

Fuzzification of Strategies on Social Sustainability in Urban Infrastructures in Ghana

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Research Article

Keywords: Cities, Fuzzification, Infrastructure, Sustainability, Social Sustainability, Urban

Posted Date: April 24th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9487961/v1>

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Additional Declarations: No competing interests reported.

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Abstract

Sustainability is a vital issue in academia and urban infrastructure discourse worldwide. Social, economic and environmental sustainability are the three major pillars of sustainability. However, while economic and environmental dimensions have received much attention, less is focused on social dimensions of urban infrastructure developments. This study is intended to evaluate effective strategies to enhance social sustainability in urban infrastructure. A quantitative questionnaire was piloted and distributed to 312 experienced stakeholders to solicit for their view on the effective strategies for enhancing social sustainability. The questionnaire consisted of relevant statements derived from literature and respondents were asked to rate the level of effectiveness of each strategy. Descriptive statistics were used to rank the strategies. Furthermore, exploratory factor analysis categorized the 21 variables into three major components (inclusive and diversity strategies, welfare of workers, stakeholder engagement). A synthetic fuzzification technique was used to assess the criticality of each component. From the fuzzy analysis, inclusive strategies are the major strategies for the enhancement of social sustainability, and followed by welfare of workers, and stakeholder's engagement. The overall criticality level for all three components was 3.966. This is an indication of the criticality of the three components to drive social sustainability in urban infrastructures. This study provides deeper understanding for practitioners into social sustainability in the developing countries context. This study also contributes to deepening knowledge in literature on the social dimension of sustainability for urban infrastructure.

Keywords: Cities, Fuzzification, Infrastructure, Sustainability, Social Sustainability, Urban

1. Introduction

As a tool for improving lives in urban communities, the infrastructure sector makes a significant contribution when it comes to meeting the demands of the people (Alwan et al. 2017, Doan et al. 2017, Hwang et al. 2017). However, this industry produces about 45-65% wastes that ends up in landfills and also responsible for producing 35% of CO₂ emission into the atmosphere worldwide (Liu et al. 2025). As a means to combat these issues, both professionals in the industry and academia have shifted their attention to sustainability over the last decade (Kiani Mavi et al. 2021, Lima et al. 2021). Sustainable development as explained by World Commission on Environment and Development (WCED) in 1987 is meeting the needs of the present people without compromising the future generation to meet their own (Nti et al. 2022). It worth mentioning that within this definition, sustainable construction has emerged as the industry's specific response to the broader sustainability agender by focusing on sustainability practices (Kordi et al. 2024). Both

economically and less economically developed countries are gradually incorporating sustainable principle into their construction process as a means of achieving sustainable development which is centered on improving the quality of sustainability indicators (social, environmental, and economic) (Jabbour et al. 2019, Fernando et al. 2019). According to Zuo et al. (2012), the three bottom line approach is made up of the three major components of sustainability which are the social, economic, and environmental. As way of achieving sustainability, none of these components must be ignored (Edum-Fotwe and Price 2009). In the construction industry, the environmental and economic dimensions have received much attention from past research works leaving the social dimension unattended. Several authors (Sierra et al. 2018, Rostamnezhad and Thaheem 2022, Popovic et al. 2018, Missimer et al. 2017, Karji et al. 2019, Goh et al. 2020, Almahmoud and Doloi 2020, Ajmal et al. 2018) have confirmed that much have not been researched when it relates to the social dimension in the building sector. This is because social dimension is usually a term that varies depending on circumstance. But as (Zuo et al. 2012) noted, ignoring the social aspect in building projects can result in differences in people's quality of life, which includes things like health, security, equity, and access to basic needs.

The social aspect of sustainability is the involvement of clients, workers, suppliers, and the local communities as a means of ensuring that both their present and future needs are met (Herd-Smith and Fewings 2008). The goal of the social concept is to ensure high client satisfaction, attend to people's needs throughout the construction activities (from the commissioning process through to the demolition stage), and work hand-on-hand with staff, clients, suppliers, and the entire communities as a whole (Memon 2013). Valdes-Vasquez and Klotz (2013) also pinpointed out that incorporating social dimensions such as worker safety, community impacts, education, and stakeholder inclusion can enhance project longevity and improve lives. However, accomplishing social sustainability in construction infrastructure is still difficult because different regions have different socioeconomic conditions, regulatory frameworks, and industry practices. Social sustainability is becoming increasingly integrated into construction policies and regulatory frameworks in developed nations due to the government's policy-making authority, incentives, education, technology development, and statutory power to regulate and monitor the sustainability performance of businesses involved in the construction industry. Some developed countries have implemented sustainable procurement guidelines into their procurement processes, which require government organizations to take social benefits into account when awarding contracts. This ensures that public construction projects are completed while social requirements are met (Shooshtarian et al. 2020). These policies have been proved to increase social sustainability in Spain's construction industry (Reverte 2015). On the other hand, poor regulatory enforcement, deregulated labor markets, and financial limits create more severe impediments to social sustainability in nations with lower incomes. Adopting social sustainability techniques is challenging for developing nations due to these obstacles (Karji et al. 2019, Govindan et al. 2021, Fatourehchi and Zarghami 2020). Novelo et al. (2021) assert that to reduce poverty and inequality, the building sector in developing countries needs to understand the significance of social sustainability and how it impacts urban infrastructure.

Furthermore, practicable strategies to improve social sustainability have been disregarded. For example, the research conducted by Karakhan and Gambatese (2017) concentrated mostly on the

health and safety of employees, which is a significant but limited component of social sustainability. For a more thorough knowledge of sustainability in construction, a wider variety of social sustainability dimensions such as community involvement, labor rights, and long-term social benefits were not well reflected by this narrow emphasis. The identification of social sustainability attributes in Dubai's urban areas by Hossein and Khaled (2021) also contributed, however the lack of expert respondents' suggestions for improvement tactics further jeopardizes the results' practical use. Given the foregoing context, the purpose of this study is to assess the most successful methods for improving social sustainability in urban infrastructure. The results will enable policymakers, construction companies, and industry stakeholders to develop socially responsible construction methods that strike a balance between community well-being, environmental responsibility, and economic feasibility. This study will contribute to the broader goal of achieving truly sustainable development in the construction sector, benefiting both present and future generations. The study is unique as the first ever to provide empirical evidence on social sustainability by using the fuzzy synthetic evaluation statistical method within the context of urban infrastructures from the developing country perspective.

