Sustainable Digital Transformation: SDG-Aligned Bibliometric Mapping

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Abstract

Although interest in the intersection of sustainability and digital transformation is growing, Sustainable Digital Transformation (SDT) remains under-defined and empirically thin. A comprehensive review of the SDT literature was done in this study to assess the extent of empirical research. Searches of Scopus and Web of Science were refined for relevance and complemented by bibliometric mapping and SDG alignment. Findings indicate a post-2018 publication surge, with six thematic clusters, and SDG attention concentrated on SDG 9 and SDG 13 (with links to SDG 11). Use of "sustainable" is often rhetorical, with few designs tracing outcomes to specific SDG targets. Results show that SDT research remains fragmented, and that clearer concepts, SDG-linked indicators, and designs demonstrating measurable SDG outcomes are needed to inform policy and practice.

Keywords: sustainable digital transformation, digitalisation, sustainability, SDG mapping

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Sommario

Sebbene l'interesse verso l'intersezione tra sostenibilità e trasformazione digitale sia in aumento, la Sustainable Digital Transformation (SDT) rimane concettualmente poco definita e con basi empiriche limitate. Il presente studio conduce un'analisi sistematica della letteratura sulla SDT per valutare l'estensione della ricerca accademica disponibile su questa tematica. Le ricerche su Scopus e Web of Science sono state affinate per pertinenza e integrate con mappatura bibliometrica e allineamento agli SDG. I risultati evidenziano un forte aumento delle pubblicazioni dopo il 2018, sei cluster tematici, e una focalizzazione sugli SDG 9 e 13 (con collegamenti all'SDG 11). L'uso del termine "sostenibile" risulta spesso retorico, con pochi disegni di ricerca capaci di collegare gli esiti a target SDG specifici. I risultati mostrano che la letteratura scientifica sulla SDT è ancora frammentata e che sono necessari una concettualizzazione più chiara, indicatori collegati agli SDG e disegni in grado di dimostrare esiti misurabili in logica SDG per orientare policy e pratica.

Parole chiave: trasformazione digitale sostenibile, digitalizzazione, sostenibilità, mappatura SDG

1. Introduction

Recent technological advances are forcing organisations to adapt in two ways: digitalisation – using technology to support routine activities, and digital transformation – reconfiguring processes and business models to gain and sustain competitive advantage. Shifts in academia and industry indicate major production – and consumption-side changes driven by digital applications. Technology is advancing rapidly and causing significant changes to business models in a short amount of time (Savastano *et al.*, 2022a). Innovative technologies such as artificial intelligence (AI), big data analytics, robotics, blockchain, additive manufacturing and the Internet of Things (IoT) are having a major technological breakthrough characterised by the dimensions of flexibility, adaptability and learning. Digital ecosystems are revolutionising the global economy and serving as a critical engine for growth (Shang and Zhang, 2022); physical spaces across all industries and sizes have transformed into digital environments (Yacob and Peter, 2022). With whole industries dedicated to digitalisation, this transformation is generally seen as positive (Pūraitė *et al.*, 2020).

Given the constant emergence of new technologies, staying up to date has become essential to remaining competitive in the market (Ginting *et al.*,

2022). Today, for most companies to stay ahead and maintain their competitive advantages, they must continuously adapt to the ongoing digital transformation (Nurova and Freze, 2021). This challenge has led to two concepts, digitalisation and digital transformation, which are often used interchangeably but actually refer to distinct processes (Bican, Brem, 2020). The meaning and context of these terms and the difficulties they present are particularly highlighted in the industrial sector (Abdallah *et al.*, 2022). The rise of digitalisation, fuelled by advancements in technology, is revolutionising society by enabling increased connectivity and networking that improve communication, services, and trade (Linkov *et al.*, 2018). Digitalisation has slowly but surely impacted civilisation, economic growth, industry innovation, and organisational effectiveness (Zamiri *et al.*, 2021).

