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CONSTRUCTION EPCCSU PROJECTS: THE NEGLECTED INFLUENCE OF INTEGRATION AND KNOWLEDGE ON SUSTAINABILITY ISSUES

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Abstract:

The growing global concerns on sustainability and the vitality of our planet is subject to a strong implication of the construction industry and its significant global value chain. Previous studies show the impact of the construction industry to the earth while a major concern on sustainability knowledge and intellectual capability to mitigate the impact of the industry is pointed out. Furthermore, the EPCCSU (Engineering, Procurement, Construction, Commissioning and Start-Up) levels segregate the global industry supply chain. This empirical study is orientated by its associated empirical questions through a deep review of previous and current construction sustainability issues and the meaning of EPCCSU phases described on literatures. The review is critically analysed and discussed using content analysis. Construction projects are inevitably subject to hybrid and integrated stages illustrated by its EPCCSU phases. The lack of description of these phases from literatures is mentionable, especially the CSU and its integration. Sustainable construction barriers can be broken down into four categories, namely: economical, construction related, political and client. The study emphasizes the prominent knowledge related character of sustainability issues and its linkage with integration and the hybrid resolution methods to tackle those issues. Further opportunities of study are recommended in the field of knowledge management benefits to tackle and integrate EPCCSU construction levels and its sustainability barriers.

Keywords:

Sustainable Construction, Knowledge Management, EPCCSU Projects

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Introduction

The definition of Sustainable Development is globally argued and can be perceived differently by governments, academicians, and professionals due to the contingent nature of the sustainable development needs throughout numerous industries and organizations. The World Commission on Environment and Development initiated in 1987 the concept of sustainable development from a linkage study between environmental and economic issues (Keeble, 1988).

Sustainable development is defined as the process of conducting developments that meet the needs of the present without compromising the future generations to meet their own needs (Nicole & Duarte, 2022). The application of development necessitates a gradual and continuous social, environmental, and economic metamorphosis in the whole society.

The study of sustainable development and sustainability are frequently interpreted as interrelated and as synonyms in many fields of scientific and academic research (Olawumi & Chan, 2018) although various schools underline the fact that sustainable development is incorrectly perceived due to the impracticability of sustaining an infinite development inside a limited earth (Fisher, 2006; Spaiser, Ranganathan, Swain, & Sumpter, 2017).

For this reason, the meaning of sustainable development is still argued and often related to economic growth (Gaspar, Marques, & Fuinhas, 2017). Although economic growth may be perceived as unviable on a limited planet (Spaiser et al., 2017), it is claimed that economic growth, illustrated by the environmental Kuznets curve, is a key driver to attain environmental sustainability due to the required resources in doing so (Stern, 2004).

This study firstly adds to the current literature further insights on the EPCCSU stages of construction projects with an emphasis on both the EPC (engineering, procurement, and construction) and the CSU (commissioning and start-up) stages which tend to be overlooked or not integrated. An in-depth understanding of current sustainable construction barriers and their interaction with EPCCSU phases aim to strengthen the current literatures. The empirical and pragmatic approach of the study significantly help to open insights, increase awareness, and enlarge the scope of the study to various professionals seeking sustainability initiatives in the construction industry considering integrated and hybrid solutions by all stakeholders involved in the EPCCSU value chain. Finally, the paper illustrates the strong need of implementing knowledge management and integration as key drivers when tackling sustainability barriers in the global construction industry.

Research Methodology

Empirical Research Questions

This research is driven by the core theories and themes of the research which are discussed in the literature review, namely: Sustainability and Sustainable Development, EPCCSU phases, and Sustainable Construction. The synergy between these theories and themes is thoroughly studied using various articles and journals to shape a strong contextual background for the research. The empirical research is undertaken to guide the evidence of the study based on the current experiences of EPCCSU projects and to transfer the theories and themes into practicable research questions relevant to those theories and themes:

International Journal of Innovation and Industrial Revolution
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DOI 10.35631/IJIREV.412001

1) What are the key concepts of sustainable development and sustainability and how do they interfere with each other?
2) What are the EPCCSU phases in construction projects and how do they interact with each other?
3) Why is it critical to adopt knowledge-driven and integrated sustainable initiatives to tackle sustainable EPCCSU barriers?

