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Review

Sustainability and Digital Transformation within the Project Management Area: A Science Mapping Approach

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Abstract: Although many studies have focused on digital transformation and sustainability within the realm of project management, there has been a lack of research that comprehensively reviews the current state of the art of the aforementioned subject using a holistic approach. This oversight hampers the amalgamation of DT and sustainability in project management, waning the steps to be taken for the realisation of a smart and sustainable built environment. To fill the identified knowledge gap, this study presents a science mapping approach to meticulously examine the literature published on DT and sustainability within the realm of project management. In doing so, a bibliometric review together with a comprehensive Scientometric mapping analysis was carried out on the literature published from 2011 to 2022. The findings obtained in this study provide insightful accounts for both project managers and academics. Project managers are not only enlightened on revamping their business models but are also given insights into utilising digital strategies for bringing the maximum level of sustainability into their projects. Meanwhile, researchers are given insight into the emerging trends, timelines, and emerging streams that will be explored in future endeavours.

Keywords: sustainability; digital transformation; project management; bibliometric review; science mapping

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1. Introduction

Several studies have investigated the process changes in projects related to new digital technologies and digital transformation as part of the analysis of the development of project management as a distinct field of knowledge [1]. While the former refers to the utilisation of cutting-edge technologies for managing relevant projects in a better way (such as the Internet of Things, artificial intelligence, big data, cloud computing, robotics, etc.), the latter denotes a paradigm shift from traditionally managed projects to the technology-oriented ones [2,3]. DT is basically defined as incorporating digital technologies into a company's business processes [3]. In current discussions, DT projects use new technologies to change organisations' workflows to enhance operational efficiency and facilitate better decision making [4]. Warner and Wäger [5] contend that digital transformation [1] entails more than just utilizing digital technology; it involves executing a creative strategy and overhauling business models to meet the needs of new markets and achieve a competitive edge. Hence, it is crucial for project managers to comprehend how to effectively manage projects to leverage the advantages of digital technology and reconsider business models when they embark on implementing digital strategies. Although organisations apply digital strategies to challenge the status quo in their transitional period, around 66% to 84% of DT projects fail [6]. This is because the process of transforming traditional projects to DT projects is

fraught with uncertainty and has high interdependency stemming from their occurrence order, complicating the decision making process of DT projects' portfolio selection [7] and strategy execution. One of the reasons that project managers implement poor strategies is that they do not pay sufficient attention to sustainability.

With the above in mind, sustainability combines social, environmental, and economic responsibility to rationalise the use of current resources and provide an better life for future generations [8]. Many companies have adopted sustainability as part of their mission statements and strategic plans. However, the definition of sustainability barely applies to current needs and gives little guidance on technologies and resources to help determine preferences in programs or projects [9]. To build on the relationship between sustainability and project management, it is vital to move beyond the original definition, considering processes and techniques from the perspective of projects [10]. Among various perspectives, Chen [11] illustrates that DT is one factor that efficiently improves project sustainability performance. DT and sustainability complement each other. For instance, the use of technologies minimises the waste generated in a construction project, or the use of smart sensors for heating and cooling installed inside buildings improves the social aspect of the sustainability pillar (that results from residents' improved quality of life).

Moreover, project managers focus on rebuilding business models to maximise the impact of their DT strategy and rise to the challenge of approaching sustainability in project management [12]. It integrates the diverse perspectives on strategy and the relationship between a firm's strategy and performance by building on the theoretical traditions of business strategy [13]. Nonetheless, within digital economy and in the DT process, new business models have been given excessive commercial profit-grabbing functions by companies, negatively impacting society and neglecting the sustainability of projects [14]. As a result, scholars are exploring various business model elements in order to develop a framework for defining business models that cater to specific solutions. This is an emerging topic with few results, so the science mapping approach is applied in this research project to specify the various correlations between DT, sustainability, and business models in the context of project management based on the literature.

Though some studies have focused on DT and sustainability within the realm of project management, there has been a lack of research that comprehensively and holistically reviews the current state of the art of the aforementioned subject. Notwithstanding the essential criteria required for a successful project, sustainability and DT have been treated separately, as if they are two different themes with no points of intersection. Sustainability and DT do share common points in realising successful projects. The reduced environmental burden resulting from utilising digital technologies (to facilitate collaboration and data exchange among the stakeholders involved in a project) is the epitome of this interconnection. Having said that, to the best of the authors' knowledge, there has not been a review that compiles the published sources in each of these themes and analyses them in holistically. To fill this gap, this review paper aims to combine the two research streams of DT and sustainability to enable the successful delivery of projects. To this end, a science mapping review approach is employed to analyse topics and trends that shed light on the future of project management research. The findings obtained in this study provide insightful accounts for both project managers and academics. Project managers in particular are facing challenges in revamping their business models or designing digital strategies for sustainable projects, and scholars similarly need insights into the emerging research streams and the existing gaps in research. Thus, producing a review paper on the interconnection of DT and sustainability in the area of project management can ease off the said intricate concerns. In a nutshell, the contributions of this paper are as follows:

(1) Unveiling the trends of publications over the selected period;
(2) Uncovering the leading authors, countries, and institutions that contribute to this paper's area of interest;
(3) Unveiling co-citation analyses, networks, and timelines in the corpus of the literature;
(4) Uncovering co-occurrence-related analyses;

(5) Delineating the gaps that exist in the relevant literature, as well as the corresponding future endeavours to be taken into account.

The remainder of the paper is as follows. Section 2 provides a contextual background related to DT, sustainability, their intersection, and science mapping; the steps of the review approach are expounded in Section 3. Section 4 elucidates the results of the analysis undertaken and discusses the obtained findings. Section 5 expounds on the limitations of this review and future research directions. Finally, the conclusions drawn from this review are provided in Section 6.

2. Contextual Background

This section firstly elaborates on the application of DT and sustainability in the field of project management alone, followed by expounding on the linkage between each and the field of project management. Finally, a brief introduction to the science mapping approach and its application is provided.

2.1. Digital Transformation in Project Management

DT has enabled a high-quality user experience and has changed businesses' outcomes and management. Business management encompasses project management, which is the application of processes, principles, methods, and techniques to manage objectives effectively and clarify projects in an organisational context. However, many organisations in DT projects usually do not pay enough attention to the project management methods, failing to project transition. A DT project can be moved forward quickly by keenly observing the rules and regulations of a DT project [4].

Berghaus and Back [4] believe that the organisational culture and the employees' expertise minimise the chance of DT projects' failure. The organisational culture has been strengthening its commitment and enhancing employee consistency to help employees use new technologies and understand what is more important. Firstly, employees should be able to embrace new technology in the workplace, meaning staff have to be given time to focus their efforts on higher-value work and seize opportunities in changing environment. Secondly, Matt, Hess and Benlian [4] point out that the improved collaboration between employees or third parties is a critical factor that drives the success of DT projects. Instead of letting employees work individually, they have been allowed to use digital tools to address many of their collaborative needs. Project managers should highly value cross-functional collaboration in projects because employees gain better insight and spur innovative ideas during co-opetition. Furthermore, the projects that do transform digitally have been creating highly engaged customers.

Maintaining and improving customer relationships is becoming increasingly important [4]. As a result of the transition from traditional to digital projects, project managers are under pressure to implement project changes. It is a modification of the work scope, including specifications, project delivery, project roles, and schedule. Management changes during project delivery to meet customer needs and enhance their experience has become a critical factor for success in DT [4]. Because of improved digital technology, DT projects enable the upgrading of communication channels and product innovation to meet customer needs or change the customer experience.

In addition to focusing on customer relationship management, project managers should also consider how to provide an effective workplace while engaging in DT. During project operations, systems and processes become more efficient, and the performance and profits of the business are enhanced [4]. However, in an accelerating market environment, the response of resource-based organisations decreases due to inertia. Consequently, project managers need to find new strategies to reduce project costs through task automation and the increased operational capacity of digital technology [4].

Creating new strategies has been associated with reshaping existing business models, aiming to deliver core business services in new ways, driving revenue growth, and expanding customer outreach through various channels [4]. Nevertheless, managers may neglect

to build a successful platform business model and an associated ecosystem, which is one of the reasons for the failure of DT projects. A project seeking to maximise the impact of DT should consider the project's sustainability [4].

2.2. Sustainability in Project Management

Many organisations increasingly focus on sustainability in their projects, and the published literature on sustainability has grown. However, the studying the intersection between sustainability and project management is still rare, with little research focusing on both topics [5]. Moreover, there are few empirical assessments of the relationship between project sustainability management and success through a review of the previous literature [5]. The success factors for sustainable projects have been hardly defined, so several impact factors of managing projects' sustainability are presented.

