

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

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Abstract

This study introduces a novel bibliometric model to enhance the integration and application of interdisciplinary theories in construction project management (CPM), focusing on sustainability. Utilizing bibliometric methods and tools such as VOSviewer, the research systematically identifies and maps interdisciplinary intersections in CPM. Grounded in pragmatism, the study emphasizes practical applications of theoretical insights and diverse perspectives to address real-world problems. The analysis highlights dominant sources like Sustainability Switzerland and Energies, and leading institutions such as Delft University of Technology and University of Johannesburg, which contribute significantly to sustainable construction literature. Prolific authors including Wang N., Aranda-Usón A., and Yuan J. frequently employ theories like Governmentality Theory, Lean Theory, and Ecological Modernisation Theory, demonstrating their impact on advancing theoretical and practical knowledge. The findings reveal a reliance on established theories to address sustainability issues and underscore the need for more structured theoretical approaches in future research. Despite notable contributions, there is a gap in the systematic application of theoretical frameworks, necessitating a rigorous theoretical foundation for empirical investigations. A thematic analysis of 41 documents showcases the varied application of

theoretical frameworks and their implications for transdisciplinary research. The results highlight the importance of theory in providing structured frameworks for analysis, fostering interdisciplinary integration, and enhancing predictive power. The study advocates for promoting theory-driven research, developing comprehensive theoretical models, and enhancing bibliometric tools for 'co-theory' analysis. These steps aim to foster innovative solutions and sustainable practices in construction, ensuring theoretical advancements effectively contribute to sustainable development goals. This research underscores the critical role of theory in addressing the complex challenges of sustainable CPM.

Keywords: Bibliometric analysis, Construction project management, Co-Theory, Model of Transdisciplinarity, Identifying Theory using Bibliometrics.

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Highlights

- Developed a novel Bibliometric Model of Transdisciplinarity for reviewing theory.
- Governmentality Theory reveals governance impacts on public-private partnerships.
- Lean Theory links efficiency with industrial sustainable practices adoption.
- Stakeholder Theory examines social impacts and roles in construction projects.
- Institutional Theory analyzes norms in certification and supply chain sustainability.
- Resource-Based View assesses firm's resources in eco-innovation efforts.
- Develops emphasis on theory-driven research for innovative, sustainable construction solutions.

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: Visualization 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. However, it is important to acknowledge that while the weaving and casting of these

'nets' - the hypotheses - gather insights whether they pertain to the tangible world around us or the more elusive abstract dimensions of reality, this metaphor does not encompass all scientific methods. Beyond hypothesis-driven research, various other methods and approaches, such as exploratory, observational, and computational research, play crucial roles in scientific discovery. 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 (CPM) 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 involving 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 emphasizes precision, safety, and efficiency, ensuring that projects meet specified standards and performance criteria [10].

Simultaneously, from a social science perspective, CPM addresses the human and organizational aspects of project execution [11-14]. It includes managing stakeholder relationships, understanding organizational behavior, 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]. Furthermore, CPM 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 CPM 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.

Utilizing Theory for SDG-Driven Sustainable Development

Interdisciplinary research merges diverse disciplines, offering holistic solutions to complex global challenges such as 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 underutilized [29]. In sustainable development, integrating varied fields—from architecture and economics to public policy—is vital for addressing multifaceted stakeholder engagement [4,30,31]. Such integration stimulates creativity, driving breakthroughs beyond the scope of isolated disciplines [18,25,32]. The interdisciplinary nature of the Sustainable Development Goals (SDGs) underscores the necessity of this approach to comprehensively address issues like poverty, health, and environmental degradation [33-35]. However, 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].

Summarizing 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. This study defines and develops 'co-theory' as a novel framework designed to enhance the integration and application of interdisciplinary theories within construction project management. It utilizes bibliometric methods to systematically identify and map the intersections of various disciplines that contribute to the field [39].

However, it is important to acknowledge the inherent ontological and epistemological challenges that arise when integrating materials (e.g., research papers, conference proceedings, etc.) with different philosophical positions. The integration of such diverse materials may not always be logical and rational, potentially complicating the use of 'co-theory'. Despite these challenges, by leveraging a detailed analysis of project management literature, the co-theory framework aims to reveal 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 analyzing theoretical intersections and collaborative patterns among diverse academic disciplines, and the model derived in this study, acts as its fundamental vehicle for achieving this.

In this context, when the authors mention 'key theoretical constructs,' they refer to the fundamental components or elements of theories that are identified through 'co-theory' bibliometric analysis. These constructs include concepts, variables, and relationships that are integral to the formation of theories within construction project management. It is crucial to consider whether these constructs are compatible with theory building, as the process involves integrating various interdisciplinary insights and ensuring logical coherence [2,41,42]. Bibliometrics helps identify these constructs, but their compatibility with theory building depends on the rational integration of diverse disciplinary perspectives.

Therefore, while the co-theory serves as a strategic tool for advancing methodological rigor and fostering innovation through the amalgamation of diverse disciplinary perspectives, it is crucial to remain cognizant of its limitations. Integrating interdisciplinary theories may pose challenges that need to be carefully managed to ensure rational and logical coherence. Ultimately, this approach aims to contribute to the achievement of the Sustainable Development Goals (SDGs) within the construction industry [43].

The Research Problem

Construction project management (CPM) encompasses intricate challenges that extend beyond technical and managerial confines, incorporating socioeconomic and environmental considerations crucial for achieving the Sustainable Development Goals (SDGs). As a discipline that combines many fields of study, the body of knowledge within CPM remains scattered, with scant methodology to visualize similarities across various disciplines [6-9,44]. 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 [45].

However, it is essential to acknowledge that bibliometrics, while powerful, come with inherent biases and shortcomings. These include the potential for skewed citation practices, over-reliance on quantitative metrics, and challenges in accurately representing diverse philosophical and methodological perspectives. Despite these limitations, bibliometric analysis can still offer valuable insights by systematically mapping the intersections of various disciplines and identifying key theoretical constructs. This approach aligns with Popper's advocacy for systematic scientific exploration and rigorous theory evaluation [2,39,46-48]. By highlighting potential areas for transdisciplinary collaboration, bibliometrics can enhance the synthesis of diverse theoretical insights, thus improving the capacity of CPM to address the multifaceted challenges associated with sustainable development.

Implementing such a model requires careful consideration of the biases and limitations inherent in bibliometric methods. Strategies to mitigate these issues include cross-verifying bibliometric findings with qualitative analyses, promoting transparency in data handling, and incorporating a critical assessment of citation practices. Through these measures, the integration of cross-disciplinary perspectives can be more effectively achieved, ultimately contributing to the achievement of the Sustainable Development Goals (SDGs) within the construction industry.

Aim of the Study

This research aims to develop a bibliometric model that integrates rigorous methodological approaches and collaborative efforts to predict and synthesize interdisciplinary theories within a comprehensive framework using the Visualization of Similarities Viewer (VOSviewer). By identifying pathways for transdisciplinary cooperation, enhancing methodological precision, and fostering innovation in scientific exploration, the study intends to construct a robust theoretical foundation for sustainability through transdisciplinary research in CPM, emphasizing its interdisciplinary nature [49]. 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 [2,50,51].

Aristotle's approach to scientific inquiry emphasized systematic observation, logical analysis, and the categorization of knowledge [51]. This study incorporates these principles by systematically analyzing bibliometric data to categorize and understand the theoretical constructs within CPM. The detailed mapping of interdisciplinary intersections aligns with Aristotle's method of organizing knowledge to gain comprehensive insights [52]. Karl Popper advocated for rigorous scientific investigation through falsification and critical evaluation of hypotheses [2]. This study adopts Popper's principles by critically evaluating interconnected theories and practices in CPM. The use of this novel form of bibliometric analysis allows for the identification of theoretical intersections and collaborative patterns, which are then subjected to critical scrutiny to ensure their validity and applicability.

