Management of Sustainable Infrastructure Projects: A Scientometric Analysis

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Abstract. Infrastructure projects play a vital role in the social and economic developments in both developed and developing countries. In the last few years, many studies have examined the application of project management theories and practices in the context of sustainable infrastructure projects. Consequently, considerable research has been performed to devise new strategies and refine existing project management practices to enhance sustainability in different aspects of project delivery. Previous studies reveal various social, economic, and environmental issues encountered over the life cycle of infrastructure projects. This paper undertakes a 10-year (2010- 2019) scientometric analysis of 51 relevant journal articles found in the Scopus database to identify the research trends in the management of sustainable infrastructure projects. It provides insights into the key research themes gaining the interest of the researchers globally. For instance, the review identified four major research clusters viz. sustainability metrics, processes and factors, community impact, and sustainability triangle. An enquiry into the countries and authors with the maximum number of publications and the collaborative network of the authors reveals a lack of research on project management in sustainable infrastructure projects in the context of developing countries. The findings are expected to inform future studies in this research area.

Keywords: Sustainable Infrastructure, Project Management, Infrastructure Projects, Scientometric Analysis.

1 Introduction

Infrastructure projects drive social and economic growth during both construction and post-construction phases of their life cycle. However, they also contribute heavily to greenhouse gas emissions. While sustainability has captured extensive attention of practitioners and policymakers in the construction industry globally [1], there has been a lack of focus on the sustainability of infrastructure projects. As per the Rio Declaration (1992), sustainable development should be the theme for all development

projects. Infrastructure projects have significant effects on implementing the principles of sustainable development [2,3]. Cost-effective and environmentally sound infrastructure can underpin a country's economic development [4]. Additionally, resilient, robust, and adaptive infrastructure projects can meet the long-term social, economic and environmental goals of sustainability and overcome the threats associated with unsustainable development [5].

Previous studies show that infrastructure projects are increasingly embracing the principles of sustainable development or at least incorporating the perspective of sustainable development in the traditional approach of project design and execution. In the last few years, the sustainability criterion has become increasingly important in the delivery of infrastructure projects as stakeholders are focussing more on eco-friendly and economically efficient construction methods and practices during the life cycle of the project [6]. Similarly, a noticeable increase can be observed in research on sustainable infrastructure projects. However, most of the previous studies focus on the technical aspects of project delivery to improve sustainability and consequently, research efforts directed at project management practices in sustainable infrastructure projects are scarce [6].

Since the number of infrastructure projects is likely to grow in the future, especially in developing economies [2], the proper management of sustainable development shall play a crucial role in improving the sustainability performance in these projects. For instance, Ibrahim et al. [7] proposed a set of risk-related factors to be included in the earned value management calculation to assess and evaluate the progress of modern sustainable infrastructure construction projects. Meng et al. [8] found that top managers' leadership competence, with managerial competence being the primary determinant, followed by intellectual competence, directly drives the entire life cycle of an infrastructure project to accomplish infrastructure sustainability.

This review paper undertakes a scientometric review of studies on project management in the context of sustainable infrastructure projects published during the last ten years (2010-2019). It is expected that the outcomes of this study will direct more research efforts in this area by providing the findings of previous studies in a concise manner. The review will also identify a few research gaps that offer opportunities for further research.

2 Review Approach

The present study utilises the scientometric mapping technique to analyse the extant literature on the management of sustainable infrastructure projects. The scientometric analysis is a generic process of domain analysis, which serves the purpose of identifying the intellectual structure of a scientific domain [9]. It provides a reliable and straightforward quantitative methodology comprising bibliometric tools and methods

to analyse the literature and its outputs and to recognise the potentially insightful patterns and trends in research [10]. This technique is suitable for visualising significant patterns and trends in a large body of literature and bibliographic data [11]. The quantitative overview of the research landscape in the field of enquiry provides useful insights into the existing literature that would not be possible through other methods [12]. In the last few years, scientometric analysis approach has found growing acceptance among researchers in the built environment [13,14].

A comprehensive desktop search was conducted under the **title/abstract/keyword** field of the Scopus database. Keywords for searching were 'sustainable infrastructure project', 'infrastructure project', and 'project management'. Project management is relevant across various sectors and disciplines, and it is not just limited to infrastructure projects. Therefore, the researchers limited the search results to construction literature to make meaningful and well-focused inferences from past studies as the fields of sustainability and project management are large and diverse. After the first round of search, 78 articles were identified. In the second round, both researchers reviewed the abstracts of the identified list of articles independently. It was found that project management in sustainable infrastructure projects was not the primary focus of 27 papers. As a result, these articles were removed from further analysis. Finally, the remaining 51 studies were included in this review. Previous studies show that a sample size of more than 50 papers provides a suitably large sample for using scientometric analysis [15].