Methods

A semi-systematic literature review is adopted to address the key empirical research questions to analyse the concepts and issues of sustainable EPCCSU projects and their progress in previous and recent studies. The data collected from the literature is analysed with the assistance of thematic and content analysis to identify, analyse, and report relevant findings driven by the empirical research questions. For this purpose, a summary of sustainable construction barriers is discussed thematically under the EPCCSU phases based on the content of the literature. The data analysis is also beneficial to showcase the further state of knowledge and potential research in the field of sustainable construction, EPCCSU projects, and their common integration.

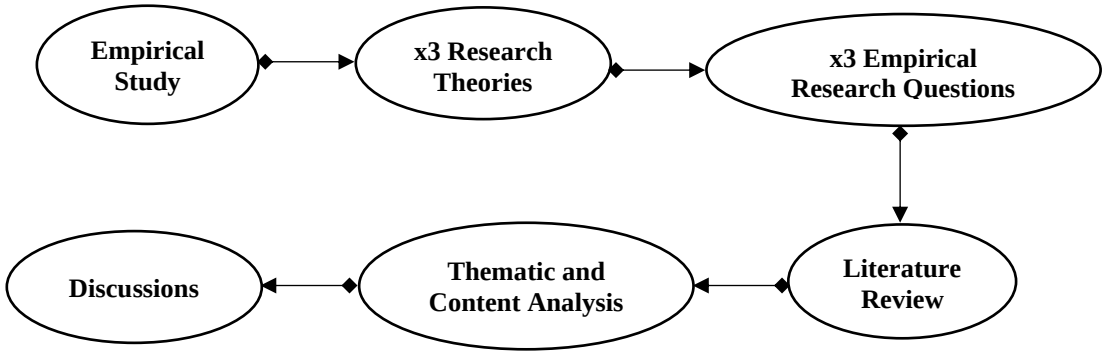

Figure 1: Research Outline

Literature Review

Sustainability And Sustainable Development, A Paradigm

The sustainable development and sustainability paradigm is deliberated through the outline of the "strong" and "weak" sustainability principles. The notion of weak sustainability refers to the optimistic environmentalist and human-driven approach which believes that any balance between the demand and the supply, can be sustained by humankind with its sustainable development capability while the strong sustainability school, conversely, emphasizes the deep consideration of the environmental rights and the need of a radical humankind change on the consumption of global resources and the way countries and governments produce (Ayres, Van Den Bergh, & Gowdy, 2001).

International Journal of Innovation and Industrial Revolution
IJIREV
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Figure 2 outlines the disputed paradigm of sustainability and sustainable development as per below:

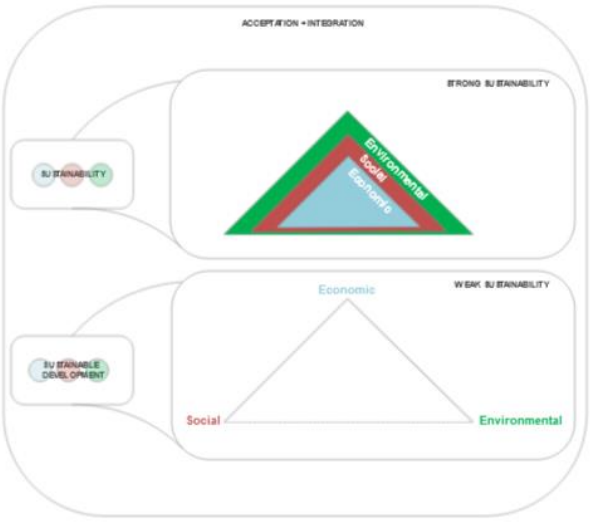

Figure 2: Outline of Sustainability and Sustainable Development Paradigm
Source: Adapted from Morandín-Ahuerma, Contreras-Hernández, Ayala-Ortiz, & Pérez-Maqueo, 2019.

