation		.80990	
	Minimum		2.00	
	Maximum		5.00	
	Range		3.00	
	Interquartile Range		1.00	
	Skewness		-1.092	.170
	Kurtosis		.405	.339

The descriptive of the five main criteria were described in the table below and for the sake of testing normality, the extent of which the skewness and kurtosis can be observed and can be able to tell the level of normality by computing the ratio of statistical skewness or kurtosis over the standard error if its z value range from -3 to +3, it is assumed to be normally distributed. But this process doesn't always work due to the low and high number of samplings. The z-score value of the samples (for example, taking skewness as a measure of social criteria, z-score=-0.681/0.170=-4.00) doesn't fall in the range specified, therefore it is suggested that the distribution is not normally distributed. However, the test of normality would be sound if other methods such as Shapiro-Wilk were employed. Therefore, the test for the hypothesis was conducted using Shapiro-Wilk test of normality as shown below (Table 2).

Null hypothesis (Ho): The data values sampled are normally distributed.

Alternative hypothesis (H1): The data values sampled are not normally distributed.

Table 2. Test of normality of sustainability criteria

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Social Criteria	.257	204	.000	.808	204	.000
Environmental Criteria	.245	204	.000	.821	204	.000
Economic Criteria	.250	204	.000	.788	204	.000
Institutional Criteria	.336	204	.000	.739	204	.000
Technical and Technological Criteria	.328	204	.000	.748	204	.000

a. Lilliefors Significance Correction

Both the test of normality using Kolmogorov-Smirnov and Shapiro-Wilk resulted in the same significance amount (0.001) which is less than the p value of 0.05 and this test suggests that there is a significant deviation of the sampled data distributions from a population that follows a normal distribution. Before just rejecting the null hypothesis, it is also suggested to observe quantile-quantile (Q-Q) plots or the frequency distribution histograms of descriptive statistics. The following graph show the frequency distribution histogram of the data sampled for the respective criteria (Figure 2 & Figure 3). The plot for all of them tends to offset to one direction and does not have a normal distribution.

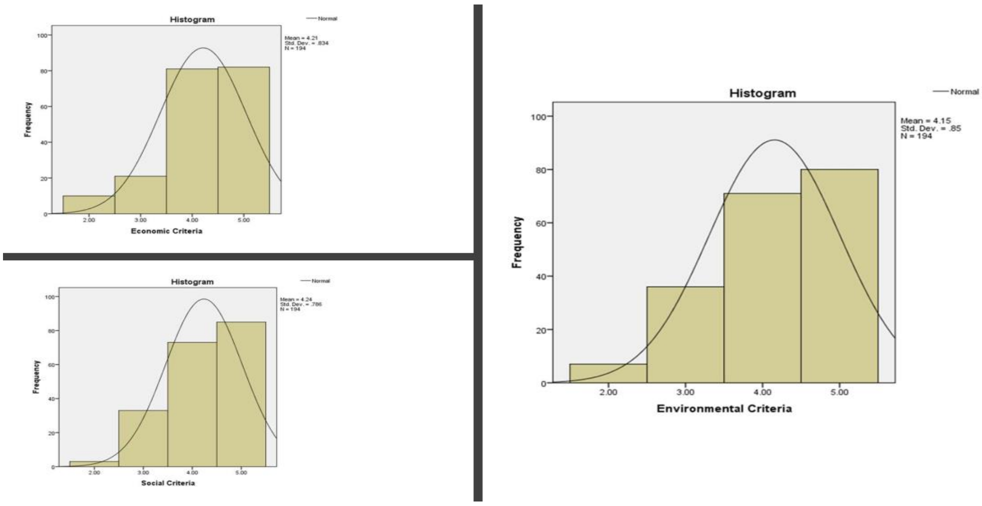

Figure 2. Frequency distributions of sustainability criteria (1)

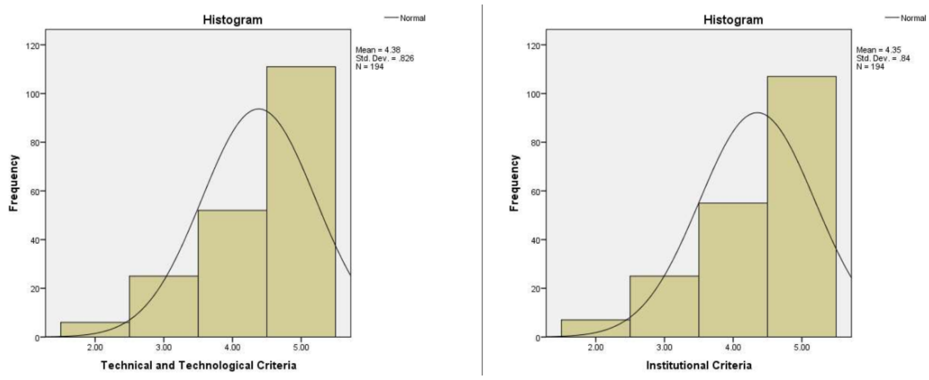

Figure 3. Frequency distributions of sustainability criteria (2)

Therefore, based on the above justifications, the null hypothesis is rejected, and the alternative hypothesis is accepted, and the data value of the samples to assess the applicability of sustainability in the design of urban bridges is not normally distributed. This calls for a study of nonparametric testing of the data.

The Spearman rank order correlation can be employed to the data if the data has a characteristic of monotonicity (the value of one variable would increase or decrease as the value of the other variables increase or decrease, respectively) the distribution of the data shall also be linearly related. As can be seen from the relationship of the variables, Figure 4 illustrates a scatter dot plot matrix of the five variables. The variables of having a good linearity and monotonicity are institutional criteria and technical and technological criteria and environmental criteria and economic criteria. This finding would also be checked using Spearman's rank order correlation coefficient (Table 3).

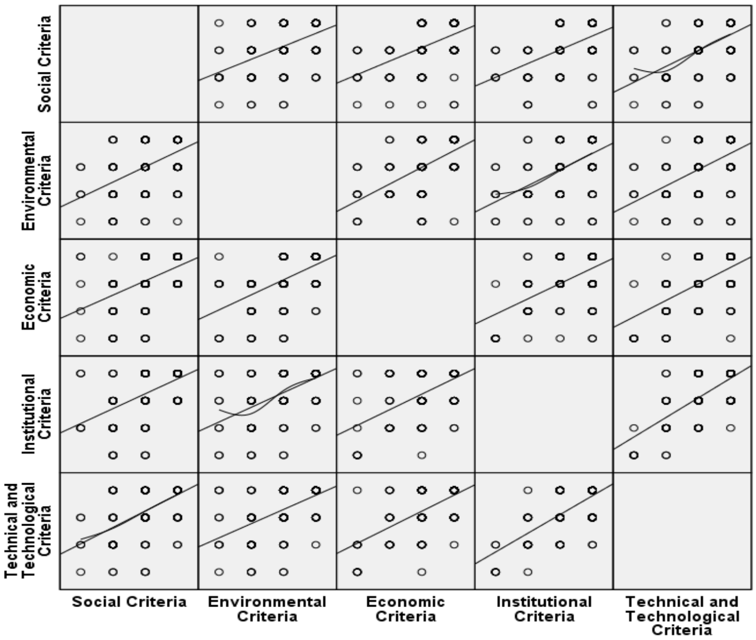

Figure 4. Scatter dot plot matrix of sustainability criteria

The Spearman's coefficient(r) and p-value of each variable can be implied for the decision whether the variables are significantly correlated or not. Association is measured using the range of r values suggested by [6] as absolute magnitude of the observed correlation coefficient interpretation, 0.00–0.10, Negligible correlation, 0.10–0.39, Weak correlation, 0.40–0.69 Moderate correlation, 0.70–0.89 Strong correlation, 0.90–1.00 Very strong correlation. All Spearman r coefficients are positively correlated with a moderate association at a 1% significance level. Table 3 clearly shows that the variables of institutional criteria and technical and technological criteria showed a moderate correlation in the positive direction (r=.604, p=.001, N=204). In addition, environmental criteria and economic criteria have got a moderate association with a correlation coefficient (r=.624, p=.001, N=204).