2 Literature Review

2.1 The concept of social sustainability

Along with environmental and economic sustainability, social sustainability is one of the three fundamental pillars of sustainable development. Social sustainability is the least researched of the three, yet it is increasingly recognized as being essential to attaining sustainable goals. The ability to define is one of the main challenges among all those associated with the phrase social sustainability (Karji et al. 2019, Hale et al. 2019). For instance, Zarghami and Fatourehchi (2020) described social sustainability as the process of designing for areas that successfully promote wellness and meet people's needs in their living environments. Karakhan and Gambatese (2017), defined social sustainability as quality for life improvement effort for aiming for social fairness, an area ranging quality for life improvement for all members in the populace. Polèse et al. (2000) defined social sustainability as development for aim for promoting social inclusion, quality for life improvement for all members in the populace. As in the body of literature, no clear meaning for social sustainability is shown, meaning is identified as an integral factor in the building construction, promoting stakeholders' interaction for satisfying demands for current as well as future populace and communities (Valdes-Vasquez and Klotz 2013). Social dimension is among the vital components for the three pillars in sustainability, but majority of firms focus more on the economic and environmental dimensions. As demonstrated, certain building construction projects continue to prioritize socioeconomic performance over the social dimension (Valdes-Vasquez and Klotz 2013, Torres-Machi et al. 2018). According to Montalbán-Domingo et al. (2018), there are a number of different categories for social criteria based on (a) the evaluation of construction projects during the planning, conceptual, and feasibility design phases; (b) performance reviews of construction companies; (c) supplier assessment processes; (d) life cycles for social products and materials; and (e) the decision-making processes for social construction projects during the phases of construction, design, and operation. However, it is not explicitly stated what criteria

should be used to evaluate social sustainability in building projects, and in many cases, only few social variables are considered (Ekener et al. 2018). Social sustainability is an area of concern in the human dimension for sustainability. Social sustainability is concerned in terms of quality-of-life issues and makes professionals concerned about the social impacts people's decisions would generate. Social sustainability is an overlapping phrase for corporate social responsibility, and social sustainability is concerned about humankind's as well as people's well-being as well as societies' well-being in terms of social asset administration (Sarkis et al. 2010, Panigrahi et al. 2019, Govindan et al. 2021); poverty decrease, in accordance with justice, human rights, accident coverage, child work, and worker well-being (Popovic et al. 2018, Krause et al. 2009); as well as workplace practice transparency (Kumar and Rahman 2017, Govindan et al. 2021). Social sustainability on corporate levels indicate value co-creation for the community as people's human-capital is developed and societies' societal-capital is cultivated (Dyllick and Hockerts 2002). Corporate sustainability is significant for an organization's vision materialization without compromise on the competitive advantage while materializing companies wide financial growth as well as environmental responsibility and provisioning for social responsibilities (Koç and Durmaz 2015). Firm managers for non-developed nations are ignorant regarding value of social sustainability or are less worried about such matters (Govindan et al. 2021). There is no distinct sustainability program for most developmental nations, which was taken after structures for mass residential buildings, without attracting much attention on the social side of sustainability (Zarghami et al. 2019). Bashir et al. (2024) identified that construction managers sanctioning belief for social sustainability in their building project have much tendency for change in a significant way.

Furthermore, each construction project is distinct. What would be accepted in as socially sustainable in a region could not be acceptable as minimally sustainable in another region (Karji et al. 2019). Social values, political institutions, cultures, as well as economies, differ significantly between regions. Additionally, social sustainability is region-specific in nature, making measuring it effectiveness challenging. The distinctiveness can lead to a colossal difference in social sustainability practices implementation when practiced differently between various firms, depending on each firm's unique characteristics as well as span of operation (Bashir et al. 2024). Even so, inclusion of social criteria in construction firms is fundamental if construction firms are under pressure to compete on social capacities which are to contribute valuable to the sustainability's economic as well as natural pillars. Construction firms which are concerned about social performance to a larger extent are on higher chances for their employee retention, higher financial performance, as well as value creation for external as well as internal stakeholders in the long term.

2.4 Strategies for improving social sustainability in urban infrastructures

Enhancing the standard of living for people and communities impacted by development is the main goal of social sustainability in urban infrastructure. Improving human life quality, enhancing transparency, implementing skill training, pursuing intergenerational equity, equitable construction costs distribution, and capacity building for the underprivileged are the primary advantages of implementing social sustainability (Popovic et al. 2018, Pocock et al. 2016).

Throughout the project lifecycle, from planning and design to execution, handover, and even the post-occupancy phase, academic and industry professionals have discovered various strategies for improving social sustainability. Workplace health and safety conditions are one of the most important social sustainability strategies. To safeguard employees' physical health and well-being and lower the risk of occupational accidents, illnesses, and injuries, health and safety working conditions are crucial (Govindan et al., 2025). This can be supported by promoting health and safety culture throughout the construction activities by ensuring that the standards of health and safety are included to enhance the well-being of all workers (Popovic et al. 2018). The project team plays an important role by working closely with the community stakeholders as a way of identifying any issues and concerns that might persist during the project (ISI 2015). This engagement will ensure that the feedback of the people in the community are incorporated into every stage of the construction process, this will help in the successful completion of the project without any misunderstanding from the community (Sierra et al. 2016, Montalbán-Domingo et al. 2018, ISI 2015). According to Rostamnezhad et al. (2020), employee education and training, reducing the disruption of public transportation which is caused construction activities, identifying the expectation of all stakeholders, the concerns and expectations of the community, and a requiring management plan to increase construction workers' projectivity are the most important five factor influencing the social dimension of sustainability and should be concentrated on as a means of enhancing the lives of those being affected by the construction activities. The nature of human needs i.e. both psychological and physical, is the foundation of social sustainability (Landorf 2011). Studies have identified hard and soft infrastructure as a way of meeting the physical and psychological needs of humans. Authors such as Almahmoud and Doloi (2015) identified hard infrastructure as a way of meeting the physical needs of humans and it includes water, education, employment opportunities, housing, safety and security, and access. Several authors on soft infrastructure also focused on maintaining culture and identity, facilitating participation, facilitating social connections and communication, and offering comfort as a way of meeting the psychological demands of human (Sutriadi 2023, Rashidfarokhi et al. 2026, Kavanagh et al. 2022).

