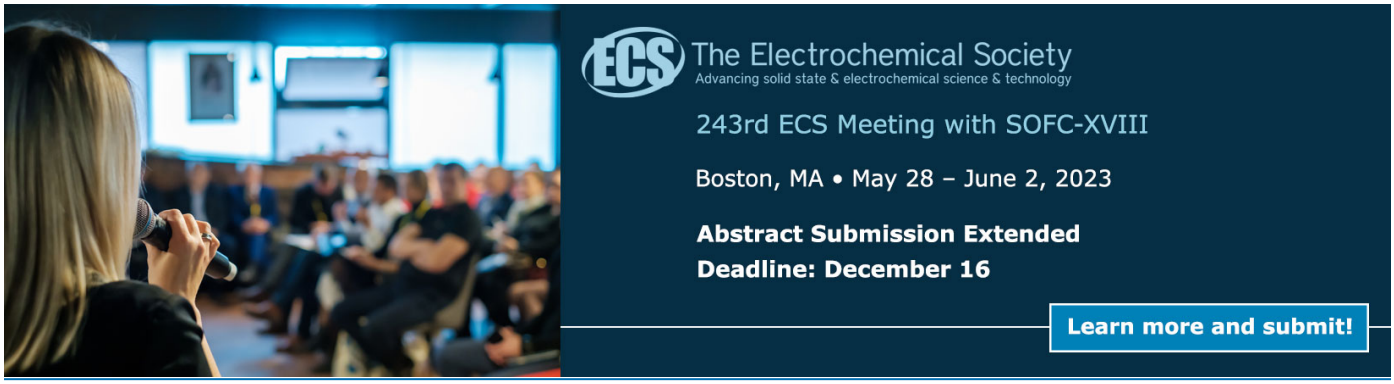
Sustainability Indicators in Building Construction Projects through the Lens of Project Delivery Elements



Sustainability Indicators in Building Construction Projects through the Lens of Project Delivery Elements

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Abstract. Sustainability indicators have been developed since 1990s to be utilized in construction projects as tools and instruments for achieving higher level sustainability. Achieving sustainability goals in construction projects can be affected by the delivery model in place in a positive or negative manner, as it accounts for accomplishing project definition, design, planning, and execution phases. With any construction project we can recognize three main delivery elements which are project organization, contractual relationships, and operational system. This study aims to address the role of these project delivery elements in the application of sustainability indicators in building construction projects. To do so, a literature study was carried out and qualitative analysis of the relevant studies led to the identification of sustainability indicators, barriers, and enablers in building construction. Then, these indicators, barriers, and enablers were analysed and structured within a model based on their relation to the elements of construction project delivery. The findings present a sustainability model for building construction, revealing the connection between the project delivery elements and the identified barriers and enablers for the application of the sustainability indicators. These findings contribute toward facilitating sustainable construction through project delivery and provide a frame of reference for the future studies.

1. Introduction and theoretical background

Construction projects play a significant role in the development of infrastructure and economic growth of nations. However, research studies show that this contribution has also destructive impacts on the environment, society, and the economy itself [1,2]. An important part of this disadvantage is related to the massive waste generated by construction projects and their subsequent harm to environment because of the polluting emissions and reckless use of raw materials [3]. According to [4], "construction projects are responsible for about half of all carbon emissions, one-third of landfill waste and consume about one-eighth of total raw materials." These consequences of construction projects not only negatively affect the existing human beings' quality of life, but also jeopardize the future generations' right and opportunity to take advantage of natural resources as well as safe and clean environment.

The recognition of these issues as a big challenge, in the big picture, for construction industry resulted in the emergence of sustainability concept in 1990s, as the subset of the sustainable development goals outlined by United Nations (UN) [5]. Sustainability in building construction refers to the development, commitment, and management of a healthy built environment through prudent consumption of resources and complying to ecological principles [2]. Abolore [6] defined sustainable construction as sustainable practices concerning the design approach and the selection of materials including construction methods in a manner that improves performance, thereby reducing any form of the environmental impact that

may result from the project. Moreover, Aghazadeh and Yildirim [7] stated that sustainability in construction is the development in which three key factors of the environment, the economy, and society, are balanced, thereby providing solutions against traditional patterns of development. Sustainable construction can prevent problems such as shortages of natural resources, devastation of the ecosystem, environmental degradation, and decreased quality of life [7].