Context Of EPC Projects (Engineering Procurement And Construction)

EPC projects emerged significantly in the construction industry due to the widespread turnkey business model and contracts in the international construction market (Nikjow, Liang, Qi, & Sepasgozar, 2021). As a multidisciplinary, integrated, and hybrid construction project delivery system, EPC projects offer extensive turnkey services which leverage engineering, procurement, and construction needs resulting in costs and time savings (Shen et al., 2017).

The large scope of EPC services is provided by a broad stakeholders value chain to strengthen the capabilities of the contractors such as suppliers, consultants, manufacturers, and compliance parties in addition to the project owner (Abou Chakra & Ashi, 2019). This system allows the contractors to mitigate the lack of knowledge, skills, and resources and rely on other parties with a durable and strong mutual collaboration and common agreements reflected in the project delivery system.

The Necessary Consideration Of The CSU Phase (Commissioning And Start-Up) And Its Significant Position In Project Delivery

Although a thorough explanation of EPC principles in literatures is widely recognized, its robust interlinkage with the CSU (Commissioning and Start-Up) phase is rather neglected despite the uncontested "fit-for-purpose" EPC agreements which go beyond the engineering, procurement, and construction phases (Nguyen, 2017). Indeed, EPC agreements are intended to provide specific services, infrastructures, or facilities at a certain agreed level that covers testing and capital project completed as part of the CSU phase (O'Connor, James T. Shrestha, Winkler, & Choi, 2021; Winkler, 2015).

Numerous industrial projects struggled to complete the project under-investment during the CSU due to operability and functional testing problems emerging from the engineering and construction stages (API, 2013). The poor achievement of project objectives and overall success factors is mainly due to the lack of consideration of the CSU execution plan and planning which tend to be neglected by the parties at the outset of the statement of work

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DOI 10.35631/IJIREV.412001

(O'Connor, James T. Shrestha et al., 2021). A lack of a CSU plan may result in project delivery delays, additional materials supply, repetitive testing, late engineering changes, and accidents and safety concerns (O'Connor, James T. Shrestha et al., 2021). The hiatus nature of CSU is also illustrated in the academic field where a low representation of EPCCSU is available in literatures as a single interrelated delivery system.

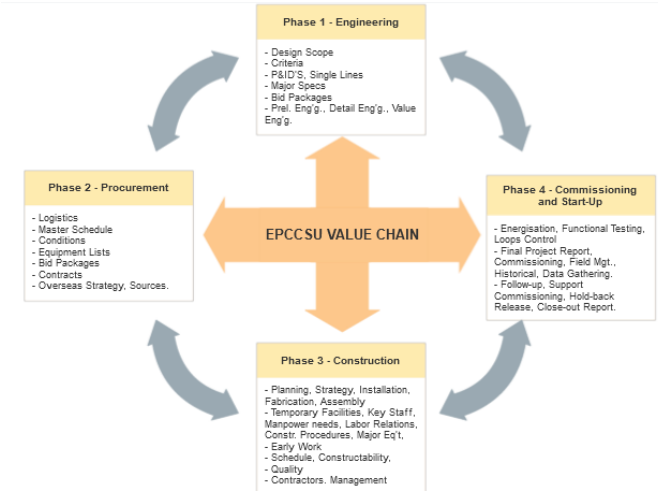

Figure 3: Cycle of EPCCSU Value Chain with Key Activities

Source: Adapted from Nguyen, 2017.

Barriers To Implement Sustainability Concepts In EPCCSU Projects

Economical Barriers

The economic challenges are commonly perceived as the main barrier to sustainable construction by researchers and industry professionals (Saleh & Alalouch, 2015). Indeed, sustainable construction is commonly perceived as more expensive with high-cost involvement than conventional construction projects (Durdyev, Omarov, Ismail, & Lim, 2017; Durdyev, Zavadskas, Thurnell, Banaitis, & Ihtiyar, 2018). In a survey research conducted in the United States, researchers culminated with a list of the most significant barriers to sustainable construction and concluded that the perceived high cost at design and operation stages is a top significant barrier (Ahn, Annie, Yuhong, & George, 2013). In addition to that, sustainable construction is often considered less profitable due to the longer duration of return on investments and the unfamiliarity of construction professionals with sustainable materials and equipment (Tokbolat, Karaca, Durdyev, & Calay, 2020) leading to an unwillingness to invest and misunderstanding of the economic advantages (Lowe, 2003). This lack of comprehension impact contractors' and project managers' capability and awareness to promote and undertake sustainable construction and technology. The perception of unforeseen costs related to unpredictable sustainable practices is still a main economic barrier as a result of a lack of reliable benchmarks and practices to support project managers (Charles, 2016).

