Original article

A SYSTEMATIC LITERATURE REVIEW OF INDUSTRY 4.0 AND PROJECT MANAGEMENT

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Abstract: Industry 4.0 and underlying advanced technologies are gaining importance more than ever before and triggering digital transformation of organizations across industries. At the same time, an increasing number of organizations are using a temporary project-based way of working, thus creating dynamic systems in which projects are not merely tools for performing processes, but also strategic options for dealing with complex business environments. Therefore, it comes as no surprise that significant focus is being placed on the link between these concepts. With the aim of examining applications of digital technologies in project management, a comprehensive review was conducted on 188 academic articles published between 1991 and 2023 and indexed in the Web of Science database. Bibliometric and systematic literature review methods were used through co-occurrence, along with visual representation of interconnected data. The results highlight the prominent research topics in the field - challenges and opportunities for project management in the digital age, advanced project management in construction projects, artificial intelligence and project success, and managing information and production systems. Finally, potential research directions include the critical importance of striking a balance between technology and human relations to achieve success in modern project management in the midst of the Industry 4.0 era.

Keywords: Advanced technologies; Bibliometrics; Digital transformation; Industry 4.0; Literature review; Project management.

1. INTRODUCTION

As organizations across industries start to apply advanced technologies to project management, significant changes are expected in the field (Boudreau, 2019). According to research conducted by Gartner analysts (2019), by 2030 around 80% of project management tasks will be carried out by Artificial Intelligence (AI) and supported by Machine Learning (ML), Internet of Things (IoT), Big Data, digital fabrication (3D printing) or natural language processing, which could bring additional evolution of the profession and progress in a multitude of areas (Kanski & Pizon, 2023). These areas include, but are not limited to (Dodevska et al., 2018; Feuillet, 2019; Marjani et al., 2017; Nieto-Rodriguez & Viana Vargas, 2023; Prieto, 2019; Roh et al., 2021; Wachnik, 2022): a) project selection and prioritization and balancing project portfolio (with faster identification of projects that are ready for implementation and have higher chances for success or value creation, support to decision-making, removal of human biases or making decisions using robots); b) defining the project scope, scheduling project activities and choosing the suitable methodology/s for

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project management or creating a completely new one/s; c) communication and sharing relevant knowledge (with chatbots taking over activities such as planning and scheduling the meetings, allocating tasks to people and sending task reminders or follow-ups); d) data analytics, progress, performance and compliance monitoring, quality control, cost and risk management and project optimization; e) status updates, reporting and gathering feedback; and f) testing (including early detection of potential problems and self-correcting processes). Consequently, this could significantly reduce the cost of labor and also make a shift in the role of project managers by removing them from routine, repetitive and manual tasks, administrative processes and technical expertise towards strategic activities, managing complex adaptive systems, training, coaching, motivating and developing their teams (which will require a good understanding of the technologies applied, soft skills and in some cases completely new skill sets), facilitating high performance, managing changes and problem-solving (based on the data provided by the system), managing stakeholders and creating value for the company (Cabeças & Silva, 2021; Chakkravarthy, 2019; Fridgeirsson et al., 2021; Nimmo & Usher, 2020). However, the level of maturity of technologies in project management is quite low as organizations and project leaders are still using outdated tools such as spreadsheets, collaboration or specialist project management software (Cabeças & Silva, 2021). Although some improvement has been seen in project portfolio management applications, the parts which include planning and team collaboration capabilities, automation and intelligent features are still lagging behind (Nieto-Rodriguez & Viana Vargas, 2023). Furthermore, although both project management and Industry 4.0 gained significant attention among researchers and practitioners, the impact of application of Industry 4.0 technologies in project management has not been sufficiently studied (Aliu et al., 2023; Marnewick & Marnewick, 2019). Based on that, the aim of this research is to contribute to the profession by exploring the development of literature on the connection between the concepts of Industry 4.0 and project management with the focus placed on two research questions:

Research question 1: *What are the current trends in research related to Industry 4.0 and project management?*
Research question 2: *What are the potential research directions for Industry 4.0 and project management?*

In order to answer the research questions, a bibliometric analysis based on keywords co-occurrence was used, as it allowed the authors to conduct a more thorough investigation of the current literature which proved to be effective in classifying trends in similar scientific fields (Aghimien et al., 2020; Aliu et al., 2023; Obradović et al., 2021; Slavinski et al., 2023). The rest of the paper is organized as follows: a brief introduction of the bibliometric methodology and collected data is given, followed by visualized results of keywords co-occurrence analysis, summary of the findings and discussion, and conclusion with suggestions for future streams of research in the field and limitations.

2. BIBLIOMETRIC METHODOLOGY

The authors conducted an integrative literature review based on the guidelines by Callahan (2010) and Torraco (2005) (Fig. 1).

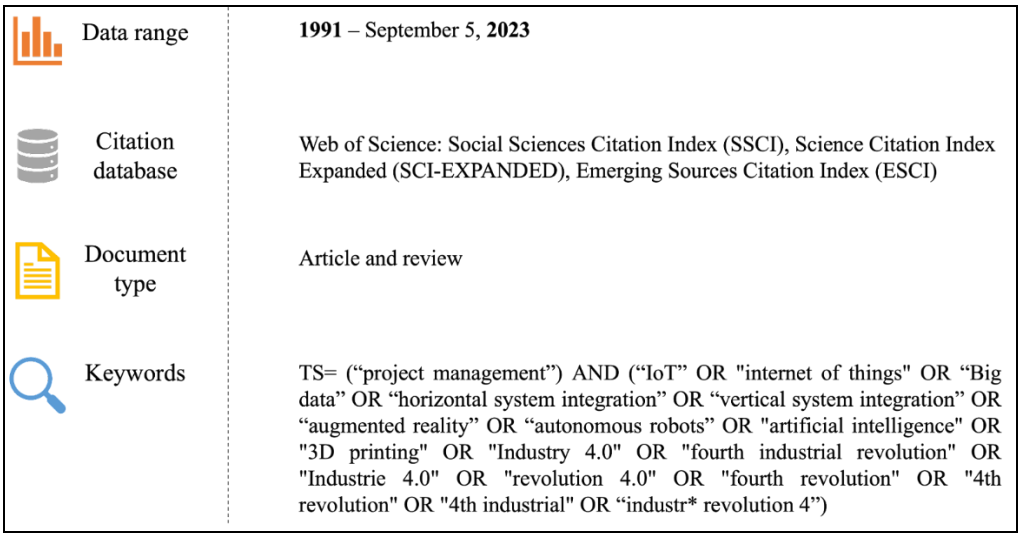

Figure 1: Literature review procedure

The search was carried out on September 5th, 2023 and included articles and review articles published in English language indexed in the Web of Science database. In order to make it comprehensive and retrieve all relevant publications published to date, the authors used the following string for scanning titles, abstracts and keywords: TS= ("project management) AND ("loT" OR "internet of things" OR "Big data" OR "horizontal system integration" OR "vertical system integration" OR "augmented reality" OR "autonomous robots" OR "artificial intelligence" OR "3D printing" OR "Industry 4.0" OR "fourth industrial revolution" OR "Industrie 4.0" OR "revolution 4.0" OR "fourth revolution" OR "4th revolution" OR "4th industrial" OR "industr* revolution 4"). The initial search identified 343 articles that matched the search parameters. However, after a detailed manual review focused on ensuring that the papers contained both focus on project management and digital technologies, 155 papers were omitted from further analysis as they were not related to the object of research. On the remaining 188 articles, a bibliographic analysis was made using software for construction and visualization of bibliographic networks - VOS viewer, version 1.6.18. To gain a better understanding of the current state in the field of research, the authors examined co-occurrence between the keywords with focus on a minimum of three occurrences of each keyword, as well as connection between keywords, the strength of which increases as they occur in combination with each other more often (van Eck & Waltman, 2022).