Following the sustainability initiative by UN, the research community and project professionals in the construction field have put substantial effort for realizing sustainability goals through developing indicators representing economic, social, and environmental aspects of sustainability (e.g., [8,9,10]). In terms of the research activities, a few scholars have identified environmental, social, and economic indicators of sustainability in building construction projects. For instance, a study carried out by Oladokun et al. [2] identified 22 sustainability indicators for building construction projects, categorized in three groups of environment, economy, and society. Moreover, Agyekum et al. [11] found that effects of the project on water quality, air quality, energy use and conservation, and environmental compliance and management are two critical indicators of environmental sustainability. The studies conducted by Shen et al. [12] and Stanitsas et al. [13], alike several others, looked at the sustainability indicators from the perspective of environment, economy, and society. Besides this comprehensive perspective, there are also a few studies which have solely focused on the social aspect of sustainability in the building construction and topics such as health and physical comfort, accessibility, integration, employment, and local stakeholder engagement have been found of importance [14,15,16,17,18]. In terms of the practice-oriented efforts, some of the sustainability assessment tools developed by recognized construction industry agencies include the Building Research Establishment Environmental Assessment Methodology (BREEAM), Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Building Energy Efficiency (CASBEE) and green star [19].

Notwithstanding these efforts, findings of previous studies show that construction industry, particularly building construction projects, are still struggling with the complete realization of sustainability indicators related to 2030 targets of sustainable development [11,20]. In this regard, a few studies have been conducted to discover enablers and barriers of sustainability in building construction. Enablers and barriers, here, refer to those factors, which facilitate or hinder the realization of sustainability indicators in building construction. In terms of the barriers, the studies carried out by Warnock [21], Haavik et al. [22], Rafindadi et al. [23] and Qazi et al. [24], have identified factors such as complexity of building construction, plethora of sustainability assessment tools and indicators, limited skill, knowledge as well as experience and lack of incentives as the berries toward sustainability in building construction. In terms of the enablers and solutions of sustainable building construction, several studies have been undertaken and factors such as leadership competencies, recycling and waste management, stakeholder engagement, integration of BIM and sustainability practices, and mandatory regulations concerning sustainable building construction have been found significantly useful for facilitating the realization of sustainability indicators in building construction [25,26,27,28,29,30,31,32].

The existing body of knowledge and practices on sustainability in building construction projects, as briefly explained earlier, covers various aspects of sustainability. However, there are few, if any, studies looking at the role of project delivery system in place and its elements (project organization, operational system, contractual relationships) as a theoretical lens [33] for addressing the realization of sustainability indicators in building construction projects. This study aims to fill the mentioned knowledge gap through identifying sustainability indicators, barriers, and enablers in building construction and modelling them based on their conceptual relevance to the mentioned project delivery elements.

The resultant paper is structured in four sections. The current section, containing introduction and theoretical background, is followed by the explanation of data collection and analysis process in the methodology section. Then, findings are presented in the results section. Finally, the discussion of the findings and the subsequent conclusions are stated.

2. Research methodology

This study aimed to address the role of project delivery elements in the application of sustainability indicators in building construction projects. To that end, a literature study was performed through locating the relevant studies from ScienceDirect and Emerald databases by searching for the presence of certain keywords on the title of the previous studies. The abstract and full text of the located studies were then reviewed to identify and exclude repetitions and irrelevant studies and to extract the required research data. In terms of the publication period, 85% of the analyzed studies were published between 2011-2021. This is particularly important as the relevance of recent publications is usually higher. Table 1 shows the keywords as well as the descriptive statistics concerning the conducted search for locating the relevant studies from the literature.

Table 1. Descriptive statistics of the conducted search for locating the relevant studies

Keyword	Database	Number of located studies	Number of excluded studies	Number of analyzed studies
Sustainability in construction projects	ScienceDirect	39	5	34
	Emerald	7	0	7
Sustainability indicators for construction projects	ScienceDirect	12	3	9
	Emerald	1	1	0
Sustainable building construction	ScienceDirect	35	18	17
	Emerald	6	3	3
Total		100	30	70

The process of analyzing the obtained research data from the previous studies included four steps: (i) identifying sustainability indicators in building construction projects, (ii) detecting barriers for sustainability in building construction projects, (iii) discovering enablers for sustainability in building construction projects, and (iv) modelling the above-mentioned data based on their relation to project delivery elements. Developing syntheses of the identified indicators, barriers and enablers were carried out based on the sameness or similarity of the title or meaning. Concerning the enablers and barriers, those ones with more than one frequency of appearance in the literature were qualified as the important ones and are presented in the findings. Figure 1 shows the analysis and modelling process.