Sustainability (Switzerland) has published the highest number of relevant publications, which is eight, followed by *International Journal of Project Management* (four publications), and *WIT Transactions on Ecology and the Environment* (three publications). Four other journals, namely, *Journal of Cleaner Production*, *Journal of Construction Engineering and Management*, *Journal of Management in Engineering* and *Construction Management and Economics* have two publications each. The search covered the period 2010–2019 and was not limited to a particular region. Table 1 presents an overview of the sources.

Table 1. Sources of reviewed articles

Journal	*Number of articles*
Sustainability (Switzerland)	8
International Journal of Project Management	4
WIT Transactions on Ecology and the Environment	3
Journal of Cleaner Production	2
Journal of Construction Engineering and Management	2
Journal of Management in Engineering	2
Construction Management and Economics	2
Others	28
Total	**51**

Scientometric analysis was performed on 51 journal articles using *VOSviewer*. In scientometric analysis, author keywords reflect the core content of scholarly publications and identify the main areas of research activity within any domain [16]. Probing a network of connected keywords can provide investigators with an accurate picture of scientific knowledge production, revealing patterns, relationships, and intellectual organisation of areas of research activity [17]. The analysis of the data comprised of importing the extracted and filtered Scopus dataset comprising title, abstract, and keyword fields into *VOSviewer* and selecting the map based on text data option. It created a term-co-occurrence map based on text data to identify the prominent research clusters.

3 Review Findings

3.1 Wave of Research in the Management of Sustainable Infrastructure Projects

Fig.1 shows that the wave of research has risen in the field of project management in sustainable infrastructure projects. Based on the Scopus database, 14 journal publications were published on this topic in 2019 alone, which is a sharp increase from four articles published in 2018. It can be argued that the research interest on project management in infrastructure projects is catching the attention of researchers due to more emphasis on sustainability criterion in the construction industry.

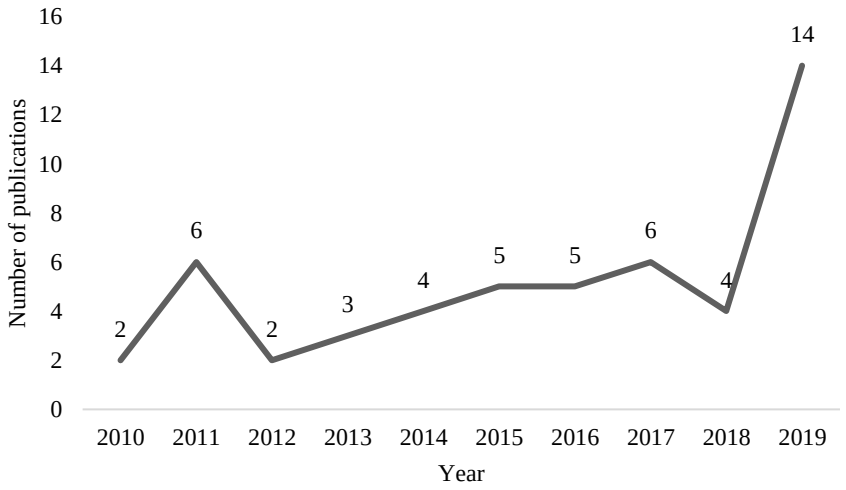

Fig. 1. Year-wise publications on project management in sustainable infrastructure projects

3.2 Leading Researchers, Institutes and Countries

The awareness of the existing scientific collaboration networks could facilitate access to research funds, specialities, and research expertise. It also enhances research productivity and assists investigators in developing collaborative networks with each other to work together on future research and funded projects [18]. Consequently, these insights are useful in promoting scientific collaboration and scholarly communications among researchers working across different parts of the world [18]. The data on co-authorship is a useful metric for scientific collaboration and research productivity. Previous studies show that collaborative research is generally published in outlets with higher impact and receives more citations [19]. Therefore, knowledge of the current scientific collaboration networks in the research domain of project management in sustainable infrastructure projects can encourage further collaboration and access to research funds and expertise.

The analysis of the most influential countries based on research output and collaboration between researchers from these countries reveal the United States (US), United Kingdom (UK), Australia, and China lead research in the area of project management in sustainable infrastructure projects. An inquiry into the institutes leading the research output in this field shows that leading researchers in this area are affiliated to the University of Hong Kong, Hong Kong Polytechnic University, Arizona State University, University of Queensland, and University of Melbourne. An analysis of the various researcher networks in the area of project management in sustainable infrastructure projects was also performed to identify various leading researchers currently associated with this field and their collaborative networks. It was found that Shen, L, Kumaraswamy, M and Liu, B have produced the maximum number of journal articles in this research area.