3. FINDINGS

3.1. Information about articles and authors' keywords

The results of the analysis of the collected articles show they were published from 1991-2023, with a significant growth in 2019 and a continuous increase until 2023. The articles were most frequently published in the following eight journals, covering 25% of all observed articles (Tab. 1).

Table 1: Journals according to the frequency of publication of observed articles

Journal	Number of publications	Cumulative percentage
Sustainability	9	4.78%
Automation in Construction	8	9.04%
Journal of Construction Engineering and Management	8	13.29%
Applied Sciences-Basel	6	16.48%
Operations Management Research	4	18.61%

Journal of Information Technology in Construction	4	20.74%
Buildings	4	22.87%
Engineering Construction and Architectural Management	4	25%

Distribution of published articles by year shows that 8.51% of articles were published between 1991-2009, 19.15% between 2011-2019, while the majority of 72.34% in the last four years from 2020-2023 (Fig. 2). The fact that the interest in the observed topic is increasing, additionally confirms the importance of implementation of bibliometric analysis in the area of interest (Tranfield et al., 2003).

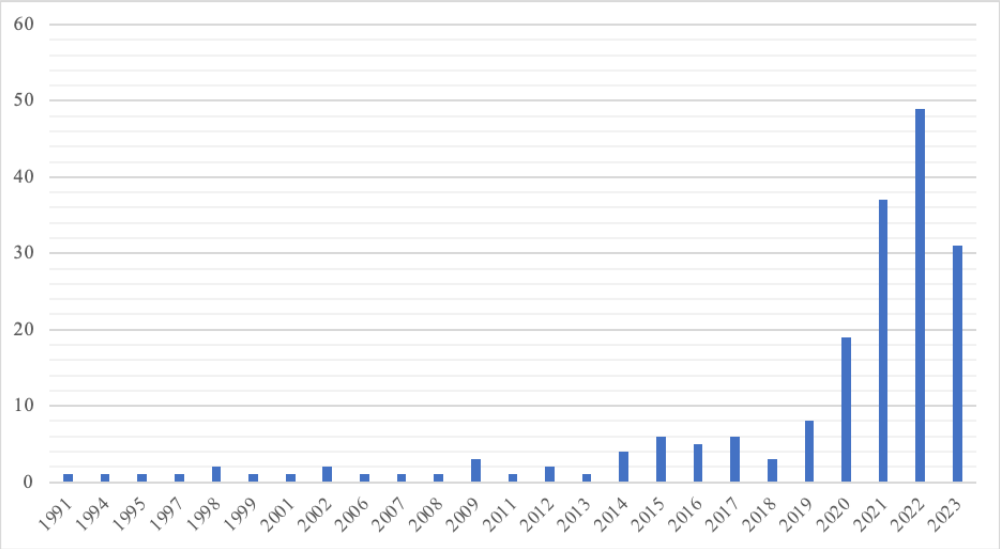

Figure 2: Publication of articles by years (1991-2023)

Topics such as planning, resourcing, and construction have always been vital aspects of project management. Even when Industry 4.0 brought new technologies and paradigms, these core areas were still relevant and crucial for effective project execution. These themes have clear practical implications for project managers and organizations. Effective resource management, planning and construction processes directly affect the success and efficiency of a project, making them key areas of study (Faghihi et al., 2015; Herroelen & De Reyck, 1999). As the era of Industry 4.0 has progressed, researchers have expanded their focus to more advanced areas such as artificial intelligence, the Internet of things, big data analytics, and the opportunities and barriers of digital transformation for project management (Naz et al., 2022; Sun et al., 2023). However, the underlying themes remain important and ongoing research continues to explore how Industry 4.0 technologies can advance and transform these key aspects of project management.

