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ORIGINAL RESEARCH



LCT-Based Framework for the Assessment of Sustainability: From the Perspective of Literature Review

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Abstract

In the context of sustainable development, urban transformation should encourage the use of life cycle thinking tools for infrastructure development. By adopting sustainable economic, social, and environmental criteria, this study presents a review of sustainability assessment tools to build a framework for urban infrastructure. It incorporates a variety of methods that economists and industrial ecologists use for evaluating their projects, in addition to the LCT approach. To recognize the strategic sustainability indicators and criteria, the framework uses LCC, LCA, and SLCA in conjunction with stakeholder evaluation and multi-criteria decision analysis, which recognizes the foremost three pillars of sustainability, i.e., economy, environment, and society. Additionally, system dynamics and agentbased modelling are used to optimise the framework. The prominence of the framework is to understand the route an urban infrastructure development should follow to achieve key sustainability interests involving the interconnected environmental and socio-economic aspects. This sustainability assessment framework can be utilised by consultants or supporting agencies to help organisations carry out and monitor such projects.

Keywords Life cycle thinking tools \cdot Sustainability assessment \cdot MCDA \cdot Sustainability indicators

1 Introduction

The urban structure is made of critical utility systems such as means of transportation, water supply and waste management, green infrastructure, housing, energy, communication, etc. (Neirotti et al., 2014). Multiple urban development projects are undertaken to serve the rising population of the cities (Li et al., 2017). However, they need a symmetry

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among economic, social, and environmental factors. Thus, a standard shift in perspective is necessary to address infrastructure concerns and their potential interconnectedness in conjunction with public health, public debt, and limited environmental resources (Larsson & Larsson, 2020). Though sustainable assessment of urban structures is one of the more complex sorts of assessment approaches, it involves an effective way to assess the functionality of these projects in terms of socioeconomic and environmental aspects before their implementation. Management plans for infrastructure practices should increase the benefits and reduce the asserted risks and additional stressors that will occur in the future. "Sustainable Development (SD) is defined by (Brundtland, 1987) as 'the development that fulfils the needs of the current generation without compromising the ability of future generations to meet their needs,'." It can be described as an attempt that supports policymakers and decision-makers in determining which measures should be carried out and what not to be carried out in struggling to build a sustainable society (Emas, 2015; Tomislav, 2018).

In the context of sustainable construction (SC) projects, sustainable development is assessing proposed plans, policies, or legislation from a sustainability perspective before implementation (Devuyst, 1999). Environmental pollution, carbon dioxide emissions, climate crisis, natural resource depletion, waste generation, land use changes, and pollution are all factors that impact the environment due to infrastructure construction (Alwan et al., 2017; Chen et al., 2010; Polo-Mendoza et al., 2023). In infrastructure projects, the construction industry utilises 50% of the entire natural resources extracted and generates massive amounts of demolition and construction waste (Darko & Chan, 2017; Hu et al., 2010) states that roughly 40% of the world's natural resources, 40% of its energy, and 25%of its water are used for construction, and more than 45% of overall waste is produced by construction (Sbci, 2009). Another report determined that the construction sector consumes a considerable amount of material in developed countries (Wrap, 2009). One study found that just the building sector consumes 42 percent the energy in the European Union, earth-mined resources 50 percent, greenhouse gas emissions 35 percent, and 30 percent of water consumption and waste generation (Europea, 2007; European Commission, 2011; Kylili & Fokaides, 2017). In another study, the construction sector's CO_2 emissions were analysed in 40 countries, considering 26 kinds of energy use and non-energy use. Nearly 60% of all CO₂ emissions from the total construction sector come from developing economies. A large part of the contribution comes from China. In addition, the intensity of direct and indirect CO_2 emanations in developing nations is higher than that in developed nations (Huang et al., 2018). It has become increasingly apparent from the scholarly literature that the construction industry impacts the environment (Chan et al., 2009; Wieser et al., 2021; Zhang et al., 2021) as well as social and economic life (Stanitsas et al., 2021), and this issue is becoming increasingly significant. It has been argued that construction sustainability is fundamental to the achievement of sustainable development (Adebowale & Agumba, 2023; Sharaf, 2023; Shen et al., 2007).