Political Barriers

The political barriers relate to governments, policies, and incentives that play a major role in the execution of sustainable initiatives for construction projects (Ifije, Clinton, & Wellington, 2019; Serik, Ferhat, Serdar, & Rajnish, 2019). Policies and governments dramatically influence the project knowledge of construction contractors and therefore, their understanding of adopting sustainability concepts (Hyojoo, Changwan, & Jui-Sheng, 2011). Sustainable

International Journal of Innovation and Industrial Revolution
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construction policies and guidelines help construction practitioners to better understand the implementation of sustainability which is critical to lead the industry on its sustainability journey (Rui-Dong, Veronica, Zhen-Yu, & George, 2016). In addition to the sustainability understanding and the economic features, governments are key players when it comes to the impact on communities. Indeed, relevant policies support communities through empowerment initiatives and also help construction stakeholders to assist the communities with a deeper understanding of communities' sustainability issues (Garde, 2009). The political barriers hinder the adoption of sustainable construction as a result of a lack of regulatory and governance frameworks to support the implementation of sustainability practices (Alfredo, Jorge, & Sergio, 2013). Moreover, an unfavourable view from project stakeholders emerges associating these political barriers with the high cost and additional project delays.

Construction Professionals Barriers

Construction Professionals are the key players in the implementation of construction initiatives and delivery of projects, and therefore, may be the source of barriers to the adoption of sustainability. The main barriers hindering sustainable practices and related to construction professionals are the lack of skills, training, and education (Opoku & Ahmed, 2014; Samari et al., 2013; Tokbolat et al., 2020), lack of knowledge and transparency (Durdyev et al., 2018; Tokbolat et al., 2020), lack of awareness on sustainable issues and practices and also the resistance to change due to the complicated nature of the industry which may result in a lack of demand from clients and project owners (Ametepey, Aigbavboa, & Ansah, 2015; Tokbolat et al., 2020; Williams & Dair, 2006). Construction workers were found to be interested in sustainable construction but not empowered with relevant and adequate competencies to adopt sustainable initiatives (Alkhaddar, Wooder, & Sertyesilisik, 2012). In a study using a survey research method comprised of members of the United States Green Building Council (USGBC) and North Carolina (NC) Triangle Chapter, Ahn et al. (2013) emphasized the crucial role of innovation to accelerate the adoption of sustainable construction. Indeed, the level of innovation in exploring ways to improve sustainability benefits in the construction industry is necessary using sustainable knowledge. This interaction between knowledge and innovation to enhance the awareness and ability of construction professionals requires a strong integration of construction stakeholders and the environment involved in the construction phases (Richardson & Lynes, 2007). Project cooperation is also one of the construction professional barriers which have a direct influence when making timely decisions based on the ad-hoc information received from the teams to adopt sustainable initiatives (Hwang & Tan, 2012). The lack of sustainable information, knowledge, and benchmarks is the cause of the poor implementation of sustainable technologies due to the perceived risky and costly involvement associated with these technologies by construction professionals (Shi et al., 2016). The industry is focused on operational results and oriented by concepts such as engineering, leadership, management, and so on rather than long-term innovation and sustainability issues. Therefore, there is a need to consider sustainability at the core of project management guidelines at organizational and cultural levels driven by common integrated sustainable analysis and methods for the benefits of construction projects (Bebbington et al., 2007; Cole, 2007; Deakin et al., 2010; Singh et al., 2012).

