

Achieving Sustainable Transdisciplinary Research in Construction Project Management: A Novel Bibliometric Approach to Reviewing Literature for Theory

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Abstract

Contemporary construction project management faces a significant challenge: the existing academic literature, spanning various disciplines, remains underutilised due to a lack of systematic integration for transdisciplinary collaboration. This study aims to forecast connected disciplinary thought through a novel bibliometric model, developing 'co-theory analyses' to identify potential collaboration gaps capable of effectively addressing transdisciplinary research in construction project management. This novel method explores interdisciplinary theory using a detailed bibliometric analysis of project management literature from Scopus. It identifies interconnected relationships with construction project management, categorises papers by theory, and reveals interdisciplinary intersections and potential collaborations. It statistically predicts research effectiveness, providing a roadmap for success across various disciplines. The analysis uncovers significant, yet previously unexplored, theoretical intersections, focusing on construction project management and other co-keyword disciplines. These intersections suggest specific areas where collaborative research can yield substantial advancements in the future. The study also identifies key institutions and academic experts whose combined expertise could be pivotal in bridging these research gaps. This bibliometric analysis method enhances transdisciplinary collaboration and contributes significantly to advancing transdisciplinary

research. It addresses complex challenges and promoting sustainable innovation, it identifies key theories for future exploration, offering a framework for strategic academic partnerships through targeted theoretical exploration.

Keywords: Bibliometric analysis; Construction project management; Co-Theory; Model of Transdisciplinarity; Identifying future theory using bibliometrics.

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Highlights

- Developed a novel Bibliometric Model of Transdisciplinarity for reviewing theory in interdisciplinary research.
- Identity's diverse applications of key theories for effective transdisciplinary collaboration.
- Identifies dominant sources, leading institutions, and prolific authors in the field for interdisciplinary science.
- Emphasises the importance of theory-driven interdisciplinary research for methodological rigour and innovation.

Abbreviations

BIM: Building Information Modelling, BMT: Bibliometric Model of Transdisciplinarity, CPM: Construction Project Management, CSV: Comma-Separated Values, MRQ: Main Research Question, RIS: Research Information Systems (file format), SDGs: Sustainable Development Goals and VOSViewer: Visualisation of Similarities Viewer.

Introduction

Background: The Importance of Theory in Scientific Discovery

"Hypotheses are nets: only he who casts will catch," Friedrich von Hardenberg, known as Novalis, poignantly captures the essence of intellectual pursuit.

Friedrich von Hardenberg, whose life spanned the late 18th to early 19th century, often delved into the realms of knowledge and understanding through his writings. His profound words echo a deep reflection on the significance of theory development, as in this case, the development of 'co-theory', both as a metaphysical exploration and a means to make sense of observable phenomena. It is in the weaving and casting of these 'nets' - the hypotheses - that gather insights, whether they pertain to the tangible world around us or the more elusive, abstract dimensions of reality. Novalis, in his time, underscored this timeless truth: that the quest for understanding is an active, dynamic process, requiring not just the creation but also the courageous deployment of theories to unravel the mysteries of both the seen and the unseen [1,2].

The Interdisciplinary Nature of Construction Project Management (CPM)

Construction project management is a comprehensive discipline that integrates principles from both engineering and social sciences to ensure the successful execution of construction projects [3-5]. From an engineering perspective, CPM is a complex discipline as it involves the application of technical knowledge, such as structural analysis, materials science, and construction methods, to design, plan, and construct buildings and infrastructure [6-9]. This technical dimension emphasises precision, safety, and efficiency, ensuring that projects meet specified standards and performance criteria [10]. Simultaneously, from a social science perspective, construction project management addresses the human and organisational aspects of project execution [11-14]. It includes managing stakeholder relationships, understanding organisational behaviour, and ensuring effective communication among diverse project teams [4]. This dimension focuses on leadership, decision-making, conflict resolution, and the socio-economic impacts of construction projects on communities [15-17]. Construction project management encompasses principles of economics, legal studies, and environmental science [6,8,18]. It involves budgeting, financial analysis, and cost control to ensure projects are economically viable [19,20]. Legal considerations include contract management and compliance with regulatory requirements, ensuring that projects adhere to legal and ethical standards [21,22]. Environmental science principles are applied to promote sustainability, assessing and mitigating the environmental impacts of construction activities [21,23,24].

The interdisciplinary nature of construction project management is evident in its integration of these diverse fields. Effective project managers must possess a holistic understanding of technical, human, economic, legal, and environmental factors to deliver projects that are not only structurally sound but also socially responsible, economically feasible, and environmentally sustainable.

Utilising Theory for SDG-Driven Sustainable Development

Interdisciplinary research merges diverse disciplines, offering holistic solutions to complex global challenges like climate change and socioeconomic disparities [18,25-28]. Despite its importance in fostering innovation, its application, particularly in empirically understanding theory for problem-solving, remains underutilised [29]. In sustainable development, integrating varied fields—from architecture and economics to public policy—is vital for addressing multi-faceted stakeholder engagement [4,30,31]. Such integration stimulates creativity, driving breakthroughs beyond the scope of isolated disciplines [18,25,32]. The SDGs' interdisciplinary nature showcases the necessity of this approach to tackle issues like poverty, health, and environmental degradation within sustainability comprehensively [33-35]. Yet, the slow permeation of interdisciplinary research across academic fields hinders SDG progress, as observed in South Africa's challenges in meeting the 2030 agenda [36-38].

Summarising Bibliometrics as an Avenue to Explore Theory

Embracing a 'co-theory collaboration' in construction project management is crucial for advancing SDG commitments, offering a more nuanced understanding, and informing policy to navigate the complexities of these global imperatives effectively. In this context, the study defines and develops 'co-theory' and refers to it as a novel framework designed to enhance the integration and application of interdisciplinary theories within construction project management, utilising bibliometric methods to systematically identify and map the intersections of various

disciplines that contribute to the field [39]. By leveraging a detailed analysis of project management literature, the co-theory framework reveals potential areas for transdisciplinary collaboration, thus addressing complex challenges associated with sustainable development [40]. The core objective of co-theory is to predict and facilitate transdisciplinary research by statistically analysing theoretical intersections and collaborative patterns among diverse academic disciplines. This approach not only identifies key theoretical constructs used in construction project management but also highlights the synergistic relationships between them, offering a comprehensive understanding of how interdisciplinary insights can be effectively amalgamated to promote sustainability. Therefore, co-theory serves as a strategic tool for advancing methodological rigour and fostering innovation through the amalgamation of diverse disciplinary perspectives, ultimately contributing to the achievement of the Sustainable Development Goals (SDGs) within the construction industry [41].

The Problem Statement

Construction project management encompasses intricate challenges that extend beyond technical and managerial confines, incorporating socioeconomic and environmental considerations crucial for achieving the Sustainable Development Goals (SDGs), it is a discipline that combines many a field of study, and as such the body of knowledge remains scattered with scant methodology to visualise similarities across various disciplines [6-9,42]. Existing methods and theories within project management frequently operate within disciplinary silos, lacking the integrated, cross-disciplinary perspective required to effectively address these complexities. A significant research gap persists in the empirical investigation of theories from an interdisciplinary standpoint [29]. To bridge this gap, there is an urgent need for a novel bibliometric model designed to predict interdisciplinary connections and foster transdisciplinary collaborations within the field of Informetric Science [43]. This problem resonates with Popper's advocacy for systematic scientific exploration and rigorous theory evaluation [2,39,44-46]. Implementing such a model would facilitate the synthesis of diverse theoretical insights, enhancing the capacity of construction project management to address the multifaceted challenges associated with sustainable development.

Aim of the Study

This research aims to develop a bibliometric model that integrates rigorous methodological approaches and collaborative efforts to predict and synthesise interdisciplinary theories within a comprehensive framework through the Visualisation of Similarities Viewer (VOSViewer). By identifying pathways for transdisciplinary cooperation, enhancing methodological precision and fostering innovation in scientific exploration. It intends to do this by constructing a robust theoretical foundation for sustainability through transdisciplinary research in construction project management as a focal point do its interdisciplinary nature [47]. Grounded in the systematic methodologies of scientific investigation championed by Aristotle and Karl Popper, the study focuses on the critical evaluation of interconnected theories and practices [2,48,49]. This fusion of Aristotle's foundational insights and Popper's philosophical scientific rigour informs the study's methodological approach, driving the creation of a model that bridges disciplinary gaps and formulates a comprehensive theoretical understanding of sustainability within a collaborative, transdisciplinary research framework. This approach will allow for the rapid identification of where theories co-exist amongst disciplines, how they are used, adapted and formed, and thereby fostering the 'co-theory' method to bibliometric analysis.

Main Research Question

MRQ: How can a new bibliometric model, grounded in systematic methodology and collaborative focus, predict and weave interdisciplinary theories within a theocratic framework, uncover routes for transdisciplinary cooperation, and thereby strengthen methodological precision and innovation in scientific exploration to construct an overarching theory of sustainability achieved via transdisciplinary research in the field of construction project management?

Research Sub-Questions

To dissect the overarching MRQ on developing a bibliometric model for transdisciplinary sustainability in construction management, this study formulates three interrelated sub-questions:

R1: How does bibliometric analysis enable the systematic amalgamation of interdisciplinary theories, enhancing sustainability understanding in construction project management?

R2: How can the bibliometric model predict interdisciplinary integration, and how might this prediction aid in carving out opportunities for transdisciplinary collaboration within construction management?

R3: In what ways does the co-theory approach, underpinned by bibliometric analysis, contribute to methodological precision and drive scientific innovation, ultimately leading to a holistic theory of sustainability in construction project management?

These questions segment the MRQ into targeted inquiries that leverage bibliometric methods to evaluate research patterns, each probing a distinct dimension of the bibliometric model's utility in fostering a transdisciplinary sustainability framework.

Research Objectives

The study delineates its objectives for leveraging bibliometric analysis with the co-theory methodology to address the MRQ's complexity:

O1: Utilise bibliometric analysis to systematically identify and synthesise diverse interdisciplinary theories within project management disciplines, enhancing the grasp of transdisciplinary sustainability in construction management.

O2: Deploy the bibliometric model to forecast disciplinary interconnections and promote the discovery and advancement of transdisciplinary collaborative ventures in construction project management.

O3: Implement a co-theory approach, anchored in bibliometric scrutiny, to augment methodological integrity and inspire scientific innovation, culminating in a comprehensive theory of transdisciplinary sustainability for construction project management.

These objectives are crafted to methodically unravel the MRQ, facilitating a detailed and holistic evaluation of the bibliometric model's capacity to enrich the theory and application of transdisciplinary sustainability in the realm of construction project management.

Assumptions

The study's foundational assumptions, pivotal for its execution, are outlined as follows:

A1: The research posits that Scopus, being extensive and reputable, offers a complete and representative array of literature pertinent to construction management and sustainability, a cornerstone for the credibility of the bibliometric analysis.

A2: It presumes the Scopus database's data integrity, where citations, authorship, and publication specifics are presumed accurate and uniform, crucial for the validity of identifying research patterns and connections.

A3: The study is predicated on the validity of bibliometric indicators and metrics, including novel co-theory constructs and empirical methods like co-authorship networks, to effectively evaluate interdisciplinary engagements and transdisciplinary collaborations.