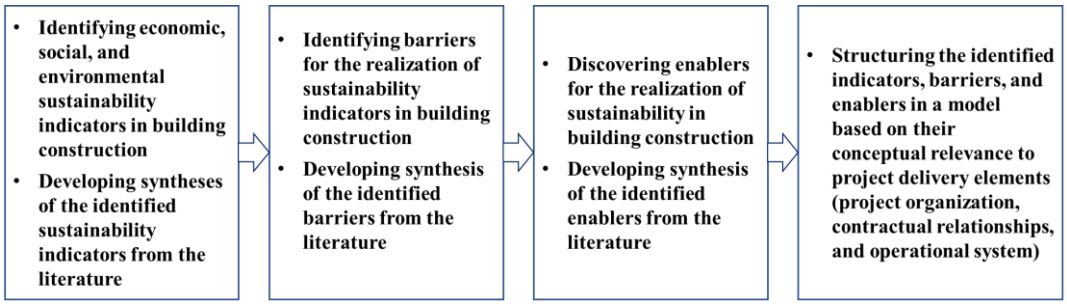

Figure 1. The process of analysis and modelling

3. Findings

3.1. Sustainability indicators in building construction projects

As the first group of findings, 15 sustainability indicators, categorized in three groups of environmental, social, and economic, are presented in Figure 2 and explained in the following. In Figure 2, there are two columns of which the first one shows the identified indicators and their main components, and the second column provides further description of the indicators. The last row in Figure 2 includes the references for the identified indicators. Special attention was paid while synthesizing the identified indicators from the literature to avoid any kind of repetition between economic, environmental, and

social indicators, thereby making the list as concise as possible. This, in turn, provided a succinct and yet comprehensive list of sustainability indicators for building construction, which can be easy to follow, understand, and to use by project practitioners.

Sustainability Indicators for Building Construction	
Indicator	**Description**
Environmental	
Adaptation to climate change - Mitigating effects of natural disasters	- Adaptation to climate change - Mitigating the effects of floods and droughts
Energy efficiency in: - Construction, and - Operation	- Energy efficiency at depots and sites - Green transport plan for sites and business activities - Energy efficiency in building use
Minimizing Pollutions - GHG emissions - Noise - Dust - Odors	- Minimizing polluting emissions - Preventing nuisance from noise, dust, and odors by good site and depot management - Using materials with low embodied energy
Protection of environment - Natural heritage (elements of biodiversity, including flora and fauna, ecosystems, and geological structures)	- Protection of the flora and fauna - Protection of sensitive ecosystems through appropriate construction practices and supervision - Considering the impact of projects on air, soil, and water quality
Waste minimization and elimination in: - Design, - Construction, - Operation, - Maintenance, and - Demolition	- Waste minimization and elimination through lean design and construction - Using recycled/sustainability sourced products - Choosing the right construction method for resource conservation
Social	
Supporting local economy and human resource - Employment - Training - Partnership with local suppliers	- Recruiting, retaining, and training local labor and experts - Equitable terms and conditions in employment - Building long term relationships with local suppliers - Transferring construction knowledge and skills to schools and neighbors
Wellbeing of project practitioners and local residents during and after project - Safety and security of workforce and local residents - Health and wellbeing of workforce and local residents - Crime prevention - Accessibility	- Accident-free construction - Accessibility (public access, human biodiversity access) - Crime prevention (e.g., through constant surveillance) - Indoor environmental quality (thermal comfort, visual comfort, acoustic comfort, indoor air quality, daylight) - The provision of green landscape - Minimizing traffic disruptions and delays - Preserving the territoriality of neighbors
Resilient planning for - Future expansions, and - Manmade hazards (epidemics)	- Resilient planning for enabling future expansions, - Mitigating the risks related to hazards such as epidemics
Stakeholder management throughout the project - Engagement in decision making - Effective communication	- Participation in decision making - Engaging neighbors in the life cycle phases of the project - Informing neighbors about the project process and timeline during construction and demolition phases
Culture - Preserving cultural heritage	- Preserving historical buildings on the project location - Alignment of project design with local character and identity of the community
Economic	
Cost management - Life cycle cost	- Design for life cycle costs - Cost incurred to users
Stakeholder satisfaction - Employee, supplier, and client	- Employee, supplier, and client satisfaction
Continuous improvement on productivity - Less defects and re-work - Reliable performance on time and cost	- Minimizing defects and reworks - Shorter and more predictable completion time - Lower cost projects with increased cost predictability - Consistent profit growth
Service value - Client's business	- Delivering services that provide best value to clients - Focus on developing client business
Management - Project management - Construction management - Governance and project delivery	- Governance and strategic management of projects - Type of contracts and project delivery models - Environmental management accreditation - Quality management accreditation
References: [2,5,8,11,14,15,17,18,26,34]	