There is no universally accepted definition of digital transformation (DT), as its scope and scale vary depending on the industry in which it is applied (Abdallah *et al.*, 2022). One proposed definition of digital transformation, according to (Bican and Brem, 2020), describes it as the outcome of digital interaction, shaped by internal organizational dynamics and external cooperation, while involving substantial changes and implications. Similarly, DT has also been described as a process of implementing fundamental changes across a business, rather than merely enhancing or upgrading specific functions (Saraji *et al*., 2021). Accordingly, in the recent literature, DT is being described as an organisational change process in which the organisation, at all levels, develops new ways of using technologies to innovate products, services and business processes (Savastano *et al.*, 2022b). This process involves both the exploitation of digital technology to enhance existing processes and the exploration of digital innovation, which has the potential to fundamentally transform business models (Ginting *et al.*, 2022). Despite this lack of agreement on the DT definition, it was recently claimed by McKinsey that a DT strategy is critical for organisations to not only compete but also survive (Lamarre *et al.*, 2023).

In addition to the challenges related to business strategies and market competition, research on environment and climate change has gained momentum due to global initiatives such as the Paris Agreement, the United Nations' 2030 Agenda, and the Sustainable Development Goals (SDGs) (Saraji *et al.*, 2021). The idea of sustainability has expanded beyond environmental concerns and now includes a company's capacity to utilise digital technology, data resources, and service-dominant logic to enhance its financial performance on an ongoing basis (Chen *et al.*, 2023). Furthermore, within the new EU industrial strategy, the green transition based on the decarbonisation objective is coupled with the role of new digital technologies in making factories environmentally more efficient, smarter and competitive

(EC, 2020). Therefore, green and digital transitions are the two sides of the same coin, fundamentally linked to be considered as "twin transition" and to represent a combined policy mandatory target in the National Recovery and Resilience Plans for EU Member States (Montresor and Vezzani, 2023). Integrating new and innovative technologies with renovated business strategies is necessary, and digital technology development can significantly benefit both the environment and human health (Saraji *et al.*, 2021). DT is crucial in achieving the SDGs since without transforming present businesses, future economic and environmental challenges cannot be sustainably addressed (Bican and Brem, 2020).

Digital technologies can help tackle sustainability challenges that were previously out of reach (Geyda *et al*., 2021). In sustainable development models, information about the likely outcomes of present and future actions is used to minimise negative impacts and maximise positive ones across planning horizons to meet current and future needs (Geyda *et al*., 2021). Integrating digital tools extends this logic by improving prediction, coordination, and monitoring of activities, enabling more effective, outcome-oriented management of sustainability goals. Although the importance is given at the global level to the "twin transition', describing the synergies between technological advancements and environmental sustainability, research studies still present a gap in its conceptualisation and definition (Lankhuizen *et al.*, 2023). Therefore, this paper seeks to clearly represent the state of the art and the evidence published so far in academic literature.

Sustainability and digitalisation-related concepts have recently gained tremendous attention (Szabó *et al.*, 2023), giving rise to a new concept called sustainable digital transformation (SDT). In an effort to define the concept of SDT (Rupeika-Apoga and Petrovska, 2022) state that it is the process of digitizing the economy in a durable, environmentally friendly, and natural manner, leveraging its core strength – innovative companies and their interconnected business ecosystems. However, the ongoing development of DT and the lack of a clear definition contribute to the challenges associated with understanding this phenomenon. The literature highlights the importance of defining and distinguishing terms and concepts related to the digital movement and the emergence of the new SDT concept. Therefore, it is crucial to have a shared understanding of these terms and concepts to exchange knowledge and apply *digital* to sustainable economic and environmentally friendly actions (Bican and Brem, 2020).

To address these practical and theoretical gaps, this research aims to take an opportunistic approach *to establish the foundation for advancing the subject of sustainable digital transformation*. In particular, the guiding research goals (RG) are as follows:

- to examine how research in SDG area has evolved over the last two decades (RG1),
- to map the existing literature with regard to SDGs (RG2).

The remainder of this paper is structured in the following manner. In section 2, a concise explanation is given of the methods utilised to recognise the pertinent research incorporated in this review. Section 3 presents the research results, including the major themes found in the literature on SDT. Section 4 discusses the crucial aspects of the research, highlights limitations, and provides potential avenues for future research. Final conclusions are provided in Section 5.