A variety of impact factors are viewed through different perspectives, which have been divided into internal and external perspectives. Carvalho and Rabechini Jr. [5] believe that the internal perspective relates to the life cycle of the project and the external perspective concerns the social and environmental determinants of the project.

In terms of internal perspectives, aligning project management and sustainability principles begins with the project's life cycle management [5]. The life cycle is a critical component of sustainability policies, businesses, and projects. All sustainability elements related to projects, which have been identified and included in this review, are life-cycle-oriented fields [5]. Several key factors influence the sustainability of a project, including the economic benefit of a project, the use of project resources, the project environment, and the technical progress in a project [6].

Regarding the external perspective, most scholars have been more concerned with the link between sustainability and environmental impacts. Rapid economic growth, accelerating urbanisation, and growing energy consumption come with inherent environmental issues, leading academics to update conceptual frameworks or ecological designs to tackle such problems [5,7]. In contrast, relatively few scholars have focused on the progress towards social sustainability. However, some scholars in the construction and public sectors have proposed identifying social sustainability indicators, which include the culture, accessibility, participation of all actors, security, public utility, etc. [8].

Similar to specifying the impact factors for managing project sustainability from internal and external perspectives, some scholars consider the environmental, social, and economic aspects concurrently while designing research frameworks. The four elements that involve the strategic and tactical views recognised by many scholars are presented by Carvalho and Rabechini Jr. [5]. This includes a sustainable innovation business model, stakeholders' management, economic and competitive advantage, environmental policies, and resource saving. Furthermore, Marcelino-Sádaba, González-Jaen and Pérez-Ezcurdia [5] propose five factors for managing the sustainability of projects, including product, process, commitment, training, and the awareness of people. Each of these factors takes into account environmental, social, and economic considerations. For example, sustainable project products have been positioned as eco-design products in the environmental dimension, eco-policy in the social dimension, and perhaps as ISO compliance products in the economic perspective. In seeking to maintain the projects' sustainability, DT can also accelerate sustainability. As seen in the previous section, DT and sustainability complement each other, as opined by [9,10].

2.3. Sustainability and Digital Transformation

Sustainability and DT are integrated mutually into projects' present and future development. An increasing number of managers are focusing on sustainability and incorporating this concept into the daily routines of their organisations using digital tools [11]. Likewise, DT can also assist organisations in assuming their responsibilities toward society, including environmental, social, and economic responsibilities toward all stakeholders [11]. Although several managers have been paying attention to sustainability and DT, there is not

much research on how to contribute to the success of a company's transformation through these two elements. In this context, it can be anticipated that how a company or project can be transformed is a little-known conceptual framework for companies. DT needs new competitive rules, which emphasise the necessity of adaptation to meet the demand for sustainability in the digital world [11]. Therefore, companies' reactions to transformation are dependent upon their familiarity with the business sustainability concept and practice, while the tools that are being used in DT, along with the lessons learned, can help develop the required skills.

To build an eco-friendly living environment and a technologically advanced society, organisations need to think about how sustainability can be effectively linked to their business strategies in the DT process [12,13]. Thus, managers have been embarking on a restructuring of business models, which the evolution of technology will influence, to ensure long-term project sustainability when implementing a digital service-oriented policy [11].

2.4. Science Mapping

The investigation and application of science mapping have been developing rapidly in recent years. With the advancement of information technology, the field of citation analysis and visualisation has gained more attention from scholars. New techniques are being applied to the visual analysis of documents, patents, and other types of information, ultimately yielding many new research results [11]. Many scholars have also provided further theoretical and technical support to the field of science mapping [14–16].

The science mapping approach is mainly used to organize the history of the discipline and to analyse the reasons behind social phenomena; it has also been used as a statistical tool for documentation within a field of research [11]. However, the merits and limitations of the scientific mapping approach are generally related to the software tools selected for this research project. To fully understand the benefits of the science mapping approach, analysts and end users should identify the principles of science mapping software tools and use them to interpret the results [11]. With the increasing number of tools available for the science mapping approach, CiteSpace was chosen as the software tool for this research project after comparing several relevant software tools on performance, data algorithms used, compatibility, and literature formats.

3. Methodology

This study comprehensively reviews the existing literature on the exploitation of DT and sustainability in project management. In doing so, a bibliometric review using a science mapping approach is undertaken, as explained in detail in [17]. The bibliometric review refers to a comprehensive search tool for finding the relevant sources for achieving the specified objectives [18]. Additionally, the science mapping review approach comprises several elements, including various types of scientometric analysis and visualisation tools [18]. For the sake of brevity, the readers can refer to the following references for an in-depth understanding of bibliometric analysis [19–21]. Figure 1 illustrates all the steps taken in this study to realise the specified objectives.

3.1. Keyword Searching

By formulating the research objectives, it has become imperative to develop a set of reflective keywords for finding a comprehensive list of published sources related to the topic under investigation [18]. In doing so, different combinations of the following keywords were considered: "sustainable project", "green project", "green construction", "sustainable building", "smart project", "sustainable infrastructure", "digitalisation", "digitalised project", and "digital transformation". Notably, the main reason for selecting these words lies in the fact that they reflect on the interconnection of DT and sustainability streams within the realm of project management. In this regard, operators (AND/OR) were used to

form a comprehensive search query. Notably, the extraction date for searching the relevant papers from the said databases was between 1 June 2022 and 15 August 2022.

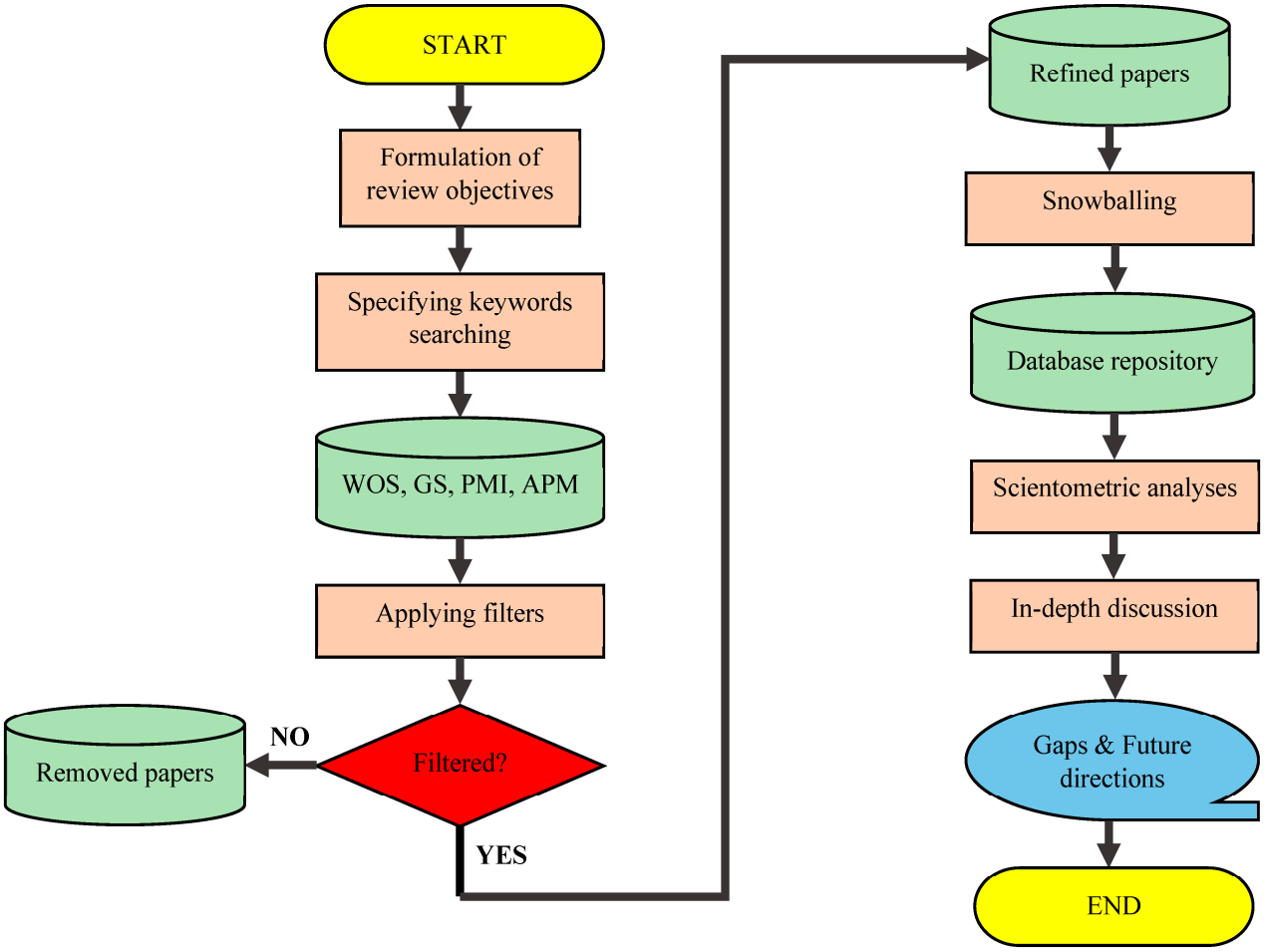

Figure 1. The review framework.