Sustainable Assessment became a valuable practice in institutional policy and project assessments; its goals must adhere to "plans and actions that produce an optimal impact on sustainability development" (Hugé et al., 2013). Similarly, urban infrastructure projects represent long-lasting assets, and their assessment will have enormous socioeconomic and environmental repercussions (Adshead et al., 2019; Montiel et al., 2021; Ramaswami, 2020), which can reduce the utilisation of natural resources, minimise threats, and maximise economic return (Thacker et al., 2019; Wang et al., 2020). Considering its spillover impacts, such as alleviating poverty, increasing universal competitiveness, and improving productivity, governments have placed a great deal of emphasis on infrastructure development. Though low-quality or limited-access infrastructure

negatively impacts the poor more than the rich, these spillover effects contribute to the accomplishment of sustainable development goals (Agarchand & Laishram, 2017). Thus, assessing the sustainability of infrastructure projects and understanding sustainability goals is crucial for policymakers and planners. Nevertheless, the practical implementation of this concept in the process of decision-making remains unclear. This shows that construction management specialists are facing serious challenges in understanding and transforming sustainable initiatives into real actions in their projects (Munyasya & Chileshe, 2018).

In infrastructure projects, impacts can be associated with the construction, operation, maintenance, and recycling/reuse phases. "Thus, sustainability assessment reinforces the use of a 'long-term approach,'." It is important to consider other factors when assessing sustainability (Lal et al., 2021). First and foremost, sustainability varies greatly depending on the economic, social, and environmental context of the project site. Second, good definitions of "sustainable infrastructure" must cover the whole life cycle, including conception, construction, operation, maintenance, and recycling and reuse (Bueno et al., 2015). Therefore, it is necessary to build up tools that let socioeconomic and environmental goals be fulfilled (Hendricks et al., 2018; Maqbool et al., 2023; Sharifi, 2021). These goals can be acquired for infrastructure by guaranteeing a life cycle thinking-based framework following Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (SLCA) tools (Kalbar & Das, 2020; Toniolo et al., 2020; Yang et al., 2023). However, LCA, LCC, and SLCA have limitations in assessing the complementarity of infrastructure systems in sustainable assessment (Mirabella et al., 2019). At the same time, there are complications in weighing the sustainability objectives, and it is not easy for the stakeholders to appraise a certain project by uniting its strengths with diverse sustainability indicators. Furthermore, computational tools, i.e., system dynamics and agent-based modelling, can be employed to calculate probable challenges in advance and create a quick and effective construction process. These tools aim to improve work performance by chasing construction systems' dynamic behaviours (Alvanchi et al., 2011). Several scholars believe that diverse approaches can lead to diverse outcomes. Thus, multiple methods and practices ought to be employed in a structure for a unified, wide-ranging solution (Cohen, 2017; Moldavska & Welo, 2019; Yang et al., 2023).

As of now, there are no standard frameworks that can be used to achieve these goals; however, the tools that are used in the literature studies can lay the foundation for the development of such a framework (Adebowale & Agumba, 2023). This study is a review of the prevailing sustainability assessment tools and methods associated with infrastructure projects. The primary goal is to identify and gauge the pertinence of existing tools according to the principles of sustainability and to integrate these tools into a framework. To contribute to the solution of various sustainability issues explored in the current literature, the main idea that motivates this research to be conducted is anchored in the below question:

"How to establish for the construction specialists a life cycle-based tool within a unified structure for the assessment of the sustainability of urban infrastructure?"

To follow the question, the aim of this article is to build an LCT-based incorporated framework for the evaluation of economic, environmental, and social aspects of infrastructure projects. The principal intent of this proposed assessment framework is to support construction consultants and supporting agencies with decision-making recommendations in a step-by-step course towards sustainable development.

This paper is structured as follows: Part 2 describes the background of the study, followed by Part 3 the materials and methods as a research methodology. Part 4 describes in detail the proposed framework, and finally, Section 5 includes a set of conclusions and describes future research recommendations.