3. Research Methodology

3.1 Questionnaire Survey Data

A comprehensive literature review was carried out to extract the different variables for the survey questionnaire's content and to collect the relevant variables for building the survey questionnaire. The literature search in the databases of Scopus, web of science, ProQuest Central, and Google Scholar led to the retrieval of 157 relevant literature. Following a comprehensive analysis of the publications, 21 relevant variables were identified for social sustainability strategies (SSSs). These were included in a questionnaire which had a first section on the respondents' profile detailing education, project and career experiences. The last section of the survey questionnaire gathered data on SSSs in urban infrastructures. Table 1 shows the list of variables for SSSs that was used for the questionnaire. The respondents were asked to rate the level of effectiveness on a Likert scale of 1 to 5 (where 1= Not effective, 2= Slightly effective, 3= Neutral, 4= Effective, and 5=

Highly effective) regarding the strategies for improving social sustainability in urban infrastructures. Piloting test was conducted to validate the questionnaire with twelve experts (nine from the construction industry and three from academia) on SSSs in urban infrastructure. The experts' feedback was addressed to ensure the suitability of the research instrument in achieving the purpose of the study. In all, 430 questionnaires were distributed to potential participants who experienced stakeholders via google form link. The opening section of the survey had a consent form for participants to agree to participate in the survey. Also, the questionnaire and the study were ethically reviewed and approved. A total of 312 responses were retrieved representing 72.56% of the 430 total number of questionnaires distributed.

Table 1. Factors for enhancing SSSs in urban infrastructures

S/N	Social sustainability strategies	Reference(s)
SSS1	Rewards and incentives	Rostamnezhad and Thaheem (2022)
SSS2	Transparent stakeholder communication	Zuo et al. (2012); Valdes-Vasquez and Klotz (2013)
SSS3	Conflict resolution systems	Zuo et al. (2012); Valdes-Vasquez and Klotz (2013)
SSS4	Community access provision	Zuo et al. (2012)
SSS5	Local authorities' involvement in design	Almahmoud and Doloi (2020); Valdes-Vasquez and Klotz (2013)
SSS6	Site-health and safety	Rostamnezhad and Thaheem (2022); Bashir et al. (2024)
SSS7	Clear rules and regulations	Rostamnezhad and Thaheem (2022)
SSS8	Perceived job security	Bramley et al. (2009); Zuo et al. (2012)
SSS9	Project planning	Bashir et al. (2024)
SSS10	Preventative actions	Rostamnezhad and Thaheem (2022)
SSS11	Equity and human rights	(Rostamnezhad and Thaheem 2022); Bashir et al. (2024)
SSS12	Community protection measures	Zuo et al. (2012)
SSS13	Traffic management	Leng et al. (2012); Zuo et al. (2012)
SSS14	Future-proof infrastructure	Zuo et al. (2012)
SSS15	Access to personal protection	Zuo et al. (2012)
SSS16	Preservation of significant sites	Zuo et al. (2012)
SSS17	Local employment opportunities	Montalbán-Domingo et al. (2018); Novelo et al. (2021)
SSS18	Workplace safety provisions	Zarghami and Fatourehchi (2020); Zuo et al. (2012)
SSS19	Reasonable work hours/breaks	Goel et al. (2020); Zuo et al. (2012)
SSS20	Access to safe drinking water	(Zarghami and Fatourehchi 2020); Zuo et al. (2012); Goel et al. (2020)
SSS21	Ongoing OH&S training	Rahdari and Rostamy (2015); Popovic et al. (2018)

3.2 Analysis of Data

The collected data was entered into the Statistical Package for Social Sciences (SPSS), version 27, which addresses SSSs in building projects. A reliability test was conducted to look at the internal consistency of the data using Cronbach's alpha. With an alpha test score of 0.939, it is evident that the data is trustworthy for the analysis. The interactions between numerous connected variables were then represented using an Exploratory Factor Analysis (EFA). To do the principal component analysis, the data from the 21 SSSs were imported into SPSS. The sample is adequate for factor analysis, as indicated by the KMO value of 0.919, which is greater than 0.5 (Hadi et al. 2016). The degree of collinearity among the SSSs variables is suggested by the Bartlett test of sphericity, which yields a chi-square value of 1246.164 and a p-value of 0.000. Finally, following the EFA analysis, the fuzzy synthetic evaluation (FSE) was carried out. The FSE's weights and membership values were assigned based on these factor groupings. In multi-criteria decision analysis, FSE aids in converting subjective assessments into objective values (Tetteh et al., 2024). It is useful for generating unbiased scores from personal opinions. In this study, FSE ranked the importance of the factors for enhancing social sustainability in construction projects. Several studies, such as those by Osei-Kyei et al. (2017) and Akomea-Frimpong et al. (2025) combined EFA and FSE. After the major components of the EFA, the next task was defining the alternative grades (Wuni et al. 2022). In this study, the alternative grades were defined on the Likert Scale of 1 to 5. Assignment of weightings and memberships to the factors in an effort to develop the fuzzy matrix (Yevu et al. 2021, Kukah et al. 2023) followed next. The final task was the fuzzy synthetic evaluation using the critical indices (Ekanayake et al. 2023).