Client Related Barriers

An understanding of the client's scope of work and the project's goals is crucial to implement further sustainability initiatives. Certainly, clients and project owners are the key stakeholders driving construction projects in all aspects such as specifications, performance, safety,

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engineering, materials, and equipment as they have ownership of the built environment and absorb most of the project's costs. Therefore, it is essential to understand the client's sustainable goals and expectations when initiating construction projects to nurture sustainable initiatives commonly (Dalirazar & Sabzi, 2020). Indeed, the lack of owner's interests has been identified as one of the most critical barriers to sustainable construction as a result of a lack of knowledge in addition to a lack of training and expertise (Rui-Dong et al., 2016; Samari et al., 2013).

Results And Discussions

Summary Of Sustainable Construction Barriers

The summary of barriers discussed in the literatures is listed into the following table.2. The literatures discussed numerous sustainable construction barriers broken down into four major themes: Economical Barriers (EB), Political Barriers (PB), Construction Professionals related Barriers (CPB), and Client related Barriers (CB). For this purpose, the summary of barriers undertakes the four themes to harmonize the classification of sustainable construction barriers.

In addition to that, an overview of each barrier has been categorized and segregated into associated EPCCSU phases to support the reader's understanding of construction barriers hindering the adoption of sustainability for each phase of the construction life cycle.

ID	EPCCSU Phase	Sustainable Construction Barriers	References
ECONOMICAL BARRIERS - EB			
EB.1	E	Perception of hight-cost at the design stage	Durdyev, Omarov, Ismail, & Lim, 2017; Durdyev, Zavadskas, Thurnell, Banaitis, & Ihtiyar, 2018 Ahn, Annie, Yuhong, & George, 2013
EB.2	CCSU	Perception of hight-cost at the operation stage	Ahn, Annie, Yuhong, & George, 2013
EB.3	P	Longer procurement time due to poor availability of sustainable materials	Häkkinen, 2011; Hayles & Kooloos, 2008; Ifije et al., 2019; Kasai & Jabbour, 2014; Peter Oluwole, 2015
EB.4	E	ROI is perceived as less profitable	Tokbolat, Karaca, Durdyev, & Calay, 2020 Lowe, 2003
EB.5	EPCCSU	Lack of comprehension and familiarity with cost benefits	Tokbolat, Karaca, Durdyev, & Calay, 2020 Lowe, 2003
EB.6	EPCCSU	Perception of unforeseen costs	Charles, 2016 Tokbolat, Karaca, Durdyev, & Calay, 2020

International Journal of Innovation and Industrial Revolution
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IJIREV
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EB.7	EPCCSU	Lack of reliable costs benchmarks	Charles, 2016
POLITICAL-RELATED BARRIERS - PB			
PB.1	EPCCSU	Lack of understanding of Sustainable Construction at the governmental level	Michael, Matthew, Mike, & Jennifer, 2009
PB.2	EPCCSU	Lack of government financial incentives	Anthony & Yong, 2004
PB.3	EPCCSU	The complexity of government codes and regulations	Ifije et al. 2019
PB.4	EPCCSU	Lack of government regulatory framework	Alfredo, Jorge, & Sergio, 2013
PB.5	EPCCSU	Poor integration between communities and construction professionals	Garde, 2009
CONSTRUCTION PROFESSIONALS BARRIERS - CPB			
CPB.1	EPCCSU	Lack of skills, training, and education	Opoku & Ahmed, 2014; Samari et al., 2013; Tokbolat et al., 2020
CPB.2	EPCCSU	Lack of knowledge and transparency	Durdyev, Zavadskas, et al., 2018; Tokbolat et al., 2020
CPB.3	EPCCSU	Lack of awareness	Ametepey, Aigbavboa, & Ansah, 2015; Tokbolat et al., 2020; Williams & Dair, 2006
CPB.4	EPCCSU	Resistance to change	Ametepey, Aigbavboa, & Ansah, 2015; Tokbolat et al., 2020; Williams & Dair, 2006
CPB.5	EPCCSU	Lack of willingness and commitment	Williams & Dair, 2006
CPB.6	EPCCSU	Lack of knowledge management related to sustainability	Alkhaddar, Wooder, & Sertyesilisik, 2012 Durdyev, Zavadskas, et al., 2018; Tokbolat et al., 2020
CPB.7	EPCCSU	Lack of Innovation to explore sustainability initiatives	Ahn et al., 2013 Richardson & Lynes, 2007
CPB.8	EPCCSU	Poor integration among construction stakeholders to enhance knowledge	Ahn et al., 2013 Richardson & Lynes, 2007
CPB.9	EPCCSU	Lack of project cooperation and communication	Hwang & Tan, 2012
CPB.10	EPCCSU	Perception of risk, fear of the unknown	Shi et al., 2016
CPB.11	EPCCSU	Lack of available sustainable construction	Bebbington et al., 2007; Cole, 2007; Deakin et al., 2010;