2. Methodology

To map and organise scientific literature on SDT the authors first agreed upon keywords aligned with the paper's aims and defined RGs. To examine the broader literature and map it according to SDGs, we followed qualitative design guidelines and complemented the results with a bibliographic analysis.

2.1. Paper Identification

This paper applied a keyword search-based approach for finding relevant papers (Creswell and Creswell, 2018). Thus, the selection of relevant literature started with the initial search of keywords digital* and sustainab* via Scopus and Web of Science (WoS) scientific databases. This search initially yielded over 50000 papers in total. Therefore, to access the most focused literature on the chosen topic, the search was limited to sustainab* and digital* keywords only in the paper title. Results were confined to articles, conference papers, and the English language. The initial (broader) search query was: (TITLE (sustainab*) AND TITLE (digital*)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (LANGUAGE , "English")).

Results were further analysed, and for the purpose of mapping the literature about SDGs, we considered the content of titles and abstracts according to the most frequent keywords for each SDG from the methodology developed by (Rivest *et al.*, 2021). The keywords used for each SDG are based on the latter study's model, whose goal was to improve the Scopus and Aurora queries for identifying papers that support the UN SDGs by applying the machine learning approach (Rivest *et al.*, 2021). This procedure was carried out using Excel.

Aligned with the tried-out methodology (Manfreda, Mijač, 2024; Tricco *et al.*, 2018) and guided by the research goals of our paper, after screening the titles of collected papers from the broad search, we identified that too many irrelevant papers appeared in the list. Based on that, we repeated the process but with modifying the search query. We decided to search for a narrower query: (TITLE ("sustainab* digital*") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (LANGUAGE, "English")).

The same search query was deployed both on Scopus and WoS databases on January 30, 2025.

2.2. Science Mapping

The bibliometric review was conducted on the results of the second query. Bibliometric reviews of the literature have the advantage of processing a larger volume of studies published over a more extended period, requiring fewer resources and less time while still providing a comprehensive overview of the research topic (Ninčević Pašalić and Mijač, 2023).

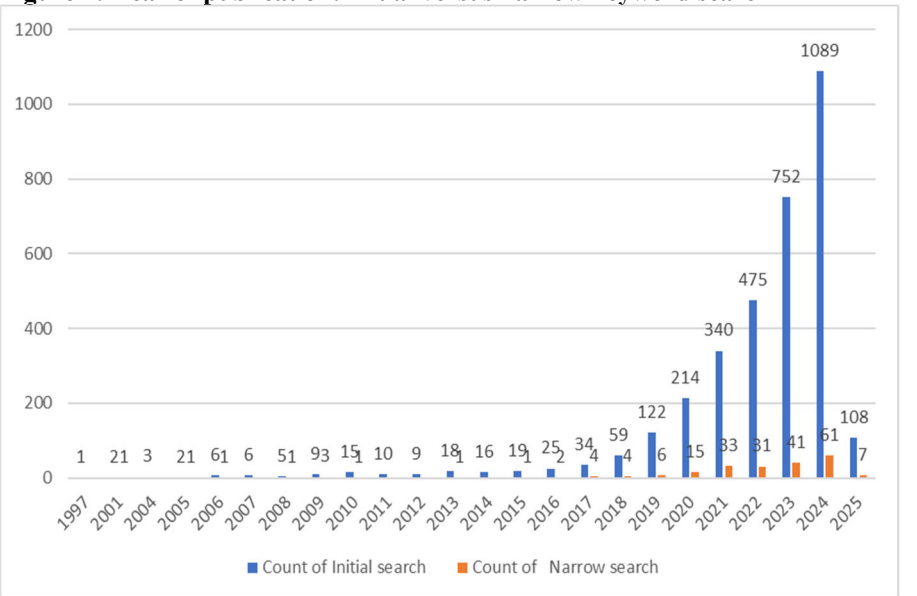
3. Results

3.1. Evolution of significant SDT literature

Seeking a relevant scientific corpus started with a broader search, which resulted in 2297 papers from WoS and 3343 from Scopus. After removing the duplicates, the unique number of papers was 3343. Among these yielded papers (n=3343), one paper originated from the year 1997. However, a substantial intensification in the number of published papers on this topic was noted from the year 2018. The number of papers in 2024 reached 1089. The second query (narrower) yielded 228 papers from Scopus and 143 from WoS. After removing the duplicates, the total number of papers was 214.