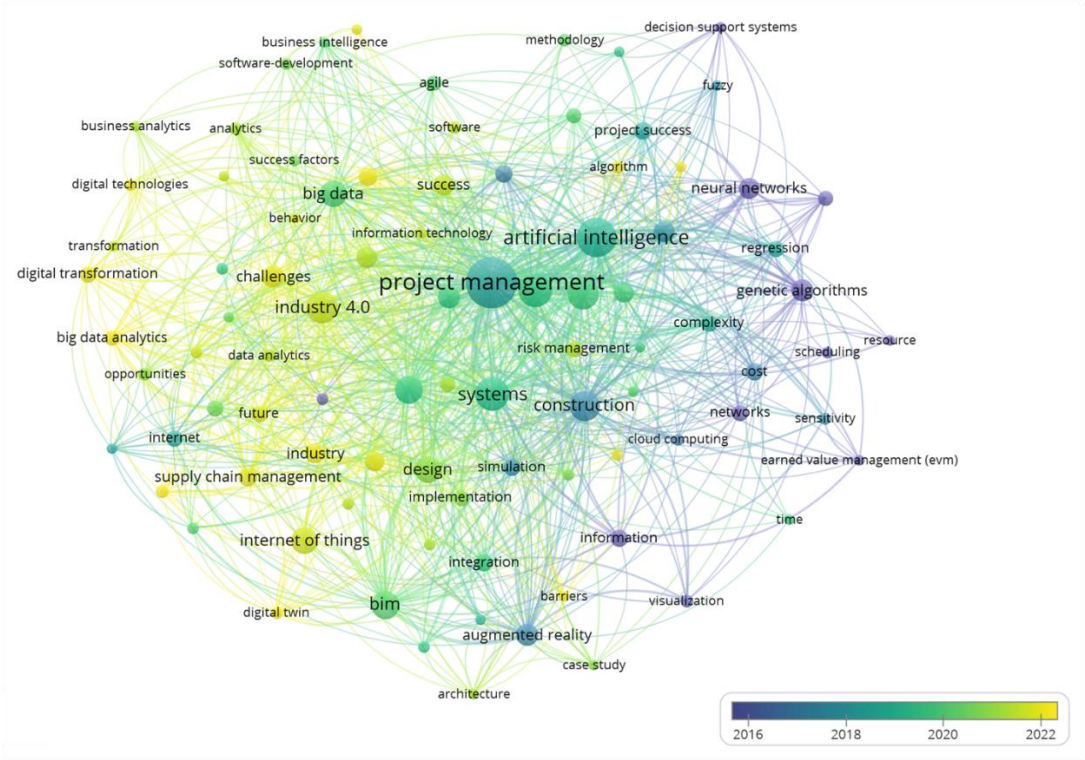

Figure 3: Keywords by year of article publication

3.2. Results of the bibliometric analysis

The conducted bibliometric analysis groups the results into four different clusters representing different research areas resulting from the observation of the application of digital technologies in project management (Fig. 4): 'challenges and opportunities for project management in digital age' (blue cluster), 'advanced project management in construction projects' (green cluster), 'artificial intelligence and project success' (red cluster), and 'managing information and production systems' (yellow cluster).

