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A Theoretical Framework to Promote LCA in the Construction Industry of Saudi Arabia

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Abstract: The building and construction sector in the Kingdom of Saudi Arabia (KSA), experiencing rapid growth, is in the early stages of embracing sustainability measures. In the years ahead, the booming building sector in business-as-usual scenarios may pose serious energy and environmental challenges for the Kingdom. This situation will require the Saudi building sector to adopt robust sustainability measures. Embedding life cycle assessment (LCA) as a standard practice can be a useful strategy for improving the energy and environmental footprint of buildings. This paper proposes a theoretical framework within which to promote LCA in the Saudi Arabian construction industry. This framework comprises three pillars: policy, social, and technical. The framework covers the role of the Saudi building sector's stakeholders such as policy makers, building industry professionals, representatives of relevant governmental bodies, and academics. Adaptation of this LCA framework can help substantially improve the energy and environmental performance of buildings. The proposed LCA framework is aligned with the international as well as the Saudi government's drive for sustainability in the building sector.

Keywords: life cycle assessment; construction; Saudi Arabia; sustainability

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1. Introduction

The effects of climate change are already being felt globally in the form of frequent extreme weather conditions. The Intergovernmental Panel on Climate Change (IPCC) proposes active participation from all industrial sectors to develop sustainable solutions [1]. In this context, the construction industry, which is one of the most important contributors to socio-economic development and a major consumer of energy, is responsible for more than 30% of the total natural resource extraction, producing around 25% of the total solid waste across the globe and generating over one-third of the total greenhouse gas emissions [2–4]. It is therefore essential to enhance the involvement of the construction industry in the efforts to achieve the United Nations' Sustainable Development Goals (SDGs) across the globe.

In the Kingdom of Saudi Arabia (KSA), to fulfill the needs of the rapidly increasing population and economic development, the construction industry is also growing quickly, which is evident from the many large-scale construction projects in planning and/or execution phases (e.g., NEOM) [5,6]. The energy consumption data of the existing buildings are a matter of concern as the existing buildings consume more than 70% of the total electricity generated in the country [7–10]. For these reasons, it is essential to consider the development of different methodologies which can ensure/enhance the sustainability of the existing and planned projects.

Another important aspect in the context of Saudi Arabia is its population and its related characteristics. Saudi Arabia's population is expected to increase by approximately 45% by 2050 [11]. Moreover, while around two-thirds of the population is under the age of 30 years, estimates suggest that in order to meet the needs of the growing population, the country has to build 2.32 million new homes [12,13]. In addition, the country's per capita CO_2 emissions are around four times the world average, which is a matter of concern in the wake of national efforts to make buildings more sustainable [14]. It is also noteworthy that KSA has pledged to become carbon neutral by 2060, a target that also demands a paradigm shift in terms of emissions [15,16].

In the past, sustainability has not been the main priority for the Saudi building sector; its main emphasis appeared to be on issues like cost, modernity, durability, and architectural outfit [17]. However, with the growing realization of the importance of the environmental performance of buildings, among other options, life cycle assessment (LCA) is required to be adopted as a regular feature in building activities and practices.

Since the 1990s, LCA (Figure 1) has been widely used as a standardized approach to evaluate the environmental impacts of products and processes throughout their life cycles, i.e., from raw material extraction to the end-oflife [18,19]. As LCA involves detailed consideration of various environmental impacts at all stages of a product or process, it is considered a powerful tool for comparing different products, processes, or technologies. In LCA, the identification and quantification of various inputs and outputs—which, among others, include the energy, different wastes, pollutants, and materials of a system—highlight the environmentally critical hotspots in a product/process's life cycle that cause most of these environmental impacts [20]. Identification of such hotspots in turn helps to steer attempts to decrease the overall environmental impacts linked to a process, technology, or product. Another important advantage of LCA is its potential to prevent the shifting of environmental burdens from one stage of the life cycle to another stage [19]. For instance, using a novel lightweight material may reduce energy consumption and environmental impacts during the use of a product, but may increase environmental impacts at the end of the product's life due to a lack of proper recycling methods. LCA helps to highlight such tradeoffs and helps to mitigate overall environmental impacts.

Figure 1. Life cycle stages of a building: (1) raw material extraction; (2) transportation of raw materials; (2) construction; (4) use; (5) end-of-life recycling and demolition.