3.2. Search Engine

To find a prudent and comprehensive list of papers relevant to the goal of this study, selecting the appropriate database repositories is very important [18]. In this regard, one of the most inclusive databases is Web of Science (WoS); as noted by multiple researchers, it is one of the most commonly used search engines because it includes numerous articles from different publishers in diverse disciplines (including journals, conference papers, newspapers, reports, books, etc.) [18]. In addition, Google Scholar [12] was also taken into account in this review paper, since it covers a wide variety of published sources, including dissertations, articles, books, and conference papers [18]. Additionally, two famous professional search engines in the realm of project management—namely PMI (Project Management Institute) and APM (Association for Project Management)—were taken into account in this study. We only considered high-quality journal papers (Q1-ranked papers) in our review, and accordingly, other types of intellectual properties were not collected. The main reason for excluding Scopus lies in the fact that Scopus provides more accurate search results for non-English publications, whereas Web of Science's non-English coverage is somewhat limited. Likewise, the Web of Science is often considered more reliable for citation analysis, as it has a longer history of indexing citations and provides more detailed citation data.

3.3. Refinement of Relevant Papers

By retrieving the relevant materials from the literature, several filters were considered for the exclusion of irrelevant papers, including the date of publication (which had to be from January 2011 to August 2022); the scope of the found publications (which had to be related to the areas of engineering, business, and management), and the language of the publications (which had to be English). Afterwards, as opined by [18], the snowballing technique for enlarging the retrieved sample size was applied to this review paper. Following this, the relevant papers were refined for further consideration, and accordingly, the irrelevant ones were removed. Notably, the interconnection of DT and sustainability streams within the area of project management had not received attention from researchers until 2011 (Q1 journals); thus, this range was considered for selecting the relevant papers from the literature. It is also important to note that the emphasis for reviewing the literature was placed on technical journal papers and industrial reports.

3.4. Data Analysis

After retrieving the metadata for the selected documentation, the appropriate software tool should be chosen for automatically converting and analysing the relevant studies. In this state-of-the-art study, CiteSpace was used for the following reasons. CiteSpace is a freely available tool used to visualise and analyse the critical paths, thematic evolution, and trends of scientific publications [18]. Although the data pre-processing of CiteSpace is more complex than other software, this process ensures the validity and reliability of the data, and this software tool offers significant advantages in terms of comprehensive functionality. In addition to the extraction of various bibliometric networks and the use of multiple analysis methods, CiteSpace has great advantages in terms of database and data visualisation. Notably, the Citespace software cannot process more than one language. In addition, the vast majority of journal papers is in English, and the research team is proficient in English. Due to all these reasons, we used English as a working language to effectively extract and analyse documents. For data visualisation, the network nodes in CiteSpace express the number of occurrences and node centrality, which reflects the importance of the node in the network connection. Furthermore, CiteSpace's time-domain plots better reflect the characteristics of the study over time. Therefore, CiteSpace was chosen as the software tool for science mapping for this research project. Notably, the reasons for selecting CiteSpace instead of VOSviewer are as follows. First, CiteSpace is a highly customizable tool that specializes in detecting and visualizing intellectual turning points, trends, and patterns of the scholarly literature. Second, it is particularly useful for identifying emerging research areas, identifying influential authors and publications, and mapping co-citation and co-authorship networks. Third, CiteSpace also provides advanced features for exploring and filtering data, such as time slicing, keyword filtering, and cluster analysis; however, CiteSpace has a steeper learning curve than VOSviewer, and its advanced features may require some technical expertise to be used effectively. Furthermore, CiteSpace is preferred by researchers who require advanced features for detecting and visualizing intellectual turning points and trends.

4. Analysis and Discussion

This section provides the results of the analyses conducted in this study, as well as the related interpretations.

4.1. Analysis of Publications Chronological Distribution

The chronological distribution of the literature reflects the relationship between time and the number of published papers, revealing the current status and forecast trends in this research field. The number of published papers related to project management, DT, and sustainability during the 11 years from 2011 to 2022 is shown in Figure 2. It illustrates the low number of publications with no fluctuation from 2011 to 2015. A significant upward trend can be observed since 2015, although a decline begins in 2022 because the number of

articles published this year has not yet been fully counted. The upward trend indicates that more academics are focusing on using DT in project management and have built awareness of sustainability.

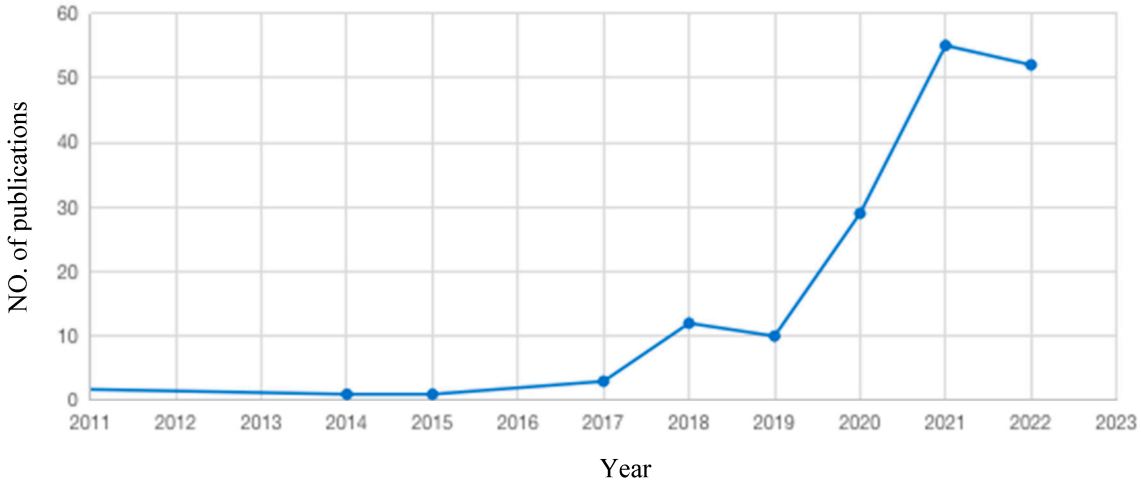

Figure 2. The trend of publications over this review study.

4.2. Geographical Distribution

The country distribution analysis and country collaboration network are other ways of explore development in project management, DT, and sustainability. The results of the country distribution analysis can be seen in Tables 1 and 2, which depict the top 10 countries based on frequency and the top 10 countries based on centrality. Frequency is the number of publications at a certain citation number, and centrality identifies the boundary-crossing potential that could result in transformative discoveries [19].

Table 1 shows the ten countries with the highest frequency in this research field, and the Peoples' Republic of China tops the list with 38 publications. Other countries with a high frequency are England, Germany, and the USA. The hotpots of project management, DT, and sustainability research show a regional imbalance; more researchers in Europe have focused on this topic, represented by England, Germany, Spain, Italy, Portugal, Sweden, and Russia. Although Asia is in second place, countries in Asia have been introducing new digitalisation offers and applying them to project management faster than countries in Europe [20], so the gap in the number of publications will gradually shrink. The analysis of the number of publications alone does not give a clear visualisation of the core countries involved in this field of research. Centrality in CiteSpace is a graph-theoretic concept used to quantify the importance of a point's position in a network.

Table 1. Top 10 countries based on frequency.

Country	Frequency
China	38
England	20
Germany	20
USA	17
Spain	14
Italy	14
Portugal	11
Sweden	8
Russia	7
Austria	6

Table 2 demonstrates ten core countries based on centrality in descending order. The betweenness centrality scores are normalised to the unit interval of [0, 1]. This research project defines countries with a centrality greater than 0.05 as core countries that concentrate the research on DT, sustainability, and business model. Tables 1 and 2 show a strong positive correlation between frequency and centrality, where the countries with more publications also rank highly in terms of centrality. There is an exception, as Saudi Arabia is not in the top 10 countries based on frequency but is in fourth place with a high centrality of 0.17. This indicates that the country's research on DT and sustainability projects is limited but highly influential.