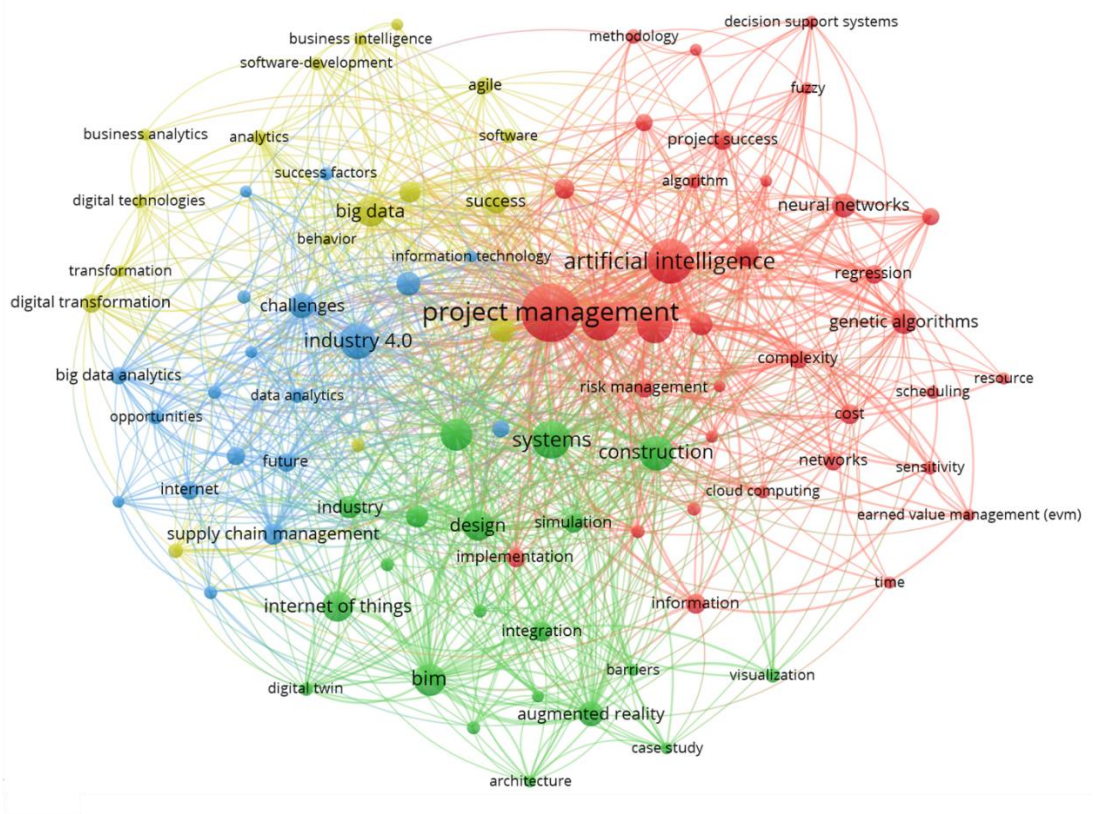

Figure 4: Bibliometric map based on author keywords co-occurrence

Blue cluster - Challenges and opportunities for project management in digital age

Authors within the blue cluster are mostly focused on challenges and opportunities of advanced technologies in project management (Fobiri et al., 2022; Suferi & Rahman, 2021; Yaseen et al., 2020). Industry 4.0 represents a great opportunity for mature industries such as manufacturing or construction. It can help companies to improve product quality, it can enable better budget control, increase productivity and boost innovation. Fobiri et al. (2022) studied benefits and challenges of reality capture (RC) technology in construction projects and concluded that RC should be mostly used in the process of planning and designing because it enables minimizing the risk of costs and time overruns. On the other hand, the most challenging point is the implementation cost of technology on construction projects. The benefits of AI have been studied from the perspective of predicting delay problems in the construction industry and for capturing the complexity of a project. For example, Yaseen et al. (2020) proposed a hybrid AI model which identifies sources of delay problems and estimates the impact of delays on project performance. This type of technology can predict project risks and can contribute to further development of monitoring in construction projects. Similarly, Afzal et al. (2021) studied the hybrid AI methods for estimating risks in construction projects. The authors concluded that the application of the methods is often limited because it is very difficult to collect data on risks, and they suggest further research in terms of identifying the necessary data related to project uncertainty. It can be concluded that advanced technologies such as AI can help managers to better predict critical success factors but also reduce risks.

