Research

A framework for systemic sustainable construction industry development (SSCID)

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Abstract

The quest for construction industry (CI) development in developing countries has met with several challenges. These challenges are numerous and varied. The study aimed to provide a framework by which the construction industry development agenda in developing countries could be prosecuted through a more structured and systemic approach. The qualitative research approach was adopted for the study. This approach was employed within the constructivist epistemological paradigm. Regarding information gathering, the study used the integrative literature review approach to elucidate the construction industry's nature and its proper systemic context. Complexity, interconnectedness, fragmentation, culture, and informality were found to be common challenges inherent in most CIs. Concerning the development of the industry, the approach was to (1) consider the industry as a system of systems (enabling the use of the principles of systems thinking and systems engineering), (2) apply the concepts of sustainable development as considered within the sustainable development goals (SDGs) and specified in the triple-bottom-line (TBL), i.e., the economic, environmental, and social dimensions, (3) identify the components of CI development (eight components were identified), which are: technology development, corporate development, human resource development, institutional development, material development, documentation, practice and procedure, and operating environment), and (4) Integrated studies. A conceptual framework was modelled from all the identified constructs. Based on this model, it was possible to propose a framework for assessing the maturity level of a country's sustainable construction industry development and, thereby, monitor its systemic development.

Keywords Construction industry · Sustainable construction · System thinking · SDGs · Maturity framework

1 Introduction

Construction industry development has been a global agenda. Developing countries at various development levels have put in efforts towards this objective [1, 2]. However, much has not been achieved due to several challenges facing the construction industries. According to Gyadu-Asiedu [3], most of the problems militating against achieving the desired effect on any country's construction industry have to do with the project execution challenges. The common problems of low productivity, delays, and cost overrun have been nearly over-researched with very related results (e.g., [4–7]). Windapo and Cattell [8] undertook a literature review research and identified 12 perceived challenges facing the South African Construction industry as follows: (i) Public-sector capacity, (ii) Mismatches between available skills and required

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skills, (iii) Globalisation/critical global issues, (iv) Procurement practices and the capacity for sustainable empowerment, (v) Access to affordable mortgage/credit and interest rates, (vi) Poverty, (vii) Technology, (viii) Availability of suitable land for construction, (ix) Availability of Infrastructure, (x) High rate of failure of enterprises, (xi) Increases in the costs of building materials, and (xii) Statutes and regulations. Results from other countries are very much related to these [9–12].

After several years of conferences, workshops, and reports by workgroups on the construction industry in developing countries, the International Council for Research and Innovation for Building and Construction (CIB) identified the following as the main challenges facing the construction industry in developing countries [13]: (i) The need for a new model of development, (ii) Linkages between urban and rural development, (iii) The need for sustainable housing, (iv) Sustainable education, (v) Sustainable construction through innovative building materials and methods, (vi) Indigenous technologies in the modern era, (vii) Bridging the gender divide, (viii) Appropriate financing and delivery systems, (ix) Issues of governance and management across the industry, (x) Appropriate procurement systems, (xi) Project management, (xii) Access for Local Firms. These and other challenges have impeded the progress being made towards many developing countries' CI developmental agenda. The problems are nearly common to most developing countries but with varying degrees of intensity. Others have considered the inherent nature of the industry and identified key challenges, including the following: fragmentation [14], complexity [15] and interconnectedness [16], informality [17], and the impact of culture [18]. These are considered the core challenges since they are common to all CIs.

However, the preceding suggests that each industry must clarify its myriads of problems through a taxonomy of structural challenges. This taxonomy is recommended as the first step towards any structural-developmental programme. The reason is that developing the industry has to be done with restructuring, re-engineering, and re-modelling. However, there are also issues about the approaches being used to achieve construction industry development.

2 The need for a sustainable construction industry development maturity framework

The absence of Systems Thinking in the solution package for these core challenges facing the industry indicates a significant CI research gap. Also, efforts at sustainable construction have not met the desired expectations over the years [19]. Problems militating against sustainable construction include cultural, governmental, institutional, technology, legislation, cost, capacity and knowledge, and cooperation [20–25]. Concerns have also been raised about the lack of appropriate tools to measure and monitor sustainability [26, 27]. The thrust of the matter is that it is difficult to ascertain the following vital positions regarding a specific construction industry:

- i. The extent to which the construction industry of a country has successfully pursued its development agenda.
- ii. The extent to which this development has included sustainability.
- iii. The process of measuring, monitoring, and managing a construction industry's maturity level over the years.

It is impossible to know the level of development a construction industry has reached at any point in time. Ofori [2] has said that the absence of measurable performance targets is one reason why there is a lack of progress in the industry's development programmes.

In light of these challenges, this study aimed to provide a framework by which a more structured and systemic approach could prosecute construction industry development agendas in developing countries.

3 Methodology

The study used the qualitative research approach in its inquiry. The constructivist epistemological paradigm underpinned this approach. Such concepts as system thinking and sustainable development (emphasising the economic, environmental, and social pillars) were employed as an invaluable tool for the study's scope definition. Regarding the methods of information gathering and analyses, the study used the review research strategy to analyse existing literature to elucidate the various aspects of the construction industry that needs to be considered for its systemic, sustainable development. The process involved examining extant literature to systematically identify contents in terms of pre-known and anticipated classes of knowledge [28]. The review of existing literature is a recognised and well-accepted way of knowledge expansion [29]. This process has been used as a methodology in various research

areas. For example, Mahamid [30] used it for researching construction business failures. In contrast, Ofori [31] used it as a methodology to study the nature of the construction industry, its needs, and development over a decade. According to Snyder [32], this approach has been used in business research citing such examples as in Covington [33], Gross [34], and Mazumdar et al. [35].

The integrative approach of the review research was used. It involved undertaking an overview, an assessment, a reconceptualisation, and a synthesis of the literature on the chosen topic in a way that enables new theoretical frameworks and perspectives to emerge [32, 36].