These presumptions are integral to the research design, signifying reliance on Scopus for comprehensive data and trust in bibliometric techniques as instruments for dissecting and decoding academic discourse in sustainable construction project management.

Hypotheses

In alignment with its objectives and under the premise of using Scopus-based bibliometric analysis to investigate transdisciplinary sustainability in construction project management, the study posits the following hypotheses for empirical testing:

H1: Bibliometric analysis applied to Scopus-sourced literature will uncover a substantive confluence of interdisciplinary theories in construction management, reflecting a shift towards a holistic methodology for addressing transdisciplinary sustainability challenges [45,46]

H2: The bibliometric scrutiny of project management texts will facilitate the identification of interdisciplinary thought patterns, unveiling pivotal junctures for transdisciplinary cooperation vital for advancing sustainable practices within the sector, and therefore aid in the resolution of complex multifaceted problems [47].

H3: Implementing a co-theory modality, informed by bibliometric examination of Scopus data, will enhance methodological precision and contribute to the development of a comprehensive theoretical framework for transdisciplinary sustainability in construction project management.

These hypotheses are formulated to rigorously evaluate the bibliometric model's efficacy in detecting research directions, fostering collaborative ventures, and promoting theoretical innovations pertinent to transdisciplinary sustainability in construction project management.

Literature Review

Introduction

From a theoretical perspective, interdisciplinarity refers to a mode of research, education, and problem-solving that integrates insights, theories, methods, and concepts from two or more academic disciplines to advance fundamental understanding or to address complex issues that cannot be adequately resolved within the boundaries of a single discipline [40]. This approach is characterised by its focus on creating new frameworks, knowledge, and methodologies by synthesising elements from distinct fields to foster innovation and holistic understanding [40]. Theoretically, interdisciplinarity can be contrasted with multidisciplinary and transdisciplinarity [12,17,40,50,51]. In multidisciplinary approaches, disciplines work alongside each other, each

contributing its own perspective without necessarily integrating them [52-54]. In contrast, interdisciplinarity requires a deliberate blending and integrating of disciplinary perspectives to generate new insights that are not possible through a single discipline's lens alone [55].

Key Theoretical Dimensions of Interdisciplinarity

The core of interdisciplinarity lies in the integration of different academic disciplines to form a cohesive framework that can address complex problems more effectively than any single discipline could on its own [56]. By merging disciplinary boundaries, interdisciplinarity aims to create new knowledge that is more comprehensive and nuanced. This involves not just borrowing from different fields but also transforming and synthesising these elements to develop novel theories and solutions [18]. Interdisciplinary research often starts with a complex problem that does not fit neatly into a single disciplinary category, necessitating an approach that draws on multiple areas of expertise to fully understand and address the issue [57]. It embraces diverse epistemological perspectives, recognising that different disciplines offer unique ways of knowing and understanding the world. This diversity is harnessed to achieve a more robust and multifaceted understanding [58,59]. Effective interdisciplinarity relies on collaboration and communication among scholars from different fields, fostering a culture of mutual respect and intellectual exchange that enables the integration of diverse perspectives [58-60].

In essence, interdisciplinarity is a dynamic and integrative process that transcends traditional academic boundaries to foster comprehensive understanding and innovation in addressing complex, multifaceted problems.

The Theory of Transdisciplinarity (ToT) and CPM Sustainability

To elucidate the study's phenomenon, which involves integrating interdisciplinary theories and identifying transdisciplinary collaboration in construction project management with a focus on transdisciplinary sustainability, the 'Theory of Transdisciplinarity' is selected for its core tenets being in alignment with the study's third hypothesis (H3). This theory posits that complex problems, particularly those related to sustainability, necessitate insights and methodologies from multiple disciplines for effective understanding and resolution [55,61-63]. The Theory of Transdisciplinarity, as applied to addressing complex, real-world issues by transcending traditional academic boundaries, was developed and significantly shaped by multiple scholars. Among these, Basarab Nicolescu, a theoretical physicist, has been a pivotal figure. Nicolescu's articulation and promotion of transdisciplinarity concepts, especially through his seminal work have been instrumental in advancing the field [55]. His contributions underscore the necessity of transcending disciplinary limits to tackle the multifaceted nature of sustainability challenges effectively.

By leveraging the Theory of Transdisciplinarity, a comprehensive theoretical framework that supports transdisciplinary collaboration and sustainability in construction project management can be developed, thereby validating the hypothesis that such an approach enhances methodological precision and scientific innovation.

The Importance of Theory: Embracing Complexity and Multidimensionality

The importance of theory in construction project management, particularly from an 'Embracing Complexity and Multidimensionality' perspective, cannot be overstated. Theories provide a structured framework for understanding and addressing the intricate challenges that arise in this

field, which are often multifaceted and extend beyond simple technical solutions. In the context of transdisciplinary sustainability, these challenges encompass technical, economic, social, and environmental dimensions, each contributing to the overall complexity [2,23]. The 'Embracing Complexity and Multidimensionality' perspective is grounded in the Theory of Transdisciplinarity, which posits that effective problem-solving requires a comprehensive approach that transcends traditional disciplinary boundaries [55,61]. This theoretical framework acknowledges that real-world problems, such as those encountered in sustainable construction project management, are inherently complex and multidimensional. Addressing these problems necessitates the integration of diverse disciplinary insights and methodologies. By incorporating multiple dimensions and embracing complexity, theories enable project managers and researchers to develop holistic solutions that account for various interconnected factors. This approach fosters a deeper understanding of the intricate relationships and interactions between different elements of a project, leading to more robust and sustainable outcomes [64].

The importance of theory lies in its capacity to provide a comprehensive and integrative framework for understanding and addressing the multifaceted challenges of construction project management. This theoretical approach not only enriches the field's methodological rigour but also promotes innovation and sustainability by fostering transdisciplinary collaboration.

The Importance of Theory: The Logic of the Included Middle

The Logic of the Included Middle is a central tenet of the Theory of Transdisciplinarity, emphasising the importance of embracing and integrating seemingly contradictory perspectives to solve complex problems. In construction project management, this theoretical framework is crucial for addressing the multifaceted challenges associated with sustainability. The Logic of the Included Middle posits that instead of choosing between binary opposites, effective solutions can be found in the spaces between these extremes, where diverse viewpoints intersect and inform each other [55]. Theories that embody the Logic of the Included Middle are essential in construction project management because they allow for the reconciliation of conflicting interests and priorities. This approach facilitates the integration of technical, economic, social, and environmental considerations, ensuring that sustainable practices are not only technically feasible but also economically viable and socially acceptable [23]. By applying this logic, project managers can navigate the complexities of sustainability by fostering collaboration among stakeholders with divergent perspectives. This collaborative process is crucial for developing comprehensive solutions that address the needs and concerns of all parties involved. For example, integrating environmental sustainability with economic constraints requires an inclusive approach that balances ecological goals with financial realities, ultimately leading to more resilient and adaptable strategies [61]. The Logic of the Included Middle also enhances methodological rigor by promoting a holistic understanding of construction project management. It encourages the use of diverse methodologies and epistemologies, allowing for a richer analysis of the problems at hand. This inclusivity leads to innovative solutions that are more robust and adaptable to the dynamic nature of construction projects [64].

The Logic of the Included Middle is fundamental to the importance of theory in construction project management. It provides a framework for integrating diverse perspectives, promoting collaboration, and enhancing methodological rigour. This approach is essential for developing innovative and sustainable solutions to the complex challenges facing the construction industry.

The Importance of Theory: Transcending Disciplines

Transcending disciplines is a fundamental principle of the Theory of Transdisciplinarity, highlighting the necessity of integrating knowledge and methodologies from multiple academic fields to address complex issues in construction project management. This approach is particularly critical for fostering sustainability, as it enables a comprehensive understanding that goes beyond the limitations of any single discipline [58]. The theoretical framework of transcending disciplines posits that sustainable solutions require the amalgamation of diverse disciplinary insights. This perspective acknowledges that the multifaceted nature of construction projects—encompassing technical, economic, social, and environmental dimensions—cannot be effectively addressed through isolated disciplinary approaches. Instead, a transdisciplinary methodology synthesises these diverse perspectives to create more holistic and innovative solutions [55,58,60,61]. In construction project management, transcending disciplines involves integrating engineering principles with insights from economics, sociology, environmental science, and more. This integration facilitates a deeper understanding of the intricate relationships and interactions among different project components, leading to more resilient and adaptable project strategies [58,64]. For instance, combining engineering solutions with social science approaches can enhance stakeholder engagement and ensure that sustainability initiatives are both technically sound and socially acceptable [58,63,65].

The importance of theory from a transcending disciplines perspective in construction project management is paramount. It provides a framework for integrating diverse academic insights, promoting comprehensive understanding, and fostering innovative solutions. This approach is crucial for addressing the complex, interconnected challenges of sustainability and enhancing the overall effectiveness and resilience of construction projects.

The Importance of Theory: Stakeholder Participation

Stakeholder participation is a critical aspect of the Theory of Transdisciplinarity, emphasising the necessity of including diverse perspectives and expertise in addressing complex issues in construction project management. This approach is vital for fostering sustainability, as it ensures that all relevant voices are heard and that solutions are comprehensive and inclusive [4]. The theoretical framework of stakeholder participation posits that sustainable solutions require the active involvement of various stakeholders, including project managers, engineers, architects, clients, community members, policymakers, and environmental experts. This inclusive approach recognises that each stakeholder brings unique insights and expertise, which are essential for addressing the multifaceted nature of construction projects, this paralleled thought must also apply to construction project management research. By engaging stakeholders from the outset, projects can better align with the needs and expectations of all parties involved, leading to more successful and sustainable outcomes [64]. In construction project management, stakeholder participation enhances the relevance and acceptability of project decisions. It fosters a sense of ownership and commitment among stakeholders, which can improve project implementation and sustainability. For instance, involving community members in the planning and design phases can ensure that their needs and preferences are considered, leading to greater acceptance and support for the project [4]. This proactive approach is particularly important in the context of sustainability, where balancing economic, social, and environmental considerations often involves navigating competing interests and priorities [23]. The importance of stakeholder participation also lies in its potential to drive innovation. Collaborative engagement encourages the exchange of ideas and fosters creative problem-solving. By leveraging the collective knowledge and

experience of stakeholders, projects can benefit from innovative approaches that might not emerge within a more insular, discipline-specific framework. This collaborative innovation is crucial for developing sustainable practices that are both effective and adaptable to changing circumstances [57].