Table 3. Nonparametric correlations of sustainability criteria

Correlations

			Social Criteria	Environmental Criteria	Economic Criteria	Institutional Criteria	Technical and Technological Criteria
Spearman's rho	Social Criteria	Correlation Coefficient	1.000	.518**	.517**	.503**	.598**
		Sig. (2-tailed)	.	.000	.000	.000	.000
		N	204	204	204	204	204
	Environmental Criteria	Correlation Coefficient	.518**	1.000	.623**	.573**	.569**
		Sig. (2-tailed)	.000	.	.000	.000	.000
		N	204	204	204	204	204
	Economic Criteria	Correlation Coefficient	.517**	.623**	1.000	.512**	.516**
		Sig. (2-tailed)	.000	.000	.	.000	.000
		N	204	204	204	204	204
	Institutional Criteria	Correlation Coefficient	.503**	.573**	.512**	1.000	.604**
		Sig. (2-tailed)	.000	.000	.000	.	.000
		N	204	204	204	204	204
	Technical and Technological Criteria	Correlation Coefficient	.598**	.569**	.516**	.604**	1.000
		Sig. (2-tailed)	.000	.000	.000	.000	.
		N	204	204	204	204	204

**. Correlation is significant at the 0.01 level (2-tailed).

3.2 Exploratory factor analysis

The 62 variables of sustainability criteria have also been explained in factor analysis in the following discussions to reduce the large number of dimensions available. However, 18 variables were excluded in the component analysis since the factors do not load substantially and some of them also loaded in to more than one component. The factor extraction method employed was Principal Component Analysis with orthogonal rotation using a method of Varimax with Kaiser normalization. The steps followed are stated below:

-Step 1. Determine KMO and Bartlett's Test of Sphericity and if the results range within a 5% significance level and KMO more than 0.500, proceed with FA analysis.

-Step 2. Compute the communality by the given extraction and rotation method and observe the value of extraction shall be more than 0.500.

-Step 3. Explain the total cumulative variance of the generated components and they should explain more than 50% of the total variance of the components and observe the eigenvalue which should be more than 1. It is also good to do parallel analysis by using Monte Carlo PCA simulations to determine which eigenvalues

shall be considered.
-Step 4. Finally, check the components in the rotated matrix thoroughly if there is any overlapping and crossing over of component factors.
-Step 5. Validity and reliability of the component factors shall be checked.

EFA is mainly used in research that divides up many variables (observed variables) into smaller, more manageable factors but unobservable. Investigating whether there is any smaller number of unobservable factors in the 44 multiple variables that measure identifying multi-attributes of sustainability in urban bridge design on which the data is available. Initially items identified to measure the type of criteria of sustainability were 62, the intention would be to assess if there are any underlying dimensions. The excluded 8 variables were unable to comply with the requirements identified in the EFA analysis.

Table 4. KMO and Bartlett's test of sphericity of sustainability criteria

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.905
Bartlett's Test of Sphericity	Approx. Chi-Square	8222.862
	df	946
	Sig.	.001

A statistic called the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is used to assess the suitability of factor analysis depending on the study's sample. Kaiser has presented the range as follows: statistic >0.9 is marvelous, >0.8 meritorious, >0.7 middling, >0.6 mediocre, >0.5 miserable, and <0.5 unacceptable. Therefore, KMO=0.905 (Table 4) is an acceptable sample size for EFA.

It is determined whether the population correlation matrix is an identity matrix using Bartlett's test of sphericity. The existence of the identity matrix raises doubts about the validity of the factor analysis. P value less than 0.05 show that the population correlation matrix is not an identity matrix. Table 4 shows a p value of 0.001, which signifies that the population correlation matrix is not an identity matrix and EFA can be conducted.

In order to account for the common and unique variances of the factors using a rotation method of Varimax, EFA is carried out with the assumption that orthogonal rotation would produce insignificant correlations between factors. Therefore, after many iterations of loading and excluding the cross loadings and loadings of less than 0.5, a communality of factor extraction is observed (Table 5) and 44 communalities are considered in the analysis.

Table 5. Factor communality extracted from sustainability criteria

Communalities		
	Initial	Extraction
SOC4	1.000	.698
SOC5	1.000	.704
SOC6	1.000	.526
SOC7	1.000	.661
ENC1	1.000	.621
ENC2	1.000	.711
ENC3	1.000	.658
ENC4	1.000	.675
ENC5	1.000	.684
ENC6	1.000	.726
ENC7	1.000	.576
ENC8	1.000	.644
ENC13	1.000	.611
ECC2	1.000	.683
ECC3	1.000	.791
ECC4	1.000	.735
ECC5	1.000	.698
ECC6	1.000	.766
INC1	1.000	.575
INC2	1.000	.732
INC3	1.000	.692
INC4	1.000	.613
INC5	1.000	.706
INC6	1.000	.732
INC7	1.000	.717
INC8	1.000	.661
TAC1	1.000	.614
TAC2	1.000	.534
TAC6	1.000	.640
TAC8	1.000	.587
TFC1	1.000	.624
TFC3	1.000	.679
TFC5	1.000	.677
TFC6	1.000	.662
TTC1	1.000	.588
TTC2	1.000	.526
TTC3	1.000	.687
TTC4	1.000	.817
TTC5	1.000	.668
TTC6	1.000	.556
TTC8	1.000	.629
TTC9	1.000	.534
TAC4	1.000	.597
TAC5	1.000	.573
Extraction Method: Principal Component Analysis.		

The amount of variance in the study's chosen variable that is connected to a factor is known as its eigenvalue. The elements with more than one eigenvalue are included in the model according to the eigenvalue criterion. Scree Plot: The eigenvalues and component (factor) number are plotted in the Scree Plot in the order of extraction. The optimal number of elements to be preserved in the final solution is determined using the plot's form (Figure 5).