The process of selecting publications for the study followed three strategic approaches. The information on construction industry development and its challenges received a broad consultation of literature, primarily. However, a deliberate attempt was also made to focus more on researchers in this field of study, especially those focused on developing countries. Regarding the review on other variables of the construction industry system, the publications' selection was a bit more controlled based on the study's focus.

For the information on system thinking, the approach was to allow for backward integration of knowledge that dates back to the earliest relevant writings on system thinking and the general systems theories. The aim was to identify the study with the 'roots' of the concept. Regarding the concept of sustainability and sustainable construction, the approach was to identify the link between the sustainable development goals (SDGs), the pillars of sustainable construction, also called the triple bottom line (TBL), and construction industry development goals. Identifying these was seen as a critical part of the study. The reason being that, in the opinion of the authors, development should have everything to do with sustainability. This position is especially so in the era of the SDGs.

Thus, several library databases were used to search and collect references for this review, including Science Direct, Taylor & Francis, Springer, Wiley, and McGraw-Hill.

Figure 1 shows the methodology used in selecting the articles and the conduct of the study.

Fig.1 Methodological framework for the study

3.1 Constructivism and the identification of the main constructs for the study

The constructivist epistemology posits that humans generate knowledge and meaning from an interaction between their experiences, ideas, and existing knowledge. Based on this epistemology, it was decided to categorise the study into four stages. Stage one yielded the main challenges as captured in the introduction and the problem statement of this paper. Stages two and three yielded the constructs that form the basis of the study's conceptual framework. Stage four provided the information used in modelling the framework for assessing the industry's maturity level.

- i. Identifying the critical challenges confronting the construction industry development agenda.
- ii. Identifying tools for structuring and defining the problem.
- iii. Identifying the parts of the industry.
- iv. Developing a maturity framework for CI development.

The first three were the focus of the review study. The final stage was the synthesis stage, where the constructs were integrated into a conceptual and a maturity framework.

1. First stage: identifying the challenges facing the CI

This stage of the review identified the critical challenges militating against the construction industry in several countries. At this stage, it was found that various researchers identified challenges as they prevail in their area of study. However, it was possible, through qualitative value judgement, to categorise them to (i) those inherent in the industry and (ii) those imposed by institutional weaknesses and other external factors.

2. Second stage: identifying the tools for the study

At this stage, it was necessary to identify the relevant tools for structuring the problem the study seeks to address. The following were identified as essential tools:

- *Systems thinking, systems engineering*: to address the problem relating fragmentation and interconnectedness, culture and informality, and also to and to clarify the nature of the industry
- *Sustainable development principles (the TBL and the SDGs)*: to address the industry's development aspect and mitigate culture's impact through its universal appeal.
- *Integrated studies*: to bring all the constructs together into a solution framework

3. Third stage: identifying the parts of the industry

At this stage, the construction industry is treated as a system of systems. Therefore, it is essential to identify its parts, its systems, or its organisations. The idea is that the industry's development should be seen as an emergent state resulting from the aggregation of its parts' development.

4. Fourth stage: developing the conceptual framework and the maturity framework

At this stage, the relevant constructs of the study have been identified in (1), (2), and (3). The next activity was to model the constructs so identified in the study into a conceptual framework and a maturity framework which address the main research problem. At this stage, the constructs are developed into a measurable form and, therefore, become variables.

3.2 Limitations

In this study, some limitations were identified. Firstly, the literature materials selected considered only those in English. Scientific works published in other languages that were inevitably disregarded may have increased the study's arguments' strength. Secondly, because the scope of the topics involved in sustainability and construction industry development is quite broad, the study could not have covered all that may have been relevant. Those materials disregarded for a qualitative sampling of literature may have provided some critical dimensions to the study.

Further, this paper's focus means that other construction industry development indicators were excluded, namely, the industry's GDP and site productivity issues. Finally, despite its contribution to knowledge, the proposed framework has not gone through the complete cycle of being launched for performance assessment and evaluation. Therefore, it has been submitted as a conceptualised model or a theoretical framework ready to be tested, verified,

Table 1 The competing objectives among the economic and environmental pillars of sustainability

Focus	Economic (Brown)	Social/economic (Green)	Environmental (Green)
Key concern	Human well-being	Business and society's well-being	Eco-systemic well-being
Time frame	Immediate	Transitory	Delayed
Scale	Local	Think global, act local	Think global, act local
Concerned about	Low-income groups	All-income groups	Future generations
View of nature	Manipulate and use	Generate, recycle and re-use	Protect and work with
Environmental services	Provide more	Optimise	Use less

Source: [42], expanded

and validated. However, the methodological approach adopted and the features of the proposed framework are such that it shows promise of a theoretical construct and the capacity of instigating further studies.

4 Results and discussion

This section contains the results that emanated from the literature review methodology. The main issues discussed were sustainable development and system thinking as a crucial part of a framework for studying construction industry development. In the process, the components of construction industry development were identified. Also, the key stakeholders in the industry were identified. These findings formed the basis for modelling (1) a conceptual framework for the study and (2) a proposed framework for measuring the maturity level of the construction industry in its path towards development.

4.1 Construction industry development: a systemic and sustainable view

Apart from the fundamental challenges inherent in the industry, approaches used by countries to develop the industry also need to be investigated. This investigation is vital because attempts at developing the industry towards efficiency must necessarily include principles and strategies needed to address the challenges emanating from its nature, processes, and practices. Firstly, it will require identifying all the relevant components of construction industry development, all the organisations that make the construction industry, all the external environmental factors that impact the industry's growth or otherwise, and the project as a special (temporary) organisation. Secondly, it will require the need to know what to do to ensure that they contribute to its development. A well-structured approach to overcoming the challenges is the surest way of successful development. Thus, there is the need for a holistic (systemic) approach towards the industry's development. Therefore, systems thinking and systems engineering philosophies must be the governing paradigm for such approaches. The approach is to view the entire construction industry as a system, or more succinctly, a system of systems. Within the parlance of systems engineering, the construction industry must be seen as a system of several different subsystems. Therefore, its development must focus on the development of its systems. Sustainable construction is the subject of discussion in this sub-section.