By combining these foundational insights, the study aims to create a model that bridges disciplinary gaps and formulates a comprehensive theoretical understanding of sustainability within a collaborative transdisciplinary research framework [53]. This approach facilitates the rapid identification of where theories co-exist among disciplines, how they are used, adapted, and formed, thereby fostering the 'co-theory' method to bibliometric analysis. The rigorous

methodology and critical evaluation process embody the scientific rigor championed by both Aristotle and Karl Popper, ensuring that the findings are robust, valid, and capable of addressing complex sustainability challenges in CPM.

Addressing Disadvantages of Bibliometrics

Bibliometrics, while powerful, come with inherent biases and limitations, such as skewed citation practices and an over-reliance on quantitative metrics. These issues could potentially impact the formulation and articulation of research questions. To mitigate these disadvantages, the study incorporates the following strategies into the model [54-62]:

Cross-verification with Qualitative Analysis

Bibliometric findings are cross verified with qualitative thematic analysis analyses to ensure a comprehensive understanding of the theoretical constructs [2,63,64].

Transparency in Data Handling

Transparent and consistent data handling practices are maintained to reduce biases and enhance the reliability of the results [65-69].

Critical Assessment of Citation Practices

A critical assessment of citation practices is undertaken to identify and address any skewness or over-representation of certain authors or papers [55,57,62].

Incorporation of Diverse Philosophical Perspectives

By integrating diverse philosophical perspectives, the study ensures that the identified theoretical constructs are logically coherent and applicable across different disciplines [1,70-72].

These measures ensure that the disadvantages of bibliometrics do not adversely impact the formulation and articulation of the research questions, thereby maintaining the integrity and robustness of the study's findings.

Main Research Question

MRQ: How can a new bibliometric model, grounded in the philosophical underpinnings of Aristotle's systematic methodologies and Karl Popper's scientific rigor, predict and weave interdisciplinary theories within a coherent 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, considering its philosophical foundations and potential biases, enable the systematic amalgamation of interdisciplinary theories to enhance sustainability understanding in construction project management?

R2: How can the bibliometric model, informed by the limitations and advantages of bibliometrics, 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 and critical evaluation, 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: Utilize bibliometric analysis to systematically identify and synthesize 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 CPM.

Addressing Assumptions and Methodological Limitations

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 significant and representative array of global interdisciplinary scientific information pertinent to construction management and sustainability, culminating in the largest body of epistemology incorporating and fully covering Science Direct, Web of Science, MEDLINE and EMBASE [73,74]. As such, Scopus is a comprehensive bibliographic database covering a wide range of disciplines, making it suitable for developing this novel method [75].

A2: It presumes the Scopus database's data integrity, where citations, authorship, and publication specifics are considered accurate and uniform [76]. However, this assumption is tempered with caution, acknowledging that data inaccuracies and inconsistencies can occur [77]. To mitigate this, data was meticulously validated and cross-checked to enhance the reliability of identifying research patterns and connections [63].

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 evaluate

interdisciplinary engagements and transdisciplinary collaborations effectively. However, several critical points are considered, recognizing that bibliometric analyses rely on specific databases, which may not cover all relevant literature, despite the use of the most prevailing body of knowledge. Additionally, high citation counts do not necessarily reflect the quality of the work, and newer publications may be underestimated due to limited time for accruing citations [78].

By incorporating these considerations, the study provides a more nuanced and critical application of bibliometric methods, ensuring a balanced and comprehensive evaluation of interdisciplinary research in CPM and sustainability.

Hypotheses

In alignment with its objectives and under the premise of using Scopus-based bibliometric analysis to investigate transdisciplinary sustainability in CPM, 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 [47,48]

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, thereby aiding in the resolution of complex multifaceted problems [49].

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 CPM.

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 CPM.

Literature Review

Theoretical 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. This approach focuses on creating new frameworks, knowledge, and methodologies by synthesizing elements from distinct fields to foster innovation and holistic understanding [40]. Theoretically, interdisciplinarity can be contrasted with multidisciplinary and transdisciplinarity [12,17,40,79,80]. In multidisciplinary approaches, disciplines work alongside each other, each contributing its perspective without necessarily integrating them [81-83]. 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 [53].

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 [84]. 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 synthesizing 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 [85]. It embraces diverse epistemological perspectives, recognizing that different disciplines offer unique ways of knowing and understanding the world. This diversity is harnessed to achieve a more robust and multifaceted understanding [86,87]. 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 [86-88].

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 (CPM) with a focus on transdisciplinary sustainability, the 'Theory of Transdisciplinarity' is selected for its core tenets aligning 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 [53,89-91]. The Theory of Transdisciplinarity, as applied to addressing complex real-world issues by transcending traditional academic boundaries, was significantly shaped by scholars like Basarab Nicolescu, whose contributions underscore the necessity of transcending disciplinary limits to tackle the multifaceted nature of sustainability challenges effectively [53].

By leveraging the Theory of Transdisciplinarity, a comprehensive theoretical framework that supports transdisciplinary collaboration and sustainability in CPM can be developed. This approach validates the hypothesis that such integration enhances methodological precision and scientific innovation.

The Importance of Theory: Embracing Complexity and Multidimensionality

The importance of theory in CPM, 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 [53,89]. This theoretical framework acknowledges that real-world

problems, such as those encountered in sustainable CPM, 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 [92].

The importance of theory lies in its capacity to provide a comprehensive and integrative framework for understanding and addressing the multifaceted challenges of CPM. This theoretical approach not only enriches the field's methodological rigor 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, emphasizing the importance of embracing and integrating seemingly contradictory perspectives to solve complex problems. In CPM, 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 [53]. Theories that embody the Logic of the Included Middle are essential in CPM 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 [89]. The Logic of the Included Middle also enhances methodological rigor by promoting a holistic understanding of CPM. 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 [92].

The Logic of the Included Middle is fundamental to the importance of theory in CPM. It provides a framework for integrating diverse perspectives, promoting collaboration, and enhancing methodological rigor. 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 CPM. This approach is particularly critical for fostering sustainability, as it enables a comprehensive understanding that goes beyond the limitations of any single discipline [86]. 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 synthesizes these diverse perspectives to create more holistic and innovative solutions [53,86,88,89]. In CPM, 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 [86,92]. 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 [86,91,93].

The importance of theory from a transcending disciplines perspective in CPM 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, emphasizing the necessity of including diverse perspectives and expertise in addressing complex issues in CPM. 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 recognizes that each stakeholder brings unique insights and expertise, which are essential for addressing the multifaceted nature of construction projects. 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 [92]. In CPM, 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 [85].