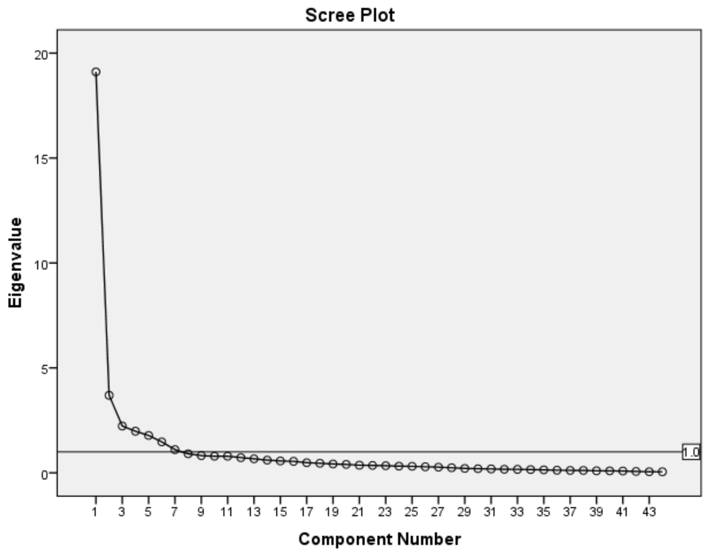

Figure 5. Scree plot of sustainability criteria

The Monte Carlo PCA parallel analysis (Figure 6) has also been able to confirm five parameters with and eigenvalues less than the standard PCA analysis. The comparative graphical solution is provided in Figure 7.

The Scree plot's goal is to visually distinguish an elbow, which is the location when the eigenvalues start to form a linear falling trend. Criteria for Percentage of Variance: It provides the proportion of variance that can be assigned to any factor in relation to the sum of all other factors' variances. The idea of the cumulative percentage of variance serves as the foundation for this strategy. The number of factors that the model should consider when the cumulative percentage of variation reaches an acceptable level. It is generally advised that the components contributing between 60% and 70% of the variation be kept in the model. Table 6 shows that there is more than 65% variation explained by the five components.

```
Monte Carlo PCA for Parallel Analysis
Version .

9/1/2022   11:17:46 PM
Number of variables:     44
Number of subjects:     204
Number of replications: 100

+++++++++++++++++++++++++++++++++++++++++++++++++++++
Eigenvalue #     Random Eigenvalue     Standard Dev
+++++++++++++++++++++++++++++++++++++++++++++++++++++
      1              2.0372               .0686
      2              1.9166               .0453
      3              1.8216               .0408
      4              1.7535               .0357
      5              1.6835               .0311
      6              1.6198               .0331
      7              1.5622               .0272
      8              1.5115               .0284
      9              1.4577               .0285
     10              1.4136               .0254
     11              1.3684               .0235
     12              1.3225               .0251
     13              1.2797               .0242
     14              1.2345               .0245
     15              1.1964               .0220
     16              1.1595               .0212
     17              1.1209               .0198
     18              1.0851               .0219
     19              1.0499               .0234
     20              1.0161               .0181
     21              0.9809               .0189
     22              0.9495               .0201
     23              0.9152               .0187
     24              0.8825               .0199
     25              0.8513               .0166
     26              0.8226               .0160
     27              0.7920               .0168
     28              0.7605               .0172
     29              0.7323               .0165
     30              0.7030               .0150
     31              0.6755               .0144
     32              0.6481               .0162
     33              0.6216               .0152
     34              0.5960               .0157
     35              0.5678               .0160
     36              0.5428               .0178
     37              0.5163               .0165
     38              0.4881               .0143
     39              0.4626               .0136
     40              0.4353               .0180
     41              0.4074               .0174
     42              0.3787               .0173
     43              0.3488               .0168
     44              0.3108               .0199
+++++++++++++++++++++++++++++++++++++++++++++++++++++
9/1/2022   11:17:56 PM

Monte Carlo PCA for Parallel Analysis
©2000 by Marley W. Watkins. All rights reserved.
*****************************************************
```

Figure 6. Monte Carlo PCA parallel analysis of sustainability criteria

The extracted factors of communality were investigated in the total variance explained (Table 6), showing that five components (component 1 up to component 5) out of 44 variables have an initial eigenvalue of more than one (1.0) and these components explained more than 65% of the total variance factors.

Table 6. Total variance explanation of sustainability criteria

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	19.105	43.421	43.421	19.105	43.421	43.421	9.690	22.022	22.022
2	3.692	8.391	51.812	3.692	8.391	51.812	6.212	14.119	36.141
3	2.228	5.063	56.874	2.228	5.063	56.874	5.031	11.433	47.574
4	1.982	4.504	61.378	1.982	4.504	61.378	4.606	10.468	58.043
5	1.780	4.045	65.423	1.780	4.045	65.423	3.247	7.380	65.423
6	1.473	3.347	68.769						
7	1.104	2.509	71.278						
8	.906	2.059	73.337						
9	.820	1.864	75.201						
10	.791	1.798	76.999						
11	.788	1.791	78.790						
12	.723	1.644	80.433						
13	.666	1.514	81.948						
14	.603	1.371	83.319						
15	.563	1.281	84.600						
16	.547	1.244	85.843						
17	.481	1.093	86.936						
18	.454	1.033	87.969						
19	.421	.956	88.924						
20	.401	.912	89.837						
21	.362	.822	90.659						
22	.351	.797	91.456						
23	.337	.766	92.222						
24	.318	.724	92.945						
25	.309	.702	93.647						
26	.288	.654	94.301						
27	.269	.611	94.912						
28	.240	.546	95.459						
29	.209	.474	95.933						
30	.193	.440	96.372						
31	.183	.417	96.789						
32	.168	.381	97.170						
33	.164	.373	97.543						
34	.154	.349	97.892						
35	.141	.320	98.212						
36	.122	.277	98.489						
37	.115	.261	98.750						
38	.114	.259	99.009						
39	.095	.217	99.226						
40	.092	.210	99.436						
41	.085	.192	99.628						
42	.063	.143	99.771						
43	.053	.120	99.891						
44	.048	.109	100.00						

Extraction Method: Principal Component Analysis.

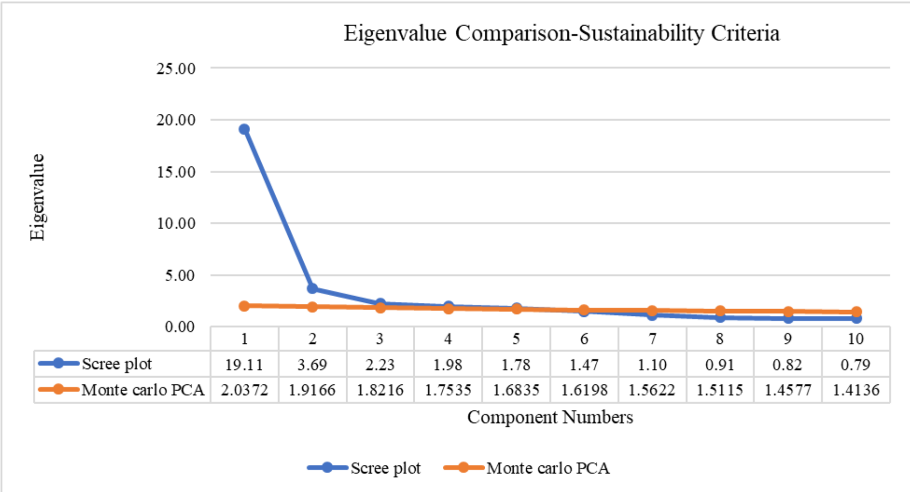

Figure 7. Eigenvalue comparison of sustainability criteria

A rotation is required because the original factor model may be mathematically correct but may be difficult in terms of interpretation. Interpretation will be very challenging if several factors have substantial loadings on the same variable. Rotation overcomes this type of interpretational challenge. The main objective of rotation is to produce a relatively simple structure in which there may be a high factor loading on one factor and a low factor loading on all other factors.