4.1.1 Sustainable construction

The CIs development should be based on the development and the sustainability of its core activity: construction. The construction industry must exist to deliver today and continue to do the same in the future so long as shelter and transportation infrastructure continue to be relevant to human existence. Regarded as an industry that consumes a large percentage of the world's natural resources, the fear of the long-term negative impact on the environment led to the need to consider sustainable construction within the broader concept of sustainable development [37]. Sustainable construction has been spearheaded by Kibert [38], Du Plessis et al., and Du Plessis [39, 40]. In several countries, attempts are being made to focus on the six principles of sustainable construction as contained in Agenda 21 [37]: (1) Minimisation of resource consumption, (2) maximisation of resource re-use, (3) use of renewable and recyclable resources, (4) protect the natural environment, (5) create a healthy and non-toxic environment, and (6) pursue quality in creating the built environment. Ultimately, sustainable construction must, of necessity, be linked with the developmental agenda of the industry.

4.1.2 Sustainable construction and the conflict between the triple bottom line

The Earth's capacity to regenerate itself is affected directly by society, the environment, and the economy (also known as "people", "planet", and "profit", respectively) [41]. It is also referred to as the triple bottom line (TBL) adopted for this paper. As the Brundtland report suggests, only when the requirements of all the three complementary forces are balanced will sustainability be genuinely achieved. Sustainable construction demands that all three areas should be given equal and important attention. Further to this, the "Russian Doll and Five Capital Model" shows that economic activity is centrally placed and is constrained by social issues, which in turn are constrained by environmental factors [41].

It is essential to show the existence of an inextricable link and competing interest among the TBL. As an illustration, it is significant to know that they have different objective to pursue, and they sometimes contend with one another. For example, the dichotomy is evident between the quest for economic growth (brown) and that of environmental protection (green) [42]. The former aims at consumption, while the latter focuses on protection. The factors that promote the

Table 2 Linkages between construction and SDGs

1st Degree linkage	2nd Degree linkage	3rd Degree linkage	4th Degree linkage
Construction as an essential/a basic requirement	Infrastructure required Construction as a needed requirement	Infrastructure required Construction as a necessary requirement	Infrastructure required Construction as an indispensable requirement
1. No poverty (G1)	Offices, factories for production, Banks and Financial Institutions	Health facilities, Hospitals	Classrooms, Staff Offices, and Bungalows
2. Zero Hunger (G2)	Offices, Production Factories, Agricultural facilities	Offices, Production Factories	Water Treatment Facilities, Offices, Waste Treatment Facilities
3. Gender Equality (G5)	Offices, Accommodation	Accommodation, Housing, Roads, Bridges, Railways, Offices, Production Factories	1. Industry, innovation, and infrastructure (G9) 2. Sustainable cities and communities (G11)
4. Responsible consumption and production (G12)	Offices, Production Factories	Offices, Conferences, Scientific laboratories	Courts, Parliament Houses, Police Stations, Military Barracks, Prisons Quarters
5. Life below water (G14)	Offices, Tunnels, Facilities on Land and Undersea	Offices, Conferences, Scientific laboratories	International Organisation offices, Offices, and houses for diplomatic corps, International Courts
6. Partnership for goals (G17)	Offices, Production Factories	Offices, Production Factories	Offices, Production Factories

Table 3 Stakeholders (organisations) in the construction industry [48]

Stakeholder	Roles and responsibilities
National and local policy-makers	Policy- and decision-makers at the national and local level are essential in establishing the enabling environment for the construction industry's development and promoting the type and volume of public infrastructure to be provided. Close cooperation between the private sector and policy-makers is thus essential
Clients, public and private	Clients identify needs and initiate works, procure consultants and contractors for the design, execution, and supervision of works, and monitor and payment service providers. For infrastructure works, the main clients are relevant sector ministries at various levels and local authorities
Consultants for design, supervision, and other functions	Engineering consultants conduct studies (such as feasibility, social and environmental safeguard studies, geological and hydrological surveys), design infrastructure, prepare cost estimates, prepare contract tenders, and supervise contractors' works
Contractors main and subcontractors	Contractors execute infrastructure works and supply the necessary resources (labour, tools, equipment, and materials). Depending on the type of contract, the work being done by contractors may be supervised by consulting engineers. Relatedly, the main contractor may sublet some of the works to smaller or specialised firms called subcontractors
Suppliers	Suppliers are often specialised firms selling construction materials, tools and equipment—and spare parts. Suppliers are expected to offer and sell safe and sound quality goods
Banks, insurance companies, and private investment funds	Bank and insurance companies provide financial services, including loans, performance bonds, and guarantees. They also provide financing for infrastructure works and play a significant part in contractors' development and operations
International partners and donors	Includes bilateral and multilateral development partners that provide finance and support services, e.g., technical assistance, research
Regulatory and standard-setting bodies	Regulatory and standard bodies may be governmental or private institutions, which may operate nationally or internationally. Their primary function is to develop and maintain product specification standards, process standards, and behavioural standards, e.g., anti-corruption, corporate social responsibility
Legal service providers	The services of lawyers and other legal persons may be required for all types of legal matters but mainly about procurement regulations, conditions of contract, disputes, and auditing
Auditors	Internal and external auditors carry out technical and financial checks of infrastructure works during and after implementation. These checks are necessary to assure the client and the public that the work is being carried out following specified norms and standards and within budget
Professional associations	Associations play an essential role in the construction sector, both for contractors and engineers. Their central role is to promote their members' interests, develop industry standards, and provide support services (e.g., training, advice, promotion), and lobby for works
Trade unions	Trade unions protect workers' rights and promote their common interests in the fairness of pay, safe working environments, hours of work, benefits
Tertiary education institutions	Universities and other higher learning institutions provide the construction industry with the required professionals. It is their responsibility to closely cooperate with the construction sector partners to formulate and implement appropriate educational programmes, both theoretical- and practice-oriented