Some other advantages of LCA in relation to the building sector include that it can determine the environmental impact of different building materials used in projects and it can help construction companies to select eco-friendly options, etc. For instance, LCA can identify those materials and processes that emit fewer greenhouse gases, have less energy consumption, and result in less toxicity. LCA can also pinpoint ways to optimize energy usage in construction projects. For example, LCA might recommend energy-efficient lighting in buildings, energy and water-efficient HVAC systems, and appropriate building orientation in order to lessen energy consumption. LCA also helps in reducing waste from construction by pointing to options like construction material reuse, recycling, and packaging minimization. LCA can also conserve water in the construction industry, for instance, by recommending low-flow fixtures and rainwater collection/reuse. LCA can optimize transportation as well, for example, by using local construction materials to cut emissions or through improvements in material transport logistics. Overall, LCA identifies areas for improvement that lead to lower environmental impact, efficient resource use, and cost savings. Through these benefits, LCA offers various opportunities for improvement in Saudi Arabia's construction industry. By implementing these solutions, construction companies can move toward sustainability and can support the mitigation of the environmental footprint of Saudi Arabia's construction industry.

Within the aforementioned context, i.e., construction industry-associated environmental concerns, special challenges related to the Saudi Arabian context, and the benefits of LCA, this paper aims to develop a theoretical framework for promoting LCA in the Saudi Arabian construction industry. Some of the prominent features of this framework include the identification of the key stakeholders and essential policies that are required to promote the use of LCA in the construction industry and the provision of a roadmap to involve all the relevant stakeholders in reducing the environmental burdens of buildings.

2. Methods

This work relies on the literature review and framework development methodologies. A state-of-the-art review of the scientific literature is a commonly used methodology for exploring the current status of research on a certain subject [21,22]. Such studies help in the development of comprehension of existing research topics, highlight shortcomings in scientific understanding, and provide directions for upcoming scientific explorations. Through careful selection of scientific databases and relevant keywords, it is possible to investigate the latest research on a specific topic of interest. Moreover, by outlining clear criteria according to the objectives of a study, a researcher can sort the scientific literature and filter highly relevant studies, which helps to elucidate the current status of research on that specific topic. Finally, by expanding the literature search through exploring the citations in selected studies, more studies that are relevant to the specific study can be found [23].

The studies considered in this review article were discovered by performing searches on the Internet as a whole and in scientific databases. Keywords considered in the search included "Saudi Arabia", "LCA" and "Construction". The main database used to search for scientific publications was Scopus. The reason for this is that the most important and common journals on the subject of sustainability, energy, and climate change are registered in this database. Moreover, the time period for the search in the Scopus database was restricted to 1990–2020, as LCA utilization became more common after the 1990s. Additionally, scientific studies in English were considered as for most undergraduate and graduate-level studies in Saudi Arabia, the medium of instruction is English. A general search of the Internet was also performed to explore studies conducted by NGOs and the industry; this is because studies of these entities are typically not published in the scientific literature.

According to the Oxford Advanced Learner's Dictionary, the word "framework" is defined as "a set of beliefs, ideas or rules, that is used as the basis for making judgments, decisions, etc." [24]. In the context of research, there are two main kinds of framework:

theoretical frameworks and conceptual frameworks. Imenda [25] argues that both types of framework help researchers to see the main concepts and variables of a study, provide them with a general approach, and guide researchers' data collection, interpretation, and explanation. Nonetheless, theoretical and conceptual frameworks are not conceptually or methodologically the same, and they have different application scopes. Theoretical frameworks are "adopted from a pre-existing theory", whereas conceptual frameworks are created by researchers "from a variety of conceptual or theoretical perspectives". In essence, a conceptual framework is a "synthesis of relevant concepts", and a theoretical framework is an "application of a theory as a whole or in part" [25]. As such, in this study, the developed framework is a theoretical framework that draws on insights extracted from the literature.