The rotated matrix of components of perception of sustainability are extracted based on the orthogonal rotations (Varimax method) and the findings are shown in Table 7.

The rotated loadings of factors (Table 7) have been assigned to the five components with a loading of 0.5 and above, which agrees the standard value [7].

Therefore, the hidden or latent variables that exist in the multi-attributes of sustainability application in urban bridge design are five unobserved variables, and to confirm the component model, a test of reliability and validity of the component factors are conducted. Reliability statistics of the N=44 items of factors result at Cronbach's alpha of 0.968, which is an acceptable value of more than the value of 0.7 as a standard value. Whereas on the side of validity, there are different approaches of testing the component model. Face validity which is a face observation of component factor relationship in the rotated component matrix. Convergent validity which considers that the variables within a single factor are highly correlated [7]. This is evident by the factor loadings. The sample size of the dataset determines whether loadings are sufficient or substantial [8]. The loadings of each factor for N=204 samples shall be more than 0.4, but the factor loadings are greater than 0.5 as can be seen in Table 7.

The other type of validity that can be tested before component structure confirmation is a test of discriminant validity, which refers to the extent to which factors are distinct and uncorrelated [7]. Variables must have a stronger relationship with their own factor than with another factor, according to the rule.

Table 7. Rotated component matrix of sustainability criteria

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
INC3	.786				
INC6	.763				
INC2	.755				
INC7	.732				
INC5	.723				
INC8	.701				
INC4	.680				
INC1	.665				
TAC1	.656				
TAC4	.644				
TFC1	.636				
TAC5	.628				
TFC3	.627				
TFC6	.618				
TAC2	.592				
TAC6	.580				
TAC8	.552				
TFC5	.527				
ENC4		.805			
ENC6		.781			
ENC2		.768			
ENC3		.732			
ENC1		.724			
ENC8		.716			
ENC13		.704			
ENC5		.689			
ENC7		.551			
TTC4			.825		
TTC3			.743		
TTC5			.699		
TTC8			.618		
TTC2			.612		
TTC6			.560		
TTC9			.540		
TTC1			.533		
ECC3				.791	
ECC2				.753	
ECC6				.726	
ECC4				.712	
ECC5				.699	
SOC4					.763
SOC5					.750
SOC7					.690
SOC6					.588

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

When conducting an EFA, there are two main ways to assess discriminant validity [6, 9]. The first method is to examine the component or pattern matrix. Variables should load significantly only on one factor. If "cross-loadings" do exist (variable loads on multiple factors), then the cross-loadings should differ by more than 0.2 ([6, 7]). Correlations between factors should not exceed 0.7 (49% of shared variance) (Ibid). The second method is to examine the component transformation matrix, as shown below (Table 8). Correlations between factors should not exceed 0.7(0.7*0.7=0.49=49% of shared variance) [10].

Table 8. Component transformation matrix of sustainability criteria

Component Transformation Matrix					
Component	1	2	3	4	5
1	.658	.410	.410	.390	.281
2	-.436	.891	-.100	-.047	-.066
3	-.159	-.031	.839	-.255	-.453
4	.433	.163	-.111	-.871	.121
5	-.405	-.107	.325	-.146	.835

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Table 8 shows that the correlation matrix of the components which load across the factors, for example, is 0.405(16% shared variance), far below the 0.70(49%) correlation coefficient and the components self-correlation is greater than the cross correlations for example (0.835>0.405). Therefore, the component matrix developed is proved to be a working model of identifying the latent components of the criteria of sustainability in the design of urban bridges in Ethiopia. The data from the rotated matrix would be used for further factor analysis using CFA to confirm the existing latent variables using Measurement Model.

The following framework, which comprises of main parameters and sub parameters, can be created in the design stages by formulating design challenges based on the results of the exploratory factor analysis. The three phases of the framework are the design problem, the design objectives, and the design layers. Design problems try to comprehend the scope of the design with the help of possible stakeholders by establishing important design priorities. While the design objectives center on utilizing important design characteristics and considering every factor that would improve and achieve the design goal.

Additionally, careful consideration must be given to the detailed design layers, which are the stages of the design activity (Figure 8).

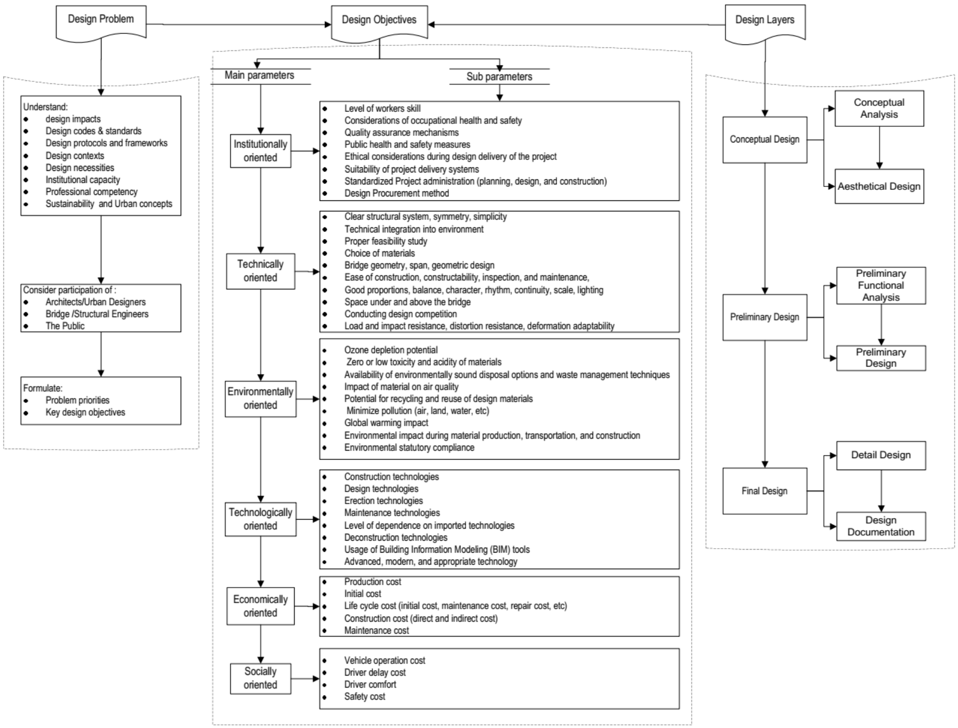

Figure 8. Multicriteria framework for sustainable urban bridge design

3.3 Confirmatory factor analysis

Confirmatory factor analysis is the stage that comes after exploratory factor analysis to determine the factor structure of a particular dataset (CFA). In the EFA, look at the factor structure (the connections between the variables and how they are organized based on intervariable correlations), and then check it in the CFA. After that, the covariance relations would be investigated by measurement models. The IBM Statistics Amos 23 application is used to carry out the measurement model due to its familiarity and the researcher's past knowledge with the program. From the EFA analysis, the following observable variables were collected (Table 9).