Table 2. Top 10 countries based on centrality.

Country	Centrality
USA	0.34
China	0.31
England	0.25
Saudi Arabia	0.17
Germany	0.15
Sweden	0.14
Italy	0.08
Austria	0.07
India	0.06
Spain	0.05

Once the data analysis was performed in CiteSpace, the visualisation was selected. The node display type chosen for this research project is the tree-ring history, whose size reflects the frequency, and the ring of the node represents the number of citations in a given year [22]. The wider the ring for a specific year, the more the citations or the higher the frequency for that year. Moreover, purple rings indicate nodes with high centrality in the outermost area.

In terms of the country's collaboration network, the size of the ring highlights the frequency of the country's issuance. The colour indicates the year of publication, and the outer purple ring shows countries with high centrality. Collaboration between countries can be analysed by colour and links. The colour indicates when the two countries first cooperated; the strength of the links reflects the closeness of the collaborative relationship between countries.

As evidenced by the results shown in Figure 3, the network of collaborating countries consisted of 58 nodes and 137 links between 2011 and 2022. The visualisation of the top 10 countries based on frequency and centrality is consistent with the results in Tables 1 and 2. The ten countries have primarily established cooperative relationships, as indicated by the lines' colours, in the past five years. Compared to other countries, Germany collaborated with the USA, China, and Portugal earlier in 2014, and has close relationships with them. As time progressed, the countries in Europe collaborated more closely with each other, while there was not so much collaboration among the countries in Asia. The country collaboration network shows that the topics of DT and sustainability projects have attracted scholars from various countries to collaborate in recent years. Therefore, the next section will investigate the authors involved in DT and sustainability projects.

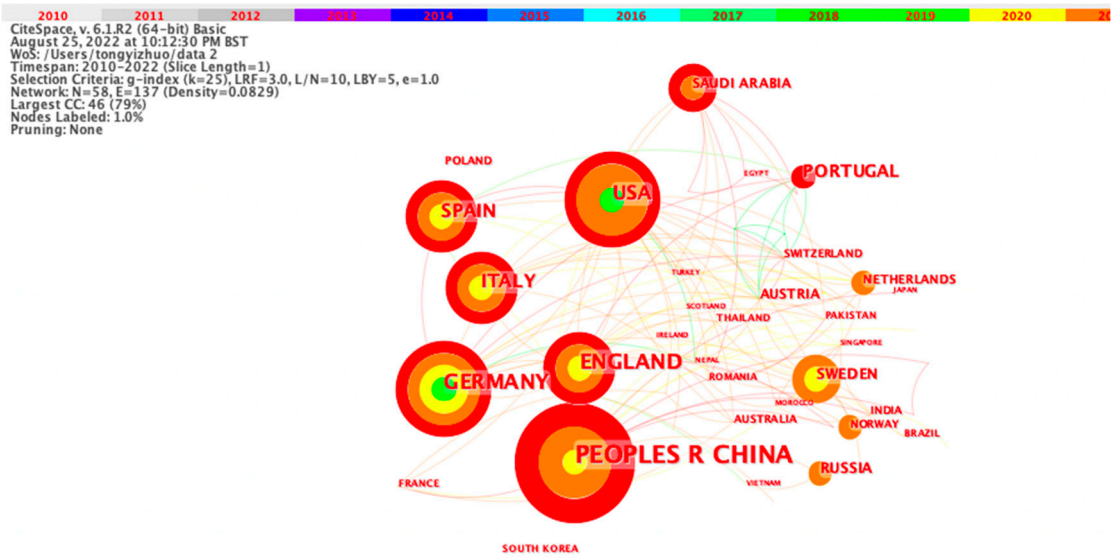

Figure 3. The country's collaboration network.

4.3. Leading Authors

In this sub-section, the following analyses are provided: the list of the most prolific authors (see Table 3), author collaboration network (see Figure 4), the author co-citation network (see Figure 5), and the most cited authors (see Table 3).

Table 3 shows the authors with the most publications in a particular year. As can be seen, the frequency of two publications in a year was set out as a threshold value, based on which it is observed that there are eight authors who have the highest number of publications in a year.

Table 3. Top 8 authors based on frequency.

Author	Frequency	Year
Wang J	2	2022
Li K	2	2021
Wang X	2	2022
Wang S	2	2021
Madureira R	2	2022
Galleo S	2	2022
Codina R	2	2020
Matos F	2	2020

Figure 4 reveals that there are 155 nodes and 173 links in the author collaboration network. After the clustering algorithm in CiteSpace, the modularity is 0.8529, and the mean silhouette is 0.8951, representing good reliability and validity. The network for the project management, DT, and sustainability areas shows an overall fragmentation. Most clusters of the network lack strong connections among themselves, despite a large number of participants. This illustrates that more scholars have been working on DT and sustainability projects in recent years, but they have not been collaborating frequently. Apart from a few scholars collaborating in this field in 2017, most of the collaborations have occurred in groups of three or four in recent years. Additionally, Asian authors collaborated with Western authors relatively infrequently; they tend to collaborate more with local authors. Differences in DT and sustainability projects across geographical areas [21], regional constraints, and cultural differences between East and West may lead to the problems described above.

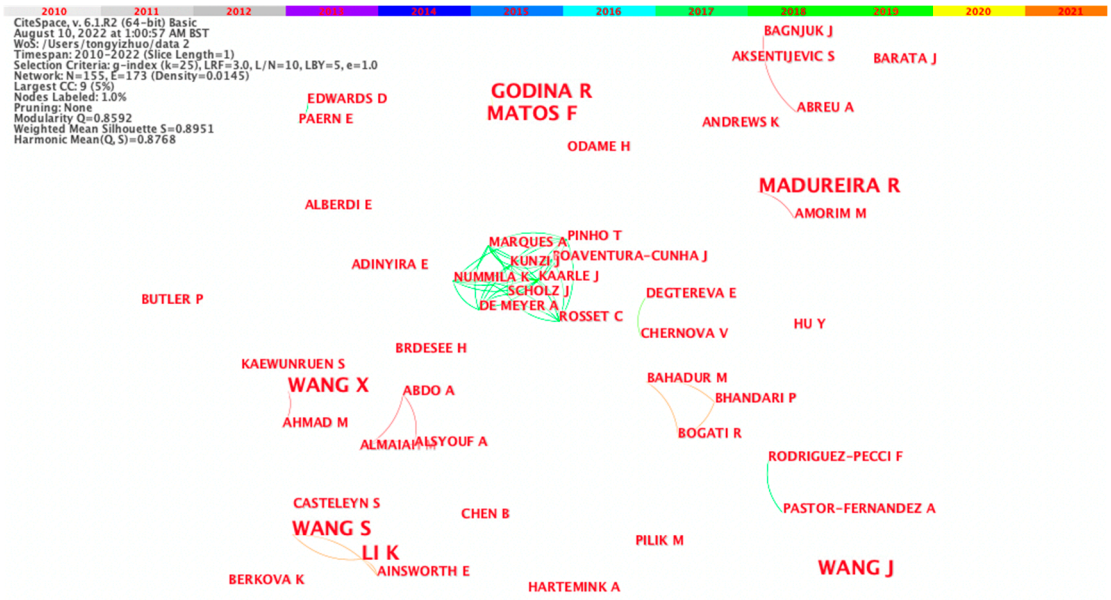

Figure 4. The authors' collaboration network.

Author co-citation analysis refers to two or more authors citing other authors simultaneously, but it relies on a simple co-citation count and does not consider the content of the citations. The network allows the identification of influential scholars, and the clustering analysis provides insight into the distribution of similar research topics in this field. To offer a more comprehensive outlook on the general distribution of author co-citations and core authors in the research domain of project management, DT, and sustainability, visual representations of the author co-citation network and the top 10 most frequently cited authors are generated. This provides additional insights into the research area and enhances the understanding of the relationships between various authors and their contributions to the field.

The top cited author is Yin RK, with a score of 16 in frequency and 0.02 in centrality. According to Figure 5, he mainly explores digital technology in the field of DT and sustainability projects. In comparison to Table 2, the top 10 most productive authors and the top 10 most cited authors are not correlated with the top 8 most influential authors. Table 4 shows fewer authors from Asia and more authors across the country compared to Table 3, indicating that Asian authors are committed to publishing DT and sustainability project articles, but the frequency of citations is not proportional to the number of publications. Thus, scholars must focus on the publication numbers and the quality of their articles to increase their influence in the field of DT and sustainability projects.