Figure 2. Sustainability indicators for building construction

3.2. Barriers of sustainability in building construction projects

The findings show that there are eight important barriers for sustainability in building construction. These barriers have been appeared in the literature more than once. As can be seen in Figure 3, lack of competent human resource, lack of consensus among project professionals on the ontology and measurement methods of sustainability, and lack of sufficient and relevant building acts, codes, and regulations to enforce sustainability are the top three ones in the list.

Barrier/ Reference	[3]	[5]	[7]	[21]	[22]	[23]	[24]	[35]	[36]	[37]	[38]	Frequency of appearance
Lack of human resource competency on sustainability	√			√	√	√		√		√	√	7
Lack of consensus among project professionals on the ontology and measurement method of sustainability		√	√	√						√		4
Lack of sufficient and relevant building acts, codes, and regulations to enforce sustainability				√				√		√	√	
Lack of convincing justification for proving return of investment on sustainability					√	√		√			√	
Lack of sufficient information and control on the availability and performance of human resource						√	√		√			3
Lack of collaboration, cooperation and coordination among numerous actors working towards the goals of sustainability				√						√		2
Complexity of building construction				√		√						
Lack of sufficient knowledge and experience both on the demand and supply side of the benefits of sustainable buildings				√	√							

Figure 3. Main barriers to sustainability in building construction

3.3. Enablers of sustainability in building construction projects

The obtained results also present 14 enablers of the sustainability in building construction which have been mentioned in the literature more than once. It is interesting to see that enablers of sustainable building construction have received more attention from the research community, compared to the barriers, as can be understood from the number of studies which have addressed these topics (see Figure 4).

Enabler/ Reference	[2]	[12]	[14]	[21]	[22]	[25]	[27]	[28]	[29]	[30]	[31]	[32]	[39]	[40]	[41]	[42]	[43]	[44]	[45]	[46]	[47]	[48]	[49]	[50]	Frequency of appearance
Human resource competency (motives, traits, self-concept, skill, knowledge)	√					√			√	√		√								√					6
Stakeholder management			√					√				√								√	√				
Technology advancement and implementation						√	√					√			√									√	5
Management						√		√				√								√	√				
Mandatory building codes and regulations for implementation and evaluation of sustainability principles					√	√					√	√													4
Recycling and waste management						√						√					√								3
Lean design and construction						√						√						√							
Organizational culture supporting sustainability						√						√								√					
Integrating sustainability policies and instruments				√																			√		2
Integration of different actors contributing toward sustainable building construction				√																√					
Integration of sustainability in project feasibility study		√											√												
Incentive system						√						√													
Modular construction														√								√			
Integrating the assessment of carbon emission in approval process of building projects																√			√						

Figure 4. Enablers of sustainability in building construction

As can be seen in Figure 4, human resource competency, stakeholder management, and technology advancement as well as implementation are the top three enablers in the list. It is also interesting to see that the identified enablers (solutions) indicate a match with the barriers in terms of conceptual relevance. The fourth enabler, management, in Figure 4 refers to managerial considerations (e.g., using local community workforce, commitment to ethics, establishing equality), top management support, operation management, clear definition of responsibilities, risk management, commitment, and training.

3.4. Sustainability indicators, barriers, and enablers through the lens of project delivery elements

The obtained findings provided a basis for meeting the main purpose of this study to discover the role of project delivery elements in the application of sustainability indicators in building construction projects. This was accomplished through developing a model by structuring the identified sustainability indicators, barriers, and enablers based on their conceptual relevance to project delivery elements. As can be seen in Figure 5, the model is consisted of four components, presented in four columns. The first component is the identified barriers which have been matched with the relevant element of project delivery as the second component. Then, the third column shows the most relevant solution (from identified enablers) for the identified barrier and its related project delivery element. Finally, the last column (component) reveals which of the identified sustainability indicators (Figure 2) is mostly benefited from the discovered solutions for the given barriers, representing a certain element of project delivery.