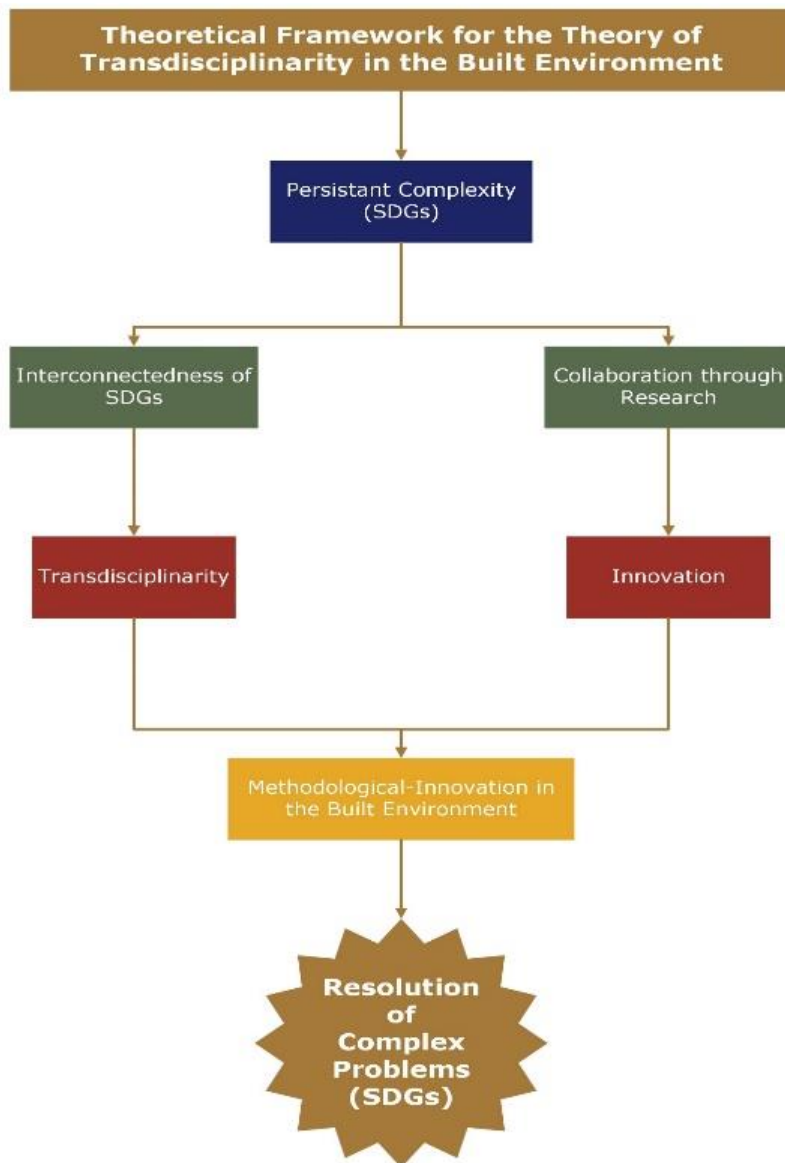
From a theoretical perspective, stakeholder participation is indispensable in CPM. It provides a framework for integrating diverse perspectives, promoting comprehensive and inclusive decision-making, and fostering innovative solutions. This approach is essential for addressing the complex challenges 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 CPM. 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 [17,94]. The theoretical perspective of fostering novelty and innovation posits that addressing complex challenges in CPM 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 [53,86]. In CPM, 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 [86,89]. 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 [92]. 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, CPM 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 [31,91].

From a theoretical perspective, fostering novelty and innovation is critical in CPM. It provides a framework for integrating diverse disciplinary insights, promoting creative problem-solving, and enhancing methodological rigor. 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, helps navigate the complex landscape of sustainable CPM. 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 [51,53].

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

The model recognizes 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 [51,53,92].

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 [4,47,50,51,91].

T4: Promoting Methodological Innovation (MRQ)

The model applies bibliometric analysis to foster new pathways for understanding and addressing the SDGs. By developing specific metrics and indexes, the BMT advances methodological innovation and enhances the capacity to evaluate and implement sustainable practices in CPM [50,89].

Empirical Literature Review

The Interdisciplinary Nature of Construction Project Management (CPM)

Construction Project Management (CPM) is a multifaceted discipline that integrates various fields of study, including engineering, architecture, economics, environmental science, and social sciences [4,23,95-98]. This interdisciplinary nature is essential for addressing the complex challenges associated with modern construction projects, particularly those related to sustainability [99-102]. Beyond the technical and managerial aspects, CPM requires consideration of ethical issues, innovation, and the educational and training dimension [103-107].

Ethical considerations are paramount in CPM due to the significant impact construction projects can have on communities, the environment, and stakeholders [108-111]. Ethical issues in CPM encompass sustainability and environmental responsibility, ensuring that construction practices contribute to sustainable development without harming the environment [112]. Prioritizing safety and health of workers and the public, ensuring equity and fairness for all stakeholders, and maintaining transparency and accountability in decision-making and project execution are also crucial. Addressing these ethical concerns necessitates an interdisciplinary approach, integrating insights from ethics, law, sociology, and environmental science to develop comprehensive and responsible construction practices [108,113-123].

Innovation is a driving force in CPM, enabling the development of new methods, technologies, and processes that improve efficiency, quality, and sustainability. Technological advancements such as Building Information Modeling (BIM), artificial intelligence, and automation enhance project planning, execution, and management [124-130]. Sustainable practices, including the development and implementation of innovative materials, construction methods, and energy-efficient designs, promote sustainability [131-134]. Additionally, process improvements like Lean Construction and Integrated Project Delivery (IPD) streamline project management, reducing waste and enhancing collaboration. Innovation in CPM requires collaboration across disciplines,

bringing together expertise from engineering, technology, management, and environmental science to drive continuous improvement and adaptation to emerging challenges [135-138].

Education and training are critical to preparing the next generation of construction project managers and ensuring that current professionals stay abreast of evolving industry standards and practices [139-142]. The educational and training dimension of CPM involves curriculum development, which designs comprehensive educational programs covering technical, managerial, ethical, and sustainable aspects of CPM [139,140,143-147].

The interdisciplinary nature of CPM extends beyond the integration of technical and managerial disciplines to include ethical considerations, innovation, and the educational and training dimension. By addressing these additional aspects, CPM can better navigate the complexities of modern construction projects and contribute to sustainable development. An interdisciplinary approach incorporating insights from diverse fields is essential for developing comprehensive and responsible construction practices that meet the needs of all stakeholders.

The Current State of Bibliometrics and Existing Approaches

Bibliometrics, the statistical analysis of written publications, has become an indispensable method for evaluating research output, impact, and trends across various academic fields [47,54,148,149]. Tools such as VOSviewer have revolutionized how researchers visualize and analyze co-authorship networks, citation patterns, and research collaborations, enabling the identification of key authors, influential papers, and emerging research areas [150]. Despite its utility, the current application of bibliometrics primarily focuses on quantitative metrics such as citation counts, publication frequency, and h-index [151]. These metrics, while useful for evaluating the impact and visibility of research, fall short in assessing the theoretical underpinnings of scientific work [152-154]. Bibliometrics traditionally does not engage with the qualitative aspects of research, such as the development, integration, and application of theoretical constructs, limiting the ability to fully understand the epistemological and ontological foundations of research within interdisciplinary and transdisciplinary contexts [155].

Despite its widespread use, bibliometrics has inherent shortcomings when it comes to assessing theory. Quantitative bias can overshadow the qualitative depth of theoretical contributions, as high citation counts do not necessarily correlate with theoretical rigor or innovation [156,157].

Bibliometric analysis inadvertently reinforces disciplinary silos due to discipline-specific citation practices and publication venues, obscuring the interdisciplinary and transdisciplinary integration of theories [158-161].

Existing bibliometric tools do not systematically map theoretical constructs across publications, limiting the ability to track the development and application of theories over time. Moreover, bibliometric analyses do not adequately capture the philosophical foundations of research, such as the epistemological and ontological positioning of studies.

Clarifying the Role of Disciplinary Work for Integration

While the literature review emphasizes the importance of interdisciplinary work, it is crucial to recognize that disciplinary foundations provide the necessary depth and expertise required for effective integration. Transdisciplinarity builds upon these disciplinary insights by transcending traditional boundaries, allowing for a more holistic approach to complex problems. The

integration of constructs drawing on transdisciplinary efforts does not negate the role of disciplinary work; rather, it leverages and extends it to address multifaceted challenges comprehensively.