2 Background of the Study

A sustainable development concept is the combination of concepts such as development (socioeconomic development), needs (ensuring a high quality of living for each), and future generations (using resources to guarantee a high value of life for future generations). Sustainable development was introduced in 1972 at the UN Convention on Human Environment in Stockholm, the first global convention devoted exclusively to environmental concerns (World Health Organization, 1972). A number of additional high-ranking events were held in conjunction with the UN following these events. Throughout these conferences, "there has been a shift from a stress on environmental problems to a combined attention on environmental and socio-economic development" (Paul, 2008; Tomislav, 2018). The essence of the SD notion comes from the triple bottom line approach, which entails the offset among the three pillars of sustainability. Although there have been more than a hundred definitions of sustainability, the consensus among most scholars is that it emphasises the importance of balancing social, environmental, and economic objectives. These three objectives are also known as the pillars of sustainable development (Azapagic & Perdan, 2000; Labuschagne & Brent, 2005; Manioudis & Meramveliotakis, 2022). To achieve complete sustainability, all pillars must be balanced, yet achieving the desired state is not easy because each pillar must not upset the interests of the other pillars to achieve its targets (Tomislav, 2018).

The concept of sustainability in construction was introduced during the first international conference on sustainable construction (SC) in 1994 (Kibert, 1994). A definition of SC was introduced at that conference by (Hill & Bowen, 1997): SC is the creation and operation of a healthy built environment using resource efficiency and environmental design. Dickie & Howard, 2000, defines SC as the contribution of construction to SD, and Kibert, 2016, suggests that SC is a subset of SD. Certainly, "construction sustainability is crucial for the achievement of sustainable development" (Shen et al., 2007). The implications of construction on the environment, society, and economy have drawn the interest of policymakers, administrative authorities, politicians, construction specialists, as well as consumer and scientific communities throughout the world (Kylili & Fokaides, 2017; Maqbool et al., 2023). Increasingly, infrastructure projects must be evaluated in terms of sustainable development in the context of socioeconomic, environmental, and social factors. Governments have shown that companies' execution projects are required to build approaches, action plans, and indicators of performance that will contribute to sustainable development (Yanarella & Bartilow, 2000). According to (Bossink, 2002), the Dutch government's policy for SC created modern sustainable and design approaches within the Dutch construction industry. Similarly, it is becoming more and more of a priority for the government, at least at the local level, in many countries (Ross et al., 2010). Additionally, international policies and regulations are pushing the infrastructure sector towards sustainability. In the construction sector, for instance, the EU Energy Performance of Building Directive (European Commission, 2010) to have zero-energy buildings is causing confusion and leading to radical changes in current practices (Albino & Berardi, 2012; Dalla Mora et al., 2017; European Commission, 2010). Interestingly, customers are also increasingly demanding sustainable policies in construction processes. A growing number of consumers are looking for suppliers and contractors that are more environmentally friendly, and government agencies and big corporations are setting targets for implementing sustainable methods and management to increase the sustainability of their projects (Häkkinen & Belloni, 2011; Tan et al., 2011). Thus, according to (Kwatra et al., 2020; Yahya et al., 2016), sustainable infrastructure practices have been a strategic focus for the construction industry for several years now. Kwatra et al., 2020, explained that SD can be applied to construction in a variety of ways and with distinct approaches: "from the extraction of raw materials to the construction planning and design of buildings and infrastructure, and finally to the demolition and disposal of their waste."

A number of different studies have been conducted to develop tools that diagnose environmental and socio-economic impacts stemming from the activities of construction at different life cycle phases: from innovation, consumption, and reprocessing of resources to procurement, plan, construction, operation, and maintenance, devastation and waste management, rules, and environmental management plans (Alwan et al., 2017; Hendricks et al., 2018; Munyasya & Chileshe, 2018; Pietrosemoli & Monroy, 2013; Pitt et al., 2009; Shen et al., 2010). Several tools or methodological frameworks are used in practice to evaluate infrastructure projects, which include the concept of sustainability to varying degrees. A variety of current sustainability tools are included in these methods and tools, including traditional methodologies. In this context, studies have primarily focused on developing indicators for assessing the sustainability of infrastructure projects (Stanitsas et al., 2021; Verma & Raghubanshi, 2018). Besides studies on the development of indicators, there have also been studies undertaken on themes such as developing methodology for identifying sustainability assessment indicators (Devuyst, 1999; Fernández-Sánchez & Rodríguez-López, 2010), and integrating sustainability in decision-making at all stages of a project's life cycle (Adebowale & Agumba, 2023; Rosasco & Sdino, 2023). They are designed, however, to evaluate whether the projects contribute to sustainability at a certain stage of the project life cycle (Kalbar & Das, 2020; Mirabella et al., 2019; Rosasco & Sdino, 2023; Toniolo et al., 2020).