Table 4. Top 10 most cited authors based on frequency.

Author	Frequency	Centrality	Author	Frequency	Centrality
Yin RK	16	0.02	Eisenhardt KM	7	0.19
Porter ME	10	0.00	Dubey R	7	0.01
Liu Y	9	0.01	Frank AG	7	0.07
Vial G	8	0.01	Hess T	7	0.01
Jabbour ABLD	7	0.05	Oecd	6	0.03

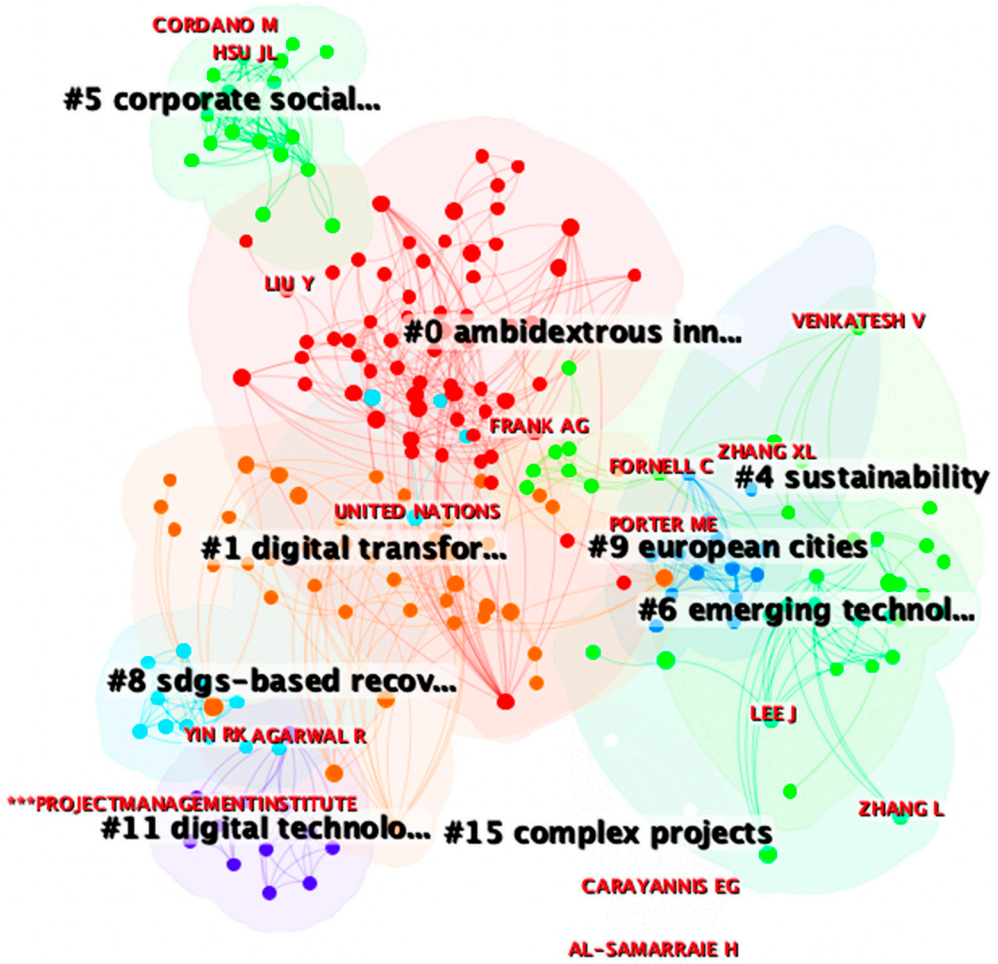

Figure 5. Author co-citation network.

4.4. Leading Institutions

Similar to the contributing authors' analysis of sustainability projects in DT, the analysis explores the institutions that have researched the field more intensively from a meso perspective. Core institutions were identified based on the frequency of publication (Table 5), and the contribution of institutions in the research area of this discipline was explored based on the visualisation of each institution's collaboration network (Figure 6). It is noteworthy that in a scientometric review paper, frequency analysis can be used to identify the most productive institutions within a field of study. The analysis can be conducted at different levels, such as the number of publications or the number of citations. By comparing the frequency of publications or citations for different institutions, it is possible to identify which institutions are the most active in a particular field. In a scientometric review paper, frequency analysis can be used to identify the most productive institutions within a field of study. The analysis can be conducted at different levels, such as the number of publications or the number of citations. By comparing the frequency of publications or citations for different institutions, it is possible to identify which institutions are the most active in a particular field.

A preliminary demonstration of the number of publications by different institutions is provided in Table 5. The frequency of publication also shows that sustainability in DT projects is a relatively new topic; the University of Aveiro ranks first on the list, with only three publications in 2022. The other nine institutions have published two relevant articles in the last four years. Most of these research institutions are university institutions, which suggests that university and educational institutions dominate most research sites for project management, DT, and sustainability. In addition to prestigious universities, CSIRO

Land and Water has produced knowledge on DT and sustainability projects. CSIRO Land and Water is an organisation that focuses on delivering biophysical and socioeconomic outcomes across land, water, and ecosystems. This illustrates that sustainability projects in DT are a broad research topic, and that collaboration between institutions is shown in the next section.

Table 5. Top 10 institutions based on frequency.

Institution	Frequency	Country	Year
Univ Aveiro	3	Portugal	2022
Graz Univ Technol	2	Austria	2018
CSIRO Land & Water	2	Australia	2021
Chinese Culture Univ	2	China	2019
Inst Univ Lisboa ISCTE IUL	2	Portugal	2020
Univ Portucalense	2	Portugal	2022
Natl Distance Educ Univ UNED	2	Spain	2022
Swiss Fed Inst Technol	2	Switzerland	2022
Natl Kaohsiung Univ Sci & Technol	2	Taiwan	2021
Xian Jiao Tong Univ	2	China	2021

Figure 6. Institutions collaboration network.

Figure 6 shows that 143 institutions and 95 collaboration links were formed between 2011 and 2022. A relatively loose structure and fewer close relationships indicate that this research community is relatively young. Combined with Table 4 and Figure 6, most institutions collaborating are core institutions with higher frequency, and cross-country collaboration still accounts for a portion of the limited cooperation. Although The University of Aveiro, the University Institute of Lisbon, and Portucalense University are situated in Portugal, other institutions cooperate with each other from different countries. For instance, the National University of Distance Education in Spain and Bayer AG in Germany established a cooperative relationship around 2021. Moreover, it is evident that the cooperation with green links among the Graz University of Technology in Austria, Chinese Culture University in China, Institute for Systems and Computer in Portugal, etc., started in 2014. In short, while the sustainability projects in DT are an emerging trend, as evidenced

by the number of publications, the analysis of countries, authors, and institutions, the cross-national collaboration between institutions is moving in a positive direction.

4.5. Co-Citation Analysis

Journal co-citation analysis provides a distribution of significant sources of knowledge in the field, enabling end users to understand which journals are cited in the field and the links between journals. Journal citations reflect the quality of articles in journals and provide a snapshot of their role and impact in the global research community. The following, therefore, shows the top 9 most cited journals based on their co-citation frequency (Table 6) and a visualisation of the journals' co-citation network (Figure 7).

Table 6 presents data on the top ten most cited journals that serve as sources for articles that collectively discussed project management, DT, and sustainability from 2011 to 2022. All of the journals listed are in Quartile 1 (Q1) lists, meaning that they are among the top 25% journals for at least one of their classified subdisciplines. While articles in this field have only been frequently discussed in recent years, these journals have been cited quite frequently. The journals cover a broad range of topics, including sustainability, business research, information management, and engineering management.

The three most highly cited journals are *Sustainability*, *Journal of Cleaner Production*, and *Technological Forecasting and Social Change*. These journals interconnect social, environmental, and economic sustainability. This initial indication suggests that the majority of high-quality articles related to DT and sustainability projects are from sustainability-focused journals. The two journals with the highest centrality are *Management Information Systems Quarterly* (0.12) and the *International Journal of Production Economics* (0.10). *MIS Quarterly* is a research journal, published quarterly, on information systems management and relevant technologies, while the *International Journal of Production Economics* focuses on issues at the intersection of engineering and management. To obtain more information, the core journals will be examined using the journal co-citation network.

Table 6. Top 9 most cited journals with co-citation frequency.