Table 3 (continued)

Stakeholder	Roles and responsibilities
Vocational education and training institutions	Vocational training is essential to secure an adequate supply of competent and skilled artisans and technicians. They are the backbone of the construction industry, and thus vocational education institutes must collaborate closely with the industry and its professional associations
Communities	Communities are the ultimate users and beneficiaries of public infrastructure. They should be empowered to participate in the entire programme cycle from identification to infrastructure assets' final commissioning and operation

former's accomplishment appear to increase those factors that work against the latter. However, for purposes of sustainability, the concept of "green economy" must be invoked, where a green economy is defined as: "an economy in which economic growth and environmental responsibility to work together in a mutually reinforcing fashion while supporting progress on social development" [43]. McGranahan and Satterthwaite's views [42] as expanded to include the expected green social/economic aspect are depicted in Table 1 2. Bringing in the social dimension will undoubtedly increase the complexity of the problem due to the need for a trade-off between people's comfort and survival today under green economic and environmental conditions. It is against the backdrop of what is needed to satisfy society's unquenchable appetite to consume.

However, the ultimate constraint is the Earth's ecosystem, which must always be given the needed attention, which is the central goal of sustainability. Being a significant consumer of natural resources, focusing on the earth ecosystem will directly impact construction. The extent to which construction activities consume natural resources makes it an essential ally in the quest for sustainable development. All these go to show that the concept of sustainability is a rather complex subject [40]. Fusing it within the complex construction setting will inevitably create conditions that will underscore the challenges that need to be overcome to accomplish the industry's developmental goals.

In Table 1 2, a comparison is made among the triple bottom line in the light of six focus criteria:

key concern, time frame, scale, concerned about, view of nature, environmental services. In its original state, it was designed for a comparison between the environmental and the economic pillars. The authors introduced the social pillars to have a holistic view of the contention among the three. It could be seen that the social pillar fits nicely between the environmental and the economic pillars as a moderator between the two apparent extremes. It means that society is being seen as the reason for the struggle between the brown and the green. That is, society becomes the winner or the loser based on the result of the original conflict. Therefore, there can only be a green economy if society supports it. The table shows that there is always a link between the social and the economic pillars; it is a matter of survival. Thus, society's primary work will be to support the environmental course and support the green economy. This discussion shows the interplay of issues that must influence the three in sustainable construction industry development activities.

4.1.3 Aligning the goals of CI activities with the SDGs

Specifically, only two of the seventeen goals, i.e., goals 9 and 11, relate to construction activities. However, a critical study of the other SDGs shows that each has something to do with construction and depends on its accomplishments in varying degrees. Table 2 3 shows the dependence of the SDGs on construction or a constructed facility. In the table, the SDGs' linkages with construction have been established at varying levels of dependency. These are from the level of an essential/ a basic requirement through a needed requirement, a necessary requirement, and an indispensable requirement. Thus, the primary consideration is that every step towards sustainability in the construction industry should have at least one SDGs to accomplish.

4.1.4 Employing system thinking to sustainable development

The CI is too fragmented, interconnected, and complex to be developed sustainably without considering its systemic nature. The various parts of the CI system must be seen to depend on each other, support each other and move together as a system. According to UNESCO [44], it is not enough to depend on technology, politics, and financial consideration

Table 4 A conceptual framework for SSCID (a synthesis of [31, 41, 43, 54, 55])

Components of CI development [31]	Conceptual industry transformation framework [55]		Focusing on innovations in the The CI future megatrends as Moderators [55]		Expected benefits of CI development [54]
	Measures	Classification of action groups		TBL [41, 43]	
Technology development	Technology	Private companies undertook measures	Social Economic Environmental	Market and customer trends Sustainability and Resilient trends	Stakeholder and participant optimisation through technology
Corporate development	Strategy and business model innovation			Societal and Workforce trends Political and Regulatory trends	Viability and competitiveness of domestic construction enterprises
Human resource development	People, organisation, and culture				Stakeholder and participant optimisation of institutional enhancement through human resource development
Institution building	Public procurement Regulation and policy	Governments undertook measures	Social Economic Environmental	Market and customer trends Sustainability and Resilient trends Societal and Workforce trends Political and Regulatory trends	Stakeholder and participant optimisation through institutional enhancement
Material development	Materials and tools	Measures were undertaken by industry	Social Economic Environmental	Market and customer trends Sustainability and Resilient trends	Increased value for money for clients and industry
Documentation	Process and operations			Societal and Workforce trends Political and Regulatory trends	Environmental responsibility of the delivery process
Procedures and practices Operating environment	Industry collaboration Joint industry marketing				Stakeholder and participant optimisation through processes

when pursuing sustainable development goals. Thus, a holistic methodology that will support a resilient system and flexible structures to take care of complexity is recommended [45]. Draper [46] has said that systems thinking is understood as the ability to see the world as a complex system where everything is connected to everything else. In light of these, this paper posits a deficiency in theory and practice and counterproductive for different groups to pursue a common agenda such as sustainable development in their separate and different self-contained environments. It is even worse when this persists without any attempt to link them to consider the whole picture. The issues involved in achieving sustainable development require a holistic consideration of all the items concerned. According to Ison [47], integrating the parts into making it a whole is necessary for a system to exist. This integration should result in a special relationship between the parts with essential emergent properties. Within the CI, systems are organisations and firms operating to define the CI as a system of systems. These include clients, contractors, consultants, suppliers (Table 3 4) [48] and even projects as temporary organisations [49]. System thinking has been seen as an invaluable tool in addressing complex problems of sustainable development. Cloud [50] has said: “system dynamics and systems thinking can be taught without involving sustainability, but sustainability cannot be taught without involving systems thinking”. Systems can be defined as elements joined together by dynamics that produce an effect, create a whole or influence other elements of a system. For this reason, systems thinking, and indeed, systems engineering are fundamental approaches recommended for any studies on sustainable construction within the industry’s development agenda.