Infrastructure projects can be assessed from a socio-economic and environmental perspective in a variety of ways, but there is no uniform or commonly agreed-upon approach that provides a consistent measure of sustainability in the appraisal and evaluation of infrastructure projects (Kwatra et al., 2020; Petit-Boix et al., 2017). According to the literature on sustainable infrastructure, policymakers require practical techniques to evaluate sustainability throughout the lifecycle of infrastructure projects. Methods of assessment that are comprehensive and reliable are necessary for decision-making processes. Currently, there are several approaches to project appraisal; the first involves conventional decision-making techniques, including multi-criteria decision analyses (MCDAs), cost-benefit analyses (CBAs), life-cycle assessments (LCAs), and social life-cycle assessments (SLCAs), among others (Kalbar & Das, 2020; Osman, 2012; Rivai et al., 2023; Toniolo et al., 2020; Yang et al., 2023). Second, infrastructure projects are graded and scored based on their sustainability performance, and third, guidelines, frameworks, and standards are applied to evaluate infrastructure assets and assess sustainability. These tools can be highly helpful to decision-makers when it comes to meeting some of their specific objectives. There is, however, still room for advancement in existing assessment tools. It is their primary weakness that they tend to favour environmental or economic assessments, fail to adequately address sustainability, and focus too much on certain phases of the project lifecycle.

3 Materials and Methods

Based on the objectives of our research, this paper carried out a qualitative literature review to identify, evaluate, and deduce the current state of knowledge about the topic. A literature review of a subject matter reports the need for criticism and the prospective reconceptualization of the growing and more expanded knowledge base of the subject as it remains to develop (Ramdhani et al., 2014). The SLR approach we follow in this study is based on (Tranfield et al., 2003), which is one of the most recognised, validated, and tested by the research community. The methodological approach (Fig. 1) clearly presented a systematic assemblage and analysis of the existing body of scientific knowledge, highlighting key results and directions for future research. During the preliminary interview with some experts in the field of sustainable development and infrastructure, we defined the key themes for designing our review process. We carried out a few meetings to better understand the research process and identify the keywords best suited for the literature review of our topic. The intention of carrying out the review of literature is to capture the prevailing knowledge around the subject, pinpoint knowledge gaps for additional investigation (Kitchenham, 2004), and draw out the theoretical content of the subject matter that might contribute to the establishment of the framework. The key findings from the literature are used as inputs to structure the proposed framework (Fig. 2).

To pick the most pertinent materials, a step-by-step method was applied in order not to ignore significant research papers. Relevant materials were selected from Scopus and Web of Science (WoS), as they are the prominent sources for journals in a range of areas. A time



Fig. 1 The methodological approach



Fig. 2 Life cycle thinking based sustainability assessment framework

span from 2011 to 2023 was chosen to collect all the pertinent studies published in these years. The time span taken is enough time to critically analyse the work done on the topic during this period and develop our conclusions.

A preliminary, unrestricted exploration with the keywords "urban infrastructure and sustainability" showed thousands of papers that were tough to contemplate for this study. Several refiners were applied to limit the search results due to the preliminary analysis of the studies being identified in very diverse areas of research, many of which were not relevant to the present study. In the collection of pertinent material, the following keywords were used: infrastructure management, sustainable assessment, urban infrastructure, sustainability indicators, sustainability framework, triple bottom line approach, life cycle thinking tools, life cycle assessment, sustainability tools, life cycle costing, SLCA, and system dynamics. We considered the most relevant articles following the research criteria shown in Table 1.

Dataset	Web of science and Elsevier's scopus
Time	2011 to Oct 2023
Document type	Articles and review
Source type	Journal articles and international conference proceedings
Keywords	"Infrastructure management", "Sustainable assessment", "Urban infrastructure", "Sustainability indicators", "Sustainability framework", "Triple bottom line approach", "Life cycle thinking tools", "Life cycle assessment", "Sustainability Tools", "Life cycle cost- ing", "SLCA", and "System dynamics"

 Table 1
 Research criteria

Domain areas applied are environmental studies, ecology, urban studies, management, economics, business, construction building technology, energy fuel, social science and other topics, engineering, and architecture. Moreover, in the assortment of literature materials, prominence has been given to methodologies instead of applications.