In order to develop this theoretical framework, we analyzed several existing frameworks for promoting LCA and sustainability that have been published in the literature [26–30]. These frameworks were mostly developed for the building and construction sectors of various countries. This literature review led to the foundation of the theoretical framework proposed in this paper. We extracted and summarized the recurring themes in these frameworks, which then helped to identify the theoretical constructs for our framework. The framework proposed in this paper consists of technological, social, and policy aspects related to the promotion of LCA in the construction sector. Before explaining these aspects, we first provide a summary of existing LCA studies about the Saudi Arabian construction industry. This summary will indicate that LCA is still an new concept for the Saudi Arabian construction Industry and that there is a huge potential for promoting LCA in the Saudi Arabian Construction industry.

The literature search conducted to explore the sustainability of the building sector in Saudi Arabia revealed that LCA-related studies are very limited in number. For instance, in the context of the application of LCA in the Saudi Arabian building sector, the number of published scientific studies found was only four. In this context, Asif M. et al. [31] demonstrated a cradle-to-gate investigation of a house with three bedrooms in Dhahran, a city in the Eastern province of Saudi Arabia. The focus of the study was on the construction materials used; the authors stated that the most environmentally harmful materials, out of 18 construction materials used in houses, are concrete and steel. However, due to the limited scope of the study, is the authors suggested that a complete life cycle assessment is required, which should include the energy consumed, construction processes involved, transportation needed, and the end-of-life treatments required. Similarly, another study, which focused on residential buildings in several cities in Saudi Arabia, assessed the environmental impacts of the use of air conditioning [32]. The study revealed that air conditioners, which are extensively used in Saudi Arabia due to the prevailing harsh climate, consume more than 70% of the total energy consumed in buildings. Of all the life cycle phases, the use phase was responsible for the most impact within the life cycle. The study further revealed that electricity generated from fossil fuels is the primary source of emissions. Furthermore, a study by Rodrigues C. et al. [33] performed a comparative LCA of conventional and modern lavatories. In their study, they compared the advantages of employing modern design in five countries, which included Saudi Arabia. The authors found that conventional toilets have a global warming potential (GWP) of about 260 kg CO_2 eq. in Saudi Arabia, whereas new designs have about 75 kg CO_2 GWP. The authors also stated that the energy used to heat the water was the key player in the environmental damage caused by the modern design of these lavatories. Similarly, Alshamrani [34] also compared different construction techniques in the Saudi Arabian context. The study stated that conventional practices of construction are environmentally better than the ones that rely on pre-fabrication. They also reported that steel has the highest GWP at 38.9% of the total GWP.

Another point that can be observed from above-mentioned studies is that Saudi Arabia still heavily relies on traditional construction materials, techniques, and processes. The most common construction materials in Saudi Arabia are concrete, steel, bricks, cement

blocks, and glass. A typical construction process starts from site preparation, installing water and electricity infrastructure, laying the foundations, and developing the structural frame. After that, the exterior and interior finishing is carried out by adding roofing, cladding, insulation, plumbing, and electrical systems. Construction using prefabrication methods and modular techniques is still not very common. There is a growing emphasis on promoting sustainability in construction in Saudi Arabia by using environmentally friendly materials and reducing energy consumption.

From the above-mentioned details, it becomes evident that it is essential to promote LCA in the building sector of Saudi Arabia. Using LCA in the building design and development phase can lead to a significant reduction in the overall environmental impacts of a building. In one study [35], it was reported that up to 46% of embodied carbon in a building can be saved by using recycled materials. This saving was identified by using a cradle-to-gate LCA approach. The next sections discuss the details of developing a theoretical framework for promoting LCA in Saudi Arabia.

3. Framework for Promoting LCA

Several regulations and standards in Saudi Arabia require or encourage LCA in construction. The Saudi Building Code (SBC) [36] has set certain minimum environmental requirements for building materials and systems. Moreover, the Saudi Green Building Forum (SGBF) [37], which is a non-profit organization under the SBC, promotes sustainability in Saudi construction. For instance, the Saudi Green Building Code (SGBC 1001) aims to lessen buildings' environmental impact. In addition, SGBF also provides training and education for stakeholders to understand sustainability's importance and how to apply it in projects. Furthermore, the Saudi Vision 2030 [38], a national development plan, commits to reducing construction projects' environmental impact through sustainable materials and practices. Similarly, the Saudi Arabian Standards Organization (SASO) [39] has developed standards related to materials' and systems' environmental performance. These standards encourage using LCA to assess projects' environmental impact. In this context, in order to rigorously apply LCA in the construction industry, a framework is proposed in the next section which we expect to provide guidelines for implementing LCA and achieving more sustainability goals within the construction industry (Figure 2).