4.1.5 System engineering

Checkland [51] identified three types of systems engineering as follows:

- i. Product systems engineering (PSE): this is traditional systems engineering focused on designing physical systems consisting of hardware and software.
- ii. Enterprise systems engineering (ESE): this view of enterprises as systems, organisations, or combinations of organisations.
- iii. Service systems engineering (SSE): this is about the engineering of service systems.

The construction industry system takes after the enterprise systems engineering. ISO/IEC/IEEE 21839 [52] defines a system of systems (SoS) and the constituent System as follows:

System of Systems (SoS): set of systems or system elements that interact to provide a unique capability that none of the constituent systems can accomplish independently. Systems elements can be necessary to facilitate the interaction of the constituent systems in the System of systems.

Constituent Systems: constituent systems can be part of one or more SoS. Each constituent is a useful system by itself, having its development, management goals, and resources, but interacts within the SoS to provide the unique capability of the SoS.

These are the organisations, enterprises, and projects within the larger construction industry system of systems as listed in Table 4. The standard indicates that the formation of an SoS is not necessarily a permanent phenomenon but rather a matter of necessity for integrating and networking systems in a coordinated way for specific goals such as robustness, cost, and efficiency. Because each constituent systems (organisations) are independent, these development processes are implemented for engineering both the systems and the System of systems. They need to be tailored to support the characteristics of SoS (refer to ISO/IEC/IEEE 15288 Annex G). Indeed, the construction industry’s existent as a temporary phenomenon encapsulates it entirely as a system of systems.

4.2 Identifying the components of the CI development

Construction industry development has always been considered hinging on a deliberate process undertaken under well-managed conditions [53, 54]. Such a venture’s benefits include increased value for money, the competitiveness of construction enterprises, and the optimisation of stakeholders’ performance [50]. It brings to the fore the need to consider the industry’s needed aspects to focus on as very important to the development agenda. Ofori [31] identified what he referred to as the components of construction industry development: technology development, corporate development, institution building, material development, human resource development, documentation, procedures and practices,

Table 5 A maturity framework for systemic sustainable construction industry development

Components of CI development	Construction industry systems														Results showing sustainable development of a CI component													
	Clients (cl)		Projects (pj)		Consultants (cns)		Contractors (cnt)		Subcontractors (sc)		Suppliers (sp)		Regulatory bodies (rb)															
	S	E	Ev	S	E	Ev	S	E	Ev	S	E	Ev	S	E		Ev												
Technology development (T.D.)	cl-TD				pj-TD				cns-TD				cnt-TD				sc-TD				sp-TD				rb-TD			Sust.Cl-TD
Corporate development (CD)	cl-CD				pj-CD				cns-CD				cnt-CD				sc-CD				sp-CD				rb-CD			Sust.Cl-CD
Human resource development (HRD)	cl-HRD				pj-HRD				cns-HRD				cnt-HRD				sc-HRD				sp-HRD				rb-HRD			Sust.Cl-HRD
Institution building (I.B.)	cl-IB				pj-IB				cns-IB				cnt-IB				sc-IB				sp-IB				rb-IB			Sust.Cl-IB
Material development (M.D.)	cl-MD				pj-MD				cns-MD				cnt-MD				sc-MD				sp-MD				rb-MD			Sust.Cl-MD
Documentation (Dtn)	cl-Dtn				pj-Dtn				cns-Dtn				cnt-Dtn				sc-Dtn				sp-Dtn				rb-Dtn			Sust.Cl-Dtn
Procedures and practices (PP.)	cl-PP				pj-PP				cns-PP				cnt-PP				sc-PP				sp-PP				rb-PP			Sust.Cl-PP
Operating environment (O.E.)	cl-OE				pj-OE				cns-OE				cnt-OE				sc-OE				sp-OE				rb-OE			Sust.Cl-OE
Results showing Sustainable development of a CI organisation	Sust.cl-Dev				Sust.pj-Dev				Sust.cns-Dev				Sust.cnt-Dev				Sust.sc-Dev				Sust.sp-Dev				Sust.rb-Dev			Sust.Cl-Dev

Table 6 Illustrated framework

Components of CI development	Construction Industry Systems																		Results Showing sustainable development of a CI component														
	Clients (cl)			Projects (pj)			Consultants (cns)			Contractors (cnt)			Subcontractors (sc)			Suppliers (sp)									Regulatory bodies (rb)								
	E			Ev			S			E			Ev			S									E			Ev			S		
	E	Ev	S	E	Ev	S	E	Ev	S	E	Ev	S	E	Ev	S	E	Ev	S							E	Ev	S	E	Ev	S			
Technology development (T.D.)	5	6	4	6	6	7	8	9	4	6	7	4	5	6	7	7	6	6	6	6	6	6	6	6	6.05								
	5			6			8		5.67			5			6.67			6															
	7	7	6	4	4	4	8	8	7	6	7	6	5	5	6	5	6	5	5	5	5	5	5	5	6.19								
Corporate development (CD)	6.67			6			8		6.67			5.33			5.67			5															
	6	7	7	5	4	4	7	8	7	8	9	6	5	6	5	5	5	4	4	4	4	4	4	4	5.95								
	6.67			4.33			7.33		8.33			5.67			5			4.33															
Institution building (I.B.)	5	6	6	5	4	5	6	5	7	6	6	5	6	5	6	4	5	5	6	5	6	5	6	5	5.43								
	5.67			4.67			6		6			5.33			5			5.33															
	4	4	4	6	7	7	7	6	6	7	8	6	7	7	8	8	9	9	9	9	9	9	9	9	6.86								
Material development (MD)	4			6.67			6.33		7			6.67			8.33			9															
	6	7	7	7	7	7	8	8	8	8	8	6	6	7	6	5	5	5	5	5	5	5	5	5	6.67								
	6.67			7			8		8			6.67			5.33			5															
Procedures and practice (P.P.)	7	6	7	7	6	6	7	7	7	7	7	6	7	6	6	6	5	6	7	4	4	4	4	4	6.43								
	6.67			6.67			7		7			6.33			5.67			5.67															
	7	8	8	8	5	5	7	8	8	8	7	6	6	6	7	7	7	6	6	6	6	6	6	6	6.76								
Operating environment (O.E.)	7.67			6			7.67		7			6			7			6															
	6.13			5.92			7.29		6.96			5.88			6.08			5.79															
																									6.29								