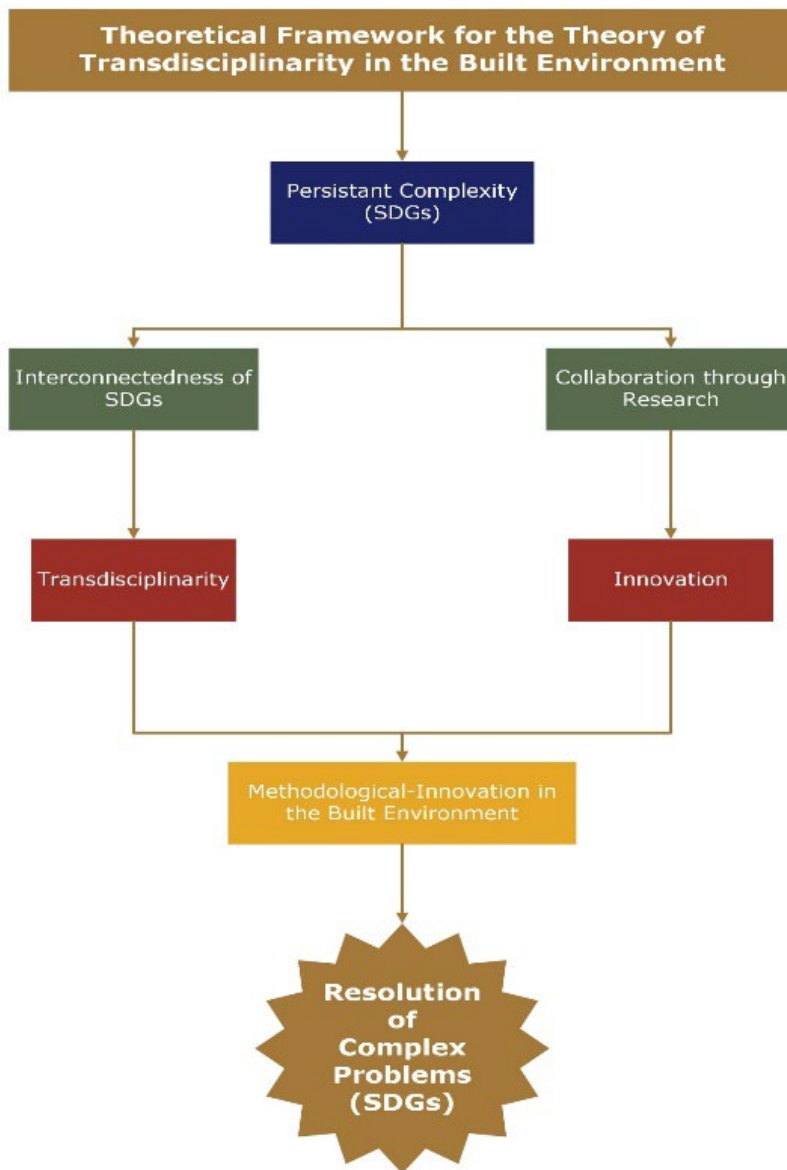
From a theoretical perspective, stakeholder participation is indispensable in construction project management. It provides a framework for integrating diverse perspectives, promoting comprehensive and inclusive decision-making, and fostering innovative solutions. This approach is essential for addressing the complex challenges of sustainability and enhancing the overall success and resilience of construction projects.

The Importance of Theory: Fostering Novelty and Innovation

Fostering novelty and innovation is a cornerstone of the Theory of Transdisciplinarity, highlighting the need for integrating diverse disciplinary insights to generate new ideas and approaches in construction project management. This theoretical underpinning is crucial for advancing sustainability, as it encourages creative problem-solving and the development of innovative solutions that transcend traditional disciplinary boundaries [17,66]. The theoretical perspective of fostering novelty and innovation posits that addressing complex challenges in construction project management requires an openness to new ideas and the integration of diverse methodologies and perspectives. This approach is essential for developing sustainable practices that are not only effective but also adaptable to the dynamic nature of construction projects and broader environmental and societal changes [55,58]. In construction project management, fostering novelty and innovation involves the systematic integration of insights from various fields such as engineering, environmental science, economics, and social sciences. This interdisciplinary approach allows for the exploration of new concepts and techniques that can enhance project outcomes. For instance, incorporating cutting-edge technologies and sustainable design principles can lead to more efficient and eco-friendly construction practices [58,61]. This diversity in methodologies not only enriches the analytical process but also encourages the exploration of unconventional ideas that can lead to groundbreaking advancements in the field [64]. The importance of fostering novelty and innovation also lies in its potential to drive progress and competitiveness in the construction industry. By continuously seeking out and integrating new ideas, construction project managers can stay ahead of industry trends and meet the evolving demands of sustainability. This proactive approach is essential for ensuring that construction projects remain relevant and impactful in addressing global sustainability challenges [31,63].

From a theoretical perspective, fostering novelty and innovation is critical in construction project management. It provides a framework for integrating diverse disciplinary insights, promoting creative problem-solving, and enhancing methodological rigour. This approach is essential for developing sustainable practices that can effectively address the complex challenges facing the construction industry and contribute to broader environmental and societal goals.

Figure 1: Theoretical Framework for The Theory of Transdisciplinarity in the Built Environment (Source: Authors)



Adapting the Tenets of the Theory of Transdisciplinarity to Form a Bibliometric Model of Transdisciplinarity (BMT)

The Theory of Transdisciplinarity (ToT), guided by an Aristotelian ethos, to navigate the complex landscape of sustainable construction project management. This innovative approach encompasses several key principles:

T1: Integration of Diverse Disciplines (H1)

The BMT advocates for a synthesis that extends beyond traditional multidisciplinary, embracing a holistic transdisciplinary sustainability perspective. This approach integrates insights from various disciplines, creating a comprehensive framework that addresses the multifaceted challenges of sustainable construction [49,55].

T2: Addressing Complex Problems through a Polymathic Lens (H2)

The model recognises the inadequacy of single-discipline solutions for the multifaceted challenges inherent in sustainable construction, which span technical, environmental, economic, and social concerns. By employing a polymathic lens, the BMT ensures a thorough analysis and innovative solutions to these complex issues [49,55,64].

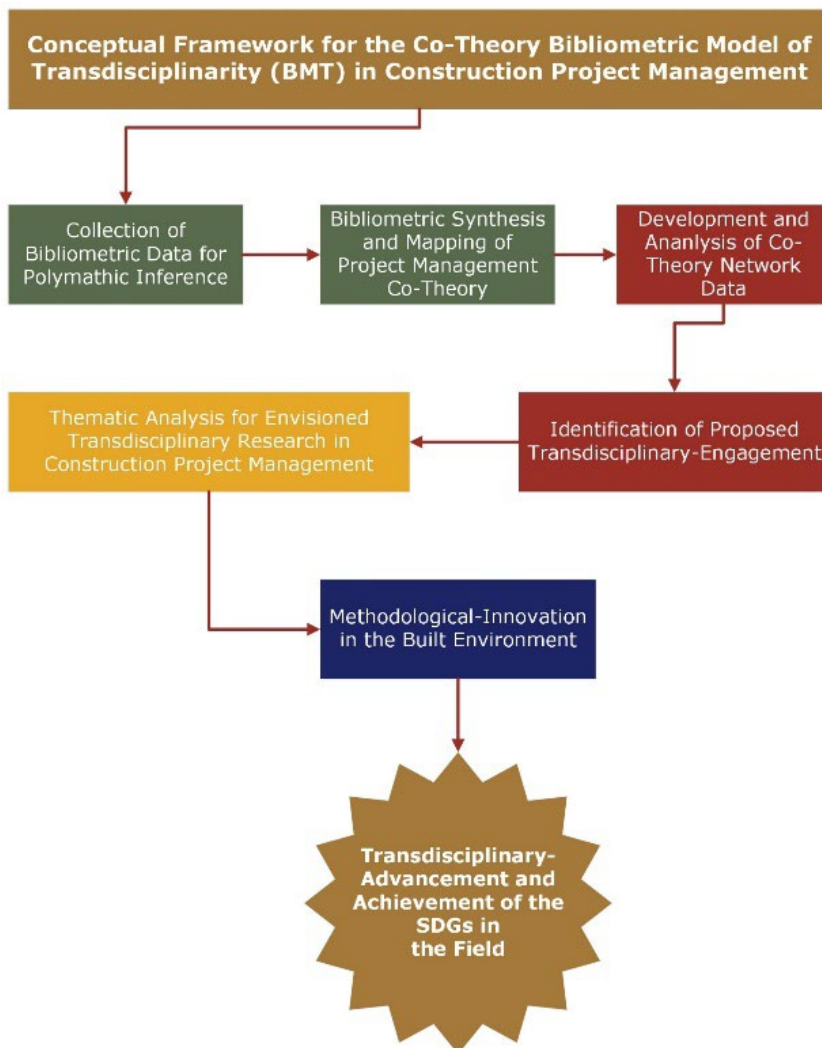
T3: Encouraging Stakeholder Participation (H3)

Stakeholder participation is crucial for enriching the analysis with diverse qualitative insights. The BMT integrates perspectives from academics, practitioners, policymakers, and community members, thereby fostering a comprehensive understanding of the issues at hand and ensuring that solutions are inclusive and socially relevant by capturing the insights gained from a multitude of studies from an epistemological lens of perspectives [4,45,48,49,63].

T4: Promoting Methodological Innovation (MRQ)

The model applies bibliometric analysis to foster new pathways for understanding and addressing the Sustainable Development Goals (SDGs). By developing specific metrics and indexes, the BMT advances methodological innovation and enhances the capacity to evaluate and implement sustainable practices in construction project management [48,61].

Figure 2: Conceptual Framework for the Co-Theory Bibliometric Model of Transdisciplinarity (Source: Authors)



Bibliometrics and Its Application in the Bibliometric Model of Transdisciplinarity (BMT)

Eugene Garfield significantly contributed to the field of bibliometrics by creating the Science Citation Index (SCI) and establishing a new paradigm for academic literature analysis [67]. This methodology underpins the Bibliometric Model of Transdisciplinarity (BMT) in construction project management, facilitating the integration and assessment of interdisciplinary research. Garfield's innovation enables the quantitative evaluation of knowledge proliferation across various disciplines, addressing sustainability within construction management by identifying key trends, influential research, and collaboration opportunities [68-70]. Bibliometrics, leveraging Scopus's extensive database, offers insights into the interdisciplinary nature of sustainable construction project management. It reveals patterns of collaboration and theoretical integration crucial for advancing transdisciplinary sustainability [71,72]. This approach underscores the necessity of systematic, objective analysis to navigate the complexities of sustainability challenges, aligning with the study's aim to explore the potential of bibliometric analysis in fostering methodological rigour and innovation in scientific inquiry [73,74]. However, the methodology is not without limitations [75]. Potential biases in citation practices and the risk of overvaluing quantitative measures often overshadow the importance of theoretical development in assessing author and academic performance [76]. Despite these challenges, the application of bibliometrics in research evaluation, policy-making, and strategic R&D decision-making underscores its versatility and impact across various fields, from healthcare and academic grant funding to environmental science policy [46,77-80]. The BMT, informed by Garfield's bibliometric principles and integrated with the philosophical underpinnings of Popper and Aristotle, provides the foundation required to encapsulate and advance the understanding of transdisciplinary sustainability in construction project management [67,75]. This model bridges disciplinary divides, highlighting the critical role of bibliometric analysis in synthesising interdisciplinary knowledge and fostering collaborative innovation towards achieving the Sustainable Development Goals (SDGs) within the construction industry [55].