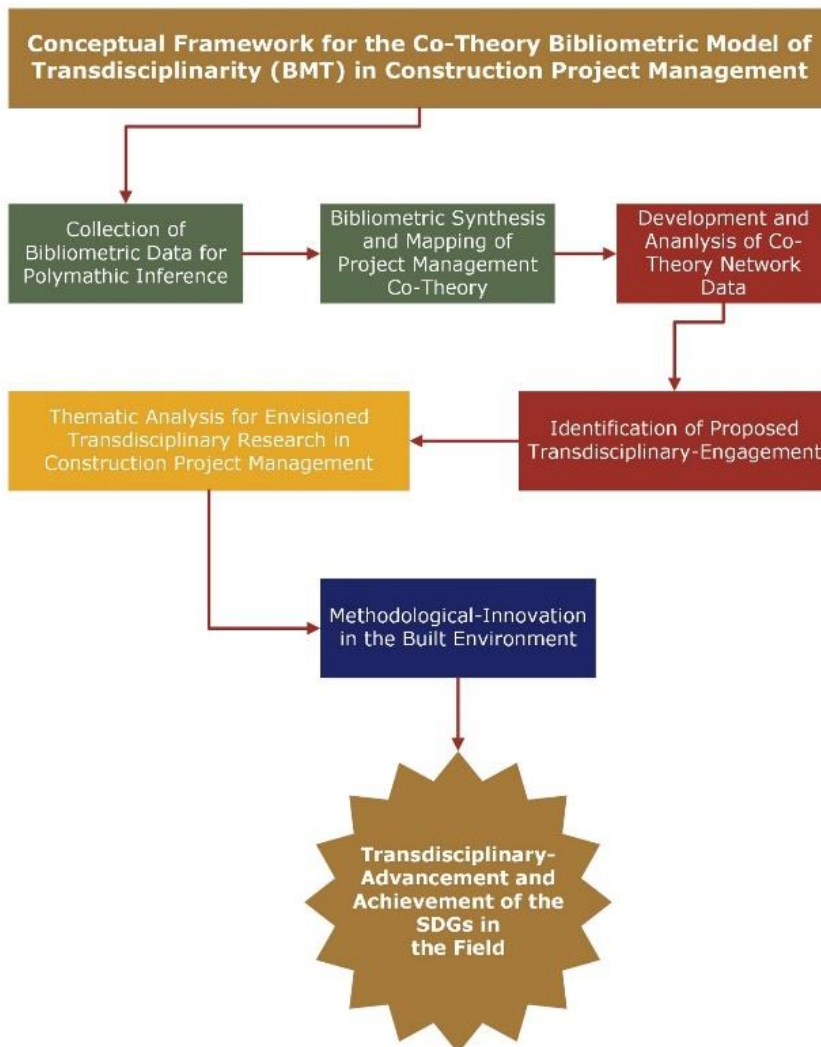
Reconciling Interdisciplinary and Transdisciplinary Approaches

The distinction between interdisciplinary and transdisciplinary endeavors lies in the scope and depth of integration. Interdisciplinary approaches blend and integrate perspectives from different disciplines to generate new insights, whereas transdisciplinary approaches go further by creating a unified framework that transcends these boundaries to address complex societal issues holistically. In the context of CPM, this means integrating engineering, environmental science, economics, and social sciences to develop sustainable practices that are both technically sound and socially responsible.

This comprehensive approach ensures that the constructs identified through bibliometric analysis are not only integrated but also compatible with the broader goals of theory building and practical application in sustainable CPM.

A Conceptual Model: Expanding Bibliometrics to Beyond its Current Ambit

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 [162]. This methodology underpins the Bibliometric Model of Transdisciplinarity (BMT) in CPM, 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 [163-165]. Bibliometrics, leveraging Scopus's extensive database, offers insights into the interdisciplinary nature of sustainable CPM. It reveals patterns of collaboration and theoretical integration crucial for advancing transdisciplinary sustainability [166,167]. 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 rigor and innovation in scientific inquiry [168,169].

However, the methodology is not without limitations [170]. 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 [171]. 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 [48,172-175]. 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 CPM [162,170]. This model bridges disciplinary divides, highlighting the critical role of bibliometric analysis in synthesizing interdisciplinary knowledge and fostering collaborative innovation towards achieving the SDGs within the construction industry [53].

Role of Bibliometrics in Fostering Academic Stakeholder Participation

Bibliometrics fosters stakeholder participation by identifying potential avenues for collaboration [176,177]. Through bibliometric analysis, researchers can map the landscape of existing research and identify key contributors, influential studies, and emerging trends. This mapping highlights areas where interdisciplinary and transdisciplinary collaborations are most needed and can be most effective [178-181]. By pinpointing these collaborative opportunities, bibliometrics helps bring together diverse stakeholders who may not have previously interacted [182-185].

For example, bibliometric analysis can reveal underexplored intersections between engineering and social sciences within CPM, prompting collaboration between technical experts and community planners. Such collaborations are essential for developing holistic solutions that are technically feasible and socially acceptable [186-190].

Moreover, bibliometrics can identify leading institutions and prolific authors who are central to the discourse on sustainability in construction. Engaging these key players can enhance stakeholder involvement by incorporating their expertise and insights into project planning and execution. By fostering these connections, bibliometrics ensures that stakeholder participation is not only encouraged but strategically integrated into the research and development process [191-195].

Stakeholder participation is indispensable in CPM [191,196-203]. It provides a framework for integrating diverse perspectives, promoting comprehensive and inclusive decision-making, and fostering innovative solutions [204-206]. This approach is essential for addressing the complex challenges of sustainability and enhancing the overall success and resilience of construction projects [207-210]. Through bibliometrics, the identification and facilitation of stakeholder collaboration are enhanced, ensuring that all relevant voices contribute to the development of sustainable practices [211-215].

In conclusion, this empirical literature review underscores the limitations of traditional bibliometrics in assessing theory and introduces a novel framework for integrating theoretical constructs into existing bibliometric analysis. By expanding the current body of knowledge on bibliometrics, this study provides valuable insights into the epistemological and ontological foundations of research in CPM, fostering a more comprehensive and integrated approach to

sustainability. This novel methodology not only enhances the theoretical rigor of bibliometric analysis but also promotes the practical application of research findings in addressing the complex challenges of CPM.

Concluding the Empirical Findings

The key contributions of this work include the integration of theory assessment by systematically identifying and synthesizing theoretical constructs used in CPM literature identified through Bibliometric analysis. This approach enhances the understanding of how theories are developed, integrated, and applied across disciplines. The study transcends traditional disciplinary silos by mapping theoretical intersections and collaborative patterns among diverse academic fields, fostering a more holistic understanding of sustainability in CPM.

Beyond quantitative metrics, the study incorporates qualitative assessments of theoretical contributions through thematic analysis, ensuring a comprehensive evaluation of research impact and relevance [70,148]. Grounded in the philosophical principles of pragmatism, the research emphasizes the practical application of theoretical insights and the integration of diverse perspectives to address real-world problems. Utilizing traditional bibliometric data, the study creates visual maps of theoretical constructs, highlighting their interconnections and evolution over time, identifying gaps in the integration and application of theories, providing a novel approach to reviewing literature, and offering a roadmap for future research. The findings promote stakeholder participation by identifying potential avenues for interdisciplinary and transdisciplinary collaboration, thereby enhancing the practical relevance of theoretical research.

Syllogistic Summary

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

This summary distills 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 [216]:

First Syllogism: Enhancing Understanding and Policy through Bibliometrics

Major Premise: Bibliometric analysis quantitatively assesses academic research's impact, facilitating the evaluation of scholarly work [162,217,218].

Minor Premise: In sustainable construction project management, understanding research impact is essential for integrating diverse disciplines and shaping effective policies [217,219,220].

Conclusion: Thus, bibliometric analysis in sustainable construction project management is pivotal for enhancing interdisciplinary understanding and informing policymaking [25,221].