To do the analysis and evaluate the measurement model, the components as well as their unobserved factors were entered into Amos Graphics. To evaluate the findings, the following thresholds were taken from the authors mentioned in Table 10 to measure the model fit. Although there is considerable controversy about the fit indices. Fit indices are not thought to offer anything to the analysis by some experts [11] and just the chi square should be understood. The concern is that the fit indices enable researchers to assert that a model with incorrect specifications is not a poor model. Other authors such as [12] argue that cutoffs for a fit index can be misleading and subject to misuse. The majority of analysts support the use of fit indices but advise against overly relying on cutoffs [11].

Table 9. List of factors for CFA measurement model

Components	Latent Variables	Observed Variables	
		Label	**Description**
1	Institutional criteria	INC3	Level of workers skill
		INC 6	Considerations of occupational health and safety
		INC 2	Quality assurance mechanisms
		INC 7	Public health and safety measures
		INC 5	Ethical considerations during design delivery of the project
		INC 8	Suitability of project delivery systems
		INC 4	Standardized Project administration (planning, design, and construction)
		INC 1	Design Procurement method
2	Technical criteria	TAC1	Clear structural system, symmetry, simplicity
		TAC4	Integration into environment
		TFC1	Proper feasibility study
		TAC5	Choice of materials
		TFC3	Bridge geometry, span, geometric design
		TFC6	Ease of construction, constructability, inspection, and maintenance,
		TAC2	Good proportions, balance, character, rhythm, continuity, scale, lighting
		TAC6	Space under and above the bridge
		TAC8	Conducting design competition
		TFC5	Load and impact resistance, distortion resistance, deformation adaptability
3	Environmental criteria	ENC4	Ozone depletion potential
		ENC 6	Zero or low toxicity and acidity of materials
		ENC 2	Availability of environmentally sound disposal options and waste management techniques
		ENC 3	Impact of material on air quality
		ENC 1	Potential for recycling and reuse of design materials
		ENC 8	Minimize pollution (air, land, water, etc)
		ENC 13	Global warming impact
		ENC 5	Environmental impact during material production, transportation, and construction
		ENC 7	Environmental statutory compliance
4	Technological criteria	TTC4	Construction technologies
		TTC 3	Design technologies
		TTC 5	Erection technologies
		TTC 8	Maintenance technologies
		TTC 2	Level of dependence on imported technologies
		TTC 6	Deconstruction technologies
		TTC 9	Usage of Building Information Modelling (BIM) tools
		TTC 1	Advanced, modern, and appropriate technology
5	Economic criteria	ECC3	Production cost
		ECC 2	Initial cost
		ECC 6	Life cycle cost (initial cost, maintenance cost, repair cost, etc)
		ECC 4	Construction cost (direct and indirect cost)
		ECC 5	Maintenance cost
6	Social criteria	SOC4	Vehicle operation cost
		SOC5	Driver delay cost
		SOC7	Driver comfort
		SOC6	Safety cost

Moreover, problematic is the “cherry picking” a fit index. That is, computing many fit indices, and pick one index that allows to make the point that it wants to make. If it is chosen not to report a well-known index (such as the TLI or RMSEA), it must provide a valid justification. Fit indices should not even be computed for small degrees of freedom models [13]. Rather, for these models, the researcher should locate the source of specification error.

Table 10. Threshold for measurement model ([14, 15])

Measure	Threshold
Chi-square/df (cmin/df)	< 3 good;< 5 sometimes permissible
p-value for the model	>.05
CFI (Comparative Fit Index)	>.95 great;>.90 traditional;>.80 sometimes permissible
GFI (Goodness of Fit Index)	>.95
AGFI (Adjusted Goodness of Fit Index)	>.80
SRMR (Standardized Root Mean Square Residual)	<.09
RMSEA (Root Mean Square Error of Approximation)	<.05 good;.05-.10 moderate;>.10 bad
PCLOSE (Close Fitting Model)	>.05

In the tradition of structural equation modeling (SEM) and confirmatory factor analysis, model fit indices measure discrepancies between observed and model-implied correlation/covariance matrices. Model fit indices often indicate differences between observed and model-implied data. Fit refers to the ability of a model to reproduce the data (i.e., usually the variance covariance matrix). A good fitting model is one that is reasonably consistent with the data and so does not necessarily require specification. Unsurprisingly, there is a lot of discussion about what is meant by "reasonably consistent with the data". Prior to analysing the structural model's causal paths, a well-fitting measurement model is necessary. The chi-square is statistically significant, which is the main justification for generating a fit index, but the researcher still wishes to term the model a "well fitting" model. Be aware that while the model can reproduce the data, most (but not all) fit indices cannot be computed if the model is saturated or just recognized [11].

It should be highlighted that a good-fitting model shall not necessarily be a valid model. For instance, a model is considered "good-fitting" if its estimated parameters are not significantly distant from zero. Conversely, it should be noted that a model, all whose parameters are statistically significant can be a poor fitting model. Heywood situations, models with weak discriminant validity, and models with nonsensical outputs (such as routes with obvious erroneous signs) can all be considered "good-fitting" models. Parameter estimates must be carefully examined to determine if one has a reasonable model. Moreover, it is important to realize that one might obtain a good fitting model, yet it is still possible to improve the model and remove the specification errors. Finally, a well-fitting model does not necessarily indicate that the model's specifications are accurate.

Therefore, for identifying multi-criteria for sustainable urban bridge design, the model fit the indices are chosen appropriately. Model Chi-square (which is the chi-square statistic obtained from the generalized least squares statistic since this method suits the non-normal distribution of the data). CFI (comparative fit index) and RMSEA (root mean square error of approximation) measurement indices have been chosen for the model fit.

Modification indices

The Chi-Square measurement is significant with p=0.001. Modification of indices were done to improve the model fit. The threshold of the modification indices is left to the researcher to decide. Those error terms which are high should be covaried, then the discrepancy will reduce to a certain extent. Hence, there were no significant error measurements that should be covaried within the component.

Estimates

In the case of the regression weights and squared loadings, the detail is shown in Table 11 with a good estimate of the correlation coefficients of the observed variables of the model in a squared loading and regression weights of observed variables and latent variables together with their standard error estimation. S.E. is an estimate of the standard error which shall be less than 1 in value, otherwise the error and the observed variables shall be deleted from the CFA analysis. Whereas in the case of C.R., which is the critical ratio obtained by dividing the covariance estimate by its standard error. Critical ratio should exceed 1.96, then it will be significant. Thus, the value of C.R. is between 7 and 16 and it indicates a level of significance with a value of p=0.001 (Table 11).

Measurement model

For example, the institutional component standardized regression weights were between 0.79(INC1) to 0.88(INC3). The squared loadings were between regression 0.62 to 0.77. In the case of the social component, the standardized regression weights were 0.74 to 0.78, whereas the squared loadings were between 0.55 to 0.61. For economy, the standardized regression weights were from 0.65 to 0.91. Its squared loadings were from 0.42 to 0.82. The covariance was ranging from 0.53 to 0.83. The larger observed covariances were between institution and social variables (0.83) and between economy and technological factors (0.81) (Figure 9).