and operating environment. The position is that the development of the components will aggregate to represent that of the entire industry. These are issues that relate to the various organisations or enterprises within the industry.

In a related discussion, the present state of construction industries and the global trends that will impact the industry was assessed by the World Economic Forum (WEF) [55]. A primary deliverable from the assessment was a conceptual industry-transformation framework that listed several measures. These measures were grouped into eight topical areas: (a) technology material and tools (b) processes and operations (c) strategy and business model innovation (d) people, organisation and culture (e) industry collaboration (f) joint industry marketing (g) regulation and policies and (h) public procurement. The similarities between these measures and Ofori's [31] are striking. These were further classified into three categories as (i) measures taken by private companies on their own; (ii) measures taken by companies in collaborations with their peers—or by the industry as a whole; and (iii) measures taken by the government, acting both as the regulator, and as a significant project sponsor. According to the report, the future transformation of the CI would be shaped by (a) market and customer trends, (b) sustainability and resilient trends, (c) societal and workforce trends, and finally, (d) political and regulatory trends. Together, the Ofori [31] model and the WEF [55] frameworks are considered to be well-positioned to address the challenges militating against the performance, growth, and deliberate development of the construction industry.

The international chamber of commerce [43] provided a green economy roadmap focusing on ten interdependencies distributed across the TBL with mutually reinforcing and cross-cutting elements at the centre as follows: (1) Economic Innovation: open competitive market, metric accounting and reporting, finance and investment. (2) Environmental Innovation: life cycle approach, resource efficiency and decoupling (3) Social Innovation: awareness, employment, education, and skills (4) Mutually reinforcing and cross-cutting elements (from the three): governance and partnership, integrated policy, and decision-making.

It is essential to look at Ofori [31] and WEF [55] in the light of the green economic framework along with its roadmap [43] completely. It is expected that this would profoundly change the industry as a system and lead it towards the path of sustainable growth. Given the construction industry's societal, environmental, and economic importance, it is expected that any performance improvement in the industry will also have a substantial effect on all three domains in different forms and degrees.

4.3 A conceptual framework for SSCID

Based on the preceding, a conceptual framework is modelled based on a synthesis of Tables 1 and 3, the components of CI development, and the industry-transformation framework (as identified above) to achieve the following purposes (Table 4 1):

1. Indicate the delineating of all the critical components of CI development.
2. The classification of the action points.
3. The future Megatrends in the CI.
4. The links with the triple-bottom-line in sustainability.
5. The expected benefits for the CI.

In Table 4 1, the first two columns show how the components of CI development are aligned with the measures of the conceptual industry-transformation framework. The Table also shows the position of the green economy roadmap within the framework. It is essential to note the similarity and how the two sets of items reinforce each other. In transforming the CI, these components are the key areas to look at and develop. This synthesis made it possible to classify these components into three groups of action points to be prosecuted by the three action groups: private companies, the government, and the industry. They form the main framework by which the CI development process should be structured and managed. Column four shows the aspect of sustainability and the TBL innovations. This aspect is crucial to the development of organisations (stakeholders) in the industry. Column five shows the four megatrends that will shape these developments, acting as moderators of the process. CI system developers must closely monitor these trends and continuously manage the components appropriately. The CI areas that stand to benefit directly from these components' developments are listed in column six. These were initially outlined by Ofori [54]. This framework contains what is needed for addressing the inherent challenges of the CI. Table 4 1 also provides the foundation upon which the proposed maturity framework was developed (Tables 5, 6).

4.4 The organisations (systems) in the construction industry

Table 3 is a list of all the stakeholders making the construction industry. These stakeholders are the organisations in the industry. Considering the construction industry as a system of systems, these become the systems in the industrial systems. The industry's development also means that each organisation needs to be developed in the eight components. Only when these systems are deliberately being developed individually in these eight components and within the TBL can one say that the industry is being developed. The extent of each of the systems' development should be measured, monitored, and managed towards the desirable level. The aggregation of all the systems' development will represent the industry's development at a point in time.

5 A proposed framework for assessing the maturity level of SSCID

Based on Tables 3 and 4, Table 5 is designed. Table 5 is a proposed framework that could guide the assessment of the typical construction industry's maturity levels. The process involves considering a CI system of systems that must capture all the relevant systems (organisations): clients, consultants, and contractors, among others, as identifiable and relevant for a specific construction industry [48]. These are made to develop along the eight (8) identified components of CI development [31]. These are (1) Technology Development (TD), (2) Corporate Development (CD), (3) Human Resource Development (HRD), (4) Institution Building (IB), (5) Material Development (6) Documentation (Dtn), (7) Procedures and Practice (PP), (8) Operating Environment (OE). For each System or organisation, the focus is to ensure a component-by-component development taking into consideration the Social (S), Economic (E), and Environmental (Ev.) dimensions [36, 42].