Titles, abstracts, and keywords were read to make sure the paper was relevant to meet the objectives. If it appears relevant, then the complete article is read to decide if it must be considered or not. This method aided in further limiting the number of inappropriate articles accessible. The complete selection process took a prolonged time to pick the very appropriate articles related to the topic (Table. 2). Articles satisfying the assessment standards were additionally assessed for the different tools and frameworks described in them. After thoroughly studying and evaluating a great number of documents, 65 articles were chosen for the analysis (Table. 2). All these articles are mentioned in the reference list. The critical evaluations of the chosen studies are reviewed, and the tools described in these materials are used as input in the development of our proposed framework.

L.		
Selection process	No. of documents	
Initial search from the web of science and Scopus for the keywords	Web of science	Scopus
"Infrastructure management", "Sustainable assessment", "Urban infrastruc- ture", "Sustainability indicators", "Sustainability framework", "Triple bottom line approach", "Life cycle thinking tools", "Life cycle assess- ment", "Sustainability Tools", "Life cycle costing", "SLCA", and "System dynamics". (With "OR" and "AND" parameters)	3056	4028
After applying multiple refineries (document type, Domain/Area)	1050	1270
After removing duplicates (1050+714)	1764	
Articles screened after the exclusion and inclusion Criteria	660	
Selection based on Title and abstract reading	105	
Selection based on full reading of the papers	75	
Following a rigorous screening process to achieve high-quality Articles	65	

 Table 2
 Articles selection process

4 Results and Discussion

4.1 LCT-Based Framework

Based on the standard approach to decision analysis (Belton & Stewart, 2002), the proposed framework utilises life cycle thinking tools, consisting of: (1) project structuring: a conceptual stage during which stakeholders reconcile; (2) project analysis: it is further divided into mandatory and optional sections; and (3) project resolution and implementation: it is at this stage that the project will be executed. The function of various elements of the framework is to make policymakers and decision-makers aware of the various potential factors that will shape the assessment outcome.

4.2 Project Structuring

To carry out a project, its scope needs to be defined first and foremost. In our proposed framework, project structuring is a conceptual step where pacification is undertaken among stakeholders. The experts' stakeholders may understand what needs to be done to meet key sustainability criteria and indicators. A sustainable development goal is established based on economic, social, and environmental criteria; therefore, it would require conciliation on different sustainability indicators and expectations among different stakeholders to reach the sustainability objectives in terms of the environment, economy, and society.

From the previous studies, we understand that the main objective of sustainability assessment should begin with evaluation and decision-making because decision-makers have a huge impact on the future sustainability performance of the project (Raimi, 2020). Since the sustainability of infrastructure systems is assessed using economic, environmental, and social factors, this framework's first stage aims to characterise the expectations and sustainability concerns of decision-makers and different stakeholders through a joint consultation. Subsequently, it will be interpreted into decision-making criteria for evaluating the project. The implementation of sustainability principles is more effective at the planning stage than at the end of the process.

Policymakers, citizens, investors, users, planners, and entrepreneurs are key actors in any infrastructure system, and all have their own demands, expectations, and goals that need to be achieved. The participation of diverse stakeholders in the course of decision-making is reflected to be one of the vital rudiments of sustainability assessment (Salem et al., 2018; Schneider & Buser, 2018). Indeed, it is normally complex and challenging to holistically take into consideration the views of a wide range of stakeholders. However, sustainable infrastructure also means balancing different demands and preferences (Ferrer et al., 2018; Yang et al., 2023). For this reason, involving stakeholders to comprehend their point of view is undoubtedly a fundamental measure in decision-making. Thus, the intention of this step is to define the sustainability issues and expectations of decision makers and stakeholders through mutual consultation, and then these will be interpreted into quantifiable indicators for decision-making criteria (Ferreira et al., 2020; Lee, 2020; Rosasco & Sdino, 2023). Moreover, the literature describes how sustainability can be integrated into decision-making and implementation processes, as well as how the term can be applied to the assessment of infrastructure projects (Kalbar & Das, 2020; Kylili & Fokaides, 2017).