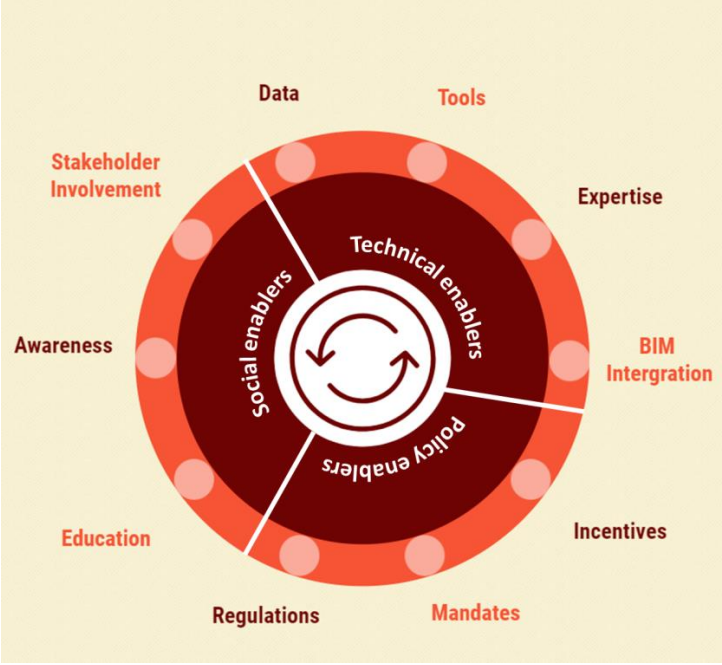

Figure 2. Three pillars of a theoretical framework for implementing LCA in the Saudi Arabian construction industry.

A policy framework from the Saudi government mandating or incentivizing LCA for projects is essential to promote its adoption. Some of the actions which can help the government in this regard include the following: the government could require environmental impact assessments or sustainability reports incorporating LCA for large projects; training and certification programs for LCA professionals could build capacity for Saudi consultants and contractors; financial incentives like tax credits or subsidies could be offered to projects that meet LCA performance targets; environmental product declarations and sustainability standards incorporating LCA metrics could become mandatory for materials in Saudi construction; and dissemination of case studies highlighting LCA's economic and environmental benefits for Saudi projects could raise industry awareness and motivation. In addition, collaboration between government agencies, consultants, contractors, suppliers, and academics could facilitate the development of a customized LCA framework for Saudi Arabia. With the right mix of mandates, incentives, training and stakeholder engagement, LCA practices have the potential to transform Saudi construction into a more sustainable and efficient sector. In this context, the proposed framework for promoting LCA in the construction industry has three main parts:

- The policy aspect: regulations, mandates, and incentives.
- The technical aspect: tools, data, expertise, and the integration of building information modelling (BIM).
- The social aspect: awareness, education, and stakeholder involvement.

The following sections explain each of these categories, aiming to promote implementing LCA and achieving more sustainable construction in Saudi Arabia.

3.1. Policy Aspect

The policy aspect refers to the policies, regulations, and standards needed to implement LCA in Saudi Arabia's construction industry. These include environmental regulations, green building standards, government procurement rules, sustainability reporting, and financial incentives. These policies provide a regulatory framework for sustainable construction practices and encourage adopting LCA as a tool for assessing projects' environmental impact. The policy aspect also involves stakeholders' collaboration to ensure policies align with Saudi Arabia's local regulations and standards. Various policy drivers can encourage implementing LCA in Saudi construction. For instance, environmental regulations can encourage the use of LCA in the industry to assess projects' environmental impacts and ensure compliance and minimization of the impacts. Similarly, within green building standards, a mandatory requirement to use LCA in designing and building will promote sustainability and encourage the utilization of eco-friendly materials and technologies. Likewise, integrating the use of LCA as a mandatory requirement in the government's procurement policies for the selection of materials and products will encourage the utilization of eco-friendly options. Moreover, to encourage the private sector's participation in these efforts, making mandatory corporate sustainability reporting, including detailed assessments of environmental impact using LCA, will promote transparency/accountability and encourage sustainable practices. Moreover, financial incentives for companies using LCA to assess their environmental impact will help reduce costs and encourage adoption. By implementing these policy drivers, LCA can be promoted and adopted, leading to more sustainable practices and reduced environmental impact. However, for successful implementation, these policies must be aligned with Saudi Arabia's local regulations and standards, which are already in use, and should have the involvement of all the stakeholders in their development. Stakeholder collaboration ensures policies consider the perspectives of different groups like government agencies, consultants, contractors, material suppliers, and academics. Their inputs are expected to help significantly in developing effective policies that are tailored to Saudi Arabia's specific needs.