However, the second search yielded more recent papers, and the peak was in 2024 (n=61). A comparison between these two searches, regarding the year in which papers were published is presented in Figure 1.

Figure 1: Year of publication: initial versus narrow keyword search



Source: Authors' elaboration.

3.2. Mapping the literature on SDT in the context of SDGs

This part of the study aims to map the existing literature on SDT matched with SDGs. As mentioned before, the broader search resulted in 3343 documents, and the mapping was conducted using the abstract fields of each document, focusing on the top three keywords linked to each SDG. The keywords associated with each SDG are derived from the study conducted by Rivest *et al.* (2021) that aimed to identify research that supports the UN SDGs. The authors mapped the corpus according to the top three keywords of the mentioned study. List of 16 SDGs and top 3 keywords as shown in the table in continuation. This analysis was conducted using Excel by applying the formula 'IF(COUNTIF(G2; "*poverty*");1;0)'.

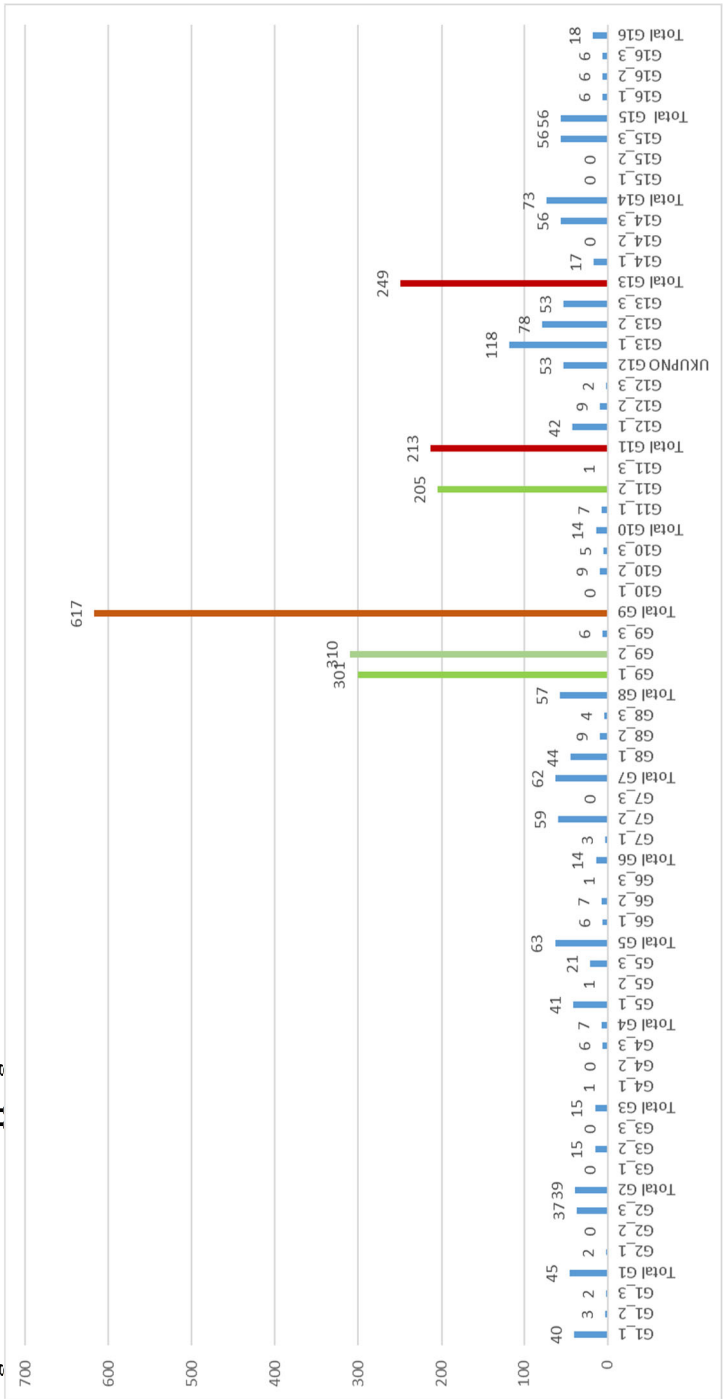
After completing the mapping process, it was found that only 488 out of 1451 documents (33%) could be successfully mapped using this approach. The results show that research on SDT in alignment with the SDGs *remains limited.* The mapping indicates that most of the research related to the SDGs focused on SDG 9 (Industry, Innovation, and Infrastructure), followed by SDG 13 (Climate action). The five most frequently mapped keywords were "manufacturing" (n=310) and "infrastructure" (n=301) from SDG 9, followed by "urban" (n=205) from SDG 11 and "climate change" (n=118) from