International Journal of Innovation and Industrial Revolution
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IJIREV
Volume 4 Issue 12 (December 2022) PP. 01-15
DOI 10.35631/IJIREV.412001

		knowledge and benchmarks	Singh et al., 2012
CPB.12	EPCCSU	Lack of consideration of sustainability in Project Management Guidelines	Bebbington et al., 2007; Cole, 2007; Deakin et al., 2010; Singh et al., 2012
CPB.13	EPCCSU	Lack of integration of sustainability practices at the organizational level	Bebbington et al., 2007; Cole, 2007; Deakin et al., 2010; Singh et al., 2012
CLIENT-RELATED BARRIERS - CB			
CB.1	EPCCSU	Lack of client interests and demand	Rui-Dong et al., 2016; Samari et al., 2013 ; Kibert, 2016
CB.2	EPCCSU	Lack of client knowledge, expertise, and training in sustainable construction	Rui-Dong et al., 2016; Samari et al., 2013
CB.3	EPCCSU	Poor definition of client's sustainability instructions and goals at the project's start	Durdyev, Ismail, et al., 2018; Durdyev, Zavadskas, et al., 2018
CB.4	EPCCSU	Client's culture of operational results-oriented instead of long-term	Zhang et al., 2015 Dalirazar & Sabzi, 2020
CB.5	EPCCSU	Lack of client's environmental concerns	Dalirazar & Sabzi, 2020
CB.6	EPCCSU	Poor integration of sustainable construction into client's project management guidelines	Dalirazar & Sabzi, 2020; Kibert, 2016

Table 2: Summary of Barriers Hindering the Adoption of Sustainable Construction

A total of 31 barriers (Economical: 7, Political: 5, Construction Professional: 13, and Client: 6) have been identified and the following correlations are illustrated in figure 5 and table 2. The literature emphasizes the homogeneous character of sustainable construction barriers associated with most of the EPCCSU phases.

This consistent nature of the sustainable construction barriers is strongly due to the knowledge management-related background (skills, training, education, integration, framework, guidelines and codes, instructions, cooperation and communication, benchmarks, and innovation) applicable to all phases of a construction project.

International Journal of Innovation and Industrial Revolution
IJIREV
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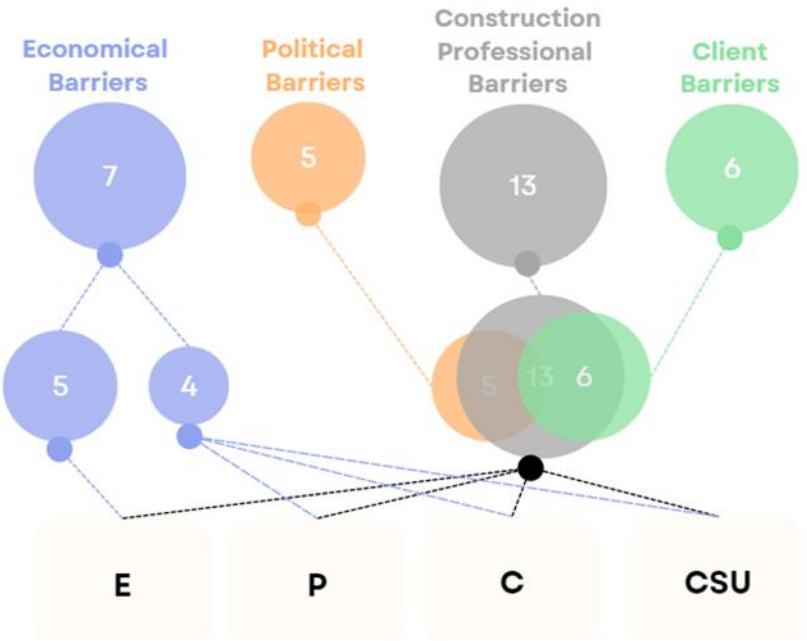