For visualising the research collaboration network map of authors, the minimum number of documents for an author was set to one, which resulted in a network map of 144 authors. Fig. 2 shows the prominent author research collaboration network of seven authors. The collaboration map of countries of affiliation of the authors is shown in Fig. 3.

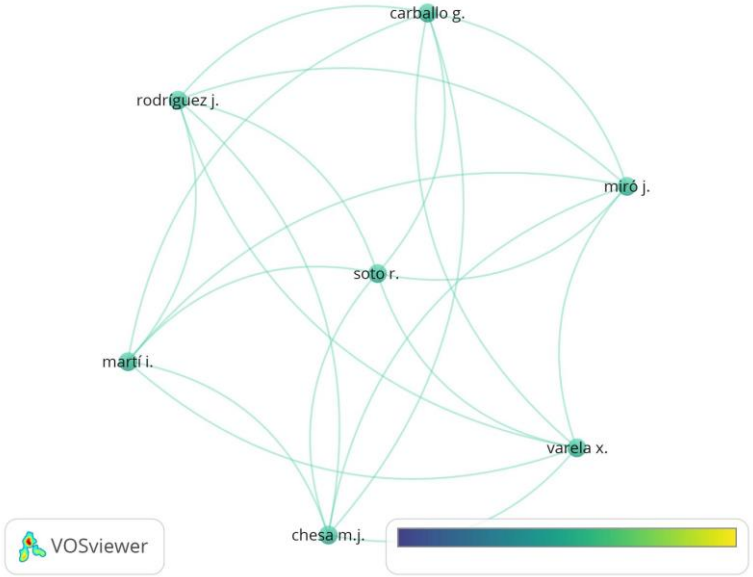

Fig. 2. Author research collaboration network (based on minimum one document)

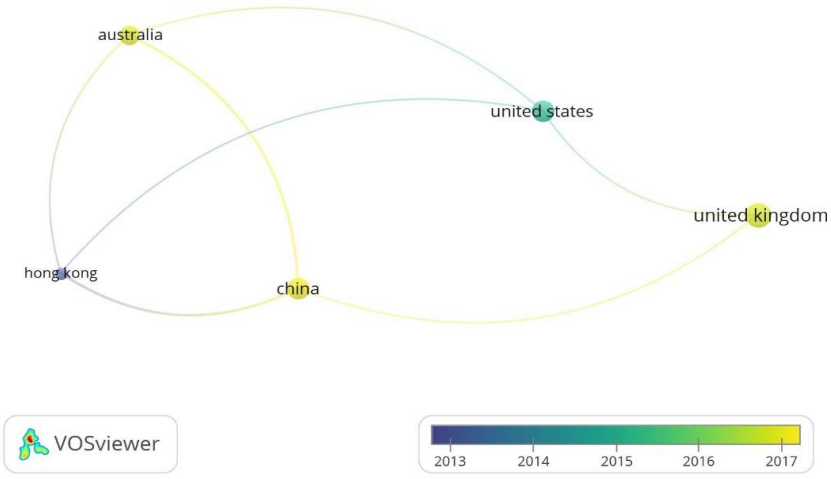

Fig. 3. Country collaboration map (based on the affiliation of authors)

3.3 Clusters of Research on Project Management in Sustainable Infrastructure Projects

A network of related keywords provides an accurate picture of scientific knowledge production in terms of patterns, relationships, and intellectual organisation of the topics covered [20]. Therefore, a co-occurrence network of keywords based on the closeness and strength of existing links was created using *VOSviewer*. The initial mapping of the extracted and filtered Scopus dataset comprising title, abstract, and keyword fields led to a discovery of 1847 terms. To refine it to observe the most prominent terms, we set the minimum number of occurrences of each term as seven. Out of 51 terms meeting this threshold, *VOSviewer* selected the top 60 per cent of the terms with a high relevance score, i.e. 31 terms. In order to obtain a meaningful network map, redundant terms such as article, methodology, integration, study, industry, and way were filtered out from the network map. Finally, the network map shown in Fig. 4 was obtained with the following four major research clusters: sustainability metrics, processes and factors, community impact, and sustainability triangle. The darker colours are indicative of matured research areas while the lighter shades depict emerging areas of research in this field. These findings on important research topics and research clusters help in the exploration of emergent trends within the specific field [21].