4.3 Project Analysis

After identifying stakeholders' sustainability concerns and expectations, we can reconcile the expected indicators and criteria to eradicate those similar indicators and adopt the most relevant indicators for building a sustainable project. The sustainability indicators acknowledged at this stage will be used as a criterion to guide the decision-making process. Many indicators can be considered in this process, depending on the stakeholders, decision-makers, other participants, and the type of infrastructure project. The main challenge is to support stakeholders in knowing their priorities and those of the other actors in order to achieve a shared solution (Stanitsas et al., 2021). To address this difficulty and the classification of each indicator, MCDA and FCM can be utilised, whereby participants are required to explain their priorities and choices for various criteria (Assunção et al., 2020; Khan et al., 2022; Kosko, 1986). This method is a suitable decision-making practice for "tackling complicated problems containing inconsistent objectives, high uncertainty, multiple interests and perspectives, diverse types of data, and the accounting for intricate and progressing biophysical and socio-economic structures." Several researchers have indicated that MCDA is a highly suitable tool to implement for decisions and choices based on an incorporated sustainability appraisal. For adopting sustainability, the MCDA incorporates the recognition of sustainability measures, the assessment of each option, the allocation of weighting factors to the criteria, and ultimately the evaluation by applying a technique for ranking the options (Jato-Espino et al., 2014; Yang et al., 2023). This method is appropriate when permitting stakeholder participation and encouraging public involvement. Its main characteristic is its ability to model interactions among diverse variables. Furthermore, the effectiveness of FCM for complex infrastructure systems has also been praised by many authors. Using FCM, neural networks and fuzzy set theory are integrated. As shown in its graphical representation (Kosko, 1986), each node represents a variable in the system and represents the system's behaviour as a network of nodes (Dickerson & Kosko, 1997). To make sure that we have selected the most relevant parameters, we can also conduct a variability and sensitivity analysis (Then et al., 2021).

Being LCT approaches, LCC, LCA, and SLCA could play a significant role in guiding the selection of environmental, social, and economic indicators. Indeed, LCA, LCC, and SLCA are approaches applied to estimate environmental, economic, and social indicators, respectively (Petit-Boix et al., 2017; Ramos da Silva et al., 2023; Toniolo et al., 2020; Wang et al., 2023). LCA is a practice for the assessment of the environmental impacts of an activity, product, or process. The application of LCA for decision-making includes an environmental performance assessment of the entire life cycle from "cradle to grave" (Yahya et al., 2016). This method has been extensively used in the decision-making process and has been utilised to a range of disciplines involving energy, transport, and road infrastructure project (Celauro et al., 2023; Ramos da Silva et al., 2023; Visentin et al., 2020).

SLCA considers the social impacts of an infrastructure project, such as the impact on local communities, labour conditions, human health, etc. It can be used to identify social risks and opportunities associated with different design options and construction materials at different stages of an infrastructure project (Rivai et al., 2023; Rosasco & Sdino, 2023). However, SLCA practices are in an initial period of development where unanimity building still has a long way to go (Toniolo et al., 2020). Furthermore, LCC is an economic tool that supports decision-makers in evaluating the life-cycle cost of various projects. It considers the initial cost of the project as well as maintenance and repair costs and disposal costs at

the end of the project life cycle. However, these tools have limitations, and all sustainability criteria are not totally integrated, but these tools can be considered as a special step to specify a comprehensive sustainability impact appraisal tools (Sarkar et al., 2023; Toniolo et al., 2020; Wang et al., 2023).

In summary, these tools are important for assessing environmental, social, and economic aspects of infrastructure development. These tools can help decision-makers identify opportunities for reducing environmental impacts, improving cost effectiveness, and maximising social benefits associated with infrastructure projects. We can capitalise on the potential of life cycle thinking tools and account for stakeholders' influence through these approaches. Though the key task is to opt for handy amounts of sustainability indicators for the process of decision-making and, in the meantime, ensure that the indicators refer to all sustainability concerns and issues,.