The working process of the framework is designed to answer the following questions towards sustainable development:

1. To what extent is each of the organisations in the industry maturing through each of the eight components?
2. To what extent the components developed in compliance with sustainability measured through the TBL in each organisation?
3. To what extent is the industry developing?

5.1 Towards mathematical validity of the framework (Table 6)

Table 6 is a simulation of the proposed framework in operation with numerical figures. The values used to illustrate how the framework could be used in actual assessment when accurate data are obtained from a field study. With this as a basis, this section illustrates how the maturity levels of (1) the systems and (2) the components, and (3) the CI are assessed.

1. The scores under the TBL

In Table 6, the values inserted into the columns represent scores obtained when each of the CI organisations (systems) are assessed across the various components in turn in the light of sustainability through the TBL. The measures are scored over ten marks. These are then averaged to represent the organisation's sustainable development (It could also be measured in percentages). The overall score is the average values across the three pillars as follows:

$$\text{Average Scores} = 1/3[E + Ev + S].$$

This figure shows the maturity level of a component under organisation within the industry.

It must be noted that each score is an industrywide average brought to the framework as the final scoreboard. The framework is the final scoreboard after all the figures are obtained by field assessment.

In Table 6, the maturity level of sustainable development of Technology Development under the clients' organisations obtained, taking cognisance of the TBLs, are E (5), Ev. (6), and S (4). The average is, therefore, $(5 + 6 + 4)/3 = 5$.

2. Measuring the maturity level of a component in the construction industry [MC]

Similarly, the maturity level of the Technology Development component scored under each of the systems is: Projects (6), Consultants (8), Contractors (5.67), Subcontractors (5), Suppliers (6.67), and Regulatory Bodies (6).

Thus, for a component under the seven systems (organisations), we use the formula:

$$MC = 1/7[\text{Clients} + \text{Projects} + \text{Consultants} + \text{Contractors} + \text{Subcontractors} + \text{Suppliers} + \text{Regulatory Bodies}]. \quad (2)$$

Table 7 Validity considerations of the proposed framework (adapted from [56])

Validity component	Definition	Relevant at this stage	Technique used/to use
Face validity	The extent that measurement instrument items linguistically and analytically look like what is supposed to be measured	Applicable	Integration of scores of items in the framework
Content validity	The extent that measurement instrument items are relevant and representative of the target construct	Applicable	Literature review method
Construct discriminant validity	The extent that measures of different constructs diverge or minimally correlate with one another	Not applicable	No Action. Not yet tested
Construct convergent validity	The extent that different measures of the same construct converge or strongly correlate with one another	Applicable	The two-way approach of the mathematical calculation yielding the same results for the maturity level of the SCID of 6.29 (Sect. 5.2)
Criterion predictive validity	One assessment tool's ability to predict future performance either in some activity or on another assessment of the same construct	Applicable	Implementation time is required. However, the mathematics illustration indicated the predictive validity of the framework at this stage
Criterion concurrent validity	The extent that the framework simultaneously relates to another framework that it is supposed to relate	Not yet applicable	No Action. No related framework found yet
Criterion postdictive validity	The extent that the framework is related to the scores on another, already established in the past	Not yet applicable	No Action. No related framework found yet
Reliability internal Consistency	The extent to which items within an instrument measure a various aspect of the same characteristic or construct	Applicable	Section 5.2 proves a construction industry's maturity level could be obtained either through the integration of scores of (1) the components (2) through the organisations (systems)

For seven organisations (or systems) in focus.

Thus, concerning Technology Development, we have:

$$1/7[(5) + (6) + (8) + (5.67) + (5) + (6.67) + (6)] = \mathbf{6.05}.$$

The average score obtained under all the systems of the industry. This result is the maturity level of Sustainable Technology Development in the CI. If all the organisation's particular construction industry organisations are considered.

3. Measuring the maturity level of system in the industry [MS]

The formular for assessing maturity level of a system in the industry is measured along all the components as:

$$MS = 1/8 [TD + CD + HRD + IB + MD + Dtn + PP + OE].$$

Using the columns (vertical) assessment for each group of organisations, e.g., the clients' organisations (systems) along all the eight components, we have:

$$1/8[TD (5) + CD (6.67) + HRD (6.67) + IB (5.67) + MD (4) + Dtn (6.67) + PP (6.67) + OE (7.67)] = \mathbf{6.13}.$$

The result is **6.13**, representing the maturity level of Sustainable Development of Clients' Organisations in the construction industry.

This process is repeated for all the other organisations or systems within the industry.

4. Measuring the maturity level of a sustainable construction industry overall [MCI]

The formula is given as:

$$MCI = \sum_{k=1}^8 (MC) = \sum_{k=1}^7 (MS), \quad (4)$$

where $\sum_{k=1}^8 (MC)$ represent the aggregation of the maturity levels of all components in the industry across the seven systems; and, $\sum_{k=1}^7 (MS)$ represents the aggregation of the maturity levels of all the systems in the construction industry across the eight components.

Each of the above summations will yield the same value representing the maturity level of sustainable construction industry development. From Table 6, the overall maturity level of sustainable construction industry development is **6.29**, using either of the two formulae.

5.2 The classification of the maturity levels

For purposes of this paper, the maturity levels are classified as follows:

1. 1–1.99 = Level 1
2. 2–2.99 = Level 2
3. 3–3.99 = Level 3
4. 4–4.99 = Level 4
5. 5–5.99 = Level 5
6. 6–6.99 = Level 6
7. 7–7.99 = Level 7
8. 8–8.99 = Level 8
9. 9–9.99 = Level 9
10. 10 = Level 10.

Level 1 is the least matured level, while Level 10 stands for the most matured level. Thus, using x = score for a maturity level, we have $1 \leq x \leq 10$.