Second Syllogism: Advancing Knowledge via Trend Identification

Major Premise: Bibliometric analysis provides insight into research trends and developments, highlighting emerging areas of study [169,222,223].

Minor Premise: In the context of sustainable construction project management, pinpointing trends and gaps is vital for knowledge progression [2,224].

Conclusion: Consequently, bibliometric analysis is crucial for propelling sustainable construction project management knowledge by spotlighting pivotal trends and filling existing gaps [225].

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 [39,167,226,227].

Minor Premise: Addressing sustainability's complex challenges in construction project management necessitates interdisciplinary collaboration [86,88,227].

Conclusion: Hence, bibliometric analysis plays a key role in promoting transdisciplinary collaboration, crucial for surmounting sustainability challenges in construction project management [53].

Research Methodology

Achieving Transdisciplinarity: A Philosophical Bibliometric Perspective

This study embodies a mixed-method approach of positivist and pragmatic ontological and epistemological stances, recognizing the practical application of theoretical constructs and empirical findings in addressing real-world problems in construction project management (CPM) and sustainability [68,70,148]. Pragmatism, as a philosophical tradition, emphasizes the utility of ideas and theories based on their practical consequences and applications. It values the integration of multiple perspectives to solve complex issues effectively [228,229].

Ontological Positioning

Ontologically, pragmatism acknowledges that reality is multifaceted and dynamic, shaped by the interactions between various elements and perspectives [70,230]. This study aligns with this view by recognizing the complexity of CPM and sustainability, which encompasses technical, environmental, economic, and social dimensions [231-234]. By adopting a pragmatic ontology, the study focuses on the practical integration of interdisciplinary and transdisciplinary insights to develop solutions that are both theoretically sound and practically applicable [70,229].

Epistemological Positioning

Epistemologically, pragmatism advocates for a pluralistic approach to knowledge acquisition and validation. It suggests that knowledge is best understood through its practical implications and efficacy in addressing real-world problems [235-237]. This study embraces this epistemological stance by employing bibliometric methods to systematically identify and synthesize interdisciplinary theories within CPM. The use of bibliometrics, while acknowledging its limitations, is justified by its practical utility in mapping theoretical intersections and fostering transdisciplinary collaborations [238-242].

Integration of Qualitative and Quantitative Methods

Pragmatism supports the integration of diverse disciplinary perspectives to address complex problems. This study utilizes bibliometric analysis to identify key theoretical constructs from

various disciplines, ensuring a comprehensive approach to sustainability in CPM [243-248]. The pragmatic approach emphasizes the practical application of theoretical insights. By developing a bibliometric model that predicts interdisciplinary connections, the study aims to enhance the practical utility of research findings in informing sustainable practices and policies [249-251]. Pragmatism values adaptability and flexibility in research methodologies [248,249,252,253]. This study's use of bibliometric methods, combined with qualitative assessments and critical evaluations, reflects a flexible and adaptive approach to addressing the challenges of integrating interdisciplinary theories.

Theoretical Mapping and Evaluation

The effectiveness of theoretical constructs is evaluated based on their practical consequences and applications [254-256]. The study's focus on developing a 'co-theory' framework for transdisciplinary collaboration aligns with pragmatism's emphasis on the utility of ideas in solving real-world problems. Through bibliometric analysis, the study 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 [257-261]. This blend of philosophies is instrumental in navigating the study's transdisciplinary scope, enabling the seamless fusion of multiple methodological and theoretical landscapes.

Methodological Approach

Methodologically, the research adopts a quantitative lens, leveraging secondary data from Scopus's extensive academic publication database to perform bibliometric analysis [258,259,262-266]. This approach quantifies academic literature patterns, facilitating a nuanced understanding of transdisciplinary sustainability in CPM through deductive reasoning. An exploratory polymathic strategy guides the inquiry, illuminating the interplay of interdisciplinary knowledge and its influence on sustainable CPM 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 [2,42,51,52,267].

Empirical Analysis and Model Development

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 [267-269]. 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 [70]. This meticulous examination draws from Scopus, focusing on sustainability-centric terminology within CPM, and employs network analysis to decode patterns of collaboration and theoretical discourse.

Addressing Philosophical Gaps

This study's framework outlines the process of collecting bibliometric data, synthesizing and mapping project management co-theory, developing and analysing co-theory network data, and identifying proposed transdisciplinary engagements. Thematic analysis for envisioned transdisciplinary research in CPM and methodological innovation in the built environment leads to transdisciplinary advancement and the achievement of the Sustainable Development Goals

(SDGs) in the field [70-72]. The inclusion of qualitative aspects through thematic analysis enriches the framework, ensuring a comprehensive approach to understanding and applying interdisciplinary and transdisciplinary theories in CPM.

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 [8,48,166,169].

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 [270,271].

Selecting Data Sources with Specific Criteria

Identifying suitable databases such as Scopus as they encapsulate a comprehensive body of knowledge such as Science Direct, Web of Science, MEDLINE and EMBASE that offer comprehensive metrics for citation analysis, content analysis, co-citation analysis, co-authorship analysis, and co-theory analysis is crucial [271,272]. Chosen databases encompass journals and publications pertinent to sustainable construction project management, ensuring alignment with the study's theoretical focus [273]. 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 [72,274].

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 [225,270,275]. 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 [276]. Essential bibliographic details were captured by 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 the 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 [47,277].

Data Cleaning and Preprocessing

The study conducted data cleansing to remove duplicates and errors and standardize data formats for analysis [278]. Where necessary, data was manually inspected for accuracy and categorized according to the analytical needs of the study, providing columns suited to the software applications' requirements [279]. Data was categorized 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 [279].

This structured approach underscores the meticulous process of bibliometric analysis in exploring transdisciplinary sustainability within the context of CPM, setting a foundation for an in-depth investigation and interpretation of the research landscape in this field [47].

Results

Introduction: The Bibliometric Approach

This study will first conduct a general bibliometric analysis, using descriptive statistics as a foundation to identify theory through bibliometrics, serving as this study's proverbial 'litmus test'. Through the identification of 'dominant sources', 'leading institutions', and 'prolific authors', this analysis will provide a comprehensive overview of the research landscape, highlighting key contributors and influential works within the field of sustainable construction project management (CPM). 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 CPM, descriptive statistics can reveal the frequency and distribution of key themes, theoretical frameworks, and methodological approaches over time [47]. 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 analyzing 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 CPM.

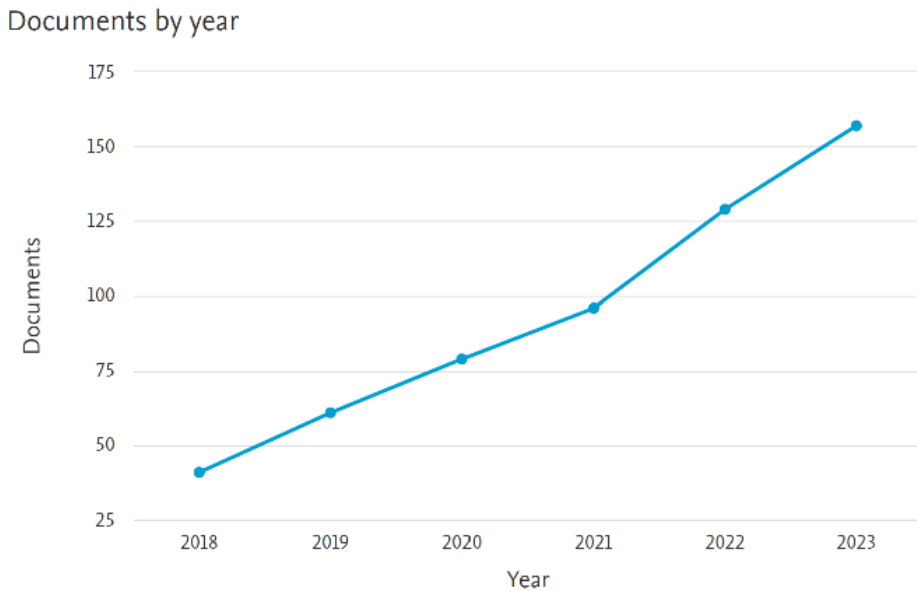
Descriptive Statistics and Its Importance to the Bibliometric Method

Descriptive statistics play a critical role in bibliometric analysis, particularly in the context of constructing the Bibliometric Model of Transdisciplinarity (BMT) for analyzing data surrounding sustainable CPM. Descriptive statistics involve summarizing and organizing 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 [168].