Table 11. Regression weights and squared multiple correlations

Regression weights			Estimate	S.E.	C.R.	P
institution3	<---	Institution	1			
institution2	<---	Institution	1.034	0.069	15.025	0.001
institution8	<---	Institution	0.98	0.08	12.287	0.001
institution1	<---	Institution	1.018	0.085	11.999	0.001
environment6	<---	Environmen	1			
environment2	<---	Environmen	0.74	0.059	12.467	0.001
environment3	<---	Environmen	0.846	0.061	13.894	0.001
environment8	<---	Environmen	0.677	0.059	11.532	0.001
environment13	<---	Environmen	0.76	0.071	10.705	0.001
environment5	<---	Environmen	0.691	0.051	13.424	0.001
environment7	<---	Environmen	0.82	0.055	14.942	0.001
technicalT9	<---	Technologic	1			
technicalT1	<---	Technologic	0.973	0.124	7.835	0.001
social4	<---	Social	1			
social7	<---	Social	0.85	0.097	8.742	0.001
social6	<---	Social	0.89	0.1	8.879	0.001
economy2	<---	Economical	1			
economy6	<---	Economical	1.452	0.177	8.225	0.001
technicalT3	<---	Technologic	0.801	0.103	7.778	0.001
technicalT6	<---	Technologic	0.981	0.123	7.949	0.001
institution4	<---	Institution	0.985	0.072	13.646	0.001

Standardized Regression Weights:			Estimate
institution3	<---	Institution	0.88
institution2	<---	Institution	0.88
institution8	<---	Institution	0.805
institution1	<---	Institution	0.786
environment6	<---	Environment	0.912
environment2	<---	Environment	0.845
environment3	<---	Environment	0.865
environment8	<---	Environment	0.748
environment13	<---	Environment	0.72
environment5	<---	Environment	0.838
environment7	<---	Environment	0.908
technicalT9	<---	Technological	0.679
technicalT1	<---	Technological	0.733
social4	<---	Social	0.761
social7	<---	Social	0.739
social6	<---	Social	0.781
economy2	<---	Economical	0.651
economy6	<---	Economical	0.906
technicalT3	<---	Technological	0.724
technicalT6	<---	Technological	0.808
institution4	<---	Institution	0.85

Squared multiple correlations	Estimate
technicalT6	0.653
technicalT3	0.524
economy6	0.82
economy2	0.424
social6	0.611
social7	0.546
social4	0.578
technicalT1	0.537
technicalT9	0.461
environment7	0.825
environment5	0.702
environment13	0.518
environment8	0.56
environment3	0.748
environment2	0.714
environment6	0.832
institution1	0.618
institution4	0.722
institution8	0.648
institution2	0.774
institution3	0.775

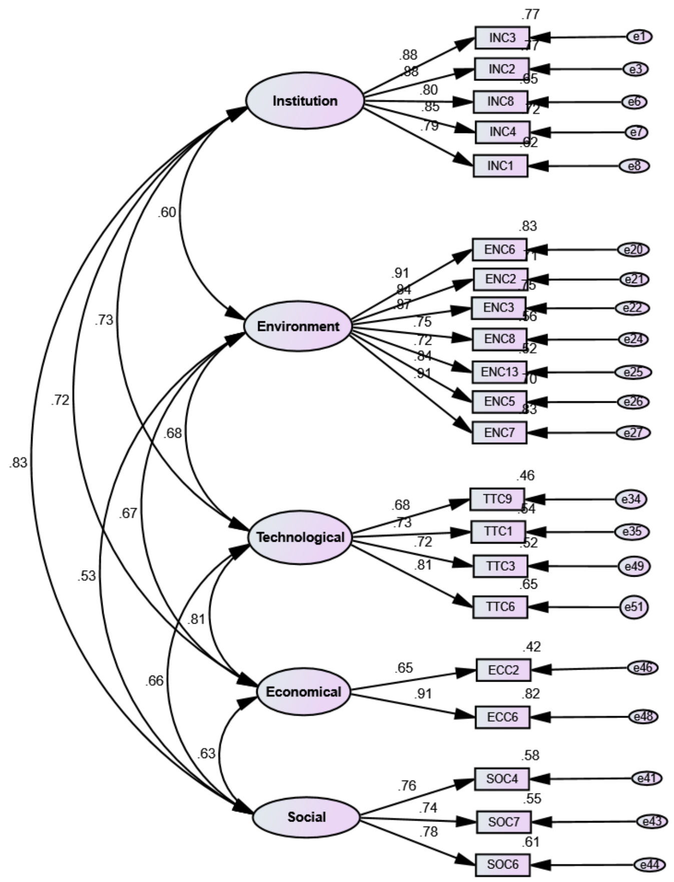

Figure 9. Measurement model for sustainability criteria

Model fit

The root mean square error of approximation (RMSEA) is 0.072, with a value less than 0.10 stressed on the ‘‘Absolute Fit’’ of the model. Further, the goodness of fit index (GFI) is 0.827, with a value close to 0.9, the adjusted Goodness of Fit Index (AGFI) is 0.776, with a value close to 0.9 and Chi-Square $\chi 2/df$ is 2.063 which is less than 3, emphasis a good fit. Additionally, the relative fit indices or the incremental fit index that are elucidated by the normed fit index (NFI), relative fit index (RFI), incremental fit index (IFI), Tucker Lewis Index (TLI), and comparative fit index (CFI) are 0.366,0.256,0.529, 0.401, and 0.489, respectively. Whereas, the parsimonious normed fit index (PNFI), Parsimonious comparative fit index (PCFI), Parsimonious Goodness of Fit Index (PGFI) and p-close that constitute the parsimonious fit results are 0.312,0.417, 0.641 and 0.001, respectively.

Table 12. Assessing overall measurement model fit

Statistic Measurement	Test indices	Test standard	Result	Model fit verification
Absolute Fit Measurement	RMSEA	< 0.08	0.072	Good Fit
	GFI	>0.90	0.827	Permissible
	AGFI	>0.90	0.776	Permissible
	CMIN/DF	<3.00	2.063	Good Fit
Incremental Fit Measurement	NFI	>0.9	0.366	Approximation fit
	RFI	>0.9	0.256	Approximation fit
	IFI	>0.9	0.529	Approximation fit
	TLI	>0.9	0.401	Approximation fit
	CFI	>0.9	0.489	Approximation fit
Parsimonious Fit Measurement	PNFI	>0.5	0.312	Approximation fit
	PCFI	>0.5	0.417	Approximation fit
	PGFI	>0.5	0.641	Good Fit
	PCLOSE	>0.05	0.001	Approximation fit

Overall, the proposed measurement model is a permissible fit to the theoretical stance of multi-criterial requirement of sustainable urban bridge design (Table 12). The proposed key criteria are needed to be incorporated while the design problem of urban bridges in addressing sustainability is deemed to be essential.

4 DISCUSSION

To promote connectedness and facilitate urban mobility for people, products, and services, it is necessary to use comprehensive frameworks when designing urban infrastructure. The main criteria for sustainable urban bridge design are described in this section, along with a description of the multicriteria framework for sustainable design. Institutional, technical, environmental, technological, economic, and social factors are the main components of a sustainable urban bridge design. In the discussion that follows, the sub parameters that support and clarify the primary criteria are also addressed.

4.1 Institutional and environmental criteria

Workers' skill level and occupational health and safety considerations are important sub-criteria [16]. Quality assurance mechanisms and public health and safety measures need to be secured. Ethical considerations during the design and delivery of the project and the suitability of project delivery systems would measure institutional commitment. Standardized project administration (planning, design, and construction) and design procurement methods are the institutional concerns in the design process of urban bridges.