4. Results and discussions

4.1 Descriptive analysis

The second table (Table 2) presents the overview of the 312 participants in this study. The table indicates majority of the participants were infrastructure engineers while some of the stakeholders were financiers, citizens (users), operators and regulators of urban projects. The table also demonstrates majority of the participants are familiar with urban infrastructure with more than 10 years. Academically, participants have formal education and knowledge on the topic at hand.

Table 2. Overview of participants

Profile details	Frequency in percentages
Participant (stakeholder) type	Citizen (18%), Infrastructure engineer (45%), Financier (20%), Operator (14%), Supervisor/Regulator (3%)
Experiences (Years)	10 - 15 years (54%), 16-20 years (35%), > 20 years (11%)
Highest education level	Undergraduate (58%), postgraduate (16%), Doctorate (4%), and professional and diploma certificate (22%)

The means of the variables (SSS) as presented in Table 3 are ranked showing the importance of such variables to the studies participants. The most important SSSs in urban infrastructures are rewards and incentives (SSS 1), Ongoing OH&S training (SSS21), and Access to safe drinking water (SSS20) with a corresponding means of 4.45, 4.43, and 4.22 respectively. The SSSs such as

14 and 12 that reported the same means as can be seen in Table 3 were separated by their standard deviations (SD). The Kruskal-Wallis test was further conducted to check the statistical differences between the responses by the participants using the Kruskal-Wallis non-parametric test. This test is verified by Shapiro-Wilk Normality test, and it does not require assumption of normality, hence making it suitable for SSS data that is not normally distributed. This test was applied to determine how SSS varies among groups, i.e. the respondent's profession. The result in Table 2 shows that all the variables posted a significant yield less than 0.05. Per the opinions of the respondents, there are no significant disparities among these SSS variables in urban infrastructure.

Table 3: Mean score ranking and descriptive statistics

S/N	Social Sustainability Strategies	Overall MS	SD	Rank	Shapiro-Wilk Normality test	Kruskal-Wallis non-parametric test
SSS 1	Rewards and incentives	4.45	1.097	1	0.00	0.665
SSS 21	Ongoing OH&S training	4.43	1.029	2	0.00	0.467
SSS 20	Access to safe drinking water	4.22	1.046	3	0.00	0.948
SSS 18	Workplace safety provisions	4.17	1.098	4	0.00	0.728
SSS 6	Site health and Safety	4.15	1.125	5	0.00	0.783
SSS 3	Conflict resolution systems	4.04	1.218	6	0.00	0.665
SSS 9	Project planning	4.04	1.142	7	0.00	0.346
SSS 19	Reasonable work hours/breaks	4.00	1.223	8	0.00	0.839
SSS 14	Future-proof infrastructure	3.96	1.233	9	0.00	0.903
SSS 12	Community protection measures	3.96	1.173	10	0.00	0.619
SSS 16	Preservation of significant sites	3.94	1.225	11	0.00	0.932
SSS 15	Access to personal protection	3.93	1.129	12	0.00	0.483
SSS 10	Preventative actions	3.92	1.179	13	0.00	0.579
SSS 7	Clear rules and regulations	3.91	1.095	14	0.00	0.793
SSS 11	Equity and human rights	3.89	1.226	15	0.00	0.613
SSS 13	Traffic management	3.87	1.127	16	0.00	0.033
SSS 17	Local employment opportunities	3.86	1.138	17	0.00	0.434
SSS 4	Community access provision	3.85	1.117	18	0.00	0.183
SSS 8	Perceived job security	3.8	1.13	19	0.00	0.587
SSS 5	Local authorities' involvement in design	3.76	1.239	20	0.00	0.173
SSS 2	Transparent stakeholder communication	3.74	0.947	21	0.00	0.551

4.2 Factor analysis

The main groups and underlying linkages within the SSS variables were identified in this section using Factor analysis (FA). Howard (2016) posited that exploratory factor analysis (EFA) is appropriate for evaluating and extracting pertinent factors in the absence of prior hypotheses. Cronbach's alpha (CA) reliability tests were one of the initial assessments used to determine the effectiveness of the EFA. The data's dependable dimensionality and internal consistency are demonstrated by the CA results, which are 0.939, over the conventional 0.7 criterion (Fellows and Liu 2021). The dataset's results from the Bartlett test of sphericity (sphericity = 1246.164) were deemed to be of very large size in addition to the CA. The variables are not identity matrices, according to the correlation matrix's associated significance level ($p = 0.000$) (Santos et al. 2019). The KMO statistics for the responses revealed that the sample data is enough for the EFA, with a value of 0.919 (Shrestha 2021). Next, principal component analysis (PCA) was used to extract the factor groups. Because PCA has stronger dimension reduction characteristics and works well with datasets that have uncorrelated coefficients, it is seen as being superior to other extraction approaches in the EFA analysis (Shrestha 2021). Varimax orthogonal rotation, which is superior to previous EFA rotation techniques in maximizing the variances and correlations between the major factors and sub-factors, was used to assist the PCA (Ahmed and Maruod 2025). In conclusion, three principal components exceeding the eigenvalue threshold of larger than 1.000 were retrieved from the EFA; the factors loading on each sub-component exceeded 0.50 and 57.76% of the total variance coming from the 21 SSSs variables (refer to Table 3). Similar studies have been conducted using the same analysis and the percentage loadings were found to be between 50% to 60% (Dobrucali et al. 2024).

4.3 Fuzzy analysis

4.3.1 Weighting scores.

From the factor groupings in Section 4.2, three principal components were established with 21 sub-components. The sub-components are assigned weights based on their contributions within each of the principal components (Akomea-Frimpong et al. 2025). The SSMs' means in Table 3 serve as the foundation for allocating the weights. Each variable's significance within a group is assigned a value by the weighting function (Ameyaw et al. 2017).