Journal	Frequency	Centrality
Sustainability	88	0.09
J CLEANPROD	54	0.05
Technol FORECASTSOC	46	0.06
J BUSRES	36	0.07
Int JPRODECON	34	0.10
Mis QUART	31	0.12
Harvard BUSREV	28	0.02
Int JINFORMMANAGE	26	0.07
Comput IND	26	0.05

By selecting the cited journal as the node type in CiteSpace, the imported journal information was debugged several times, and clustering analysis was performed to create Figure 7. In CiteSpace, the "*tf*idf*" algorithm was used to extract noun terms from the titles of the cited documents for naming the clusters, including #0 manufacturing sector, #1 IotT-enabled smart, sustainable cities, #2 functional area, #3 soil, #4 digital transformation, #5 first step, #6 transdisciplinary process, #7 smartphone crisis, #8 European cities, #11 digital technologies. The distribution of journals around Cluster #4, digital transformation, and Cluster #11, digital technology, is mainly on the environment, ecology, and information technology categories. DT and sustainability are closely related. The keyword-related analysis, through which we can explore the underlying relationship between DT and sustainability projects, is shown in the next section.

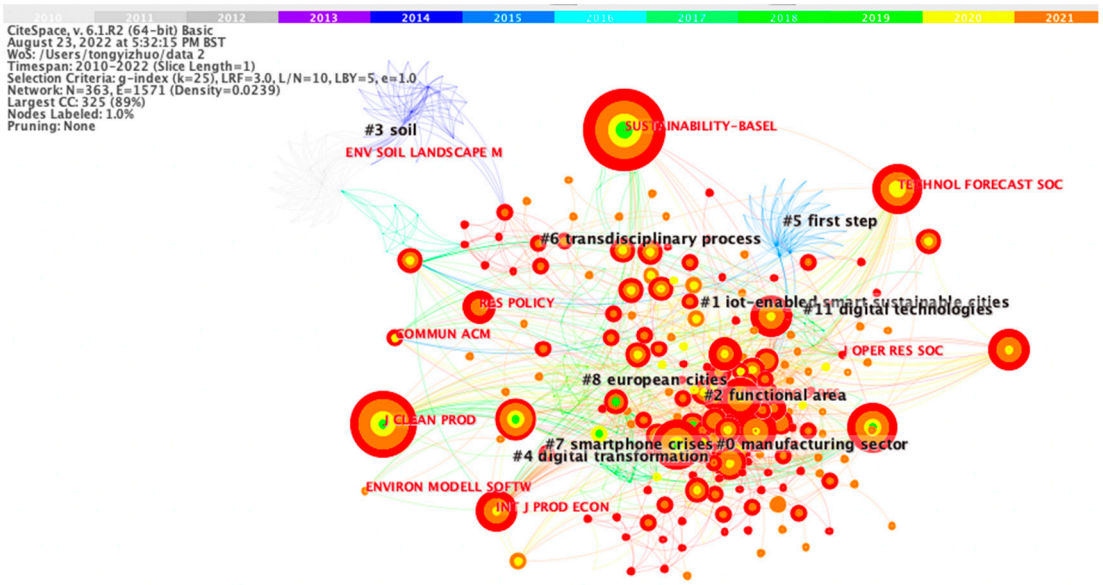

Figure 7. Journals' co-citation network.

The knowledge base for project management, DT, and sustainability can be analysed in the document co-citation analysis and journal co-citation analysis. Document co-citation helps identify scholarly communities that have received peer recognition by exploring patterns in different the literature. With the introduction of journal co-citation analysis, a dual-map overlay can powerfully visualise the association between the allocations of the cited and citing journals and, thus, enhances the transdisciplinary pursuit [23].

Document co-citation analysis is one of the most prominent features of CiteSpace, and was the first function to be theorised when CS was developed. Thus, this research project performs a timeline co-citation map of the document to analyse the relevant reference of sustainability projects in DT. By adjusting the fisheye slider in CiteSpace, one can observe from the timeline visualisation that there have been many publications in recent years. As seen in Figure 8, documents in the same clusters are positioned on the same horizontal line, with the specific time of the document at the top of the visualisation. An area where more studies are concentrated is considered more critical. Beyond this, the period of the document in the clusters can be seen on the map, further reflecting the temporal characteristics of the clusters.

The node display type chosen for the timeline co-citation map is the tree-ring history with 293 nodes and 864 links. The larger the ring, the higher the citation frequency of the nodes. It is clear that while the highest frequency of cited documents is between 2019 and 2021, the majority of the nodes in the visualisation is concentrated in 2021. It shows that the co-citation of documents on sustainability projects in DT has only frequently commenced, in the past two years. It is also a period of high growth in project management, DT, and sustainability research.

According to latent semantic indexing (LSI) on CiteSpace, cluster labels are generated on the right side of the visualisation. Clusters with dots mean that the data are too sparse to select meaningful features, and the largest cluster is Cluster #0, followed by Cluster #1. Figure 8 demonstrates that the relevant data are sparse and difficult to summarise, but exact keywords are available on CS, including DT, digital technology, sustainability, sustainable innovation, sustainable projects, lean management, business integration, stakeholder collaboration, etc. Those clusters are analysed in combination with the keyword visualisation in the next section.

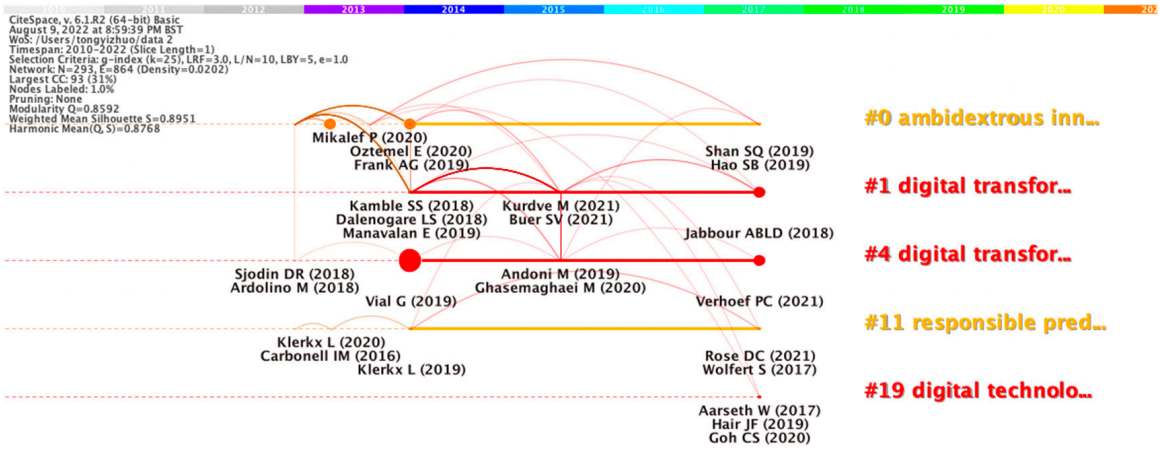

Figure 8. Timeline co-citation map of the documents.

4.6. Research Front and Emerging Trends

This section highlights keywords from the literature to identify research hotspots in project management, DT, and sustainability because the keywords represent a comprehensive summary of the article. Thus, a visualisation of the keyword co-occurrence network (Figure 9), timeline co-occurrence map of keywords (Figure 10), and top 10 keywords with the strongest citation bursts during the research history of sustainability projects in DT (Figure 11) are presented as follows.

Keywords with a higher frequency in the network are shown as larger nodes. Figure 9 shows 234 nodes and 909 links formed between 2011 and 2022. This can be observed by the size of the tree-ring history. Keywords with a higher frequency are "digital transformation", "innovation", "management", "system", "sustainability", "framework", etc. These keywords are not limited to project management, DT, and sustainability derivatives but also encompass terms from business, industry, and information technology. It follows that the diversification and gradual refinement of managing sustainability projects in DT will inevitably become a trend.