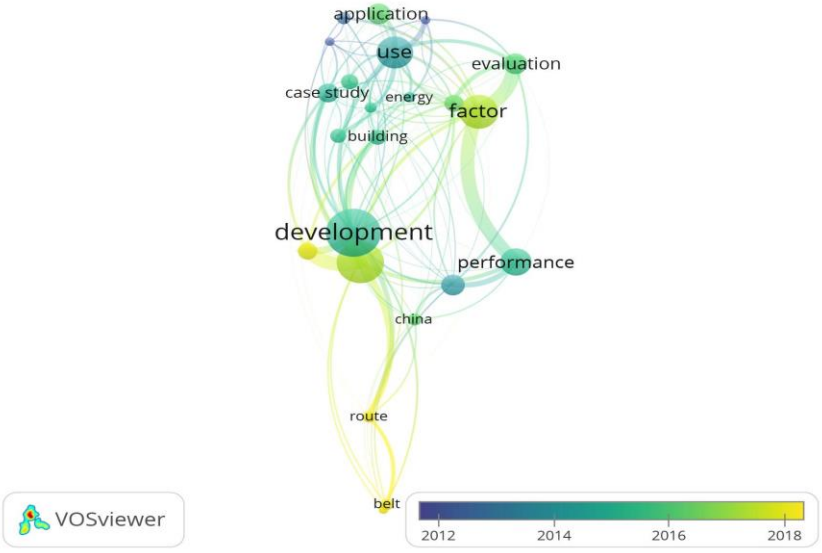

Fig. 4. Text data overlay map of co-occurrence of major research areas

3.3.1 Cluster 1- Sustainability metrics

The review shows that many researchers have focussed on developing frameworks and models for reliable sustainability assessment in infrastructure projects [22-25]. These frameworks and metrics help in evaluating sustainable practices quantitatively and thereby, assist in incorporating sustainable elements into projects. For example, Hasheminasab et al. [25] developed the sustainability indicators with regard to three pillars of sustainable development viz. environmental indicators (e.g. atmosphere, water, land and soil pollution, natural resource and biodiversity), social indicators (e.g. poverty and equality, health, safety and security, education and welfare) and economic indicators (e.g. energy consumption, financial, economic performance, occupation and earning). Fernández-Sánchez and Rodríguez-López [26] developed a methodology to identify, classify and prioritise sustainability indicators based on risk management standards. Whereas Shen et al. [27] introduced Key Assessment Indicators (KAIs) for assessing the sustainability performance of infrastructure projects. They identified five KAIs for the social dimensions (e.g. public safety and effects on local development), seven KAIs for the environmental dimensions (e.g. effect on water quality and ecological effect), and eight KAIs for the economic dimension (e.g. financial risk and life cycle cost) of infrastructure project sustainability. Aboushady and El-Sawy [28] proposed a qualitative assessment framework for identifying and prioritising sustainability indicators influencing projects. Draper et al. [29] suggested the use of the top-down-bottom-up methodology for defining and assessing sustainability criteria for maximising sustainability.

Yang et al. [30] presented a conceptual framework for managing sustainability knowledge and for raising the awareness and research efforts in the area of sustainable transport infrastructure. Similarly, Alnoaimi and Rahman [3] devised a sustainability assessment framework focusing on all aspects of sustainability throughout the infrastructure project life cycle to provide greater transparency to the stakeholders. Yu [31] proposed a project sustainability assessment system considering environmental, social, and economic criteria to achieve sustainability during the execution phase of the project life cycle.

3.3.2 Cluster 2- Processes and factors

Previous researchers have identified factors and project management processes that affect sustainability in infrastructure projects. While some researchers suggest that large infrastructure projects and megaprojects can negatively affect biodiversity conservation and ecosystem [32], others argue that such projects could resolve increasing environmental challenges through individual and community empowerment and improvements in the living standards [5]. Zhang et al. [33] recommended that different types of political risks should be considered to strengthen the sustainable development of politically sensitive infrastructure projects. A typology of political risks and

mapped different political risks in three-dimensional space could facilitate the formulation of different solutions to deal with various types of political risks [33]. Hughes [34] found that complete assessment of trade-offs between conservation and other values and investigation into environmental impacts is necessary to make good decisions for infrastructure projects based in eco-fragile regions and key biodiversity areas. The proposed road and rail routes of the Belt and Road Initiative were overlaid on key biodiversity areas and protected areas to predict biodiversity hotspots for over 4138 animal and 7371 plant species.