Table 4: Principal groups on SSM using exploratory factor analysis

S/N	Social sustainability metrics	Factor loadings	Eigenvalues	VE	CVE
SSSG1	Inclusive strategies		9.595	45.692	45.692
SSS12	Community protection measures	0.780			
SSS20	Access to safe drinking water	0.710			
SSS19	Reasonable work hours/breaks	0.695			
SSS10	Preventative actions	0.666			
SSS8	Perceived job security	0.647			
SSS14	Future-proof infrastructure	0.642			
SSS21	Ongoing OH&S training	0.545			
SSS16	Preservation of significant sites	0.532			

SSS17	Local employment opportunities	0.522			
SSS13	Traffic management	0.501			
SSSG2	Welfare of workers		1.275	6.070	51.762
SSS11	Equity and human rights	0.776			
SSS15	Access to personal protection	0.709			
SSS18	Workplace safety provisions	0.660			
SSS9	Project planning	0.600			
SSS4	Community access provision	0.571			
SSS3	Conflict resolution systems	0.537			
SSSG3	Stakeholder Engagement		1.115	5.309	57.071
SSS2	Transparent stakeholder communication	0.798			
SSS5	Local authorities' involvement in design	0.728			
SSS7	Clear rules and regulations	0.554			
SSS1	Rewards and incentives	0.511			

Table 5: Weighting scores of the principal and sub-components

S/N	Principal groups of the SSSs	Means of SSSs	Weightings of SSSs	Means total of SSSGs	Weightings of SSSGs
SSSG1	Inclusive strategies			39.96	0.501
SSS12	Community protection measures	3.96	0.099		
SSS20	Access to safe drinking water	4.22	0.106		
SSS19	Reasonable work hours/breaks	4.00	0.100		
SSS10	Preventative actions	3.92	0.098		
SSS8	Perceived job security	3.8	0.095		
SSS14	Future-proof infrastructure	3.96	0.099		
SSS21	Ongoing OH&S training	4.43	0.111		
SSS16	Preservation of significant sites	3.94	0.099		
SSS17	Local employment opportunities	3.86	0.097		
SSS13	Traffic management	3.87	0.097		
SSSG2	Welfare of workers			23.92	0.300
SSS11	Equity and human rights	3.89	0.163		
SSS15	Access to personal protection	3.93	0.164		
SSS18	Workplace safety provisions	4.17	0.174		
SSS9	Project planning	4.04	0.169		
SSS4	Community access provision	3.85	0.161		
SSS3	Conflict resolution systems	4.04	0.169		

SSSG3	Stakeholder Engagement			15.86	0.199
SSS2	Transparent stakeholder communication	3.74	0.236		
SSS5	Local authorities' involvement in design	3.76	0.237		
SSS7	Clear rules and regulations	3.91	0.247		
SSS1	Rewards and incentives	4.45	0.281		
				$\Sigma=79.74$	

An SSM's weighting score is calculated by dividing its means (as a sub-component) by the total means of principal component represented as.

$$wthsi_i = \frac{Mean_i}{\sum_i^n Mean_i}, 0 \leq wthsi_i \leq 1, \text{ and } \sum_{i=1}^n wthsi_i = 1$$

Mean_i is the SSS mean, and Wths_i is the weighting score (WS) of an SSS. The number of sub-components is denoted by i and n. For instance, the mean of SSS 12 is 3.96 with a total component mean of 39.96 in Table 5, which is used to determine the weighting score of SSS12. Consequently, SSS12's WS is:

$$wthsi_{SSS12} = \frac{3.96}{3.96 + 4.22 + 4.00 + 3.92 + 3.80 + 3.96 + 4.43 + 3.94 + 3.86 + 3.87} = \frac{3.96}{39.96} = 0.099$$

To ascertain the weighting scores of the groupings, the main components can also be calculated using this method:

$$wthsi_{SSSG1} = \frac{39.96}{39.96 + 23.92 + 15.86} = \frac{3.96}{79.74} = 0.501$$

$$wthsi_{SSSG2} = \frac{23.92}{39.96 + 23.92 + 15.86} = \frac{23.92}{79.74} = 0.300$$

$$wthsi_{SSSG3} = \frac{15.86}{39.96 + 23.92 + 15.86} = \frac{15.86}{79.74} = 0.199$$

4.3.2 Membership function

According to Ekanayake et al. (2023), the membership function (MF) of the SSS sub-components is based on the survey replies of the participants as detailed in Section 3.1. The fuzzy analysis's linguistic concepts are mapped by the membership function, which mathematically assigns variables values between 0 and 1 (Yevu et al. 2021). The proportion of answers on the Likert scale ranges from 1 to 5. The MF of SSS12, for example, is calculated using the following criteria: 46.60% for extremely effective (5), 24.10% for effective (4), 17.00% for neutral (3), 10.70% for slightly effective (2), and 3.60% for not effective (1). This formula sets this as:

$$MF_{SSS12} = \frac{0.036}{NoEt(1)} + \frac{0.107}{SLEt(2)} + \frac{0.170}{Nel(3)} + \frac{0.241}{Et(4)} + \frac{0.446}{StEt(5)}$$

Based on this data, SSS12's MF is set to (0.036, 0.107, 0.170, 0.241, 0.446). The procedure is the same for all the level 3 MFs in Table 5. Their weighting scores are multiplied by the MFs of the sub-component SSSs to determine the MFs (level 2) of the principal components (SSSGs). MFs of the level 3 and their weightings in a fuzzy evaluation matrix using the following formula as a guide:

$$FSE(Dm)_i = Wthsi \bullet MF_i$$

where "•" denotes the composite operator, MF_i is the membership function of the SSSs, $Wthsi$ is the weighting scores, and $FSE(Dm)_i$ is the FSE evaluation matrix.