Furthermore, this cluster is characterized by the adoption of Industry 4.0 technologies and opportunities related to digital transformation (Suferi & Rahman, 2021), obstacles faced when utilizing digital twins in construction project management (Salem & Dragomir, 2022), challenges in implementing data-driven approaches for managing construction projects in the big data era (Huang et al., 2021) or exploring the utilization of AR in construction projects (Ahmed, 2019). For example, Suferi and Rahman (2021) studied the simultaneous

development of both industry 4.0 and construction industry from a more managerial perspective. The authors concluded that mature and traditional industries, such as construction, can benefit from the implementation of Industry 4.0 technologies because they can reduce companies' production costs, improve product quality and communication.

Green cluster - Advanced project management in construction projects

Digital transformation has changed the way projects are managed in the construction industry. With new, advanced technologies, construction companies have the opportunity to reduce waste, make production more sustainable and improve working conditions. Authors within the green cluster focused their research on the Building Information Modeling (BIM) based projects, which became an increasingly popular topic in the construction industry in recent years (Alizadehsalehi et al., 2020; Begić et al., 2023). Intelligent BIM systems offer technical support for project management goals, yet limitations persist, notably in attracting flexibility and susceptibility to errors. Some of the limitations of using BIM can be alleviated by using advanced technologies such as the IoT. Chen (2023) concluded that IoT has served as the foundation for the effective integration of diverse project elements and information within the system, driving profound advancements in project management's intelligence.

Furthermore, Pan and Zhang (2021) studied the ways in which Internet of Things, data mining and BIM can help companies to advance their project management process. The authors highlighted that smart technologies could facilitate data communication and enable optimization of physical construction operations. Based on the systematic literature review, Ali et al. (2022) concluded that BIM was mostly studied in the context of collaboration and integration, as well as from the perspective of barriers and risks of BIM integration. Furthermore, the authors highlighted the lack of studies in this area, thus supporting the need for future research streams for companies to benefit from successful building information modeling projects. Furthermore, Oraee et al. (2017) presented a bibliometric literature review on the collaboration in BIM-enabled projects. The authors concluded that the research in the field mostly focused on the technological part of collaboration, while project and managerial antecedents remained insufficiently researched. Despite the construction industry's maturity, significant opportunities lie ahead through the integration of advanced technologies like AI, machine learning, IoT, and big data analytics, underscoring the imperative for further research to bridge existing knowledge gaps in project management.

Red cluster - Artificial intelligence and project success

AI has drawn much attention from government, industry, and academia. It is part of the development strategy of many countries, makes people's lives easier and encourages companies to adapt their business models (Di Vaio et al., 2020; Zhang & Lu, 2021). For managers, the implementation of AI includes both opportunities and obstacles. Some challenges can be related to technical issues, but most of them are related to the human side (Berente et al., 2021). Managers should create a trustworthy culture and encourage employees to work with new technologies. Wachnik (2022) studied AI development in the entire project life cycle. The author concluded that AI is used for non-complex tasks, such as simple automation of routine activities. Thus, further research in the context of implementation of AI in project management has been highlighted. Martínez and Fernández-Rodríguez (2015) concluded that the AI tools can help companies to predict the critical success factors of their projects and predict project success. The authors emphasized that AI tools such as fuzzy cognitive maps or neural networks help project managers to control and monitor their project better than the traditional tools. AI can also be seen as a useful tool for creating a sustainable supply chain, which proved very important during the pandemic. Naz et al. (2022) pointed out that AI can enable resilience in the supply chain which can reduce risks and influence successful project management.