At an organizational level, all standards, guidelines, and policies need to comply with a national regulation [17]. Organizations need to adopt sustainable design solutions, sustainable procurement, sustainable technologies, processes, and innovations while creating opportunities for education and training within a supportive organizational structure. For sustainable designs organization needs to improve a project’s whole life value through green design and ensure constructability with efficient use of resources, sustainable materials, minimum wastage, resilience, adaptability, and attractive [18, 19].

The bridge infrastructure is "Sustainable" if it can reach, during the phases of construction, maintenance, and operation, the objectives underlying the design(regulations, observance, safety, fluidity of movement, maintenance, energy efficiency, transport capacity…) in a self-sufficient way so that the system "bridge" is self-sustaining, and then it can use effectively and efficiently resources, and non-renewable materials for its needs and ensures reproducibility while maintaining the bridges [20]. Therefore, to design "Sustainable Bridges " is not enough to deal with the issues of site management, recycling of materials, procurement of resources, energy efficiency, water efficiency, air pollution, etc. But we must systematically address all issues by optimizing the interrelationships [20].

To achieve a sustainable future in the construction industry covers several features such as energy-saving, improved use of materials, material waste minimization, pollution, and emissions control, etc. A review of the literature has identified three general objectives which should shape the framework for implementing sustainable building design and construction while keeping in mind the principles of sustainability issues (social, environmental, and economic) identified [21].

Although [21] have done this framework mainly for buildings, the concept of achieving sustainability for all infrastructures will not be quite different. And especially in regard to the design approach or philosophy, it will share the majority of the basic concepts. The selection of materials will also be on a similar analogy.

Environmental criteria which impact the major roles of the design process are ozone depletion potential and zero or low toxicity and acidity of materials [22]. The availability of environmentally sound disposal options and waste management techniques is also needed to be considered in meeting environmental sustainability. The impact of materials on air quality and the potential for recycling and reuse of design materials would greatly reduce the degradation of the environment. Pollution (air, land, water, etc.) and the impact of global warming must be closely monitored through design inputs and output. The environmental impact of material production, transportation, and system construction must be dealt with.

Maintain the Earth's vitality and ecological diversity. Minimizing damage to renewable resources and minimizing the use of energy, raw materials, and specifically non-renewable resources [23]. Minimize visual damage to scenically sensitive areas [17]. Minimize the risk of air, land, and water pollution caused by construction operations [24].

4.2 Technical and technological criteria

Regarding the technical point of view, the criteria are aligned with the form and function of the built environment. Thus, the parameters can be explained by the following facts, which are practical in their stance: The clear structural system, symmetry, simplicity, and integration into the environment [25]. A proper feasibility study, as well as the selection of materials, is necessary [26]. Bridge geometry, span, geometric design, ease of construction, constructability, inspection, and maintenance are also very key sub criteria. Good proportions, balance, character, rhythm, continuity, scale, lighting, and space under and above the bridge would dictate the aesthetics and functional demands (Malekly et al., 2010. In contrast, conducting a design competition is a required parameter in the sustainable urban bridge design process [27]. Load and impact resistance, distortion resistance, and deformation adaptability assessment and consideration are essential. As it has been found from [28] the inclusion of technology in the models of sustainability is vital. The notion is that technology is one of the most essential elements of the built environment's sustainability agenda and that competent project management is necessary for attaining sustainable development. Technology refers to a tool that is required for the integrated design process, such as a sustainable infrastructure rating tool and building information modeling (BIM) [29]. Because the greatest prospects for sustainability exist at the planning stage, sustainable design may be a major success feature. All these goals lead to more sustainable infrastructure solutions and may be achieved using BIM and other technology tools that should be considered when developing sustainability frameworks or models.

On the other side, institutes' cultures of sustainable development and sustainability must be embedded into the frameworks of sustainability provision [30, 31]. The situation of culture might be reconsidered as a component of social (individual) sustainability, but the case of institutions is not addressed, and it is critical to consider it in the context of sustainable development models or frameworks. The well-known conceptualized 3-dimensional sustainability considers social, economy and environment [32, 33], however, it did not consider technological and institutional culture while observing sustainability holistically. The proposed multicriteria framework consists of 5-dimensions that include: institution, technology, social, economy, and ecology.

Currently, technology utilization in any industry is becoming a necessity. Therefore, sustainable design should incorporate the issues of both construction and design technologies [34]. Erection technologies, maintenance technology, and deconstruction technology must all be considered during the design process. Dependence on imported technologies should be minimized to avoid unnecessary expenditure. The use of Building Information Modelling (BIM) as a design tool should be considered. Advanced, modern, and appropriate technology systems' introduction in the planning and execution of design projects has become relevant these days.

4.3 Economic and social criteria

The economic consideration of sustainability points towards the initial cost, production cost, construction cost (direct and indirect cost), and life cycle cost (initial cost, maintenance cost, repair cost, etc) [27]. Within the margin of project feasibility, the conventional economic consideration must be replaced with the lifecycle effect [26]. Improve the quality of human life by ensuring secure and adequate consumption of basic needs [24].Ensure that development planning makes provision for social self-determination and cultural diversity [35]. Ensure compatibility with local human systems and technology [36]. Ensure that the social benefits of construction are equitably distributed [37].

Oyedele defines sustainable development as a “development that ensures a better quality of life for everyone now and for generations to come” is comprehensive and pre-emptive [38]. It says that we should not compromise our ability to develop our environment now due to the ability of future generations to develop theirs. But we should always think of the quality of life of future generations in all our development projects, economic, social, or political. This definition is superior to the previous in that it considers the fact that whatever we are doing now is assumed to be permanent and not to be repeated by future generations [39]. All conceptions of sustainable Development require that we consider the world as a system, a system that connects place and time [40].

The direct social criteria in relation to mobility systems are related to vehicle operation effects in terms of cost. And driver delay effects and driver comfort would be necessary parameters [41]. Furthermore, safety in the whole system of human interaction with the bridge structure would be the prior social well-being consideration [34]. Unless society benefits from the existing structure, the design objective cannot be met with sound justification.

5 CONCLUSIONS

The complexity of urban socio-economic systems and the design approach present considerable hurdles for sustainable urban bridge construction. The topic of creating a sound design framework to create sustainable urban bridges is a pertinent idea that takes into consideration essential components while aiming for sustainable design practices. The infrastructure's current and future implications cannot be managed with the design approach used today. Design frameworks will help in conceptualizing the inputs, processes, and results in the context of sustainability. The most important factors were things like how a thoughtful understanding of the design processes, concepts, methodologies, aims, and context will improve the process. The main elements of sustainable bridge design also include the five dimensions of sustainability (technical and technological, institutional culture, social, economic, and environmental).

ACKNOWLEDGMENTS

The authors of this work would like to recognize the financial support for data collection for this study granted by the graduate program at Addis Ababa University.

REFERENCES

[1] T. Yigitcanlar, Rethinking sustainable development: Urban management, engineering, and design., First ed., USA: IGI Global., 2010.

[2] J. Blizzard and L. Klotz, " A framework for sustainable whole systems design," *Design Studies,* vol. 33, no. 5, pp. 456-479, 2012.

[3] R. Fellows and A. Liu, Research Methods for construction, 3rd ed., United Kingdom: Blackwell Publishing Ltd, 2008.