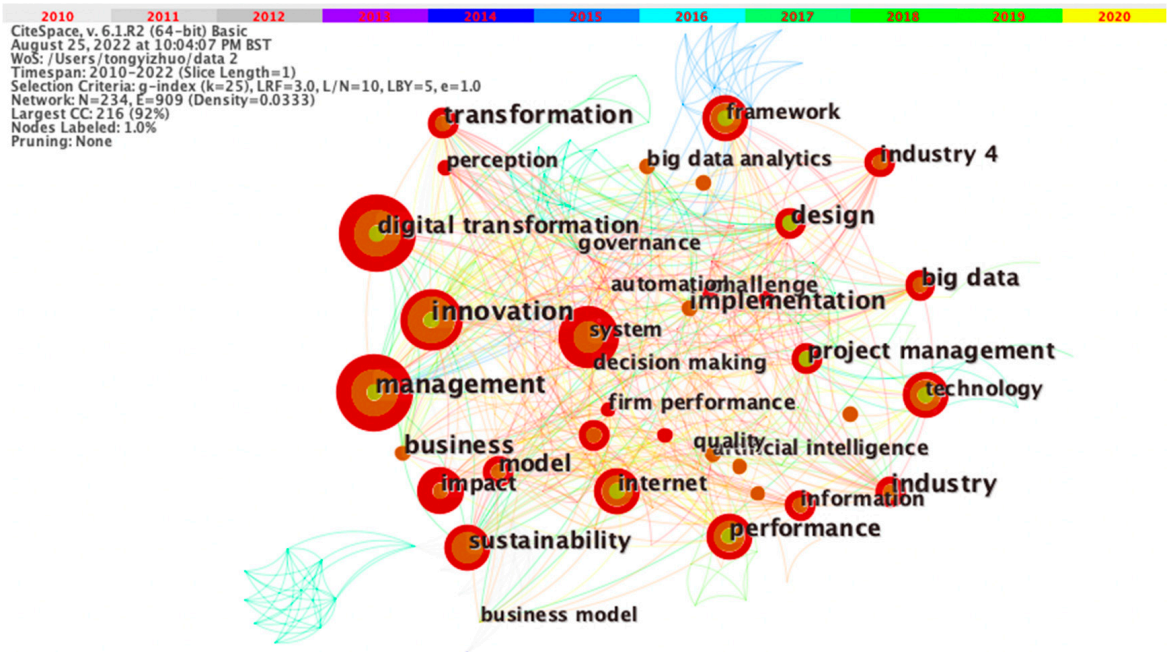

Figure 9. Keyword co-occurrence network.

To further investigate the change in hot topics in this review study, the CiteSpace was used to plot a timeline co-occurrence map of keywords. Similar to the observation in Figure 8, the horizontal axis indicates the year, the connecting link represents the co-citation relationship, the colour of the link signifies the year of publication, and the clusters are on the right side. According to the colour of the links, the research on Cluster #2 digital economy and Cluster #8 green technology started early in 2017. However, there has been increased interest in this area of research since 2021. Apart from that, all other keyword clusters have become hot research topics in the last two years. To better understand the keyword frequency rate of the changes, the figure of the top 10 keywords with the strongest citation bursts during the research history of sustainability projects in DT is shown below.

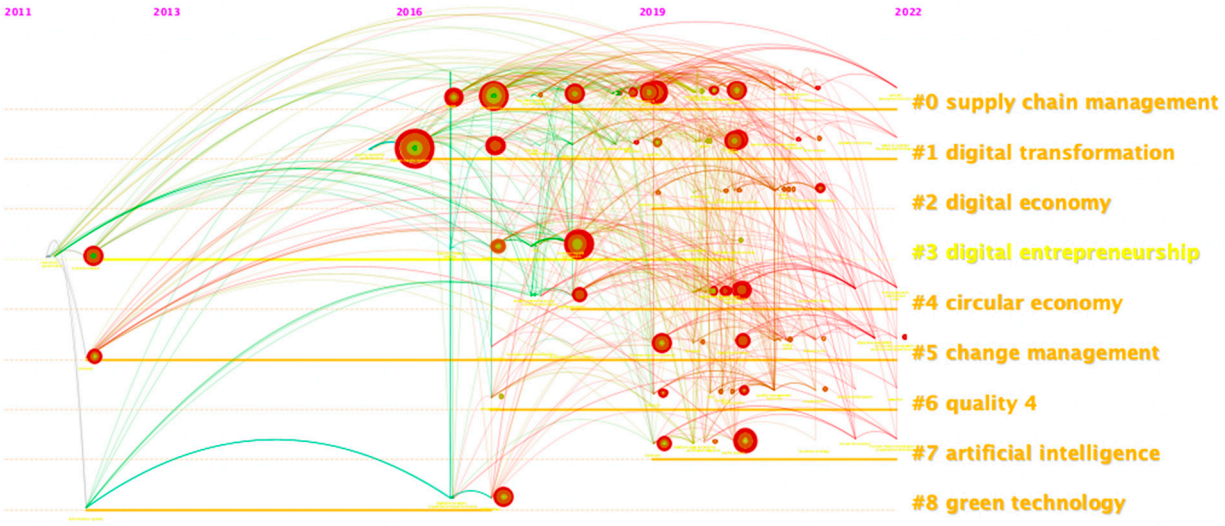

Figure 10. Timeline co-occurrence map of keywords.

Top 10 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2011 - 2022
information system	2011	1.75	**2012**	2018	
governance	2011	1.61	**2012**	2019	
stakeholder	2011	1.25	**2012**	2017	
digital innovation	2011	1.14	**2017**	2019	
challenge	2011	0.64	**2017**	2018	
business model innovation	2011	0.86	**2019**	2020	
framework	2011	1.03	**2020**	2022	
supply chain	2011	0.65	**2020**	2022	
product	2011	0.47	**2020**	2022	
tool	2011	0.47	**2020**	2022	

Figure 11. Top 10 keywords with the strongest citation bursts during the research history of sustainability projects in DT.

By using the burst detection technique available in CiteSpace, a word burst is identified as a higher-than-normal occurrence of a word, combined with the temporal distribution of its frequency. This not only indicates the frequency of a word but also predicts research frontiers and trends in managing sustainability projects in DT. This technique is helpful in identifying important and emerging topics that are gaining traction in the field, and can

assist in guiding future research in the area. The keywords with the most robust citation bursts, summarised in Figure 11, are information system, governance, stakeholder, digital innovation, challenge, business model innovation, framework, supply chain, product, and tool. Those keywords represent the research trends in DT, sustainability, and business models in project management. The period of keywords with the strongest citation bursts varies from 1 year to 7 years. In the group year 2012, the top keyword with the strongest citation bursts was an information system with a burst strength of 1.75, while the burst lasted for six years from 2012 to 2018. Six keyword bursts ended before 2020, and researchers focused on the framework, supply chain, product, and tool in the same year.

4.7. In-Depth Discussion

Based on the above results, outputs, and analysis, this sub-section discusses the findings on managing sustainability in DT regarding antecedents, processes, and outcomes. Although related keywords with a high frequency of occurrence have been explored earlier on, the discussion still focuses on the keyword-related visualisations, combined with the networks of countries, authors, and journals to identify similarities and discrepancies in theory when compared with previous studies and literature reviews.

4.7.1. Antecedents

The keywords associated with the antecedent in Figure 9 are summarised as the application of digital technology, the background of sustainable management, and factors of organisational management.

First of all, the emergence of digital technology has promoted the implementation of DT and also facilitated the success of some projects that are undergoing DT [24]. Artificial intelligence and big data analytics will upgrade communication channels and accelerate product innovation in DT projects. However, DT is not a result but a dynamic process concentrating on sustainable management [24]; this characteristic does result in DT receiving inadequate attention from managers. As indicated in Figure 9, the frequency of research on sustainability is not exceptionally high. Even more, organisational management factors, such as decision making and implementation, are more attractive to scholars. Managers hope to fundamentally change the pattern of organisational operation according to the features or variations of the project itself to effectively lower the project costs and improve employees' work efficiency [24]. Especially in project management, project managers are inclined to create an effective workplace and implement more efficient strategies to increase the firm's performance [24]. These actions are a manifestation of decision making or implementation.

4.7.2. Process

The process-related keywords exhibited in Figure 9 include "management", "impact", "project management", "automation", "innovation", "framework", "performance", "business model", etc. Proportionate to the antecedents, the previous section describes the time when high-frequency processes relating to co-occurrence keywords embrace their radical transformation. It briefly introduces the orientation that inter-domain scholars have discussed in recent years. As many cases of collapsed DT projects still exist [24], this study focuses on different keywords concerning this process, and builds an effective bridge for project management, DT, and sustainability.

DT Process

This procedure can be broken down into two primary parts: the process of DT and project sustainability. Similar to DT, the development of digital technology and the abundance of data sources profoundly affect how an enterprise creates and captures value. Furthermore, it provides technical and resource support for the innovation of corporate business models, products, digital services, and organisations. As can be retrieved from Figure 9, digital technology does not only has a linkage to keywords associated with digital

technology, but it also reveals a close relation with strategic concepts, such as innovation, framework, and business model. This dual connection is consistent with the DT strategy as Matt [25] proposes, who focuses on product, process, and organisational transformation. This strategy is employed to support the change resulting from the integration of digital technologies and the management of the enterprise after that, emphasising the concept of a blueprint. In other words, the digital business strategy looks at a sustainability state.