Syllogistic Summary

Empirical Validation of Hypotheses through Sustainable Construction Project Management as a Data Point

This summary distils empirical evidence gathered in the literature review section of the study and transforms them into syllogisms to act as epistemological proof's, underpinning the application of bibliometrics for transdisciplinarity in sustainable construction project management [81]:

First Syllogism: Enhancing Understanding and Policy through Bibliometrics

Major Premise: Bibliometric analysis quantitatively assesses academic research's impact, facilitating the evaluation of scholarly work [67,82,83].

Minor Premise: In sustainable construction project management, understanding research impact is essential for integrating diverse disciplines and shaping effective policies [82,84,85].

Conclusion: Thus, bibliometric analysis in sustainable construction project management is pivotal for enhancing interdisciplinary understanding and informing policymaking [25,86].

Second Syllogism: Advancing Knowledge via Trend Identification

Major Premise: Bibliometric analysis provides insight into research trends and developments, highlighting emerging areas of study [74,87,88].

Minor Premise: In the context of sustainable construction project management, pinpointing trends and gaps is vital for knowledge progression [2,89].

Conclusion: Consequently, bibliometric analysis is crucial for propelling sustainable construction project management knowledge by spotlighting pivotal trends and filling existing gaps [90].

Third Syllogism: Fostering Transdisciplinary Collaboration through Bibliometrics

Major Premise: Bibliometrics reveals interdisciplinary collaboration's scope by analysing citation patterns and co-authorship networks, offering a theoretical perspective on the application of theory [39,72,91,92].

Minor Premise: Addressing sustainability's complex challenges in construction project management necessitates interdisciplinary collaboration [58,60,92].

Conclusion: Hence, bibliometric analysis plays a key role in promoting transdisciplinary collaboration, crucial for surmounting sustainability challenges in construction project management [55].

Research Methodology

Achieving Transdisciplinarity: A Philosophical Bibliometric Perspective

This study embodies a hybrid of positivist and epistemological philosophies, advocating for the pragmatic application of diverse theories to decode complex real-world issues. Through bibliometric analysis, it objectively assesses theory usage and dissects data to construct a co-theory paradigm rooted in a rich history of academic discourse over the last five years. This blend of philosophies is instrumental in navigating the study's transdisciplinary scope, enabling the seamless fusion of multiple methodological and theoretical landscapes [93]. Methodologically, the research adopts a quantitative lens, leveraging secondary data from Scopus's extensive academic publication database to perform bibliometric analysis. This approach quantifies academic literature patterns, facilitating a nuanced understanding of transdisciplinary sustainability in construction project management through deductive reasoning [93]. An exploratory polymathic strategy guides the inquiry, illuminating the interplay of interdisciplinary knowledge and its influence on sustainable construction project management methodologies. This strategy, reflective of the study's innovative ambitions, is particularly apt for crafting the Bibliometric Model of Transdisciplinarity (BMT), marrying diverse knowledge spheres to spur methodological and theoretical advancements [48,49]. The research employs deductive-objective reasoning to forge new theoretical insights from empirical data, aligning with the transdisciplinary ethos by testing and refining the BMT within this context [2,48,93]. A cross-sectional bibliometric analysis frames the study's temporal approach, pinpointing literature at a specific moment to gauge prevailing trends and identify research gaps. This meticulous examination draws from Scopus, focusing on sustainability-centric terminology within construction project management, and employs network analysis to decode patterns of collaboration and theoretical discourse [93]. Despite its rigorous philosophical foundation, the study acknowledges a philosophical void in adequately capturing transdisciplinary sustainability. It offers a pathway to bridge this gap, recognising that a comprehensive philosophical solution to

sustainability's multifaceted challenges remains elusive, even with comprehensive bibliometric tools, thus marking a fertile ground for future scholarly exploration [94]. It must also be stated that the complexities on performance measurement of bibliometrics are noted, however, the study only seeks to develop a method to effectively engage with theory, regardless of prolific citation metrics, as the results are objectively deduced, some authors who appear to be prolific may be atheoretical, and as such not be considered an academic contributing this level of discourse, this model seeks to identify the theory users, creators and proliferators [95].

Data Handling

Structured Bibliometric Approach: Transdisciplinary Sustainability in CPM

The tabulation of the bibliometric data process for modelling an interdisciplinary network offers a structured overview of the actionable steps, along with considerations in the data handling process, streamlining the action of conducting a bibliometric study in the field of sustainable construction project management. This study introduces a 'co-theory' metric to achieve transdisciplinarity [8,46,71,74].

Boolean Statements and Search Strategy

The Boolean statements used in this study are designed to be broad enough to capture a wide range of relevant literature while being specific enough to focus on the intersection of project management as a discipline, construction project management as a sub-discipline, sustainability as a co-integrating factor, and the use of theory as a discerning factor for potential transdisciplinary breakthroughs [96,97].

Selecting Data Sources with Specific Criteria

Identifying suitable databases (e.g., Web of Science, Scopus, Google Scholar) that offer comprehensive metrics for citation analysis, content analysis, co-citation analysis, co-authorship analysis, and co-theory analysis is crucial [97,98]. Chosen databases should encompass journals and publications pertinent to sustainable construction project management, ensuring alignment with the study's theoretical focus [99]. Scopus was selected for its robust capabilities in fulfilling the study's requirements, providing a wide array of scholarly materials relevant to both construction project management and sustainability [100,101].

Developing a Boolean Search Strategy

The study crafted a search strategy using keywords and Boolean logic to precisely target relevant literature. It refined search terms based on initial searches to achieve a balance between the scope of search results and the specificity needed for the study's focus [90,96,102]. The search strategy implemented:

First search operation: ("construction project management" OR "project management") AND

Second confounding operation: ("sustainability") W/255 AND

Third discerning operation: ("conceptual framework").

Data Retrieval and Extraction

The formulated search strategy was employed to retrieve literature and export data in formats conducive to analysis [103]. Ensuring the extraction captures essential bibliographic details, selecting export formats such as CSV, Excel, and RIS for their versatility. Literature was exported to their respective formats and then imported into VOSViewer, with descriptive statistics being directly produced by Scopus Metrics Analysis tool. As of February 1, 2024, 563 documents were identified, adhering to specific search parameters including English language, with publications from 2018 to 2023, and content limited to research articles and conference papers [45,104].

Data Cleaning and Preprocessing

The study conducted data cleansing to remove duplicates and errors and standardise data formats for analysis [105]. Where necessary, data was manually inspected for accuracy and categorised according to the analytical needs of the study, providing columns suited to the software applications' requirements [106]. Data was categorised based on analytical criteria set out for citation analysis, content analysis, co-citation analysis, co-authorship analysis, and co-theory analysis, ensuring a streamlined and focused dataset for subsequent analysis [106].

This structured approach underscores the meticulous process of bibliometric analysis in exploring transdisciplinary sustainability within the context of construction project management, setting a foundation for in-depth investigation and interpretation of the research landscape in this field [45].

Results

Introduction

This study will first conduct a general Bibliometric analysis, analysing descriptive statistics to act as a foundation for the study's ability to identify theory through Bibliometrics, acting as this study's proverbial 'Litmus test'. Through the identification of 'Dominant Sources', 'Leading Institutions' and 'Prolific Authors'. As with traditional Bibliometric Analysis, these elements will provide a comprehensive overview of the research landscape, highlighting key contributors and influential works within the field of sustainable construction project management. The application of descriptive statistics in bibliometrics allows researchers to systematically assess the impact and relevance of scholarly work. By providing a detailed quantitative summary of the literature, descriptive statistics facilitate the identification of significant patterns and trends across different disciplines. For instance, in the study of sustainable construction project management, descriptive statistics can reveal the frequency and distribution of key themes, theoretical frameworks, and methodological approaches over time [45]. This insight is crucial for understanding the current landscape of research and for pinpointing areas where interdisciplinary integration is most needed.

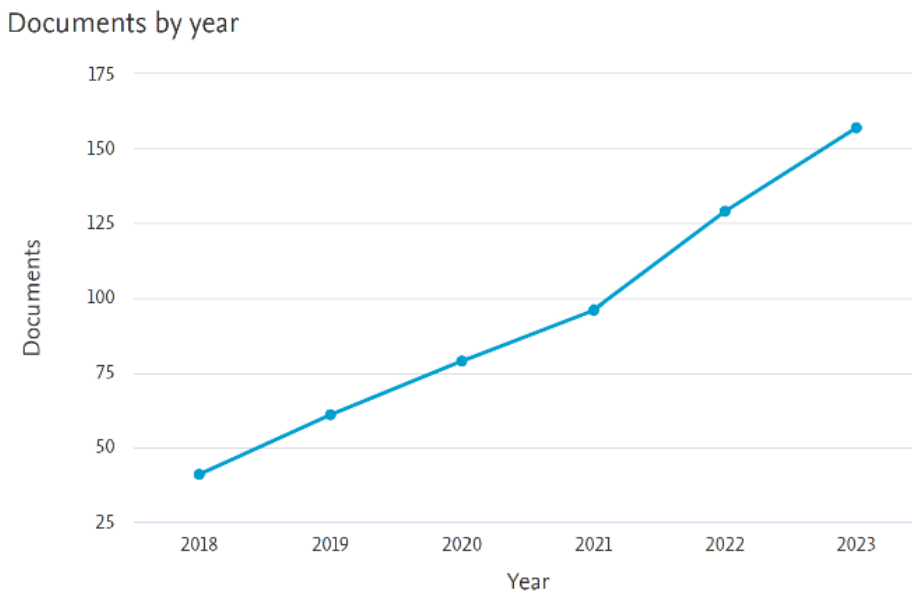
In summary, descriptive statistics are indispensable to the bibliometric method as they provide a structured and quantitative foundation for analysing and interpreting academic literature. This approach not only clarifies the current state of research but also identifies gaps and opportunities for fostering transdisciplinary collaboration, thereby advancing the field of sustainable construction project management.

Descriptive Statistics and Its Importance to the Bibliometric Method

Descriptive statistics play a critical role in the bibliometric analysis, particularly in the context of constructing the Bibliometric Model of Transdisciplinarity (BMT) for analysing data surrounding sustainable construction project management. Descriptive statistics involve summarising and organising data to provide a clear and comprehensible overview of key characteristics within a dataset. This process includes the calculation of measures such as mean, median, mode, standard deviation, and frequency distribution. In bibliometric analysis, these statistical tools are essential for quantifying various attributes of academic publications, such as citation counts, publication trends, and author productivity [73].

Analysis of Document Trends by Year

Figure 3: Documents by Year (Source: Scopus)



The graph titled “Documents by Year” represented as Figure 3, presents a clear upward trend in the number of documents published annually on sustainable construction project management from 2018 to 2023. This trend is indicative of the increasing academic interest and research activity in this field over the past five years. The graph demonstrates a steady increase in the number of documents each year. In 2018, there were approximately 50 documents published. By 2023, this number had escalated to around 150, reflecting a threefold increase over the five-year period. The annual growth rate appears to be consistent, with a notable rise between each consecutive year. The most significant increase is observed between 2021 and 2022, where the number of documents jumps from around 75 to 125, suggesting heightened research activity driven by growing global emphasis on sustainability and green construction practices. The trend line in the graph appears to be linear, depicting a consistent year-on-year increase. This linearity indicates that the field is experiencing stable and ongoing growth, without significant fluctuations.