Figure 5: Mapping of Conceptual EPCCSU Sustainable Construction Barriers

Sustainable Development And Sustainability: Key Concepts And Interference

Sustainable development and Sustainability concepts are argued globally with various theories and common initiatives being implemented by global practitioners including governments, standards bodies, construction professionals, and related sustainability groups of communities. Overall, sustainable development and sustainability aim to sustain the well-being of the current and future global population while minimizing and eliminating any detrimental impact on future generations. For this intent, the idea of sustaining can be perceived as an integrated and hybrid concept that intends to balance fairly and equitably the global consumption and production of resources to neglect over-consumption. Contradictory, the severe diminution and focus on global consumption essentially is also perceived as the only way to tackle sustainability issues as it involves non-reversible and direct environmental, economic, and social influences. These opinions may differ due to the extensive and segregated nature of the global society and its impact on the environment, the people, and the economy. Therefore, it is crucial to understand the timeless and inevitable integration requirements related to sustainable development and sustainability by all stakeholders and at the global level.

Meaning Of EPCCSU Phases In Construction Projects And Interactions

The EPC model is well recognized and favoured by many practitioners in the construction industry due to its integration and time-efficient advantages. Engineering, Procurement, and Construction phases relate to the blueprint and design of a built environment, its required supply chain to execute that design, and the final construction of the built environment aligned with the design and its associated human, material, financial, and knowledge resources, and supply. The CSU phase, which tends to be less described in literatures, is strongly linked to the EPC stages. It is during the Commissioning and Start-Up stage that the EPC lessons learned, failures, and successes of the final built environment are discovered and recognized throughout EPC troubleshooting, reworking, testing, assessment, and final commissioning validation. Thus, various stakeholders are involved under one or more EPCCSU phases to answer specific needs to hand over a built environment aligned with the agreed project's specifications,

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 4 Issue 12 (December 2022) PP. 01-15
DOI 10.35631/IJIREV.412001

standards, schedule, and budget. It is a continuous and hybrid value chain, continuously varying and interchanging among stakeholders and the objectives of the intended built environment. Consequently, the amount of information and knowledge can be significant and segregated throughout the EPCCSU phases, organizations and individuals which may lead to integration challenges.

The Impact Of Knowledge Management And Integration Initiatives To Tackle Sustainable EPCCSU Barriers

EPCCSU concerns are linked to nearly all identified sustainable construction barriers as a result of knowledge management-related issues applicable to all EPCCSU phases. Indeed, sustainable construction barriers appear to be mostly influenced by management, coordination, communication, comprehension and understanding, intellectual capital, and EPCCSU's overall knowledge related issues. Those knowledge related issues are interrelated which leads to sustainable construction barriers to be defined as a consistent integrated process that systematically influences several EPCCSU phases regardless of the nature of the barrier. Therefore, EPCCSU practitioners are required to consider commonly argued and integrated remedial actions when neglecting those barriers. The origin of the barriers may be subject to the identified economical (7 barriers), construction professional (13 barriers), the client (6 barriers), or political (5 barriers) related issues as shown in table 2. Economical barriers are exposed to a lack of confidence, understanding, benchmarks, reliable historical data, comprehension, and perception of cost benefits when implementing sustainable construction concepts. There is a strong lack of known economic success stories which leads to an increase of unknowns from EPCCSU's stakeholders. As a result, a negative perception influences the implementation of EPCCSU practitioners when considering sustainability in construction projects due mainly to a strong lack of cost-related references in sustainable construction.