SDG 13. Most of the mapped documents were journal articles (68%). These findings are illustrated in Figure 2.

Table 1: Top three keywords associated with each SDG (based on Rivest *et al.*, 2021)

SDG	Keywords used
GOAL 1: No Poverty	Poverty; social protection; health insurance
GOAL 2: Zero Hunger	Malnutrition; biological control; food security
GOAL 3: Good Health and Well-being	Cancer; aids; stroke
GOAL 4: Quality Education	Trainees; apprenticeship; professional training
GOAL 5: Gender Equality	Gender; std; women
GOAL 6: Clean Water and Sanitation	Wastewater; water management; water quality
GOAL 7: Affordable and Clean Energy	Photovoltaic; energy efficiency; biodiesel
GOAL 8: Decent Work and Economic Growth	human capital; labor market; labour market
GOAL 9: Industry, Innovation and Infrastructure	Infrastructure; manufacturing; internet access
GOAL 10: Reduced Inequality	Medicaid; social justice; financial crisis
GOAL 11: Sustainable Cities and Communities	solid waste; urban; road network
GOAL 12: Responsible Consumption and Production	Recycling; recycle; composting
GOAL 13: Climate Action	climate change; co2; co2 emissions
GOAL 14: Life Below Water	Marine; oil spill; conservation
GOAL 15: Life on Land	Bioremediation; extinction; conservation
GOAL 16: Peace and Justice Strong Institutions	human rights; corruption; community engagement
GOAL 17: Partnerships to achieve the Goal	N/A

Figure 2: Literature mapping based on the SDG Framework



Source: Authors' elaboration.

3.3. Bibliographic analysis of SDT literature

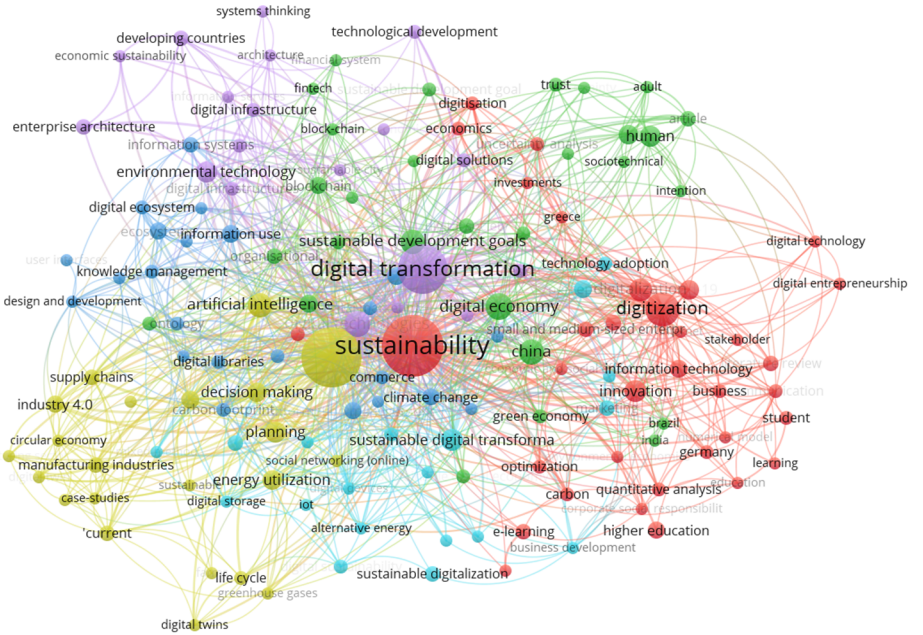
To provide further insight, bibliographic data for all the retrieved records (120) from Scopus and WoS have been downloaded and visualised. From the total of 1983 keywords, after setting the minimum number of occurrences, 3147 keywords met the threshold. Figure 3 shows a visual map of the keywords. It can be seen from the results that the keyword *sustainability* has the highest number of occurrences and therefore is represented with the largest circle. After the in depth analysis, six clusters were identified, and cluster names were proposed in accordance with the keywords contained:

- *Sustainability* (red cluster). This cluster refers to keywords such as: sustainability, digitisation, digitisation performance assessment, and innovation;
- *SDG* (green cluster). Relevant keywords related to this cluster are: human, intention to use, digital literacy, sustainable practise, software, and communication;
- *Technology* (dark blue cluster). The most relevant keywords in this cluster are development big data, artificial intelligence data visualization, information systems, and interoperability;
- *Sustainable development* (yellow cluster). Manufacturing, digital twin, industry 4.0, supply chain, decision making, energy utilisation;
- *Digital transformation* (purple cluster). Design, system thinking, business model, architecture, technological development, digital infrastructure, and system architecture;
- *Sustainable digital transformation* (light blue colour). Environmental impact, IoT, alternative energy, business development, digital services, digital sustainability.

Sustainability is a central concept, highlighting that sustainability topics are crucial in the discourse on digital transformation. Digital transformation is strongly linked to energy efficiency, artificial intelligence, and economic aspects. There is a clear connection between digitalization and business strategies, education, and innovation. Industry 4.0 and digital technologies such as IoT, digital twins, and artificial intelligence play a significant role in sustainable digitalization. The smallest cluster is the one sustainable digital transformation.

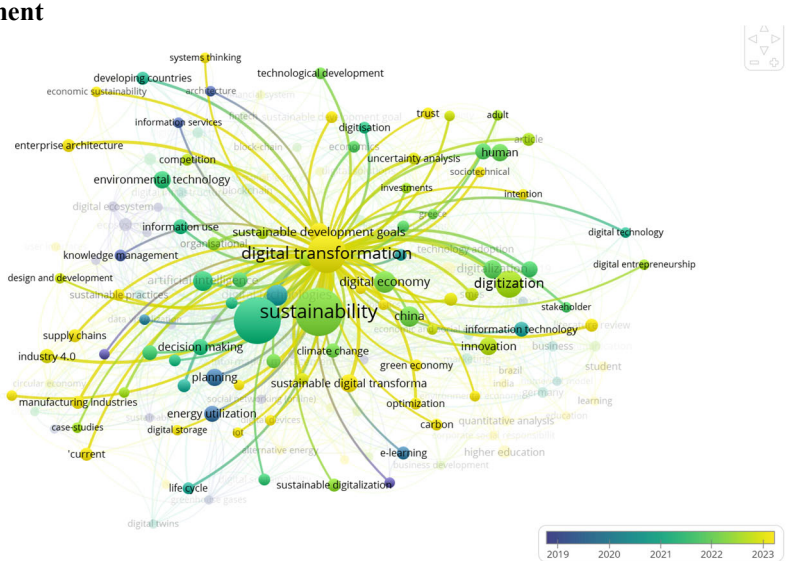
To complement the previous results, the same visualisation has been provided for each publishing year to describe the evolution trends. The yellow colour refers to the most recent topic. Thus, it is confirmed that sustainable digital transformation is a very relevant and current topic yet to be developed. This explains why the cluster sustainable digital transformation is the smallest one.

Figure 3: Keyword map visualisation



Source: Authors' elaboration using VOS viewer software.

Figure 4: Historical visualisation of the sustainable digital transformation development



Source: Authors' elaboration using VOS viewer software.