Implications for Sustainable Construction Project Management

The growing number of publications reflects the increasing recognition of the importance of sustainable practices in construction project management. This rise aligns with global initiatives such as the Sustainable Development Goals (SDGs), which emphasise sustainable industrialisation and innovation. In theory, the expanding body of literature depicts that

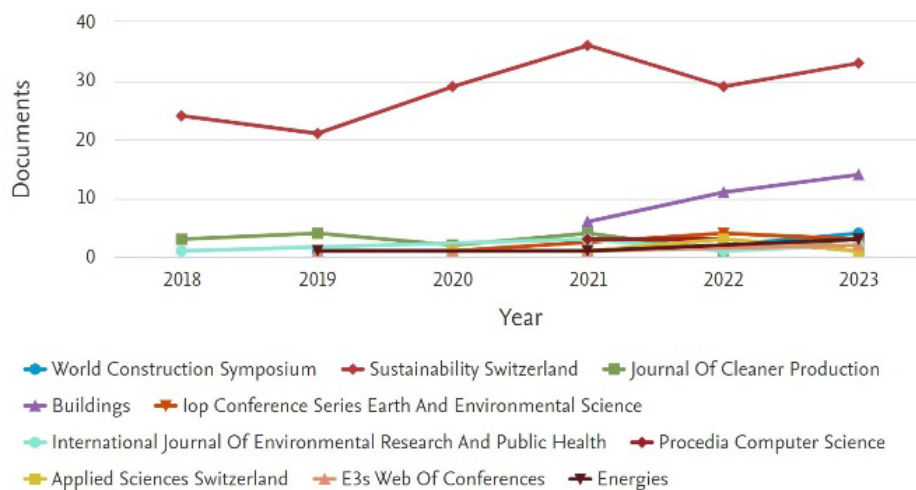
researchers are continually exploring new methodologies, technologies, and theoretical frameworks to address sustainability challenges in construction. This proliferation of research is likely contributing to more innovative and effective solutions in the field. As the volume of research grows, it provides a richer foundation for evidence-based policymaking and practice. The findings from these studies can inform government regulations, industry standards, and best practices, thereby promoting more sustainable construction practices globally.

The increasing number of documents by year underscores the dynamic and growing nature of research in sustainable construction project management. This trend is crucial for the continuous improvement and adaptation of sustainable practices within the industry, aligning with broader environmental and societal goals. The consistent rise in publications highlights the field's expanding knowledge base and its potential to drive significant advancements in sustainable construction practices.

Analysis of Documents per Year by Source

Figure 4: Documents Per Year by Source (Source: Scopus)

Documents per year by source



The graph titled "Documents per Year by Source" represented as Figure 4 in the study, presents the distribution of documents published annually from 2018 to 2023 across various academic sources related to sustainable construction project management. The graph provides insights into the publication trends within specific journals and conference proceedings, highlighting the key sources contributing to the literature in this field.

Dominant Sources

Sustainability Switzerland, this source shows a significant number of publications annually, with a noticeable peak in 2020. It consistently leads in the number of documents published, peaking at around 35 documents in 2020 and 2023. Energies, another major contributor, displays a steady increase in publications, particularly notable in 2021 and 2023, where it reaches close to 30 documents.

Consistent Contributors

The Journal of Cleaner Production maintains a steady output of publications each year, with slight variations but consistently contributing around 5 to 10 documents annually. Whereas buildings

and Applied Sciences Switzerland both sources exhibit relatively stable publication numbers, each contributing a small but consistent number of documents per year.

Emerging Sources

The IOP Conference Series Earth and Environmental Science shows an upward trend starting from 2021, indicating its growing relevance in the field and the International Journal of Environmental Research and Public Health displays a noticeable increase in publications from 2021 onwards.

Implications for Sustainable Construction Project Management

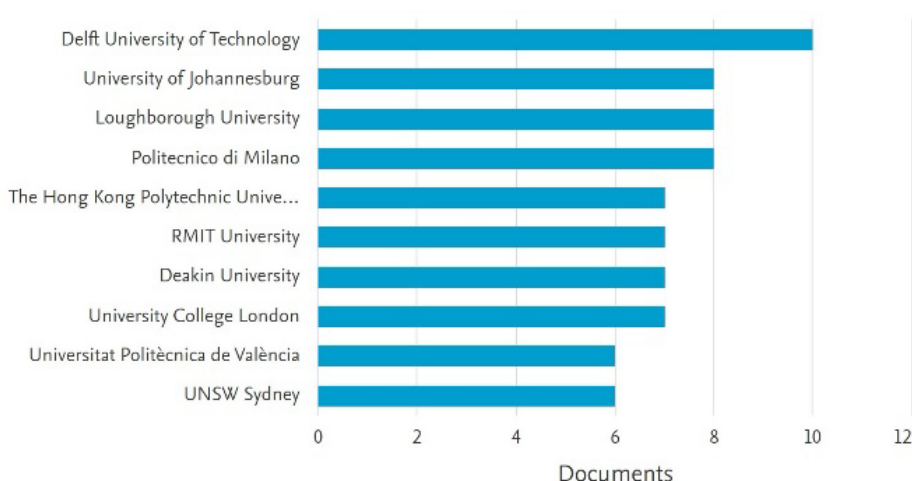
Figure 4 highlights the diversity of sources contributing to the field. The prominent role of "Sustainability Switzerland" and "Energies" suggests a strong focus on environmental and energy-related aspects of sustainable construction. The peak in publications from sources like "Sustainability Switzerland" in 2020 and "Energies" in 2021 reflect increased research activity and interest in specific aspects of sustainability during these years, potentially driven by global events such as the Ukraine and Russian War or policy shifts. The rise of contributions from sources like the "IOP Conference Series Earth and Environmental Science" and the "International Journal of Environmental Research and Public Health" indicates the expanding scope of sustainable construction research, incorporating broader environmental and public health perspectives.

The distribution of documents per year by source underscores the multifaceted nature of sustainable construction project management research. The varying contributions from different journals and conferences highlight the interdisciplinary and evolving landscape of this field. This diversity in sources enriches the body of knowledge, offering a wide array of perspectives and insights that are crucial for advancing sustainability in construction project management.

Analysis of Documents by Affiliation

Figure 5: Documents by Affiliation (Source: Scopus)

Documents by affiliation ⓘ



The graph titled "Documents by Affiliation" represented as Figure 5 in the study presents the number of documents published by various academic institutions in the field of sustainable construction project management. This analysis provides insights into the leading universities contributing to the literature, highlighting their research output and influence in the field.

Leading Institutions

Delft University of Technology leads with the highest number of documents, publishing 10 documents, demonstrating its significant research activity and influence in sustainable construction project management with the University of Johannesburg and Loughborough University following closely, each contributing 8 documents, indicating their strong engagement and research output in this area.

Notable Contributors

Politecnico di Milano and The Hong Kong Polytechnic University have published 7 documents each, showcasing their active participation and substantial contributions to the field, while RMIT University, Deakin University, and University College London, each of these institutions has published 6 documents, reflecting their consistent research efforts and contributions to sustainable construction project management.

Emerging Contributors

The Universitat Politècnica de València and UNSW Sydney have published 5 documents each, indicating their involvement and research productivity in this field.

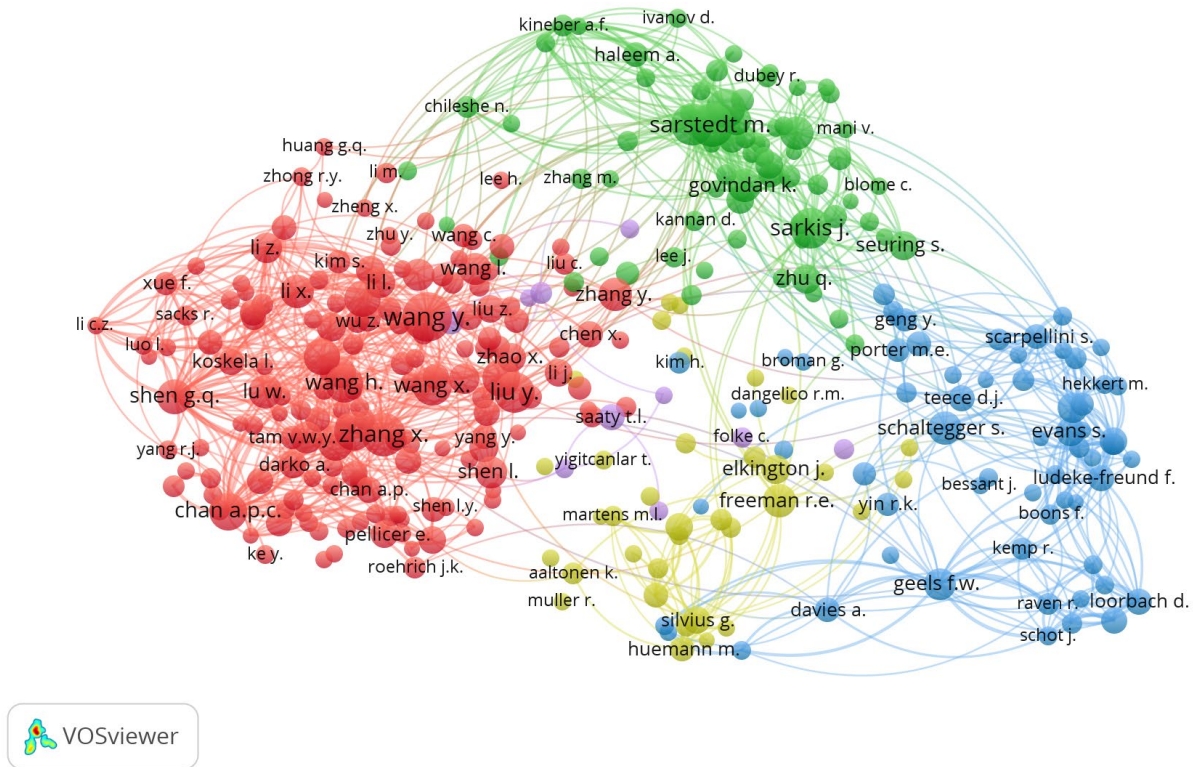
Implications for Sustainable Construction Project Management

The dominance of institutions like Delft University of Technology, University of Johannesburg, and Loughborough University highlights their leadership in sustainable construction research. Their significant output suggests a strong focus on sustainability issues within their construction management programs. The geographic diversity of the leading institutions, spanning Europe, Africa, Asia, and Australia, underscores the global interest and collaborative efforts in addressing sustainability challenges in construction project management. The substantial contributions from these institutions indicate potential opportunities for international collaboration. By leveraging the strengths and expertise of these leading universities, further advancements in sustainable construction practices can be achieved.

The analysis of documents by affiliation underscores the pivotal role that leading academic institutions play in advancing research in sustainable construction project management. The significant output from institutions like Delft University of Technology, University of Johannesburg, and Loughborough University reflects their dedication to sustainability and highlights the importance of their contributions. This global network of research-active universities provides a strong foundation for continued innovation and collaboration in the pursuit of sustainable construction practices.