Martí et al. [35] in their study on Barcelona City Council's sustainable drainage systems found that non-standardised construction practices and lack of maintenance plan could ultimately lead to management problems in the long term. Therefore, it is important to consider all aspects of the project life cycle while making decisions in sustainable infrastructure projects. Similarly, Liu et al. [36] suggested an integrated management and design process for a holistic solution that combines stormwater management and urban space improvements. Previous studies have also stressed the use of infrastructure technologies and building information modelling during different phases of infrastructure project delivery [5, 37-39]. Eriksson et al. [40] found that industrialised construction could improve both short-term efficiency and long-term innovation and sustainability in projects.

3.3.3 Cluster 3- Community impact

Previous studies show that decision making in sustainable construction is complicated by the involvement of multiple state and public stakeholders in projects [41]. Based on interviews with thirty community members, Colvin et al. [42] examined the social impacts of the TasWind proposal for the development of a wind energy facility. They recommended practitioners to use the consultation process for developing good engagement practice in infrastructure projects. In infrastructure projects such as energy infrastructure projects, where community involvement and support play an important role in project success, the consultation process around a proposed project before the social impact assessment process could help in identifying and analysing the anticipatory impacts of the proposed project [42].

Park et al. [43] found factors such as economic, construction-related, and safety-related characteristics are the most important causes of conflicts in energy infrastructure projects. The researchers proposed a conflict management strategy for more sustainable project execution. Kaminsky [44] studied the influence of national-level culture on construction permitting practices to understand how the culture shapes ways in which various approval processes govern projects. Sykes et al. [45] found that local politics and leadership as the most influential factors in community-sensitive projects. Wong et al. [46] suggested that the construction industry's interaction with the public should be a continuous process to promote safety, social and environmental responsi-

bility. Therefore, stakeholder management and community support play a crucial role in the success of sustainable infrastructure projects.

3.3.4 Cluster 4- Sustainability triangle

Previous studies show that economic performance receives the highest priority in the current practice of project feasibility study. Whereas social and environmental performance receives relatively less attention. Shen et al. [2] suggested the need for shifting the traditional approach of the project feasibility study to a novel approach based on the principles of sustainable development. Loosemore [47] concluded that traditional procurement practices need to be changed to encourage social procurement opportunities. Organisations should incorporate sustainability principles when making decisions on infrastructure investments to ensure long-term resilience [48].

Lenferink et al. [49] found that integrated Dutch Design-Build-Finance-Maintain projects could lead to more sustainable infrastructure development because of the life cycle optimisation incentives provided by the linked contract stages of design, construction, and maintenance. Zhang et al. [50] integrated relevant "people" into public-private partnerships to establish a public-private-people partnership (4P) approach for more sustainable post-disaster infrastructure projects. Hueskes et al. [51] found that sustainability considerations play a limited role in public-private partnerships resulting in the social dimensions of sustainability being neglected. Hueskes et al. [51] also noted that a "strong" sustainability perspective seems inherently incompatible with the contractual public-private partnerships project structure. Kivilä et al. [6] found that the alliance contract promotes economic, environmental, and social sustainability. Therefore, the review shows that the sustainability triangle or principles and contract types are interrelated in sustainable infrastructure projects.

4 Conclusions and Future Research Directions

The need for delivering sustainable projects in recent years has led to the management in sustainable infrastructure projects translating into one of the emerging research areas of research in the built environment. Previous studies show that there is a strong need to develop new project management strategies to enhance sustainability in infrastructure projects. While the US, UK and Australia are leading research in this field, the review found growing research interest on this topic in Asian countries such as China. The main research areas in this field were identified as sustainability metrics, processes and factors, community impact, and sustainability triangle. The review also highlights a few research gaps for directing future research on this topic. While research suggests a broader approach to project management in sustainable infrastructure projects by considering the economic, environmental, and social dimensions of sustainability [52], the challenges in formulating measurable social sustainability criteria for measuring the social dimensions of sustainability have been highlighted by

the previous researchers [51]. Therefore, developing robust project-level sustainability evaluation systems to evaluate the sustainability status of infrastructure projects during various phases of the project life cycle remains an important area of research. This review also found that socio-economic and political risks are the most common barriers to sustainable procurement in infrastructure projects. Future researchers could propose innovative approaches to project procurement to address these barriers. Similarly, research on the implementation of digital technologies in the delivery of sustainable infrastructure projects demands more attention. Additionally, future researchers should investigate the sustainability performance in megaprojects, which remains an unexplored area of research. It must be noted that the review only reflects the research published in journals indexed in the Scopus database. The articles published in conference proceedings and other publications such as books were excluded. Therefore, the use of different databases or inclusion and exclusion criteria in future studies can be expected to generate different results and new insights.

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