Globalization and digital transformation have changed the way companies operate. Moreover, due to the challenging needs of customers, companies produce multiple products and services at the same time, leading to multiple projects. Thus, it is extremely important for managers to use appropriate project management tools and to manage resource scheduling. A project manager's primary job is to ensure that the project is on time and on budget. Red cluster is also related to project scheduling, costs, resources, project complexity, and networks. Resource scheduling has been highlighted as crucial for project success, and in the digital age, advanced technologies can help managers to improve this process. For example, Wang (2022) developed a model based on deep learning that can help engineers optimize resource allocation, which is especially important in large-scale projects. Zhu and Huang (2022) studied the cloud deep learning platform which enables the estimation of current resources and examines the distribution of resources. Pan et al. (2008) created an improved Tabu Search model for reducing duration of a project by solving the problems related to resource-constrained project scheduling. Based on previous research, it can be concluded that with the help of advanced algorithms, companies can use limited resources more efficiently, improve resource allocation and enable project success.

As part of this cluster, authors also studied how advanced technologies can help in identifying and predicting project costs and project duration (Bakhshi et al., 2022; Elmousalami, 2020). For example, Elmousalami (2020) found that artificial intelligence and machine learning can predict the costs and duration of projects related to saving drinking water, but that sufficient data sets are required for effective forecasts. Similarly, Bakhshi et al. (2022) studied the use of hybrid machine learning mechanisms in predicting project time and cost. Moreover, big data analytics can be considered a valuable mechanism in project cost forecasting. With an increasing number of projects, effective big data analytics can provide advantages in data processing and enable successful project cost management and control systems (Chen, 2022). It can be concluded that the role of advanced technologies in cost management and control is a valuable research stream.

Yellow cluster - Managing information and production systems

Studies within yellow cluster focused on the adoption of digital technologies within the construction sector, particularly their impact on construction project management (Dolla & Delhi, 2023; Wang et al., 2022). Dolla and Delhi (2023) offer a comprehensive study of Industry 4.0 adoption in the Indian construction industry, providing valuable insights into stakeholder dynamics, strategies and perceptual frameworks that can guide practitioners and policy makers in advancing the use of digital technologies in construction project management. Furthermore, Wang et al. (2022) conducted a study on difficulties to digital transformation and identified three primary categories of barriers: lack of regulations, insufficient leadership, and lack of resources and expertise. Additionally, the authors established that these obstacles have a negative impact on digital transformation. Understanding the challenges associated with digital transformation can help managers in the construction industry develop relevant initiatives and policies.

Moreover, the authors discussed the potential of big data in transforming project management, highlighting the lack of research studies on its practical effect. Through interviews with French project managers, the study found that many organizations are at an early stage of adoption due to resource limitations, especially in terms of expertise (Bakici et al., 2023). You and Wu’s (2019) article focuses on the construction industry's need to harness the value of engineering data in the big data era, while highlighting challenges such as manual data entry inaccuracies and delayed data collection. To address these issues and enhance data sharing and interoperability, the authors propose the integrated data platform for companies in the construction industry. The proposed solution provides a basis for improving the efficiency of the company's business and project implementation by optimizing processes and supporting informed decision-making.

4. CONCLUSION

In conclusion, the bibliometric analysis of 188 articles provided a comprehensive overview of the development of project management in the digital age. It highlights the transformative potential of advanced technologies, particularly AI, IoT and big data analytics, while also focusing on challenges and opportunities that come with their implementation. These research clusters offer valuable insights for both academics and practitioners, pointing the way towards a technologically smarter and more efficient future in project management in the framework of digital transformation.

The study has significantly contributed to improving our understanding of how project management is evolving in the context of the Industry 4.0 era. It emphasizes the need for a balanced approach that combines technological advances with significant focus placed on the human element, keeping in mind both importance of trust and adaptability. As Industry 4.0 continues to shape the project management profession, ongoing research, especially those that do not exclusively involve the construction environment, will be critical to effectively manage this transformative journey.

However, it is crucial to acknowledge the limitations of this analysis, primarily its reliance on the Web of Science database. Future research in this area should consider broadening the scope by comparing findings across different databases to gain a more inclusive understanding of project management development. Such comparative analyses can contribute to further progress in the field.

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