Analysis of Document Trends by Year

Figure 3: Documents by Year (Source: Scopus)



The graph titled “Documents by Year” in Figure 3 presents a clear upward trend in the number of documents published annually on sustainable CPM from 2018 to 2023. This trend indicates 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, approximately 50 documents were 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 a 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

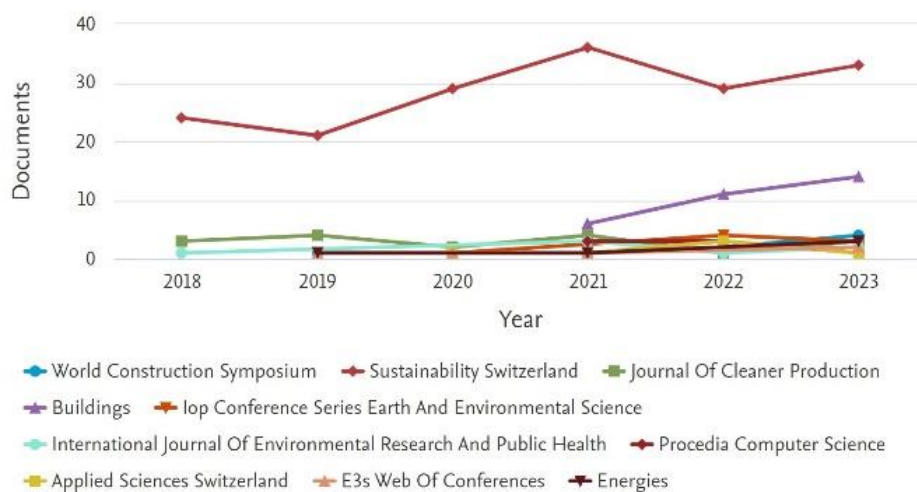
The growing number of publications reflects the increasing recognition of the importance of sustainable practices in CPM. This rise aligns with global initiatives such as the Sustainable Development Goals (SDGs), which emphasize sustainable industrialization and innovation. The expanding body of literature 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 CPM. 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" in Figure 4 presents the distribution of documents published annually from 2018 to 2023 across various academic sources related to sustainable CPM. 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, displaying a steady increase in publications, particularly notable in 2021 and 2023, where it reaches close to 30 documents.

Consistent Contributors

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

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

IOP Conference Series Earth and Environmental Science: Shows an upward trend starting from 2021, indicating its growing relevance in the field.

International Journal of Environmental Research and Public Health: Displays a noticeable increase in publications from 2021 onwards.

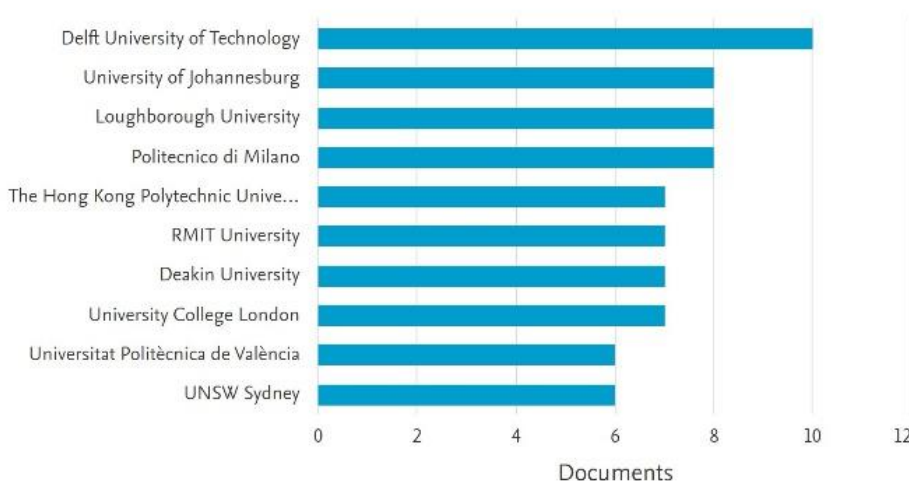
Implications for Sustainable Construction Project Management

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 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 CPM 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 CPM.

Analysis of Documents by Affiliation

Figure 5: Documents by Affiliation (Source: Scopus)

Documents by affiliation ⓘ



The graph titled "Documents by Affiliation" in Figure 5 presents the number of documents published by various academic institutions in the field of sustainable CPM. 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 CPM.

University of Johannesburg and Loughborough University: Follow 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: Published 7 documents each, showcasing their active participation and substantial contributions to the field.

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 CPM.

Emerging Contributors

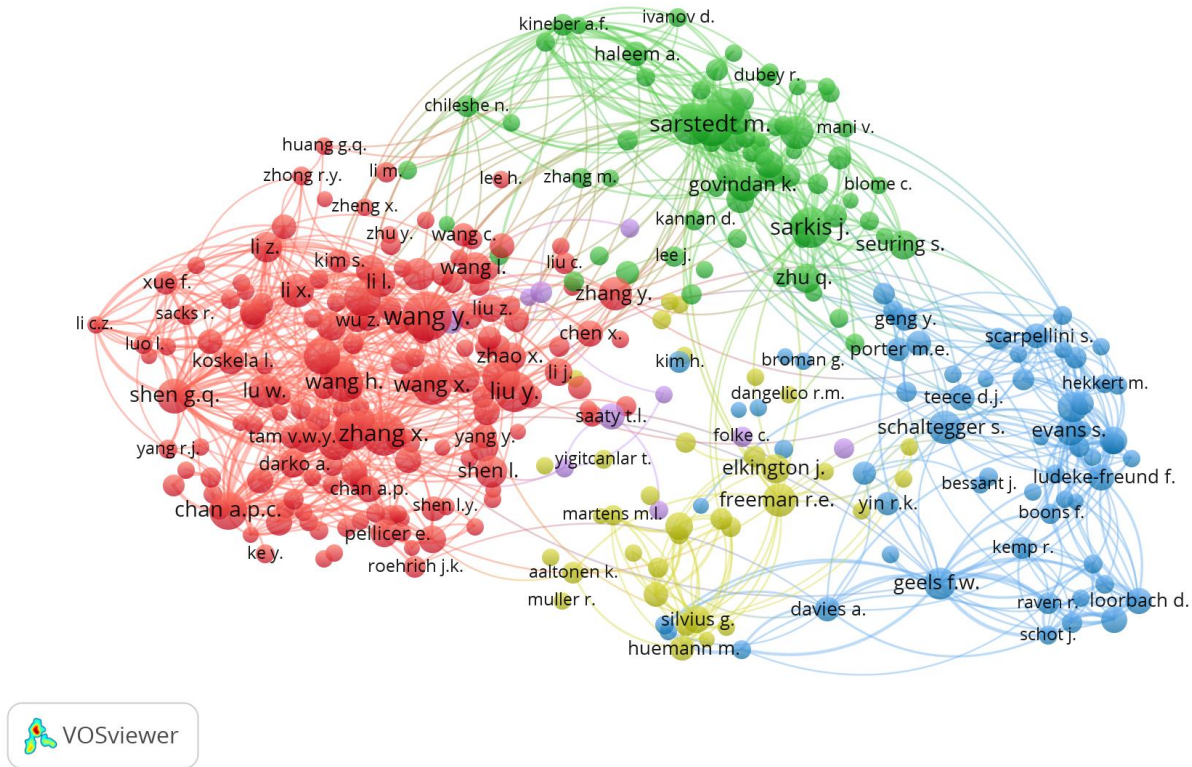
Universitat Politècnica de València and UNSW Sydney: Published 5 documents each, indicating their involvement and research productivity in this field.