Table 6: Constituents of the membership functions of the SSSs

S/N	Social sustainability strategies	Weightings	MF of SSSs (level 3)	MF of SSSGs (level 2)
SSSG1	Inclusive strategies			(0.041, 0.090, 0.158, 0.249, 0.462)
SSS12	Community protection measures	0.099	(0.036, 0.107, 0.170, 0.241, 0.446)	
SSS20	Access to safe drinking water	0.106	(0.027, 0.054, 0.134, 0.241, 0.545)	
SSS19	Reasonable work hours/breaks	0.100	(0.054, 0.089, 0.152, 0.214, 0.491)	
SSS10	Preventative actions	0.098	(0.045, 0.080, 0.223, 0.214, 0.438)	
SSS8	Perceived job security	0.095	(0.036, 0.098, 0.241, 0.277, 0.348)	
SSS14	Future-proof infrastructure	0.099	(0.054, 0.116, 0.107, 0.268, 0.455)	
SSS21	Ongoing OH&S training	0.111	(0.018, 0.071, 0.080, 0.125, 0.705)	
SSS16	Preservation of significant sites	0.099	(0.063, 0.089, 0.134, 0.277, 0.438)	
SSS17	Local employment opportunities	0.097	(0.036, 0.107, 0.188, 0.304, 0.366)	
SSS13	Traffic management	0.097	(0.045, 0.089, 0.170, 0.348, 0.348)	
SSSG2	Welfare of workers			(0.037, 0.098, 0.156, 0.255, 0.454)
SSS11	Equity and human rights	0.163	(0.054, 0.107, 0.161, 0.250, 0.429)	
SSS15	Access to personal protection	0.164	(0.018, 0.125, 0.188, 0.250, 0.420)	

SSS18	Workplace safety provisions	0.174	(0.027, 0.071, 0.152, 0.205, 0.545)
SSS9	Project planning	0.169	(0.045, 0.071, 0.143, 0.277, 0.464)
SSS4	Community access provision	0.161	(0.036, 0.107, 0.170, 0.348, 0.339)
SSS3	Conflict resolution systems	0.169	(0.045, 0.107, 0.125, 0.205, 0.518)
SSSG3 Stakeholder Engagement			(0.036, 0.091, 0.158, 0.279, 0.435)
SSS2	Transparent stakeholder communication	0.236	(0.009, 0.107, 0.232, 0.438, 0.214)
SSS5	Local authorities' involvement in design	0.237	(0.063, 0.116, 0.188, 0.268, 0.366)
SSS7	Clear rules and regulations	0.247	(0.018, 0.116, 0.188, 0.295, 0.384)
SSS1	Rewards and incentives	0.281	(0.054, 0.036, 0.045, 0.143, 0.723)

$$FSE(DM)_i = \{wths_1, wths_2, wths_i, \dots wths_n\} \bullet \begin{bmatrix} MF_{11} & MF_{12} & MF_{13} & MF_{14} & MF_{15} \\ MF_{21} & MF_{22} & MF_{23} & MF_{24} & MF_{25} \\ MF_{31} & MF_{32} & MF_{33} & MF_{34} & MF_{35} \\ \dots & \dots & \dots & \dots & \dots \\ MF_{m1} & MF_{m2} & MF_{m3} & \dots & MF_{nt} \end{bmatrix}$$

To demonstrate this formula in SSSG3 with WS of $wths_{GEBG3} = [0.236, 0.237, 0.247, 0.281]$ and MF of

$$MF_{SSSG3} = \begin{bmatrix} 0.009 & 0.107 & 0.232 & 0.438 & 0.214 \\ 0.063 & 0.116 & 0.188 & 0.268 & 0.366 \\ 0.018 & 0.116 & 0.188 & 0.295 & 0.384 \\ 0.054 & 0.036 & 0.045 & 0.143 & 0.723 \end{bmatrix}$$

Thus, the FSE(Dm) of SSSG3 is:

$$FSE(Dm)_{SSSG3} = [0.236, 0.237, 0.247, 0.281] \bullet \begin{bmatrix} 0.009 & 0.107 & 0.232 & 0.438 & 0.214 \\ 0.063 & 0.116 & 0.188 & 0.268 & 0.366 \\ 0.018 & 0.116 & 0.188 & 0.295 & 0.384 \\ 0.054 & 0.036 & 0.045 & 0.143 & 0.723 \end{bmatrix}$$

$$= [0.036, 0.091, 0.158, 0.279, 0.435]$$

The FSE(Dm) of the rest of the SSSGs are computed by using the method to calculate the FSE(Dm) of SSSG3.

4.3.3 Determination of critical indexes

The fuzzy matrix in Section 4.3.2 is combined with alternate grades to get the critical indexes. According to the Likert scale, the alternative grades in this study are set between 1 and 5 (Wuni et al. 2022). Consequently, the principal component's critical index is:

$$SSSG_{index} = \sum_{i=1}^3 (FSE(Dm)_i \times AGr_i)$$

$FSE(Dm)_i$ is the fuzzy matrix, and $AGr_i = (1,2,3,4,5)$ is the Likert scale. The following formula is used to determine the five principal components' critical indexes:

$$\begin{aligned} SSSG1 &= (0.041, 0.090, 0.158, 0.249, 0.462) \times (1,2,3,4,5) \\ &= (0.041 * 1 + 0.090 * 2 + 0.158 * 3 + 0.249 * 4 + 0.462 * 5) = 4.003 \text{ (1st)} \\ SSSG2 &= (0.037, 0.098, 0.156, 0.255, 0.454) \times (1,2,3,4,5) \\ &= (0.037 * 1 + 0.098 * 2 + 0.156 * 3 + 0.255 * 4 + 0.454 * 5) = 3.991 \text{ (2nd)} \\ SSSG3 &= (0.036, 0.091, 0.158, 0.279, 0.435) \times (1,2,3,4,5) \\ &= (0.036 * 1 + 0.091 * 2 + 0.158 * 3 + 0.279 * 4 + 0.435 * 5) = 3.985 \text{ (3rd)} \end{aligned}$$

The weighting scores of the principal components are multiplied by their membership functions to determine the overall critical indexes of SSSs. In Table 5, the SSSG's weighting scores is $Wths_{SSSG} = (0.501, 0.300, 0.199)$ and the MF is

$$FSE(Overall)_i = \begin{bmatrix} 0.041 & 0.090 & 0.158 & 0.249 & 0.462 \\ 0.037 & 0.098 & 0.156 & 0.255 & 0.454 \\ 0.036 & 0.091 & 0.158 & 0.279 & 0.435 \end{bmatrix}$$