Barrier to sustainability	Relevant element of project delivery	Identified solution (enabler)	Sustainability indicator (improvement area)
- Lack of human resource competency on sustainability	Project organization (clear definition of the roles and relationships between the participants)	- Human resource competency (motives, traits, self-image, skills, knowledge)	- Management
- Lack of consensus among project professionals on the ontology and measurement method of sustainability		- Integrating sustainability policies and instruments - Integration of different actors contributing toward sustainable building construction	- Stakeholder satisfaction
- Lack of sufficient knowledge and experience both on the demand and supply side of the benefits of sustainable buildings		- Organizational culture supporting sustainability	- Stakeholder management throughout the project - Culture
- Lack of sufficient and relevant building acts, codes, and regulations to enforce sustainability	Contractual relationships (promises of project parties)	- Mandatory building codes and regulations for implementation and evaluation of sustainability principles	- Energy efficiency - Waste minimization and elimination - Adaption to climate change
- Lack of convincing justification for proving return of investment on sustainability		- Integration of sustainability in project feasibility study - Incentive system - Integrating the assessment of carbon emission in approval process of building projects	- Minimizing pollutions - Protection of environment - Cost management - Service value - Supporting local economy and human resource
- Lack of collaboration, cooperation and coordination among numerous actors working towards the goals of sustainability	Operational system (appropriate timing and sequence of events and practices and techniques of management)	- Lean design and construction	- Continuous improvement on productivity - Wellbeing of project practitioners and local residents during and after the project - Resilient planning
- Lack of sufficient information and control on the availability and performance of human resource and equipment		- Stakeholder management - Management - Recycling and waste management	
- Complexity of building construction		- Modular construction - Technology advancement and implementation	

Figure 5. Sustainability model for building construction

4. Discussion

This study resulted in three groups of findings which were structured in a model (Figure 5). The first group of findings was 15 sustainability indictors for building construction. While these indicators are in line with previous research (e.g., [2,18,34]), the list is also concise yet comprehensive in terms of covering important sustainability issues in building construction. This simplicity not only provides project practitioners with a practical and easy to understand source of knowledge, but also contributes toward solving the problem of existing categorisations of sustainability indicators which usually include too many components (e.g., [5]).

The second and third groups of findings presented the barriers and enablers for sustainability in building construction. Interestingly, there is an obvious match between the identified barriers and enablers (as shown in Figure 5), which can be also seen as an indication of this study's reliability. Moreover, this match can imply that the identified barriers have significant visibility in real projects [21,22,23], the reason for which several studies have been conducted to find appropriate solutions, which are presented in this study as the enablers [25,28, 32,43]. This feature of the second and third groups of the findings in this study also enriches its external validity (generalizability).

Finally, the last group of results was a model concerning the role of project delivery elements in the application of sustainability indicators in building construction. The novelty of this model is related to its explanatory capacity for portraying the relationships between project delivery elements, sustainability indicators, barriers, and enablers. This model, which is the result of combining analytical and conceptual perspectives, unfolds the significance of utilizing project delivery system as a lens for pathological studies on sustainability in building construction [51]. The developed model not only can be used for understanding sustainability barriers and solutions associated with certain sustainability indicators, but also matches these items with the relevant element of project delivery.

The findings of this study have obvious scientific and practical implications. In terms of the contribution to the literature, the findings present a novel approach for studying the connection between sustainability indicators, barriers, and enablers in building construction through the lens of project delivery elements. In terms of practical implications, four groups of the findings in this study can be useful and value-adding in real projects through helping project practitioners to know the key sustainability indicators and their barriers, and how to overcome those barriers through understanding the relationship between the solutions of those barriers and project delivery elements.

5. Conclusions and recommendations for future studies

According to this study's findings, which were discussed earlier, it is concluded that barriers and enablers of sustainability in building construction are mainly rooted in people (competence, working together, exchanging information for a common goal), systems (policy, regulations, codes), and methods (assessment and promotion of sustainability). Moreover, employing project delivery elements as a theoretical lens contributes toward getting clear understanding of the problems and pragmatic solutions, as the enablers of those problems. This study and its findings also raised the following questions which can be the starting points for the future studies:

- To what extent the findings of scientific studies on sustainable building construction are effectively communicated with project professionals, and people in the society?
- Do the number and variety of sustainability indicators and assessment methods affect their efficiency and effectiveness?
- How do collaborative project delivery models and working practices contribute toward advancing sustainability in construction?
- How to build specific sustainability indicators based on the developed model (Figure 5)?

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