Process of Managing Projects' Sustainability

In managing project sustainability, scholars tend to combine the critical elements of project management and sustainability-related dimensions. For example, they integrate a project's life cycle with social, environmental, and economic aspects to create a framework for promoting project sustainability [26]. However, the keywords in Figure 9 do not allow for the extraction of economically, environmentally, and socially relevant terms. Reasonably, Fernández-Sánchez and Rodríguez-López [8] pointed out that there has indeed been little research available on joint problems involving project management and socially relevant sustainability factors up till now. Unexpectedly, based on Figures 9 and 10, it can be surmised that scholars have also not explored the social and environmental aspects of DT and sustainability intensively. Nevertheless, some scholars have recognised that rapid economic growth raises ecological issues and have updated their conceptual framework to address the problems associated with sustainability projects [7]. In the context of DT, the external aspects of society, environment, and economy in projects should still be considered and can be further explored in future studies.

In contrast to the authors' concerns, relatively few institutions focus on DT. Most core journals in this field (Table 6) are relevant to sustainability, including *Sustainability* (MDPI), *Journal of Cleaner Production*, *Technological Forecasting and Social Change*, and *International Journal of Production Economics*. DT is a new field of study compared to sustainability, so there may be fewer core institutions involved. A surge in the number of related articles published in 2019 (Figure 2) suggests that an increasing number of journals will start to investigate the problems of DT and sustainability combined in the future.

Business Model

Aiming to bridge the gap between DT and sustainability projects, this research project research has chosen a business model, which is also a keyword seen in Figure 9 to represent "process". Although business models have been studied for a considerable period, business models related to DT and sustainability projects have only started being frequently discussed in 2020. The concentration ratio of this topic was declining in 2021. As there has not yet been a consensus on whether there is a standard answer to the effective management method of sustainability projects under DT and sufficient research has not been conducted in its short life cycle, it is unknown whether more scholars will regather to discuss business models in the future. This finding is visualised in detail through CiteSpace, which would have been difficult to detect by only reviewing the previous literature.

Having said that, a review of the previous literature shows that digital and sustainable business models have been studied in the last two years, effectively linking DT and sustainability fields [4,27]. As can also be seen in Figure 9, these two models have not been widely discussed, and there is not much experimentation to prove that the probability of project success can be quickly increased with these two models. Therefore, future research could continue to examine the effect of digital business models or sustainable business models in managing sustainability projects in DT. In conjunction with the critical words relating to DT and sustainability projects, innovation, socio-environmental, and economic factors can also be regarded in the business model research.

4.7.3. Outcomes

According to the keyword co-occurrence network (Figure 9), the results of DT and sustainability projects have a wide range of outcomes, including organisational and economic

effects. Keywords related to the organisational level are "design" and "perception". The impact of DT on sustainability projects entails enhancing employees' ability to perceive digital applications [28] and designing digital ecosystems. The keywords most relevant to the economic dimension are "performance" and "firm performance". As evidenced by the size of the nodes, there is less focus on "firm's performance" than on "performance". The emphasis of scholars on firm performance is in agreement with the earlier section, which noted that while numerous researchers have delved into the combination of digital transformation and sustainability, only a few have done so at the level of the firm or project [29]. Thus, the focus on firm or project performance is also lower. When the problem is broken down to the organisational or project level, the dimensions considered are different, and the probability of sustainability project failure may be reduced during the DT process. Similar to the conclusions of the process, the main keywords in terms of project management, digital transformation, and sustainability are barely summarised at a social level. As a result, socially related elements need to be considered by future scholars in the investigation of managing sustainability projects in DT.

4.7.4. Implications

The findings obtained in this review paper offer several managerial and theoretical implications. As regards the managerial implications, unravelling the interconnection between DT and sustainability in project management can lead to increased environmental responsibility; digital tools can be used to monitor and reduce carbon emissions, track resource usage, and promote sustainable practices. Additionally, the integration of sustainability and DT in project management can improve resource efficiency. With digital tools, project managers can monitor and optimise resource usage, reduce waste, and promote circular economy principles. Moreover, such a combination can lead to better stakeholder engagement in project management. By promoting sustainable practices, project managers can engage with stakeholders on environmental and social issues, leading to improved relationships and increased stakeholder satisfaction. Furthermore, it can help project managers to identify and mitigate sustainability-related risks. By using digital tools to monitor sustainability performance and identify potential risks, project managers can take proactive steps to address them and improve project outcomes. On top of all that, the utilisation of such an amalgamation can promote innovation in project management. By using digital tools to track sustainability metrics and identify areas for improvement, project managers can create new innovative approaches to sustainable project management, leading to increased competitiveness and improved project outcomes.

Apart from the above-stated practical implications, several theoretical implications are provided as follows. Firstly, the integration of digitalisation and sustainability in project management requires the development of new theoretical frameworks that can explain the complex relationships between digitalisation, sustainability, and project management. The findings of this research can help us develop new theoretical frameworks that can advance project management theory. Secondly, research on the integration of digitalisation and sustainability in project management can help us identify best practices that project managers can use to promote sustainability and digitalisation in their projects. These best practices can be used to develop guidelines and standards for sustainable project management. Thirdly, the findings of research on the integration of digitalisation and sustainability in project management can inform project management education. The findings attained from this research help project management programs develop new courses and curricula that cover sustainability and digitalisation in project management. Fourthly, the findings of this review paper on the integration of digitalisation and sustainability in project management can inform policy development. Governments and regulatory bodies can use this research to develop policies and regulations that promote sustainable project management practices. Finally, the findings of this research on the integration of digitalisation and sustainability in project management can help advance the practice. Project managers can use this research

to adopt new tools, techniques, and practices that promote sustainability and digitalisation in their projects.

5. Limitations and Future Works

Even though this review paper provides a solid understanding of the body of knowledge, there are several limitations to be tackled in future studies. As such, the following are the limitations of this study and the corresponding potential future work:

- Considering the review undertaken, it is observed that the concept of artificial intelligence has scarcely been taken up in the research are of interest. This is the major limitation in the existing literature, imposing extra expenses on projects and consuming resources at a faster pace. Thus, the exploitation of artificial intelligence in the research area of interest can yield fruitful results, in particular, the utilisation of machine-learning-based algorithms; such exploitation could provide the relevant researchers and practitioners a lucid prediction of the desired outcomes;
- Another shortcoming is related to the uncertainty issues associated with the idea of DT integration with sustainable projects. The probability that factors that will lead to the failure of projects in which DT has been utilised has not yet been explored. Hence, the exploitation of probability- and stochastic-based algorithms, such as the Bayesian technique, Monte Carlo simulation, and Markov chains, to name but a few, could overcome this shortcoming;
- Another major concern regards the barriers impeding the adoption of DT within sustainable projects. Very few studies, if any, have been carried out to investigate the barriers hampering the adoption of DT in relevant projects; therefore, there is a need to meticulously identify and analyse these barriers;
- This review paper provides a detailed and comprehensive science mapping, and as such it has not critically reviewed the literature. Thus, there is a need to conduct a critical review in future research;
- Another limitation of the current scientometric review paper is that co-citation-related analyses—including authors' and institutions' co-citation networks—have not been captured, and as such future studies need to address these co-citation analyses.

6. Conclusions

This study presents a science mapping approach to meticulously review the materials published on DT and sustainability within the realm of project management. In doing so, a comprehensive bibliometric review in sync with various types of scientometric mapping analyses of the relevant literature was carried out. Considering the undertaken analyses from 2011 to 2022, the following conclusions are drawn:

(1) There has been a growing interest in conducting research on the utilisation of DT in sustainability-based projects over the past few years, particularly in developing countries, which have the highest number of publications;
(2) Cluster labels of the timeline co-citation map include digital technology, sustainability, sustainable innovation, sustainable projects, lean management, business integration, and stakeholder collaboration;
(3) Hot topics in this review study include supply chain management, digital transformation, digital economy, digital entrepreneurship, circular economy, change management, quality, artificial intelligence, and green technology;
(4) Information system, governance, stakeholder, digital innovation, and challenges are the top five keywords with the strongest citation bursts.

The findings obtained in this study provide insightful accounts for both project managers and academics. Project managers are enlightened on revamping business models or designing digital strategies for sustainable projects, while researchers are given insight into the emerging streams that can be explored in future research endeavours.

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