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 CPM. 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 CPM. 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 Utilizing VOSViewer

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



The VOSviewer network graph in Figure 6 presents a visual representation of the collaborative relationships and citation patterns among researchers in the field of sustainable CPM. This network analysis helps identify key authors, their interconnectedness, and the structure of the research community [280].

Prolific Authors through Cluster Identification

Red Cluster: Dominated by authors such as Wang N., Wang X., and Wang Y., indicating a closely-knit group of researchers frequently citing each other.

Green Cluster: Features prominent authors including Sarstedt M., Sarkis J., and others.

Blue Cluster: Includes key figures such as Geels F.W. and Freeman R.E.

Yellow Cluster: Although smaller, 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.

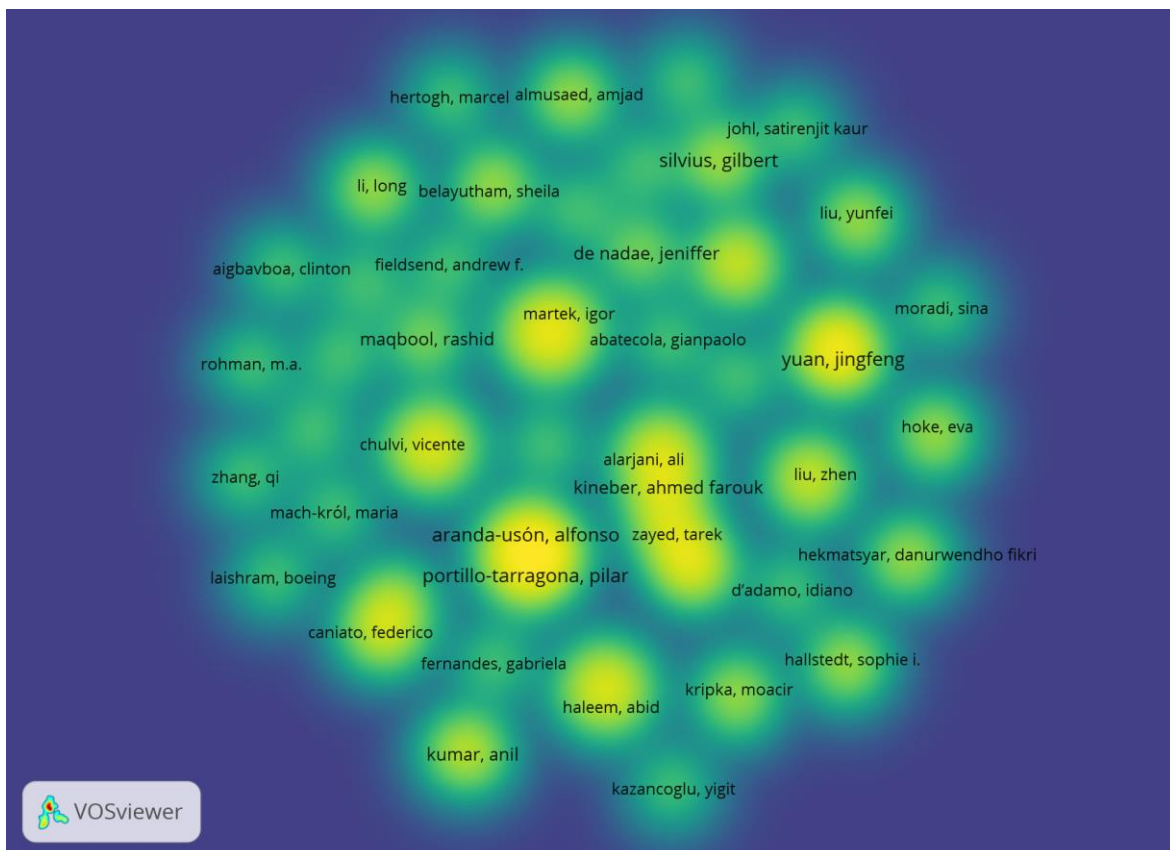
Authors with larger nodes, such as Wang L. and Sarstedt M., are highly influential within the network. Their extensive citation networks suggest that their work is foundational and widely recognized within the research community.

The network density around these key authors implies that their research significantly impacts and shapes ongoing studies in sustainable CPM.

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 specialized research areas within the broader field of sustainable CPM. 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 CPM. The distinct clusters and interconnectedness reflect the interdisciplinary nature of the field and emphasize 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 Visualization of Authors Utilizing Theory (Source: Authors)



The VOSviewer density visualization graph in Figure 7 displays the prominence and frequency of key researchers in the field of sustainable CPM based on the number of their publications and citations. The density visualization uses a color gradient from green to yellow, with yellow indicating higher prominence and green indicating lower prominence [44].

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 CPM.

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 recognized and frequently cited, indicating their influence on current and future research trends.

The density visualization 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 CPM. It underscores the field's multidisciplinary nature, integrating insights from engineering, management, environmental science, and more.

The VOSviewer density visualization provides a comprehensive overview of the key contributors in sustainable CPM. 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.

Novel 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, 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 visualization analysis. Their extensive citation networks and frequent co-authorships underscore their significant impact and leadership in advancing sustainable construction project management (CPM) 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 [44,45,280-284]. 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. Utilizing 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 analyzed 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 [285].	Governmentality Theory	Wang, N., Gong, Z., Liu, Y., Thomson, C.	Utilities Policy
Dynamic Capabilities and Environmental Accounting for the Circular Economy in Businesses [286].	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 [287].	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 [288].	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 [289].	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 [290].	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 [291].	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 [292].	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 [293].	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) [294].	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 [295].	Ecological Modernisation Theory and Stakeholders Theory	Aranda-Usón, A., Portillo-Tarragona, P., Scarpellini, S., Llena-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 [296].	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 [297].	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 [298].	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 [299].	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 [300].	Governmentality Theory	Wang, N., Ma, M., Liu, Y.	Sustainability (Switzerland)
Factors Affecting Defects Occurrence in the Construction Stage of Residential Buildings in Gaza Strip [301].	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 [302].	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 [303].	Stakeholder Theory and Triple Bottom Line Theory	Silvius, G., Marnewick, C.	Procedia Computer Science

Exploring Barriers for Circularity in the EU Furniture Industry [304].	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 [305].	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 [306].	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 [307].	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 [308].	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 [309].	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 [310].	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 [311].	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 [312].	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 [313].	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 [314].	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 [315].	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 [316].	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 [317].	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 [318].	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 [319].	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 [320].	Institutional Theory and Stakeholder Theory	Silva, M.E., Nunes, B.	Business Strategy and the Environment
Analysing Competing Logics Towards Sustainable Supplier Management [321].	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 [322].	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 [323].	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 [324].	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 [325].	Resource-based View Theory	Aranda-Usón, A., Portillo-Tarragona, P., Marín-Vinuesa, L.M., Scarpellini, S.	Sustainability (Switzerland)

Thematic Analysis and Findings

The analysis of these documents highlights the varied application of theoretical frameworks in sustainable CPM. The utilization of different theories reflects the interdisciplinary nature of the field and the diverse methodological approaches taken by researchers. The table provides a structured overview of how various theories are applied across different studies, journals, and contexts.