[4] I. Etikan and K. Bala, "Sampling and sampling methods," *Biometrics & Biostatistics International Journal,* vol. 5, no. 6, p. 00149, 2017.

[5] R. Takim, A. Akintoye and J. Kelly, "Analysis of Performance Measurement in the Malaysian Construction Industry, in Ogunlana, S. O., Chareonngam, C., Herabet, P. and Hadikusumo, B. H. W. (Eds.)," in *Globalization and Construction*, Bangkok,Thailand, 2004.

[6] P. Schober, C. Boer and L. Schwarte, "Correlation coefficients: appropriate use and interpretation," *Anesthesia & Analgesia,* vol. 126, no. 5, pp. 1763-1768, 2018.

[7] A. Gaur and S. Gaur, Statistical methods for practice and research: A guide to data analysis using SPSS, 1 ed., India: Sage, 2009.

[8] N. Faber and R. Rajko, "How to avoid over-fitting in multivariate calibration—The conventional validation approach and an alternative," *Analytica Chimica Acta,* vol. 595, no. 1-2, pp. 98-106, 2007.

[9] J. Gaskin and J. Lim, "Master validity tool.," AMOS Plugin In: Gaskination's StatWiki, USA, 2016.

[10] J. Pallant, SPSS survival manual, First ed., UK: McGraw-hill education, 2013.

[11] P. Barrett, "Structural equation modelling: Adjudging model fit," *Personality and Individual Differences,* vol. 42, no. 5, pp. 815-824, 2007.

[12] L. Hayduk, G. Cummings, K. Boadu, H. Pazderka-Robinson and S. Boulianne, "Testing! testing! one, two, three–Testing the theory in structural equation models!," . *Personality and Individual Differences,* vol. 42, no. 5, pp. 841-850, 2007.

[13] D. Kenny, B. Kaniskan and D. McCoach, "The performance of RMSEA in models with small degrees of freedom," *Sociological methods & research,* vol. 44, no. 3, pp. 486-507, 2015.

[14] J. Hair, M. Gabriel and V. Patel, "AMOS covariance-based structural equation modeling (CB-SEM): Guidelines on its application as a marketing research tool," *Brazilian Journal of Marketing,* vol. 13, no. 2, p. 2014, 2014.

[15] L. Hu and P. Bentler, "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives," *Structural equation modeling: a multidisciplinary journal,* vol. 6, no. 1, pp. 1-55, 1999.

[16] P. Joshi, P. Sharma, S. Upadhyay and S. Sharma, "Multi objective Fuzzy decision making approach for selection of type of caisson for bridge foundation," *Indian Journal of Pure and Applied Mathematics,* vol. 35, no. 6, pp. 783-792, 2004.

[17] K. I. Athapaththu and G. Karunasena, "Framework for sustainable construction practices in Sri Lanka," *Built Environment Project and Asset Management,* vol. 8, no. 1, pp. 51-63, 2018.

[18] M. Gharzeldeena and S. Beheiry, "Investigating the use of green design parameters in UAE construction projects", *International Journal of Sustainable Engineering,* vol. 8, no. 2, pp. 93-101, 2015.

[19] Y. Tan, L. Shen and H. Yao, "Sustainable construction practice and contractors' competitiveness:a preliminary study", *Habitat International,* vol. 35, no. 2, pp. 225-230, 2011.

[20] F. Corriere and A. Rizzo, "Sustaibility in Road Design:A methodological proposal forthe drafting of the Guideline," in *Procedia Social and Behaviuoral Sciences*, SIIV-5th International Conference, 2012.
[21] P.O. Akadiri, E.A. Chinyio and P.O. Olomolaiye, "Design of A Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector," *Buildings*, vol. 2, no. 2, pp. 126-152, 2012.
[22] H. Gervásio and L. Da Silva, "A probabilistic decision-making approach for the sustainable assessment of infrastructures," *Expert Systems with Applications,* vol. 39, no. 8, pp. 7121-7131, 2012.
[23] W. Adams, "The future of sustainability: re-thinking environment and development in the twenty-first century", Gland, 2006.
[24] R. Hill and P. Bowen, "Sustainable construction: principles and a framework for attainment", *Construction Management and Economics,* vol. 15, no. 3, pp. 223-239, 1997.
[25] A. Farkas, "Multi-criteria comparison of bridge designs," *Acta Polytechnica Hungarica,* vol. 8, no. 1, pp. 173-191, 2011.
[26] O. Ugwu, M. Kumaraswamy, A. Wong and S. Ng, "Sustainability appraisal in infrastructure projects (SUSAIP): Part 2: A case study in bridge design," *Automation in construction,* vol. 15, no. 2, pp. 229-238, 2006.
[27] V. Balali, A. Mottaghi, O. Shoghli and M. Golabchi, "Selection of appropriate material, construction technique, and structural system of bridges by use of multicriteria decision-making method," *Transportation research record,* vol. 2431, no. 1, pp. 79-87, 2014.
[28] G. Agyekum-Mensah, A. Knight and a. C. Coffey, "4Es and 4 Poles model of sustainability: redefining sustainability in the built environment.", *Structural Survey,* vol. 30, no. 5, pp. 426-442, 2012.
[29] Y. Liu, S. van Nederveen, C. Wu and M. Hertogh, "Sustainable infrastructure design framework through integration of rating systems and building information modeling," *Advances in Civil Engineering,* 2018.
[30] G. Ofori, "Sustainable construction: principles and a framework for attainment-comment," *Construction Management & Economics,* vol. 16, no. 2, pp. 141-145, 1998.
[31] A. Goel, "Sustainability in construction and built environment: a "wicked problem"?," *Smart and Sustainable Built Environment,* vol. 8, no. 1, pp. 2-15, 2019.
[32] G. Brundtland, Our common future: The world commission on environment and development., (Ed) ed., Oxford: Oxford University Press, 1987.
[33] J. Elkington, " "Partnerships from cannibals with forks: the triple bottom line of 21st-century business,"," *Environmental Quality Management,* vol. 8, no. 1, pp. 37-5, 1998.
[34] P. Jakiel and D. Fabianowski, " FAHP model used for assessment of highway RC bridge structural and technological arrangements," *Expert Systems with Applications,* vol. 42, no. 8, pp. 4054-4061, 2015.
[35] C. J. Kibert, "Establishing principles and a model for sustainable construction", Proceedings of the First International Conference on Sustainable Construction, ed., CIB TG 16, Florida, FL, USA, 1994.
[36] S. Hallidays, Sustainable Construction, USA: Butterworth-Heinemann Publishers, 2008.
[37] R. C. Hill, J. G. Bergmani and P. A. Bowen, "A framework for the attainment of sustainable construction," in *Sustainable Construction*, Tampa. Florida. USA, 1994.
[38] O. Oyedele, "Infrastructure Problems of Developing Nations and Sustainable Development.," *Researchgate,* 2016.
[39] O. Oyedele, "Tinubu and Integrated Waste Management," p. 33, 01 February 2006.
[40] D. Gagnier, "What is Sustainable Development?," 2010. [Online]. Available: www.iisd.org/sd/. [Accessed 18 07 2010].
[41] Y. Itoh, L. Sunuwar, T. Hirano, A. Hammad and T. Nishido, "Bridge type selection system incorporating environmental impacts," *Journal of global environment engineering,*, vol. 6, pp. 81-101, 2000.