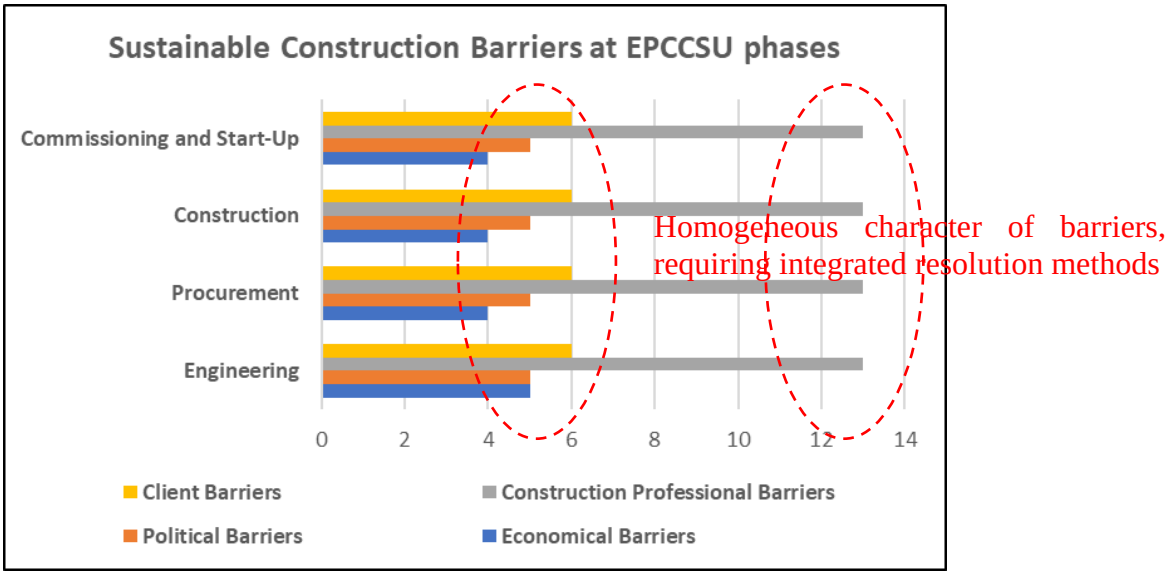

Figure 6: Distribution of Sustainable Construction Categories for each EPCCSU Phases

Furthermore, the lack of cost benchmark is reinforced by political barriers such as poor government incentives, integration among communities and construction professionals, and reliable regulatory frameworks and guidelines. Political barriers demonstrate the need for integrated and skilled governments apropos of sustainable construction concepts and issues and

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 4 Issue 12 (December 2022) PP. 01-15
DOI 10.35631/IJIREV.412001

their impact at all EPCCSU phases. Having a clear understanding of each EPCCSU phases will help governments to put in place relevant remedy actions to mitigate the sustainability barriers. Sustainability is paradoxically subject to timing challenges due to the current high concerns about future generations. Therefore, construction projects need to be incentivized accurately by the governments considering a thorough review of EPCCSU phases and their role in sustainability. Collaboration and common commitments are key drivers to acquiring integrated and hybrid resolution methods aligned with the extensible EPCCSU stages of construction projects. By doing so, knowledge management and capital intellectual play a crucial role through sharing, learning, and reusing information to perform the right decisions from the first time.

Conclusion

The increase of sustainability initiatives in the construction industry has raised concerns about the newness of concepts, ideas, philosophies, and technology to be implemented to mitigate sustainable construction barriers, especially when the industry is segregated by various EPCCSU phases. Sustainable construction barriers are numerous and can be categorized into 4 categories (economical, construction related, client, and political) impacting the life cycle of construction EPCCSU projects phases integrally and simultaneously. Knowledge management and integration-related processes may be key drivers to enhance the sustainability performance of construction projects by learning, collecting, sharing, and integrating the resources. This research supports scholars in identifying the current issues of the construction industry in implementing sustainability initiatives in addition to the emphasis on knowledge management and integration role in tackling those issues. Further studies may be considered with deeper attention to knowledge management and integration processes and tools to identify the best practices when tackling sustainability barriers in addition to the correlation between innovation management philosophies to tackle sustainable construction issues.

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