In summary, the overall fuzzy matrix of SSSG is calculated as:

$$\begin{aligned} SSSG(overall)_i &= \{wths_1, wths_2, \dots, wths_n\} \bullet \begin{bmatrix} MF_{11} & MF_{12} & MF_{13} & MF_{14} & MF_{15} \\ MF_{21} & MF_{22} & MF_{23} & MF_{24} & MF_{25} \\ MF_{31} & MF_{32} & MF_{33} & MF_{34} & MF_{35} \\ \dots & \dots & \dots & \dots & \dots \\ MF_{m1} & MF_{m2} & MF_{m3} & \dots & MF_{nt} \end{bmatrix} \\ SSSG(Overall)_i &= (0.501, 0.300, 0.199) \bullet \begin{bmatrix} 0.041 & 0.090 & 0.158 & 0.249 & 0.462 \\ 0.037 & 0.098 & 0.156 & 0.255 & 0.454 \\ 0.036 & 0.091 & 0.158 & 0.279 & 0.435 \end{bmatrix} \\ SSSG(overall)_i &= (0.039, 0.092, 0.157, 0.257, 0.454) \end{aligned}$$

The critical index of the overall SSSG is computed as:

$$\begin{aligned} SSSG_{critical\ index} &= (0.039, 0.092, 0.157, 0.257, 0.454) \times (1, 2, 3, 4, 5) \\ &= (0.039 * 1) + (0.092 * 2) + (0.157 * 3) + (0.257 * 4) + (0.454 * 5) \end{aligned}$$

$$= 3.996$$

4.4 Discussion of findings

Based on the factor analysis, three groups of strategies were revealed as important strategies for enhancing social sustainability in urban infrastructures. The three groups were then named as *Inclusive Strategies*, *Welfare of Worker*, and *Stakeholder Engagement*. It is worth mentioning that each of these groups represents interconnected strategies that align with various theoretical and empirical insights in the social sustainability in the construction industry. These results agree with other studies and extend previous research, which offers a deep understanding of how social sustainability can be operationalized in the construction industry within developing countries like Ghana.

4.4.1 SSSG1 (*Inclusive Strategies*)

Inclusive Strategies, as the most dominant factor (Eigenvalue = 9.595; VE = 45.692%) with fuzzy criticality index of 4.003 (1st ranking), which shows the critical role of embedding inclusive policies and practices into urban infrastructures. The largest part of the social sustainability strategies falls under this group. It includes strategies such as providing access to safe drinking water, promoting adequate breaks and working hours, ensuring job security, and designing projects that generate local employment in Ghana. The prominence of this grouping affirms the importance of human-centered design and operational inclusivity in urban cities in Ghana. This finding is in support of the study by Goh et al. (2020), who emphasized that sustainable construction must reflect the lived realities of the workforce and affected communities. According to Zuo et al. (2012) inclusive practices will improve long-term societal outcomes, community satisfaction, and worker retention if they are considered in urban infrastructures. The inclusion of strategies such as the preservation of significant sites and traffic management also highlights the interplay between cultural, environmental, and logistical considerations, which is increasingly acknowledged in sustainability literature (Zarghami and Fatourehchi 2020, Montalbán-Domingo et al. 2018). Compared to studies in more developed economies, the findings agree with the study of Reverte (2015), who deposited that inclusive procurement guidelines significantly improved social outcomes in Spain's construction sector. However, looking at it from developing countries like Ghana where regulatory mechanisms are weak, inclusion must be approached as a proactive and voluntary initiative by construction firms rather than a compliance necessity. The highest strategy under this group is "protection of the community during construction/demolition period of a project" with a factor loading of 0.780, indicating the combination of proactive measures that should be put in place to ensure the safety and well-being of those near the project. This strategy was, however, rated low by the study's participants with a mean score of 3.96 (10th ranking) suggesting lack of awareness of the safety of both workers and the public in Ghana. Therefore, this study further adds to the existing knowledge by how a constellation of inclusive practices can be bundled together as a coherent factor that significantly enhances social sustainability, even in resource-constrained environments.

4.4.2 SSSG2 (Welfare of workers)

The second factor, Welfare of Workers (Eigenvalue = 1.275; VE = 6.070%) having a fuzzy criticality index of 3.991 (2nd ranking), comprises of strategies such as equity and human rights, access to personal protection, safety provisions, and effective project planning in the Ghanaian context. This finding is consistent with the findings of Karakhan and Gambatese (2017), who stressed the significance of occupational safety and health as core tenets of social sustainability. It also aligns with Bashir et al. (2024), who showed that welfare-focused practices improve both productivity and long-term project viability. In this study, safety provisions (SSS18) and equitable access to personal protection (SSS15) emerged as high-weight strategies, showing the need for comprehensive occupational health and safety (OH&S) mechanisms as far as urban infrastructures are concerned. This is particularly important when it comes to developing countries where informal labor markets and lax enforcement often compromise worker wellbeing Popovic et al. (2018). The infrastructure sector in Ghana for instance, the safety and wellbeing of workers have been disregarded and is since these workers are temporary workers as such construction managers does not see the need to invest in health and safety mechanisms. Interestingly, the inclusion of conflict resolution mechanisms and access to areas surrounding the site suggests that worker welfare goes beyond physical health and encompasses psychological security and site accessibility. These findings resonate with the broader literature on social sustainability, which increasingly considers mental wellbeing and empowerment as critical metrics (Missimer et al. 2017, Goh et al. 2020). Unlike in studies from the Gulf region, such as Hossein and Khaled (2021), where spatial design and neighborhood aesthetics dominated the discussion on social sustainability, the emphasis in this study is on operational and procedural fairness, highlighting contextual differences between high-income and lower-income settings. Equity and human rights (SSS11) which serve as foundational principles in ensuring that development benefits all individuals without discrimination was however rated low (mean = 3.89) indicating neutral on the 5-point Likert scale. This implies that construction professionals in developing countries overlooked the potential of this strategy under the concept of social sustainability.