3.2. Technical Aspect

The technical aspects that can enable sustainable development in the construction industry include the availability of LCA tools, relevant data and LCA expertise along with the methodology standardization and integration of LCA with BIM. These technical enablers provide the necessary tools and knowledge to implement LCA and sustainable practices. For instance, the availability of LCA software facilitates implementing LCA by helping in the collection/analysis of data, calculation of environmental impacts of projects and generation of reports. Similarly, the availability of data from suppliers, manufacturers, and contractors regarding materials' utilization, involved processes and energy consumption also enables the implementation of LCA. The needed LCA expertise can be developed through appropriate training and education for all the stakeholders, especially from the industry. Standardization of LCA methodology can ensure consistency in calculating projects' environmental impacts and allow comparisons between projects. Integrating LCA with BIM can help collect and manage data on materials, processes, and energy used in projects, which is eventually needed to calculate environmental impacts using LCA. In summary, these technical enablers—LCA tools, relevant data, expertise, standards, and BIM integration—provide the means to implement LCA and sustainable construction practices. By implementing these technical enablers, LCA can be promoted and adopted, leading to more sustainable construction practices and reduced environmental impact. Here, again, it must be noted that it is necessary to align these technical enablers with local regulations and standards.

3.3. Social Aspect

The social enablers in the framework refer to social factors facilitating the implementation of sustainable practices in Saudi Arabia's construction industry. These include stakeholder engagement involving designers, contractors, suppliers and regulators providing insights into the local context and ensuring LCA aligns with Saudi Arabian regulations and standards. Figure 3 depicts a possible plan for stakeholder engagement in a typical LCA for a building. This figure shows six steps that required for a successful LCA project. The project is initiated, its goals and scope are defined, inventory is analyzed, an LCA is conducted, the results are interpreted, and then the design changes are implemented. Various inputs and outputs for each stage are also given in the figure. The bottom of the figure shows the engagement of various stakeholders in different stages of the LCA of a building.

Education and awareness comprising training programs, conferences, and workshops can raise awareness and knowledge of LCA and sustainable construction. Likewise, collaboration and partnerships between the stakeholders in construction can ensure shared knowledge and resources, essentially promoting the adoption of sustainable practices. Moreover, incentives and recognition in terms of financial incentives and tax breaks can be introduced to reward companies that adopt LCA and sustainable construction. Similarly, policy support in terms of regulations and standards requiring LCA use and financial support for awareness programs can play a positive role in promoting LCA's inclusion in the construction industry. Through the implementation of these social enablers, LCA can be promoted in the construction industry to achieve the sustainability-related goals of the sector. However, like the other enablers, the social enablers must align with the Saudi Arabian local culture, norms, and values to successfully achieve targeted goals. For this reason, stakeholder engagement, education, and incentives should be tailored to Saudi Arabia's social context to ensure sustainable development in construction is socially responsible and equitable. This will help to promote adopting sustainable construction practices that fit within Saudi Arabia's social norms.