4. Discussion

As the world progresses towards digitalisation, it is becoming increasingly clear that businesses must adapt by developing new products and processes to stay competitive. With the rising focus on environmental issues and climate change, the concept of SDT has emerged and gained significant attention from both industry and academia, leading to a rapid increase in related publications. New, integrated frameworks for SDT combine technological advancement with environmental management, considering economic, social, and environmental perspectives (Liao, 2024) while Green IT focuses specifically on minimizing the environmental impact of IT operations and infrastructure (Rosati *et al.*, 2024).

Digital technologies are seen as pivotal in combating climate change and reducing environmental harm while also providing opportunities for economic leadership and independence in key industries (Lankhuizen *et al.*, 2023). The goal of this paper was to examine and organise existing literature on the concept of *sustainable digital transformation.* Results have shown that when considering a much broader view, literature is extensive, but when focusing on a much narrower topic of research, there is a clear lack of it.

Although this literature review identified papers by examining the title of papers and abstracts (that should be relevant and clearly related to the paper), only a few papers used this concept as the main focus of their analysis. Despite the substantial volume of scientific literature available on the topics of sustainability and digital transformation independently, there exists a significant gap in research specifically addressing their intersection. This indicates a pronounced deficiency in scholarly work dedicated to exploring and investigating the complexity of sustainable digital transformation. Moreover, while the term "sustainable" is embedded within the concept, its application appears to be more rhetorical than substantive. The SDG mapping revealed that the use of "sustainable" in this context often lacks a concrete connection to the specific, measurable targets outlined by the SDGs. This disconnect underscores a broader issue within the field: the popularity of the term does not equate to a robust, actionable framework aligned with SDGs.

Consequently, we can conclude that the notion of sustainable digital transformation is still emerging, characterised by a lack of clarity and direction. *This phase is marked by an urgent need for rigorous research aimed at defining and operationalising the concept. This includes developing comprehensive models and methodologies that can bridge the gap between theoretical discourse and practical implementation.*

A significant and realistic confirmation of the urgent need for more attention on these interconnected topics and areas of application comes directly

from the degree of achievement of the SDGs and their targets only seven years before the Deadline of 2030. The global-level data and assessments depicted in the latest SDG report from UN paints a concerning picture (United Nations, 2023): of the approximately 140 targets that was possible to evaluate, half show moderate or severe deviations from the desired trajectory. Moreover, over 30% of the targets have either made no progress or have worsened, falling below the 2015 baseline. This evaluation highlights the critical need for enhanced efforts to advance the SDGs and achieve a sustainable future. In light of these findings, it is imperative for governments, organizations, and individuals to collaborate more effectively and implement innovative strategies that can accelerate progress toward the goals.

5. Conclusion

Despite the frequent mention of sustainable digital transformation in mainstream media and its apparent prevalence in everyday life, *the scientific exploration of this concept remains in its early stages*. The current body of research is insufficient to provide a solid foundation for understanding and advancing sustainable digital transformation in a way that is both meaningful and aligned with broader sustainability goals. More specifically, despite the significant volume of research on sustainability and digital transformation as separate entities, there is a conspicuous absence of scholarly work that effectively bridges these two domains. Moreover, despite the growing attention SDT has received in recent years, this study highlights the continuing need for further research that aligns with the SDGs. The mapping approach (re-) employed in this study offers an effective framework for systematically organizing and assessing the current body of literature on sustainable digital transformation, thereby guiding future research efforts.

Finally, several limitations of this study need to be highlighted. The second query search was very limited, focusing on phrases; thus, it could happen that some relevant papers tackled this issue but have been unintentionally omitted. As noted, this is currently a hot topic, so the number of papers is increasing almost every day. Future research should include also empirical based evidence regarding sustainable digital transformation. Despite the vast number of scientific records when querying sustainable and digital transformation, there is a limited list of records tackling this particular issue. Additionally, even though the concept includes the term “sustainable”, the results of SDG mapping indicated that it is merely a popular term, not closely related to well-defined SDGs.

While the idea of sustainable digital transformation holds significant

promise, realising its full potential will require a concerted effort from the research community. This effort should focus on developing clear definitions, robust operational frameworks, and empirical studies that can guide both policy and practice. Only through such dedicated scholarly inquiry can we hope to transform the concept from a nascent idea into a well-defined and actionable reality.

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