Bibliometric Analysis utilising VOSViewer

Figure 6: Co-Authorship Network Analysis (Source: Authors)



The VOS Viewer network graph represented as Figure 6 presents a visual representation of the collaborative relationships and citation patterns among researchers in the field of sustainable construction project management. This network analysis helps identify key authors, their interconnectedness, and the structure of the research community [107].

Prolific Authors through Cluster Identification

The red cluster is dominated by authors such as Wang N., Wang X., and Wang Y., indicating a closely-knit group of researchers frequently citing each other. The green cluster has prominent authors including Sarstedt M., Sarkis J., and others. Key figures in the blue cluster, such as Geels F.W. and Freeman R.E. Although smaller, the yellow cluster features authors like Huemann M. and Martens M.L.

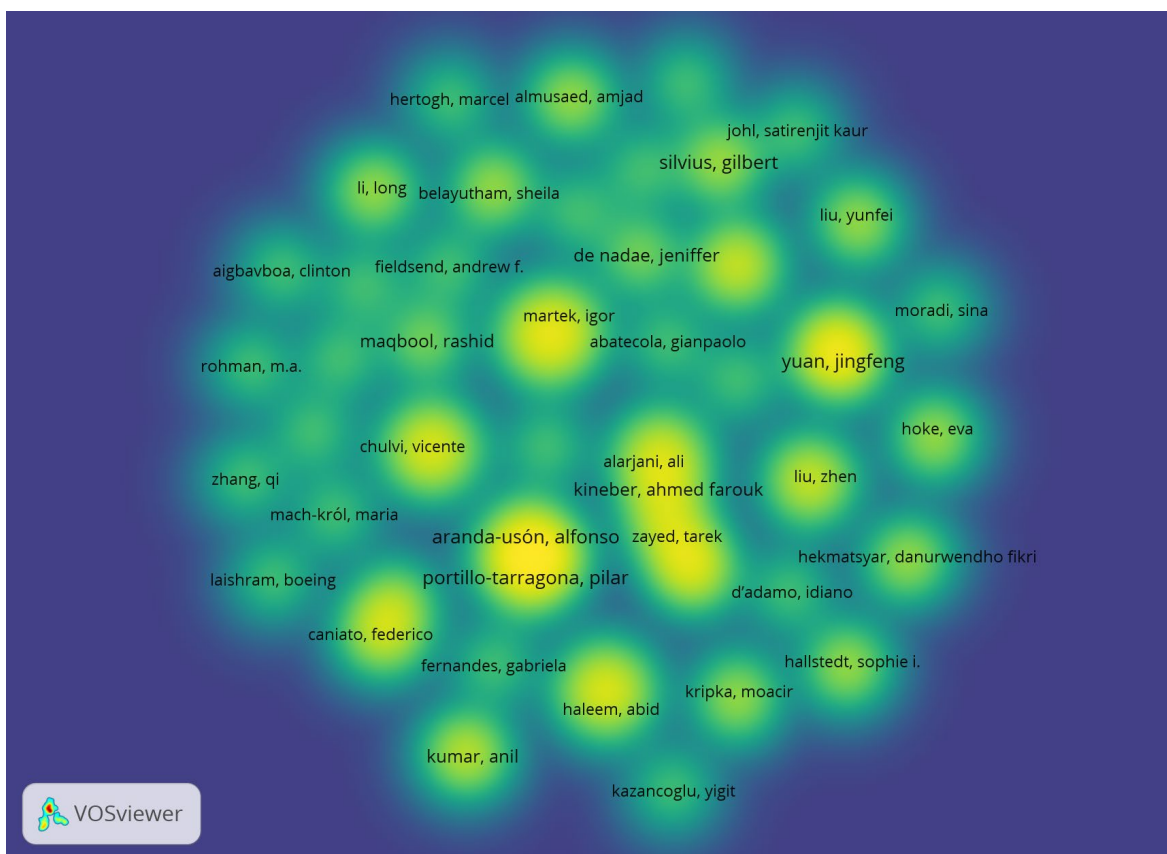
Interconnectedness

The network shows a high degree of interconnectedness between clusters, suggesting robust interdisciplinary collaboration and knowledge exchange. Authors like Sarstedt M. and Sarkis J. act as bridges between different clusters, facilitating cross-pollination of ideas. The presence of numerous connecting lines indicates frequent citations and co-authorship among researchers, highlighting the collaborative nature of the field. Authors with larger nodes, such as Wang L. and Sarstedt M., are highly influential within the network. Their extensive citation networks suggest that their work is foundational and widely recognised within the research community. The network density around these key authors implies that their research significantly impacts and shapes ongoing studies in sustainable construction project management.

Implications for Sustainable Construction Project Management

The graph highlights the importance of collaborative networks in advancing research. The interconnected clusters suggest that interdisciplinary and cross-institutional collaborations are critical for tackling complex sustainability challenges in construction. The distinct clusters indicate specialised research areas within the broader field of sustainable construction project management. Understanding these focus areas can help in identifying potential gaps and opportunities for new research. Identifying influential authors and their networks can guide researchers towards seminal works and key studies that form the backbone of current research trends. Engaging with these networks can enhance the visibility and impact of new research. The VOSViewer network analysis provides valuable insights into the collaborative dynamics and citation patterns in sustainable construction project management. The distinct clusters and interconnectedness reflect the interdisciplinary nature of the field and emphasise the importance of collaboration. This analysis not only identifies key authors and research areas but also highlights the pathways through which knowledge is disseminated and developed, ultimately advancing the field of sustainable construction.

Figure 7: Density Visualisation of Authors Utilising Theory (Source: Authors)



The VOS Viewer density visualisation graph displays the prominence and frequency of key researchers in the field of sustainable construction project management based on the number of their publications and citations. The density visualisation uses a colour gradient from green to yellow, with yellow indicating higher prominence and green indicating lower prominence [42].

High-Density Areas

The central cluster houses the most densely populated area featuring prominent authors such as Aranda-Usón, Alfonso, Portillo-Tarragona, Pilar, and Yuan, Jingfeng. These authors are highly cited

and contribute significantly to the literature, suggesting their influential roles in shaping research directions and methodologies within the field. Other significant contributors in the high-density areas include Zayed, Tarek, Martek, Igor, and Silvius, Gilbert, indicating their substantial impact and recognition in sustainable construction project management.

Medium-Density Areas

Authors such as De Nadae, Jeniffer, Maqbool, Rashid, and Kumar, Anil are situated in medium-density regions, reflecting their considerable contributions and frequent citations. These researchers play essential roles in advancing specific subtopics within the broader field.

Low-Density Areas

The peripheral areas contain authors like Hertogh, Marcel, Ali, Kineber, Ahmed Farouk, Aigbavboa, Clinton and Johl, Satrienjit Kaur, who, while less prominent than central figures, still contribute valuable research to the field. These authors may represent emerging researchers or those focusing on niche areas of sustainable construction.

Implications for Sustainable Construction Project Management

The high-density areas highlight key researchers who are central to the field's development. Their work is widely recognised and frequently cited, indicating their influence on current and future research trends. The density visualisation depicts potential opportunities for collaboration among researchers. High-density clusters represent established networks, while medium and low-density areas may benefit from increased collaboration and integration with more prominent researchers. The spread of authors across the density spectrum illustrates the diversity of research topics within sustainable construction project management. It underscores the field's multidisciplinary nature, integrating insights from engineering, management, environmental science, and more. The VOSViewer density visualisation provides a comprehensive overview of the key contributors in sustainable construction project management. It highlights the central figures and their influence on the field, identifies potential collaborators, and underscores the diverse range of topics being explored. This analysis is crucial for understanding the research landscape and guiding future investigations and collaborations.

Bibliometric Analysis for Engaging and Identifying Theory

Identification of Dominant Sources, Leading Institutions, and Prolific Authors

The bibliometric analysis reveals that "Sustainability Switzerland", and "Energies" are the dominant sources, contributing significantly to the literature with a high number of publications annually. Leading institutions such as Delft University of Technology, University of Johannesburg, and Loughborough University emerge as pivotal research hubs, for developing theory, consistently producing substantial theoretical research outputs. Among the prolific authors, individuals like Wang N., Sarstedt M., and Sarkis J. are identified as key influencers within the network, with Aranda-Usón, Alfonso, Portillo-Tarragona, Pilar, and Yuan, Jingfeng also prominently featured in the density visualisation analysis. Their extensive citation networks and frequent co-authorships underscore their significant impact and leadership in advancing sustainable construction project management research. These findings, coupled with the network density analysis, highlight the collaborative and interdisciplinary nature of the field, driven by contributions from top journals, institutions, and researchers. This comprehensive approach underscores the field's complexity and the necessity of cross-disciplinary insights to address sustainable construction challenges effectively.

Identification of Theory through Bibliometric Analysis

Due to current limitations in VOSViewer and Scopus regarding their database and analysis tools, a manual assessment of the identified 'Dominant Sources,' 'Leading Institutions,' and 'Prolific Authors' is necessary to conduct this analysis [42,43,107-111]. This manual process will continue until such time as the method of theory identification is widely accepted in practice and these tools are updated to include a 'co-theory' analysis. Utilising the Scopus extension for Google Chrome, papers were batch downloaded from the Scopus Database. Authors affiliated with either the 'Dominant Sources' or 'Leading Institutions' were then targeted for a thematic analysis of their use of theory. Specifically, authors such as Wang N., Aranda-Usón A., Portillo-Tarragona P., Yuan J., Zayed T., Martek I., Silvius G., Maqbool R., Kumar A., Hertogh M., Ali K., Aigbavboa C., Johl S.K., Hosseini M.R., Kineber A.F., Maqsoom A., Mazher K.M., and Silva M.E. were included. A total of 41 documents were downloaded and analysed for their use and discussion of theory to explain the observed phenomena in their respective studies.