4.3.1 Project Optimization

The presented MCDA and LCT tools are pondered steady-state techniques, cannot anticipate projections and future trends, and do not reflect relationships between various criteria and outcomes over time. A simulation system can be applied to foresee potential challenges in advance and build a cost-efficient and fast construction process. In this sense, it is essential to model the dynamic interrelation between variables over time (Jato-Espino et al., 2014). Computational tools, e.g., agent-based modelling (ABM) and system synamics (SD), for the assessment of sustainability can help to model the decisive variables capable of influencing the behaviour of the system to achieve more efficient results from an environmental and socioeconomic point of view (Aka, 2019; Li et al., 2020; Osman, 2012; Xu & Zou, 2021).

By considering the economic, environmental, and social dynamics within specific geographical regions, ABM, and SD can build the appropriate model required for a more resilient sustainability assessment. ABM can be an effective method for investigating construction problems, forecasting the consequences of various situations, and picking the best solution, given the complexity and dynamic nature of construction problems due to the multitudinous and unstable factors involved (Khodabandelu & Park, 2021). It is capable of processing some of the intricacies that evolve from the connections of system elements. Ding et al., 2016, recommended a five-step structure for developing an agent-base model for construction devastation waste management. An agent-based model (ABM) involves agents interacting in an environment to predict the model's future behavior. The ABM model has four main components: the agents; the environment in which it acts; the rules that direct the agents' communicational and decision-making roles; and their connections with their environment and with each other (Lee et al., 2013). The ABM technique has been applied in diverse types of construction projects (Rozo et al., 2019; Zhao et al., 2012). We may possibly model the prevailing dynamic interrelationship between sustainability indicators along with future projections.

The integration of agent-based modelling and the ideas of system dynamics offers the possibility of uniting the strengths of the two approaches (Nasirzadeh et al., 2018). System dynamics is valuable for realising the complex behaviour of systems and the impacts of casual feedback loops over time (Coyle, 1997). The system dynamics approach has been effectively applied to topics ranging from environmental, social, and manufacturing to project management systems (Golroudbary & Zahraee, 2015; Haghshenas et al.,

2015; Jifeng et al., 2008; Vafa-Arani et al., 2014). The infrastructure project is a complicated system with non-linear feedback loops amongst various variables and subsystems that are affected by socio-economic and environmental factors. Modelling causal relationships facilitates characterising crucial interrelatedness with sustainability indicators, which can lead to improved decision-making and proficient indicator-based reporting. System dynamics and agent-based modelling are approaches for examining nonlinear socio-economic and environmental systems. In some conditions in which applying SD has problems, it might be helpful to use ABM; however, both can be applied in a complementary manner with each other (Nasirzadeh et al., 2018). The recognised techniques illustrated above and computational tools can be useful for the dynamic interaction between indicators for the sustainability assessment of any system investigated. Nevertheless, in our proposed framework, these tools are optional and depend on the interests of policymaker and decision-makers and the nature of the project being implemented. Eventually, using these computational tools as a policy with other methods, such as the LCT approach and MCDA, can be combined to deliver a practical, dynamic sustainability assessment.

4.3.2 Scenarios Analysis

After the objectives and scope of the project have been defined, i.e., sustainability criteria and metrics, using the tools and techniques mentioned above, the stakeholders and decision-makers classify the different scenarios that are to be considered based on their sustainability criteria. This will assist the decision-makers in exploring various potential strategies regarding the project. Backcasting, forecasting, and foresight are the three-scenario development approaches for planning and policymaking (Dixon et al., 2014; McPhearson et al., 2016; Sadovnikova et al., 2013). Specifically, backcasting requires backward planning from a particular set of goals or desired future endpoint to the current state to determine the feasibility of that future viewpoint and the policy measures essential to achieving that state (González-González et al., 2020).

On the other side, forecasting practice is applied as a data analysis methodology to produce future conditions from current information (Montgomery et al., 2015). It facilitates preventing losses by contemplating all key knowledge when structuring applicable decisions. In this sense, forecasting makes it easier for policymakers to identify reasonable estimates of the different activities.

The foresight procedure is also used to create or alter future scenarios by linking them to the present. It could perhaps have a positive effect on sustainable infrastructure policy by allowing examination of its broader socioeconomic and environmental implications (Fernández-Güell et al., 2016).