Commonly Used Theories

This study examines the application of several key theories within sustainable construction project management, alongside the use of empirical evidence and theoretical integration. Governmentality Theory is applied in studies examining governance and public-private partnerships, providing insights into how governmental rationalities and techniques influence these collaborations. Lean Theory is used to explore industrial attitudes and behaviors in adopting sustainable practices, offering a framework for integrating efficiency and waste reduction principles into sustainability efforts. Stakeholder Theory is frequently employed to understand stakeholder influences and social impacts in construction projects, focusing on the roles and perspectives of various stakeholders involved. Institutional Theory is applied in studies related to certification adoption and sustainable supply chain management, analyzing how institutional norms and pressures affect organizational practices and standards. The Resource-Based View Theory is used to assess firms' resources and capabilities in eco-innovation projects, examining how internal assets contribute to sustainable innovation. Lastly, the Technology Acceptance Model is employed in studies exploring the adoption of new technologies in construction, investigating the factors that influence users' acceptance and utilization of technological advancements in the industry. Additionally, many studies are based on data or specific contexts without applying a distinct theoretical framework, indicating a focus on empirical evidence and case-specific insights. Some studies integrate multiple theories to provide a more comprehensive understanding of complex phenomena, such as Silvius et al., who combined Stakeholder Theory and Triple Bottom Line Theory to explore sustainability in organizational strategy and project management.

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 (CPM). 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 [285,295,297,305].

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 utilized to explore the implementation of public-private partnerships in both the United Kingdom and China,

showcasing its versatility in policy analysis [285]. Lean Theory, on the other hand, is applied to understand the environmental benefits of energy security and project management practices [287]. Ecological Modernisation Theory, combined with Stakeholder Theory, provides insights into the circular economy's adoption by businesses for cleaner production [305].

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 [2,70,84]. 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 synthesizing dominant theories, leading institutions, and influential authors, thereby fostering a deeper understanding of transdisciplinary sustainability in CPM. 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

Structured Frameworks: Theories provide a structured framework for analyzing data and interpreting results. For instance, Lean Theory helps in understanding the environmental benefits of energy security and project management practices [287,288]. Such frameworks enable researchers to systematically dissect and address specific research questions, ensuring a coherent and logical flow of analysis.

Deeper Insights: Established theories such as Governmentality Theory and Ecological Modernisation Theory allow 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 [300,305].

Predictive Capabilities: Theories often possess predictive capabilities, allowing researchers to forecast potential outcomes and trends [42,70,326,327]. This is particularly beneficial in policy-making and strategic planning, where anticipating future scenarios can lead to more informed decisions.

Interdisciplinary Integration: The use of theory promotes interdisciplinary integration by bridging knowledge gaps across various fields [23,328-330]. 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 [331,332].

Consequences of Not Using Theory

Lack of Structure: Studies that do not employ theoretical frameworks often lack a structured approach to analysis [70]. This can lead to fragmented findings and inconsistent interpretations, undermining the overall coherence of the research.

Superficial Analysis: Without the guidance of theory, research may fail to uncover deeper insights into the phenomena being studied [333]. This can result in superficial analyses that do not fully address the complexities of sustainability challenges [334].

Limited Predictive Power: The absence of theoretical grounding limits the predictive power of research, making it difficult to anticipate future trends and outcomes [285,295,297,305]. This can hinder the practical applicability of research findings in real-world contexts

Fragmented Knowledge: Studies that do not utilize theory contribute to a fragmented body of knowledge [335]. This hampers the ability to build on existing research, as findings are not anchored in a common theoretical foundation [336].

Comparative Analysis

A comparative analysis of the literature reveals that a significant percentage of studies in sustainable CPM 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 [307].

Implications for Transdisciplinary Research

The reliance on theory in the literature underscores the importance of a structured approach to transdisciplinary research [42,53,70,72,85,337]. 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 [42,53,70,72,85,337]. 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 [302]. The integration of bibliometric methods, as demonstrated in this study, serves as a foundational step towards identifying and synthesizing dominant theories, leading institutions, and influential authors. In its current state, the process is faster than other methods for reviewing literature for theory to develop an understanding of phenomena; however, an update to VOSviewer and Scopus would serve this study's methodology [44,45,280-284]. This comprehensive approach will enrich the theoretical landscape and drive the future of sustainable CPM.

Conclusion

The Crucial Role of Theoretical Frameworks in Sustainable Construction Research

This study underscores the critical importance of integrating theoretical frameworks into research on sustainable CPM. 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 utilize 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 CPM. The findings of this study emphasize the need for continued emphasis on theory-driven research to foster innovative solutions and sustainable practices.

Advancing Informetric Science through Bibliometric Theory Visualization

The integration of bibliometric methods in this study serves as a foundational step towards identifying and synthesizing 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 CPM.

Recommendations

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

Furthering the Development of Sustainability Focused Theory

1. **Promote Theory-Driven Research:** Encourage researchers to systematically employ theoretical frameworks to guide their investigations. This approach will enhance the coherence and depth of their analyses, providing more robust and generalizable findings.
2. **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.
3. **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.
4. **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.
5. **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.

6. Encourage Publication in Leading Journals: Researchers with a propensity to utilize 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.

Addressing Sustainability through Novel Bibliometric Insights

1. To effectively amalgamate interdisciplinary insights from bibliometrics to promote sustainability, the following mechanisms and strategies can be employed:
2. Cross-Disciplinary Workshops and Seminars: Organize regular workshops and seminars where researchers from different disciplines can present their findings and discuss potential intersections. These interactions foster mutual understanding and collaboration.
3. Interdisciplinary Research Teams: Form research teams comprising experts from various fields such as engineering, environmental science, economics, and social sciences. These teams can work on joint projects that address complex sustainability issues from multiple perspectives.
4. Integrated Research Frameworks: Develop integrated research frameworks that explicitly combine theories and methodologies from different disciplines. This structured approach ensures that diverse insights are systematically incorporated into the research process.
5. Collaborative Publications and Grants: Encourage collaborative publications and joint grant applications. Co-authored papers and shared funding initiatives can bridge disciplinary divides and promote the synthesis of interdisciplinary knowledge.
6. Utilization of Advanced Analytical Tools: Employ advanced analytical tools such as VOSviewer and other network analysis software to visualize and analyze the connections between different theoretical constructs. These tools can highlight the synergies and gaps that need to be addressed.
7. Policy and Practice Integration: Translate interdisciplinary research findings into practical strategies and policies. Engage with policymakers and industry practitioners to ensure that the insights gained from bibliometric analysis are applied to real-world sustainability challenges.

Limitations

This study acknowledges several limitations inherent in the application of bibliometric methods to assess interdisciplinary and transdisciplinary theories within CPM. First, bibliometric analysis primarily focuses on quantitative metrics, which may not fully capture the qualitative depth of theoretical contributions. To address this limitation, the study integrates qualitative evaluations of key theoretical constructs and their practical applications, ensuring a more comprehensive understanding of the research landscape. Second, the analysis of citation patterns may be influenced by temporal biases, as newer publications have less time to accrue citations. The study compensates for this by considering the context and impact of recent works through supplementary qualitative thematic analysis. Lastly, the study recognizes that bibliometrics does not inherently assess the non-academic impacts of research. By emphasizing the practical applications of identified theories and fostering stakeholder participation, the study aims to

bridge the gap between academic research and real-world implementation, ensuring that theoretical advancements contribute effectively to sustainable practices in CPM.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Data Availability Statement

The secondary data utilized in this study was obtained from the Scopus database, a comprehensive and widely recognized 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.

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