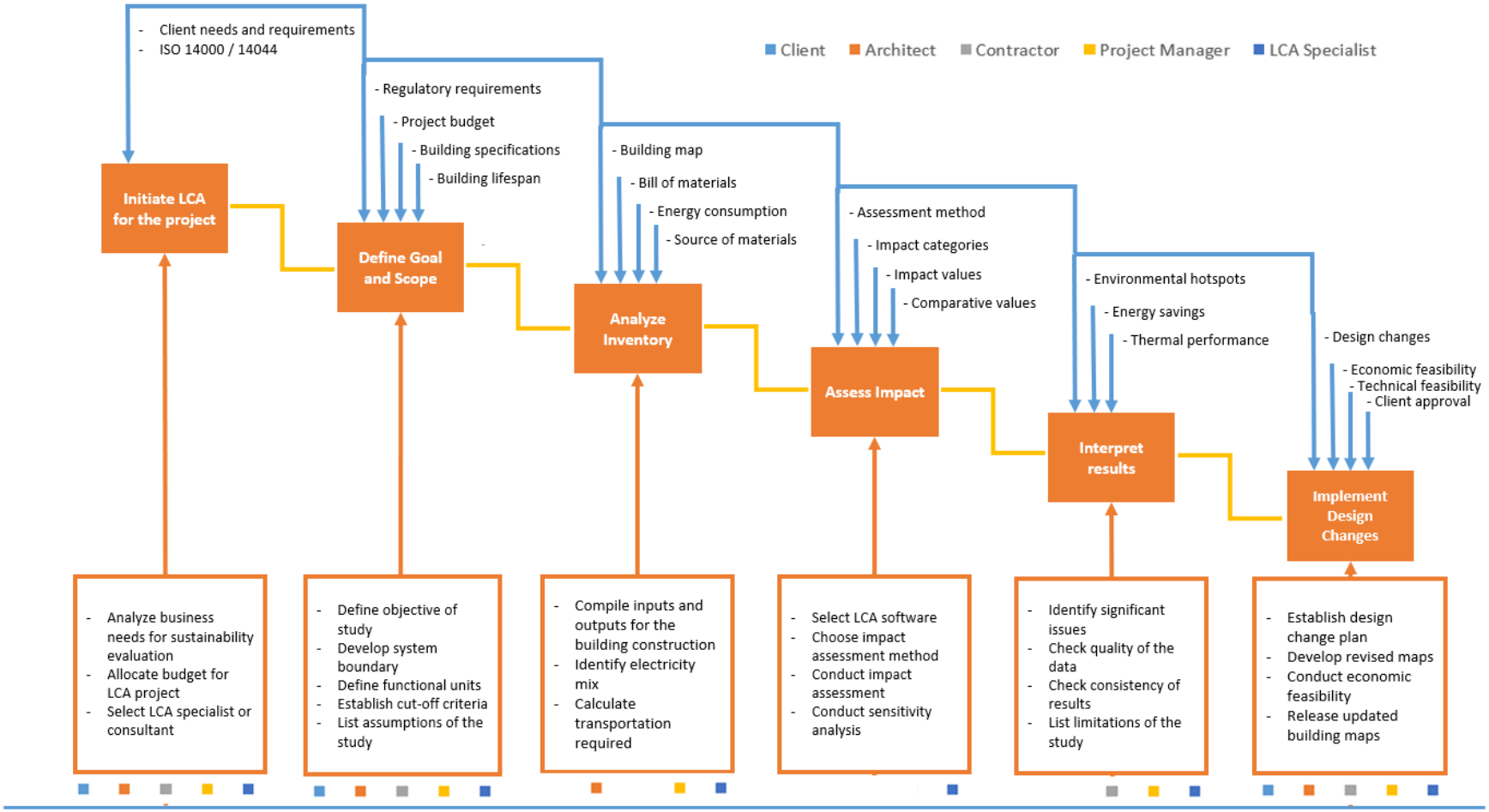

Figure 3. Stakeholder involvement in various stages of LCA of buildings [40,41].

However, it is to be noted that these aspects—policy, technical and social—are interdependent and must be addressed together to achieve successful implementation of LCA, which will essentially lead to sustainable development in the construction industry in Saudi Arabia. Once these enablers are adopted, the construction industry in Saudi Arabia can become more sustainable; they will result in a reduction in environmental impact and the promotion of economic growth and social development.

3.4. Steps in the Implementation of the Proposed Framework

Implementing the proposed framework to use LCA in Saudi Arabia's construction industry will require the involvement of environmental, social and economic considerations in project design, construction, and operations, all the while reflecting local context and regulations. The necessary actions may include considering Saudi Arabia's local climate when designing buildings and infrastructure to optimize energy efficiency and minimize artificial cooling/heating needs; incorporating renewable energy sources like solar, wind, and geothermal energy into building and infrastructure design and operation; implementing water-efficient fixtures, appliances and landscaping practices; using sustainably sourced, low-carbon-footprint and recyclable/biodegradable materials; implementing construction waste management, material reuse/recycling, and designing for disassembly and reuse; considering Saudi Arabia's cultural and social factors that impact design and construction, like using local materials and traditional building methods; taking into account projects' impacts on local communities and supporting their social and economic development; implementing sustainability performance measurement and monitoring systems to track progress and identify areas for improvement; requiring collaboration among Saudi Arabian stakeholders like designers, contractors, and suppliers to implement sustainable construction principles; and aligning practices with Saudi Arabia's local regulations and standards.