4.4.3 SSSG3 (Stakeholder engagement)

The third factor, stakeholder engagement (Eigenvalue = 1.115; VE = 5.309%) with a fuzzy criticality index of 3.985 (3rd ranking), includes rewards and incentives, open communication, involvement of Ghanaian local authorities in design, and clear rules and regulations. Even though it had the lowest eigenvalue among the three groups, its strategic importance cannot be understated. This group reflects the relational and governance dimension of social sustainability, which Zuo et al. (2012) and Valdes-Vasquez and Klotz (2013) describe as essential for collaborative project success. Reward mechanisms (SSS1) and stakeholder communication (SSS2) emerged as pivotal components, reaffirming findings by Almahmoud and Doloi (2020) who argued that active stakeholder collaboration boosts trust, compliance, and project legitimacy. These results also resonate with the findings of Shooshtarian et al. (2020), where stakeholder engagement was positioned as the link between policy frameworks and project-level implementation. However, looking at it from the developed country contexts where stakeholder engagement is often regulated and institutionalized, this study shows that in developing nations

such as Ghana, stakeholder engagement remains largely discretionary and variable across cities. The high weighting of rewards and incentives ($WS = 0.281$) with mean score of 4.45 (1st ranking) can suggest that stakeholders are more likely to participate meaningfully when they perceive benefit on the project at hand.

5. Implications of study

The findings of this study offer practical implications for multiple stakeholders in the infrastructure development of cities in Ghana and similar developing countries where the integration of social sustainability is still a challenge. By empirically grouping the strategies into three distinct but interrelated components inclusive strategies, welfare of workers, and stakeholder engagement, the study provides a practical and structured roadmap for integrating social sustainability into urban infrastructure planning and execution. Firstly, for policymakers and government agencies, the results show the urgency of developing comprehensive social sustainability policies that go beyond traditional environmental and economic considerations. The prominence of inclusive strategies such as local employment design (SSS17), job security (SSS8), and adequate breaks (SSS19) suggests that regulatory frameworks should mandate these features through social clauses in public procurement. Governments can also consider incorporating social sustainability criteria into procurement procedures as a requirement for both public and private developers to promote sustainable development in construction. Secondly, practitioners including infrastructure engineers, city planners, construction companies and project managers can draw from the prioritized strategies to build socially responsive project environments. The emphasis on worker welfare and engagement will help construction firms to pay much attention to the social dimension of sustainability by ensuring safe, equitable, and participatory work environments. Adopting these strategies could enhance firm reputation, reduce labour turnover, and boost productivity as key drivers of long-term competitiveness. The inclusion of OH&S training (SSS21) and access to personal protective equipment (SSS15) for example, can contribute significantly to worker satisfaction and firm's productivity. The study has implications for both local communities and civil society organizations. The inclusion of strategies like community protection during construction (SSS12), and access to surrounding areas (SSS4), can motivate communities to demand transparency and social responsibility from developers. The concept of social sustainability is gradually moving from concept to action, suggesting that community-based monitoring and participation will be an important way of holding contractors and government accountable. Studies in supply chain have reported that pressure from government with regular community pressure is found to increase social sustainability adoption (Golicic et al., 2020). In essence, the study bridges the gap between theory and practice, providing an actionable framework that various stakeholders can adopt, adapt, and scale to promote socially sustainable construction across different project types and regional contexts.

6. Conclusion

This study examined effective strategies for enhancing social sustainability in urban infrastructure using a rigorous empirical approach combining EFA and FSE. The analysis revealed three key components thus inclusive strategies, welfare of workers, and stakeholder engagement which comprehensively define the critical pillars of social sustainability within the context of urban infrastructure in a developing country. The results show that inclusive strategies, which involve fair treatment of workers, provision of essential amenities, and promotion of local employment, are the most influential factor group in driving social sustainability. This means construction stakeholders should pay critical attention to the basic human needs and community rights since they form the foundation of socially sustainable construction as revealed by the study. The welfare of workers appears to be a crucial factor, especially when it comes to safety, planning, and equitable rights, further strengthening the value of internal labour conditions on project outcomes. Stakeholder engagement, though it had the lowest weighting, it can be considered essential in fostering collaboration, accountability, and shared benefits among all parties involved in construction delivery. This study has empirical, theoretical and practical implications. When comparing this study's findings to existing studies, this study provides empirical validation of socially sustainable practices which are often theoretically explored. The research further extends current knowledge by prioritizing strategies that are not only context-specific but also adaptable across various project typologies. Using this study as a guide, future research can focus on the economic justification for adopting social sustainability practices in urban infrastructures. Looking at the overall critical index which yield a result of 3.996 representing neutral on the Likert scale, it suggests that construction professionals in developing countries like Ghana have limited awareness on the potentials of social sustainability. Hence it is recommended that professional institutions, NGOs, and universities should organize training programs and workshops to raise awareness on the importance of social sustainability. It worth mentioning that this study contributes significantly to the ongoing discourse on sustainability in the built environment. It gives policymakers, construction managers, and the entire community on how to improve social outcomes in infrastructure projects in cities through structured, measurable, and stakeholder-informed strategies. The insights gained lay a foundation for future research and implementation aimed at achieving sustainable development goals in the construction industry especially within the dynamic and challenging environments of developing countries.

Funding declaration

There is no funding for this article

Author Contribution declaration

E.A-Conceptualisation, literature review, data collection, data analysis and paper writing; S.A.-Data analysis and paper writing; I.A.F- supervision, paper writing and final revision; A.S.K-Review and paper writing.

Acknowledgments

We are grateful to all the anonymous reviewers who supported this manuscript.

Competing interests (include appropriate disclosures)

Authors declare there is no competing interests.

Declarations:**Data availability statement**

The data is available upon request from the corresponding author

Consent to Publish

All authors have approved the publication

Ethics approval

The paper has been ethically examined and approved

Consent to Participate

All participants voluntarily agree to participate or not participate in the study

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