Table 1: Theoretical Frameworks in Sustainable Construction Project Management: A Bibliometric Model of Transdisciplinarity (BMT) Analysis (Source: Scopus)

Name of the Study	Name of the Theory that Explains Phenomenon or Phenomena	Adapters of the Theory	Journal/Conference Name
The Influence of Governance on the Implementation of Public-Private Partnerships in the United Kingdom and China: A Systematic Comparison [112].	Governmentality Theory	Wang, N., Gong, Z., Liu, Y., Thomson, C.	Utilities Policy
Dynamic Capabilities and Environmental Accounting for the Circular Economy in Businesses [113].	No use of Theory - Based on data or Examining a Specific Context	Scarpellini, S., Marín-Vinuesa, L.M., Aranda-Usón, A., Portillo-Tarragona, P.	Sustainability Accounting, Management and Policy Journal
The Influence of Industrial Attitudes and Behaviours in Adopting Sustainable Construction Practices [114].	Lean Theory	Maqbool, R., Saiba, M.R., Altuwaim, A., Rashid, Y., Ashfaq, S.	Sustainable Development
Conserving a Sustainable Urban Environment Through Energy Security and Project Management Practices [115].	No use of Theory - Based on data or Examining a Specific Context	Maqbool, R., Jowett, E.	Environmental Science and Pollution Research
A Systematic Managerial Perspective on the Environmentally Sustainable Construction Practices of UK [116].	No use of Theory - Based on data or Examining a Specific Context	Maqbool, R., Amaechi, I.E.	Environmental Science and Pollution Research

Sustainable Infrastructure Design Framework Through Integration of Rating Systems and Building Information Modelling [117].	No use of Theory - Based on data or Examining a Specific Context	Liu, Y., Van Nederveen, S., Wu, C., Hertogh, M.	Advances in Civil Engineering
Modelling the Relationship Between Digital Twins Implementation Barriers and Sustainability Pillars: Insights from Building and Construction Sector [118].	No use of Theory - Based on data or Examining a Specific Context	Kineber, A.F., Singh, A.K., Fazeli, A., Mohandes, S.R., Cheung, C., Arashpour, M., Ejohwomu, O., Zayed, T.	Sustainable Cities and Society
A Scientometric-Content Analysis of Integration of BIM and IoT [119].	No use of Theory - Based on data or Examining a Specific Context	Jia, Y., Hosseini, M.R., Zhang, B., Martek, I., Nikmehr, B., Wang, J.	IOP Conference Series: Earth and Environmental Science
Integrated Impact of Circular Economy, Industry 4.0, and Lean Manufacturing on Sustainability Performance of Manufacturing Firms [120].	No use of Theory - Based on data or Examining a Specific Context	Ghaithan, A.M., Alshammakhi, Y., Mohammed, A., Mazher, K.M.,	International Journal of Environmental Research and Public Health
Factors Driving Success of Cost Management Practices in Integrated Project Delivery (IPD) [121].	Game Theory	Elghaish, F., Hosseini, M.R., Talebi, S., Abrishami, S., Martek, I., Kagioglou, M.,	Sustainability (Switzerland)
The Progressive Adoption of a Circular Economy by Businesses for Cleaner Production: An Approach from a Regional Study in Spain [122].	Ecological Modernisation Theory and Stakeholders Theory	Aranda-Usón, A., Portillo-Tarragona, P., Scarpellini, S., Llana-Macarulla, F.,	Journal of Cleaner Production
Proposing a Value Field Model for Predicting Homebuyers' Purchasing Behavior of Green Residential Buildings: A Case Study in China [123].	Field Theory	Zhang, Y., Yuan, J., Li, L., Cheng, H.	Sustainability (Switzerland)
Social Risk Factors of Transportation PPP Projects in China: A Sustainable Development Perspective [124].	Theory of Sustainable Development	Yuan, J., Li, W., Guo, J., Zhao, X., Skibniewski, M.J.,	International Journal of Environmental Research and Public Health

Integral Measures and Framework for Green Lean Six Sigma Implementation in Manufacturing Environment [125].	Lean Theory and Six Sigma Theory	Yadav, V., Gahlot, P., Rathi, R., Yadav, G., Kumar, A., Kaswan, M.S.	International Journal of Sustainable Engineering
Evaluating Social Performance of Construction Projects: An Empirical Study [126].	No use of Theory - Based on data or Examining a Specific Context	Xiahou, X., Tang, Y., Yuan, J., Chang, T., Liu, P., Li, Q.	Sustainability (Switzerland)
The Whole Lifecycle Management Efficiency of the Public Sector in PPP Infrastructure Projects [127].	Governmentality Theory	Wang, N., Ma, M., Liu, Y.	Sustainability (Switzerland)
Factors Affecting Defects Occurrence in the Construction Stage of Residential Buildings in Gaza Strip [128].	No use of Theory - Based on data or Examining a Specific Context	Tayeh, B.A., Maqsoom, A., Aisheh, Y.I.A., Almanassra, M., Salahuddin, H., Qureshi, M.I.	SN Applied Sciences
Exploring the Project Owner's Behaviour of Addressing Sustainability in Project Assignment and Governance [129].	Theory of Planned Behaviour and Theory of Reasoned Action	Silvius, G., Ursem, R., Magano, J.	Sustainability (Switzerland)
Interlinking Sustainability in Organizational Strategy, Project Portfolio Management and Project Management a Conceptual Framework [130].	Stakeholder Theory and Triple Bottom Line Theory	Silvius, G., Marnewick, C.	Procedia Computer Science
Exploring Barriers for Circularity in the EU Furniture Industry [131].	Contributes to Theory Development - Based on data or Examining a Specific Context	Silvius, G., Ismayilova, A., Sales-Vivó, V., Costi, M.	Sustainability (Switzerland)
Classification and Measurement of the Firms' Resources and Capabilities Applied to Eco-Innovation Projects from a Resource-Based View Perspective [132].	Institutional theory, Stakeholder Theory and Resource-Based view Theory	Portillo-Tarragona, P., Scarpellini, S., Moneva, J.M., Valero-Gil, J., Aranda-Usón, A.	Sustainability (Switzerland)

Developing Global Supplier Competences for Supply Chain Sustainability: The Effects of Institutional Pressures on Certification Adoption [133].	Institutional theory	Pereira, M.M.O., Silva, M.E., Hendry, L.C.	Business Strategy and the Environment
Labor Waste in Housing Construction Projects: An Empirical Study [134].	No use of Theory - Based on data or Examining a Specific Context	Nassri, S., Talebi, S., Elghaish, F., Koohestani, K., Mcllwaine, S., Hosseini, M.R., Poshdar, M., Kagioglou, M.	Smart and Sustainable Built Environment
Applicability of Industry 4.0 Technologies in the Adoption of Global Reporting Initiative Standards for Achieving Sustainability [135].	Theory of Knowledge	Narula, S., Puppala, H., Kumar, A., Frederico, G.F., Dwivedy, M., Prakash, S., Talwar, V.	Journal of Cleaner Production
A Systematic Review of Eco-Innovation and Performance from the Resource-Based and Stakeholder Perspectives [136].	Stakeholder Theory	Munodawafa, R.T., Johl, S.K.	Sustainability (Switzerland)
Using Multivariate Regression and Ann Models to Predict Properties of Concrete Cured Under Hot Weather: A Case of Rawalpindi Pakistan [137].	No use of Theory - Based on data or Examining a Specific Context	Maqsoom, A., Aslam, B., Gul, M.E., Ullah, F., Kouzani, A.Z., Parvez Mahmud, M.A., Nawaz, A.	Sustainability (Switzerland)
Exploring the Key Indicators of Social Impact Assessment for Sponge City PPPs: A Sustainable Development Perspective [138].	Social Impact Theory	Hamza, M., Azfar, R.W., Mazher, K.M., Sultan, B., Maqsoom, A., Khahro, S.H., Memon, Z.A.	Buildings
Disruptive Technological Innovations in Construction Field and Fourth Industrial Revolution Intervention in the Achievement of the Sustainable Development Goal 9 [139].	No use of Theory - Based on data or Examining a Specific Context	Lekan, A., Aigbavboa, C., Babatunde, O., Olabosipo, F.	International Journal of Construction Management

Exploring Perceptions of the Adoption of Prefabricated Construction Technology in Pakistan Using the Technology Acceptance Model [140].	Technology Acceptance Model and Theory of Planned Behavior	Hamza, M., Azfar, R.W., Mazher, K.M., Sultan, B., Maqsoom, A., Khahro, S.H., Memon, Z.A.	Sustainability (Switzerland)
The State of Play Regarding the Social Sustainability of the Construction Industry: A Systematic Review [141].	Stakeholder Theory, Transaction Cost Economics Theory, Grounded Theory, Agency Theory, Paradox Theory, Resource-based View Theory, Transition Theory and Ecological Modernization Theory	Gurmu, A., Shooshtarian, S., Mahmood, M.N., Hosseini, M.R., Shreshta, A., Martek, I.	Journal of Housing and the Built Environment
Integrating Sustainability into Major Infrastructure Projects: Four Perspectives on Sustainable Tunnel Development [142].	No use of Theory - Based on data or Examining a Specific Context	Gijzel, D., Bosch-Rekvelde, M., Schraven, D., Hertogh, M.	Sustainability (Switzerland)
The Relation Between Sustainable Project Management and Project Success [143].	No use of Theory - Based on data or Examining a Specific Context	Dubois, O., Silviu, G.	International Journal of Management and Sustainability
Determining the Stationary Enablers of Resilient and Sustainable Supply Chains [144].	No use of Theory - Based on data or Examining a Specific Context	Attia, E.-A., Alarjani, A., Uddin, M.S., Kineber, A.F.	Sustainability (Switzerland)
Barriers to Digital Technology Deployment in Value Management Practice [145].	No use of Theory - Based on data or Examining a Specific Context	Aghimien, D., Ngcobo, N., Aigbavboa, C., Dixit, S., Vatin, N.I., Kampani, S., Khera, G.S.	Buildings
Consumer Motivation by Using Unified Theory of Acceptance and Use of Technology Towards Electric Vehicles [146].	Unified Theory of Acceptance and Use of Technology	Abbasi, H.A., Johl, S.K., Shaari, Z.B.H., Moughal, W., Mazhar, M., Musarat, M.A., Rafiq, W., Farooqi, A.S., Borovkov, A.	Sustainability (Switzerland)
Institutional Logic for Sustainable Purchasing and Supply Management: Concepts, Illustrations, and Implications for Business Strategy [147].	Institutional Theory and Stakeholder Theory	Silva, M.E., Nunes, B.	Business Strategy and the Environment

Analysing Competing Logics Towards Sustainable Supplier Management [148].	No use of Theory - Based on data or Examining a Specific Context	León Bravo, V., Jaramillo Villacrés, M., Silva, M.E.	Supply Chain Management
Sustainable Supply Chain Management in Construction: An Exploratory Review for Future Research [149].	Sustainability Theory	Cataldo, I., Banaitis, A., Samadhiya, A., Banaitienè, N., Kumar, A., Luthra, S.	Journal of Civil Engineering and Management
A Sustainability-Based Risk Assessment for P3 Projects Using a Simulation Approach [150].	No use of Theory - Based on data or Examining a Specific Context	Bakhtawar, B., Thaheem, M.J., Arshad, H., Tariq, S., Mazher, K.M., Zayed, T., Akhtar, N.	Sustainability (Switzerland)
Examining the Influence of Sustainable Construction Supply Chain Drivers on Sustainable Building Projects Using Mathematical Structural Equation Modeling Approach [151].	Technology Acceptance Model, Innovative Diffusion Theory and Technology Organisation and Environment Model	Attia, E.-A., Alarjani, A., Uddin, M.S., Kineber, A.F	Sustainability (Switzerland)
Financial Resources for the Circular Economy: A Perspective from Businesses [152].	Resource-based View Theory	Aranda-Usón, A., Portillo-Tarragona, P., Marín-Vinuesa, L.M., Scarpellini, S.	Sustainability (Switzerland)

Diverse Theoretical Applications in Sustainable Construction Project Management

The analysis of the identified studies reveals a diverse application of theoretical frameworks in the realm of sustainable construction project management. Dominant sources such as Sustainability Switzerland and the Journal of Cleaner Production are prominently featured, indicating their central role in disseminating research on sustainability practices. Leading institutions, including Delft University of Technology, consistently contribute high-impact studies, reflecting their significant involvement in advancing theoretical and practical knowledge in this field. Prolific authors such as Wang N., Aranda-Usón A., Portillo-Tarragona P., and Yuan J. have been instrumental in shaping the discourse, frequently employing and adapting theories like Governmentality Theory, Lean Theory, and Ecological Modernisation Theory to explain various phenomena within their research contexts [112,122,124,132].