In literature, there are various statistical means, quantitative and qualitative checks, uncertainty, and sensitivity scrutiny that we can perform to enhance the robustness of the results (Cohen, 2017). However, this is possible under the assumption of good-quality data. The integration of participants' perspectives and the dynamic interrelationship of various indicators through computational techniques in the framework enhances the relevance of a valid LCT approach for urban infrastructure systems (Visentin et al., 2020).

4.4 Project Resolution

In the third phase of the proposed framework, the policymakers use the outcomes, i.e., sustainability indicators identified at the project analysis stage, for the sustainable infrastructure project. Suppose all the participants agree on the defined scenario or criteria. In that case, an evaluation can be made. The procedure will be repetitive to persuade further learning about the determined standards and assure that subsequent decisions are reached with full awareness of potential consequences. Therefore, the proposed sustainability assessment framework uses an iterative approach to adapt to stakeholders and issues. At the same time, the developed framework is generic and flexible and can be functional for diverse infrastructure projects to evaluate the project's sustainability.

5 Conclusions and Recommendations

The review conducted in the preceding sections reveals that, though the notion of sustainability has gained a growing reputation, the broad sustainability evaluation of infrastructure projects is still an unresolved issue. To achieve the sustainability goals of environmental, economic, and social aspects of urban development, a system- and life-cycle-thinking approach is necessary. In this review, we found that none of the present tools included all the necessary requirements to be appropriate for sustainability appraisal of infrastructure; specifically, the existing tools did not integrate a wide enough range of impacts to be compliant with a life-cycle approach, did not provide a rigorous method to analyse the balance among the "triple bottom line" aspects (economic, social, and environmental), and did not include the context-sensitive nature of sustainability. However, integrating these tools could lead to a more holistic approach to the assessment of sustainability for urban infrastructure. In other words, by combining the strengths of different tools, a more complete and comprehensive approach to sustainability can be achieved. Our approach to infrastructure development is based on a life cycle thinking framework that incorporates stakeholders' assessments through MCDA techniques and dynamic systems modeling. A new framework has been developed, combining life cycle thinking with computational tools, e.g., agent-based modelling, and system dynamics. According to the framework, the aim is to recognise the pathways that infrastructure projects should take in order to attain certain sustainability goals associated with numerous socioeconomic and environmental factors in order to achieve specific long-term sustainability goals. Although the proposed framework provides a method for evaluating infrastructure projects on a wide range of parameters, its limitation is that it requires a significant amount of high-quality data, which is difficult to collect unless you are directly involved in managing the project. Accordingly, in order to assess the economic, environmental, and social impact of the project, those who are actually familiar with the data of the project can use the tools provided in the framework for the life cycle assessment of the project in terms of sustainability indicators. With the help of technical staff and practitioners of life cycle thinking tools, the proposed framework can be used by decision-makers to assist them in making the best decisions concerning the sustainability assessment of urban infrastructure projects. This framework should therefore be used by construction industries and urban planners in the planning of infrastructure projects. In addition, it can be applied to evaluate projects at multiple scales and at individual and system levels to take into account the economic, environmental, and social goals of a proposed project. Sustainable urban infrastructure can be enhanced through the use of the sustainable assessment tools outlined in the framework. Furthermore, the framework helps decision-makers and construction experts' tradeoff between preferences, allowing them to make more relevant decisions.

Like all other research and despite the efforts of the authors this study has also limitation which could be perform in the future research. The finding of this study reflects only certain aspects of the proposed tools related to infrastructure implementation and didn't examine the tools in depth. In-depth examination of the tools could considerably assist in advancing the knowledge of construction sustainability. Another limitation and future research direction could be the application of the framework. Since stated above the implementation of the framework requires huge data which is difficult to acquire if not directly involved in the project. Evidently, investigating the identified tools in more real-life construction projects would provide better insights into the applicability of the tools in the framework in different cultural and industrial contexts, and of the potential new tools that are missing. Furthermore, qualitative case studies research that would discourse by what means sustainability is coped mainly in complex infrastructure projects would be of worth, since institutional and socio-political influence are typically significant in these projects. Focus-group research could also be carried out to validate the framework, the tools used in the development of framework, and its useful for the construction sustainability.

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Declarations

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