Applying LCA for sustainable construction in Saudi Arabia requires reflecting Saudi Arabia's local context in projects; engaging and supporting local communities; collaborating with Saudi stakeholders to develop customized, culturally appropriate solutions; and aligning practices with Saudi Arabia's regulations, norms, and values.

3.5. Challenges in the Implementation and Adoption of the Proposed LCA Framework

Companies face challenges in the integration of LCA into construction project decision making due to challenges related to relevant data availability, expertise availability, lack of information regarding the importance and benefits of LCA, lack of specialized tools, economic considerations, etc. Regarding challenges related to data availability, collecting data on the materials, processes, and energy used in Saudi Arabia's construction industry is time-consuming and expensive, and the quality and reliability of the data varies significantly, which essentially hinders accurate LCA analyses. Similarly, companies may lack the expertise needed to conduct and interpret LCA analyses to identify environmental hotspots and strategies to reduce impact. Likewise, some Saudi Arabian construction industry stakeholders have a limited understanding of LCA and its benefits, making it hard to communicate LCA's importance and integrate it into their decisions. Moreover, LCA is a complex methodology involving multiple stages and specialized knowledge/tools, which makes integration challenging, especially for small- and medium-sized companies. Furthermore, implementing LCA can be costly in terms of time and resources; most often, without regulatory or market pressures to adopt LCA, companies struggle to justify the investment.

To overcome these challenges, companies can adopt various actions to effectively implement LCA in their businesses. Some of these actions include partnering with LCA experts or consultants and investing in LCA training for employees and leveraging the existing data sources to reduce data collection costs. It is also important for the companies to communicate LCA's benefits to the stakeholders involved and to ensure that LCA aligns with Saudi Arabia's local regulations and standards. Moreover, for the successful integration of LCA, companies must overcome challenges including data and expertise limitations, complexity, and economic concerns.

4. Discussion

This study reveals that the application of LCA in Saudi Arabia is still in its early stages. There is great potential to apply LCA in academia as a tool for research and in the industry as a tool to assess sustainability. Some of the initiatives that can be considered to advance LCA's integration in Saudi Arabia include, among others, the development of well-tailored educational and training programs, the creation of a vibrant network of LCA experts, and the creation of a local LCA inventory/database. The upcoming sections elaborate on these initiatives further.

4.1. Development of Well-Tailored Educational/Training Programs on LCA

Academic institutions have an important role to play in the development and promotion of appropriate environmental management and assessment tools. For instance, the University of Leiden developed CML, which is a very commonly used technique for environmental assessment [42]. In the same manner, Saudi Arabian universities can take leading roles in the promotion of LCA through offering relevant graduate-level courses, developing specialized training for the industry, and publication of LCA-related research outcomes in international scientific journals. On the contrary, a general search of the LCA courses offered by Saudi Arabian universities disclosed that dedicated LCA-related courses, both at graduate and undergraduate levels, are rarely offered. In fact, presently, none of the universities in the country offer a dedicated LCA-related course; however, some programs teach LCA as a component of graduate courses on sustainability. On the other hand, dedicated LCA courses are being taught in many universities globally. Similarly, presently, it is nearly impossible to find any professional training on LCA which is designed for the industry. Moreover, the significance of supporting LCA training as an enabler to advance it globally is emphasized by the United Nations' Environmental Program (UNEP) [43]. Against this background, it is suggested that universities in Saudi Arabia should take three actions to advance LCA in the short term: making LCA-related topics an integral part of sustainability courses, teaching a comprehensive graduate-level course on LCA, and offering specialized and well-tailored professional training for the industry. With these actions, universities in Saudi Arabia can become the key players in promoting LCA in the country as a tool for research as well as a sustainability assessment approach.