Reliance on Established Theories to Address Sustainability Issues

The table elucidates a prevalent reliance on well-established theories to interpret and address complex issues related to sustainability. For instance, Governmentality Theory is utilised to explore the implementation of public-private partnerships in both the United Kingdom and China, showcasing its versatility in policy analysis [112]. Lean Theory, on the other hand, is applied to understand the environmental benefits of energy security and project management practices

[114]. Ecological Modernisation Theory, combined with Stakeholder Theory, provides insights into the circular economy's adoption by businesses for cleaner production [132].

Need for Structured Theoretical Approaches in Sustainable Construction Research

The frequent occurrence of studies examining specific contexts without the explicit use of theory underscores the need for a more structured theoretical approach in future research [2,56,93]. This trend highlights a gap in the systematic application of theoretical frameworks to guide empirical investigations. The integration of bibliometric methods in this study serves as a foundational step towards identifying and synthesising dominant theories, leading institutions, and influential authors, thereby fostering a deeper understanding of transdisciplinary sustainability in construction project management. This comprehensive approach not only enriches the theoretical landscape but also facilitates the development of innovative strategies and policies essential for sustainable practices in the construction industry.

Discussion

The Use of Theory in Sustainable Construction Project Management Literature

Benefits of Using Theory in Literature

Theories provide a structured framework for analysing data and interpreting results. For instance, Lean Theory helps in understanding the environmental benefits of energy security and project management practices [114,115]. Such frameworks enable researchers to systematically dissect and address specific research questions, ensuring a coherent and logical flow of analysis. The use of established theories such as Governmentality Theory and Ecological Modernisation Theory allows researchers to delve deeper into the intricacies of sustainability issues. These theories offer insights into policy implementation, technological innovation, and stakeholder engagement, facilitating a holistic understanding of the subject matter [127,132]. Theories often possess predictive capabilities, allowing researchers to forecast potential outcomes and trends [93,153-155]. This is particularly beneficial in policy-making and strategic planning, where anticipating future scenarios can lead to more informed decisions. The use of theory promotes interdisciplinary integration by bridging knowledge gaps across various fields [23,156-158]. Theories such as Stakeholder Theory and Institutional Theory enable the synthesis of perspectives from sociology, economics, and environmental science, fostering a more comprehensive approach to sustainable construction [159,160].

Consequences of Not Using Theory

Studies that do not employ theoretical frameworks often lack a structured approach to analysis [93]. This can lead to fragmented findings and inconsistent interpretations, undermining the overall coherence of the research. Without the guidance of theory, research may fail to uncover deeper insights into the phenomena being studied [161]. This can result in superficial analyses that do not fully address the complexities of sustainability challenges [162]. The absence of theoretical grounding limits the predictive power of research, making it difficult to anticipate future trends and outcomes [112,122,124,132]. This can hinder the practical applicability of research findings in real-world contexts. Studies that do not utilise theory contribute to a fragmented body of knowledge [163]. This hampers the ability to build on existing research, as findings are not anchored in a common theoretical foundation [164].

Comparative Analysis

A comparative analysis of the literature reveals that a significant percentage of studies in sustainable construction project management employ well-established theories to guide their research. However, there remains a notable portion of studies that examine specific contexts without the explicit use of theory. For instance, a substantial number of studies focus on empirical data without grounding their analysis in a theoretical framework [134].

Implications for Transdisciplinary Research

The reliance on theory in the literature underscores the importance of a structured approach to transdisciplinary research [55,57,93,100,154,165]. The integration of theoretical frameworks enables researchers to navigate the complexities of sustainability challenges more effectively, fostering innovative solutions and policy recommendations. Conversely, the absence of theory highlights a gap in the systematic application of frameworks, suggesting the need for a more rigorous approach in future research.

Future Directions

For transdisciplinary research to advance, it is imperative to promote the use of theory in empirical investigations [55,57,93,100,154,165]. This will not only enhance the depth and coherence of research but also facilitate the development of innovative strategies and policies essential for sustainable practices [129]. The integration of bibliometric methods, as demonstrated in this study, serves as a foundational step towards identifying and synthesising dominant theories, leading institutions, and influential authors, in its current state, the process is faster than other methods to reviewing literature for theory to develop an understanding of phenomena, however, an update to VOSViewer and Scopus would serve this study's methodology [42,43,107-111]. This comprehensive approach will enrich the theoretical landscape and drive the future of sustainable construction project management.

The use of theory in sustainable construction project management literature provides a robust framework for analysis, enhances understanding, and promotes interdisciplinary integration. While the absence of theory can lead to fragmented and superficial analyses, the integration of theoretical frameworks ensures a structured and coherent approach to research. Moving forward, it is crucial to emphasise the importance of theory in transdisciplinary research to foster innovative solutions and sustainable practices in the construction industry.

Conclusions

The Crucial Role of Theoretical Frameworks in Sustainable Construction Research

This study underscores the critical importance of integrating theoretical frameworks into research on sustainable construction project management. The analysis of literature reveals that well-established theories such as Governmentality Theory, Lean Theory, and Ecological Modernisation Theory are instrumental in providing structured and coherent approaches to understanding complex sustainability issues. These theories not only facilitate in-depth analysis and interpretation but also offer predictive capabilities that are essential for effective policy-making and strategic planning.

The Need for Rigorous Theoretical Application in Sustainability Research

The comparative examination indicates that while a significant number of studies employ theoretical frameworks, there is still a considerable portion of research that does not utilise any explicit theory. This gap highlights the need for a more rigorous application of theory to ensure a

comprehensive and systematic exploration of sustainability challenges. The absence of theory in some studies leads to fragmented and superficial analyses, limiting the overall impact and practical applicability of the research findings.

Enhancing Interdisciplinary Research through Theoretical Integration

The reliance on theory enhances the interdisciplinary nature of research by integrating insights from various fields such as sociology, economics, and environmental science. This interdisciplinary approach is crucial for addressing the multifaceted nature of sustainability in construction project management. The findings of this study emphasise the need for continued emphasis on theory-driven research to foster innovative solutions and sustainable practices.

Advancing Informetric Science through Bibliometric Theory Visualisation

The integration of bibliometric methods in this study serves as a foundational step towards identifying and synthesising dominant theories, leading institutions, and influential authors in the field. This approach not only enriches the theoretical landscape but also facilitates the development of strategies and policies essential for sustainable construction practices. Moving forward, it is imperative to promote the use of theory in empirical investigations to enhance the depth, coherence, and practical relevance of research in sustainable construction project management.

The Vital Role of Theory in Advancing Research

The use of theory in sustainable construction project management research is paramount for achieving a comprehensive understanding of sustainability challenges. Theoretical frameworks provide the necessary structure for rigorous analysis, foster interdisciplinary integration, and enhance the practical impact of research findings. As the field continues to evolve, emphasising theory-driven research will be vital for advancing sustainable practices and contributing to the broader goals of sustainable development.

Recommendations

Based on the findings and analysis of this study, several recommendations can be made to enhance the integration of theoretical frameworks in sustainable construction project management research and to the field of Informetric Science using BMT:

Promote Theory-Driven Research

Researchers should be encouraged to systematically employ theoretical frameworks to guide their investigations. This approach will enhance the coherence and depth of their analyses, providing more robust and generalisable findings. Academic institutions and research organisations should offer training and resources on the application of various theories in construction management and sustainability research. This education can help researchers choose and apply appropriate theories to their studies.

Develop Comprehensive Theoretical Models

Future research should aim to develop comprehensive theoretical models that integrate multiple theories, such as Governmentality Theory, Lean Theory, and Ecological Modernisation Theory. This integration can provide a more holistic understanding of sustainability challenges and solutions. There is a need for developing new theoretical frameworks that specifically address the unique aspects of sustainable construction project management. These frameworks should be based on empirical evidence and tailored to the complexities of the field.

Enhance Bibliometric Tools

Tools like VOSViewer and Scopus should be updated to include functionalities for 'co-theory' analysis. This enhancement will facilitate the identification and synthesis of theoretical frameworks in a more automated and comprehensive manner. Make bibliometric tools more accessible to researchers globally, ensuring that they have the necessary resources to conduct thorough theoretical analyses.

Foster Interdisciplinary Collaboration

Promote partnerships between researchers from different disciplines, such as sociology, economics, environmental science, and engineering. These collaborations can enrich the research by bringing diverse perspectives and expertise to the table. Funding bodies and academic institutions should support initiatives that foster interdisciplinary research. Grants and resources should be allocated to projects that aim to integrate multiple theoretical frameworks and methodologies.

Implement Policy and Practice Integration

Researchers should align their studies with the needs of policymakers and practitioners. By doing so, they can ensure that their findings are relevant and can be effectively applied to real-world challenges. Develop guidelines and best practices for translating theoretical insights into practical strategies and policies. This translation is crucial for bridging the gap between academic research and industry application.

Encourage Publication in Leading Journals

Researchers with a propensity to utilise theory should aim to publish their findings in leading journals such as Sustainability Switzerland and the Journal of Cleaner Production. These journals have a broad readership and can significantly amplify the impact of the research. Utilise various platforms, including conferences, workshops, and online forums, to disseminate research findings. Broad dissemination will ensure that the insights reach a wider audience, including academics, practitioners, and policymakers.

These recommendations aim to enhance the integration and application of theoretical frameworks in sustainable construction project management research. By promoting theory-driven research, developing comprehensive models, enhancing bibliometric tools, fostering interdisciplinary collaboration, aligning research with policy and practice, and encouraging publication in leading journals, the field can advance towards more innovative and sustainable solutions.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Data Availability Statement

The secondary data utilised in this study was obtained from the Scopus database, a comprehensive and widely recognised source of academic literature. All data supporting the findings of this study are available within the article and its supplementary materials. Access to the Scopus database requires a subscription or institutional access. For more information on obtaining access to Scopus, please visit the Scopus website at <https://www.scopus.com>. Any specific queries regarding the data can be directed to the corresponding author. Permission was granted to the Authors for the use of graphs figures and tables and Scopus has issued the following statement to the Authors: "1. If any part of the material to be used (for example, figures) has appeared in our publication with credit or acknowledgement to another source, permission must also be sought from that source. If such permission is not obtained, then that material may not be included in your publication/copies. 2. Suitable acknowledgement to the source must be made, either as a footnote or in a reference list at the end of your publication, as follows: "This article was published in Publication title, Vol number, Author(s), Title of article, Page Nos, Copyright Elsevier (or appropriate Society name) (Year)." 3. This permission is granted for non-exclusive world rights in all languages. 4. Reproduction (and, if necessary, redrawing or modification) of this material is granted for this and all subsequent editions, revisions, versions, derivative works, translations, ancillaries, adaptations, supplementary materials, custom editions, and in advertising and promotion thereof, in all formats and media now known or hereafter developed, throughout the world and in perpetuity. 5. Reproduction of this material is confined to the purpose and/or media for which permission is hereby given. The material may not be reproduced or used in any other way, including use in combination with an artificial intelligence tool (including to train an algorithm, test, process, analyse, generate output and/or develop any form of artificial intelligence tool), or to create any derivative work and/or service (including resulting from the use of artificial intelligence tools)."

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