For any score, " x ", which falls between $x.00 \leq x < x.50$, the level is qualified by "Low". Therefore, scores like 1.43, 5.32, 7.22 are classified as 1-Low, 5-Low, and 7-Low, respectively.

Similarly, for any score " x ", where $x.50 \leq x < x + 1$, the level is qualified by "High". Therefore, scores like 1.54, 5.66, 7.51 are classified as 1-High, 5-High, and 7-High, respectively. Thus, the result of the Sust.CID = 6.29 means the industry in question is at the level of 6-Low.

5.3 Monitoring and managing the CI development

Table 6 has indicated the process of measuring the maturity levels of the various aspect of the industry. The values so obtained indicate the general position of a particular industry. When this is done at regular intervals, it will provide a means by which the maturity level can be monitored through trend analysis of these figures. Based on these scores, deliberate action should be taken to manage the industry to the desired level.

It means that targets will have to be set, and the levels achieved should indicate deviation, which must be corrected and identified gaps filled. This approach should be seen as the scientific way an industry's transformation, growth, and development can be achieved.

5.4 Pre-requisites

Some pre-requisites should be agreed on before the framework could be used. The framework comprises main measures in three dimensions: (1) the components of the industry development, (2) the systems or organisations in the industry, and (3) the TBL. There should be agreement on the set of indicators needed to assess each of the primary measures. This process will be the basis for populating the main measures that will aggregate into the organisations' maturity level or systems and, ultimately, the construction industry. These indicators may then be adapted to suit each country's needs. Methods for measurement and compilation of the indicators should also be agreed on to facilitate standardisation and adaptation. At this stage, the framework is being proposed for predicting maturity. It is expected that it could also be a framework for benchmarking and inter-industry comparison after some modification.

A central agency will be needed to administer the construction industry development programme using the proposed framework. The duty of such an agency would be to collect, process, and disseminate critical data on the construction industry and maintain a national construction database for estimating the scores of the indicators. These data need to be updated regularly to meet the industry's current trends and needs and knowledge development. The ultimate objective shall be to regularly measure and monitor the industry's maturity level, predict growth, development, or decline for decision-making and management by the government pursuing a construction industry development agenda.

5.5 Towards the validity of the framework

The proposed framework was subjected to some fundamental validity and reliability tests as far as practicable, and the results are summarised in Table 7. The following provides a background to the contents of Table 7.

1. Literature review method

Because the framework's variables emanated from empirical studies, it is concluded that their validity and reliability as measures have been established. However, using them to model a framework means that the framework needs to pass the validity and reliability tests. Later, the framework's actual implementation will represent its validation and the testing of the theory it propounds. The issue of validation of the framework is beyond the scope of this paper.

2. By using numerical simulation where the numerical methods solve the System

In this paper, basic numerical simulation has been used to validate the mathematics underlying the framework's measurement aspect. Integrating the scores into the maturity level has been triangulated by estimating from either the systems' side or the component's side. The results have been consistent.

3. Monte Carlo simulations proposed for experimental validation

During the actual validation of the framework, multiple results obtained from the experiments could be further validated by Monte Carlo simulations, primarily as it assesses the industry's maturity levels and predicts their expected behaviour and growth. The reason is that Monte Carlo-based predictions of failure or success have been proven to be routinely reliable.

6 Conclusion

The study has shown that the issues involved in construction industry development are a more complex problem than has hitherto been considered. It has revealed that a systemic approach is needed to achieve the development agenda. Further, it has also shown that the industry's development should be considered with sustainability in mind and that the two must go together. Thus, the agenda should be sustainable construction industry development. Also, this study propounds that sustainable construction industry development should be seen as part of the global agenda of a sustainable world as it began with Agenda 21 and the SDGs. The significance of this is that construction is linked to all the seventeen SDGs in four varying degrees: as an essential requirement, as a needed requirement, as a requirement, and as an indispensable requirement for their accomplishments. At the heart of sustainable construction, a debate is the need to ensure the TBL in all cases. Decisions will have to be made in light of possible trade-offs between and among the SDGs and The TBLs.

Due to its complexity, interconnectedness, and fragmentation, integration became paramount among what to do to accomplish true transformation and development. A holistic consideration of the industry is necessary. It brings to the fore the need for systems thinking. The CI is considered part of a larger, more complex global system. Also, it is considered as a system that comprises various construction systems. As a system of systems, the systems of systems were introduced to place the industry in good stead towards its systemic development. Thus, to develop the construction industry, it is crucial to focus on developing the subsystems. The reason is that the industry's subsystems can develop on their own regardless of their individual needs and goals. They must interact within the SoS to provide its emergent behaviour. Thus, they must be engineered as a deliberate action towards the desired direction of development.

In all clarity, construction industry development should be seen as a continuous process of deliberately ensuring that a holistic approach is adopted to achieve the industry's transformational goals, considering the concept of sustainability. Thus, the researchers contributing to the debate must consider, alongside the approaches towards achieving sustainable construction goals through its subsystems, the impacts, attractions, disruptions, and distractions from other industries or systems. Thus, the ultimate goal of systemic, sustainable construction industry development (SSCID).

Based on the preceding, it was possible to design a framework by which the maturity level of the construction industry could be assessed in the light of the eight components, the TBL, and the organisations within the industry. Even though the framework is submitted as a theory to be tested, the mathematics proves that there is the potential it as a support system in the quest for systemic, sustainable construction industry development.

The study's significant contribution to knowledge is that it has demonstrated a measurement approach to the development agenda. The lack of it has been one of the weaknesses in the construction industry development programmes. This study implies that there is a need to have an expanded view of the construction industry. The study's outcome also implies that countries' construction industry development programmes should be well-structured, carefully balanced under TBL conditions, and systemically prosecuted.

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Declarations

Competing interest The authors declare no competing interests.

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