Along with universities, construction firms can develop in-house training programs for LCA. To initiate this effort, these firms can first enroll their professionals in online training programs offered by the Society of Environmental Toxicology and Chemistry (SETAC) and the Product Stewardship Institute (PSI). After the initial training, a pilot construction project can be selected to implement LCA in the design phase. LCA consulting firms like Prè Sustainability can also be approached for pilot projects. Once a successful project has been carried out, these companies can offer in-house training and continuous learning to make LCA an integral part of every project.

4.2. Development of Collaborative Networks

As far as the availability of LCA experts in Saudi Arabia is concerned, there are very few LCA practitioners; moreover consulting firms specializing in LCA are either completely absent from the country or are very limited in number. In these circumstances, the initiation of a collaborative network of LCA experts who are capable of performing industry-related LCA studies and offering specialized training for the industry is essential for the development of local capacity in the country. In this regard, many local as well as international collaborative networks of LCA experts already exist or have been started in different regions [44]. These networks play essential roles in the advancement of LCA, the development of LCA standards, and the exchange of the relevant knowledge (especially the best practices) at local and international levels. The "Life Cycle Initiative" which was initiated by UNEP, is an example of such a network [45]. The least that can be done to connect LCA experts, researchers, and practitioners is the creation of a virtual network through internet/cloud-based networking websites wherein knowledge, ideas, and best

practices can be exchanged. Moreover, arranging conferences on LCA-related topics locally can also help advance LCA within the country. With enhanced utilization and application of LCA in different industrial sectors, the developed collaborative network of experts can be transformed into a national-level organization which can support the development of local LCA software and a local LCI database that can be utilized by various economic sectors according to their specific needs.

4.3. Development of Local LCA Software and LCI Databases

The results of LCA studies are highly reliant on the LCI database chosen by LCA software. For this reason, it is essential to develop local LCI databases and LCA software as and when possible. Due to the absence of local databases, European databases are used in many published scientific studies. This results in several inconsistencies, especially when the results are used or interpreted to assess environmental impacts in relation to Saudi Arabia. Against this background, among other things, absence of and deficiency in reliable data are among the most common challenges being dealt with by LCA experts and practitioners [46]. In line with this, some countries, e.g., India and Japan, have developed their own life cycle inventory databases [47,48], and many other countries are in the process of developing their own LCI databases [49].

As the accuracy and reliability of LCA results within a specific context are essential for correctly choosing the most sustainable solutions among the available options, Saudi Arabia also needs to begin developing local LCI datasets. This action, besides enhancing the accuracy of LCA results, will also support the development of local LCA capacity. Another important aspect regarding life cycle impact assessments (LCIA) is their dependency upon (apart from the LCI database) local parameters, which include meteorological conditions and population density. For these reasons, the development of local LCIA methods that incorporate local parameters will significantly improve the LCA results of studies related to the local industry. As discussed earlier, SASO may receive significant support in this regard. As the demand for sustainable solutions is growing rapidly, developing local databases and impact assessment methods will greatly improve the accuracy and reliability of LCA results and the effectiveness of solutions developed using these results.

5. Conclusions

This study proposes a framework for the promotion of LCA application in the construction industry of Saudi Arabia. It discovered that in the context of Saudi Arabia, LCA is a relatively newer concept in Saudi Arabian academia as well as industry; this is obvious from the fact that the first LCA study in the Saudi Arabian context was disseminated in 2013 and was followed by only a few studies until now. Moreover, the majority of these studies were presented by researchers who were affiliated with institutions outside Saudi Arabia. Moreover, it found that the LCIA and data used in the majority of these publications were not based upon the local parameters of Saudi Arabia, and as such, the results of these studies in terms of environmental impact may not be reliable. Furthermore, many of these studies stated only a few impact categories, which essentially represent an incomplete picture of potential environmental impacts.

Given the specific characteristics of the Saudi Arabian economy, it is essential to advance LCA utilization as a research tool in Saudi Arabian academic institutions and as a sustainability assessment tool in the construction sector. However, the successful and extensive penetration of LCA into the overall ecosystem/broader society will require the development of local LCA capacity through local and international collaborations, academic/educational programs and training, and academia–industry partnerships. Moreover, it is also critical for meaningful and reliable LCA to develop local LCI databases. Successful implementation of these actions will essentially support the goals of diversifying and transforming the Saudi Arabian economy and ultimately achieve a more sustainable economy.

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