An Evaluation Framework of Industry 4.0’s Impact on SDGs and its Application to AI Reporting

Tamara Menichini and Nicoletta Maria Strollo
Department of Engineering, University of Rome Niccolò Cusano, Rome, Italy

tamara.menichini@unicusano.it
nicolettamaria.strollo@unicusano.it

Abstract: Digital technologies of Industry 4.0 (I4.0) are key drivers of sustainable development. However, addressing the impact of I4.0 on Sustainable Development Goals (SDGs) requires overcoming the challenge of lacking suitable assessment tools. Despite sustainability reporting serves to assess how companies face sustainability challenges, communicate efforts, and promote a sustainable corporate culture, a critical need arises for a comprehensive tool that clarifies the impact of I4.0 technologies on the economic, environmental, and social dimensions of sustainability. This paper proposes a conceptual framework that builds on existing literature regarding how I4.0 technologies contribute to SDGs and leverages the recognized linking between SDGs and Global Reporting Initiative (GRI) Standards to improve the reporting of SDG progress. Thus, the proposed framework identifies the GRI-based Key Performance Indicators necessary for a thorough understanding of how innovation stemming from I4.0, significantly impacts SDGs. Through a content analysis of sustainability reports of innovative companies in the electronic field, the study shows how the proposed framework can be applied in practice. Focusing on Artificial Intelligence (AI), the application case allows a comprehensive understanding of the transformative potential of AI solutions towards sustainable development.

Keywords: Industry 4.0, Artificial Intelligence, GRI Sustainability Reporting; Sustainable Development Goals (SDGs); Content Analysis.

1. Introduction

The United Nations 2030 Agenda for Sustainable Development is an action plan based on 17 interconnected goals that cover the three dimensions of sustainable development: economic growth, social inclusion and environmental protection (Giannetti et al., 2020). The 2030 Agenda aims to be transformative and universal making the private sector a key player for the Agenda implementation (Rashed & Shah, 2021). Indeed, is widely recognized that the company’s technological innovation is essential for sizing business opportunities and addressing contemporary global challenges (Silvestre & Tirça, 2019; Brogi & Menichini, 2024). Prior studies highlight that Industry 4.0 (I4.0)-based innovations in companies have a direct impact on Sustainable Development Goals (SDGs) progress (Ghobakhloo, 2020) whose impact is mainly positive (Varriale et al, 2024; Mabkhot et al., 2021). Additionally, several studies suggest that the adoption of I4.0 Digital Technologies (DTs) can significantly contribute to the Triple Bottom Line (TBL) sustainability by enhancing economic factors and addressing environmental and social challenges (Khan et al., 2023; Bonilla et al., 2018). However, the need to deepen the understanding of the role of I4.0 DTs in achieving the SDGs emerges (Alhammadi et al., 2024). Implementing innovation to move towards sustainability requires companies to face different challenges among them, a quantitative approach for measuring and reporting SDG impact appears to be an escalating challenge that requires specific tools and methods to be faced; especially a call emerges for a simple tool that companies can easily adopt, such as a set of KPI linked to SDGs (Mansell et al., 2020). According to Varriale et al. (2024) tools and approaches for quantifying the sustainability performance that innovation allows to achieve, both from economic, environmental, and social perspectives are necessary to verify and monitor the progress in implementing the 2030 Agenda at company levels. Considering the informative value of sustainability reporting, which allows explaining how a company’s strategies, practices and performance are achieved in line with SDGs (Bronzetti et al., 2023; Costa et al., 2022; Morioka et al., 2016), this paper proposes a sustainability reporting-based framework to quantify the impacts of I4.0 DTs on the SDG progress which are directly linked to enhanced company’s economic, environmental, and social performance. Current research on the relationship between I4.0 DTs and sustainability remain largely theoretical, lacking both rigour and comprehensiveness. Prior frameworks exist in the literature, such as the one by Narula et al. (2021), which proposes a conceptual framework for integrating I4.0 technologies with the GRI sustainability reporting framework. In addition, the conceptual framework by Varriale et al. (2024) aims to clarify the relationships among DTs, business functions, processes, and SDGs in production systems. This study, conversely, aims to provide a comprehensive framework that systematically connects I4.0 DTs to SDG progress through the Global Reporting Initiative (GRI) Disclosures, covering all three dimensions of sustainability performance—economic, environmental, and social. To this end, the proposed DTs - SDGs Progress framework considers the GRI key performance indicators, i.e. the GRI Disclosures. The GRI guidelines help firms measure their sustainability performance and the impacts of their activities on the SDGs in corporate sustainability reports, by providing a widely used common global language (Zadorozhnyy et al., 2023; KPMG, 2017). In addition, given the interconnections among innovation, managerial practices, policy, strategy, governance and stakeholder relationships (Li et al., 2022; Sun et al., 2022; Morioka et al., 2016) the proposed framework makes explicit the connection between a company's contributions to the SDGs and the strategic, governance, and stakeholder engagement areas defined by GRI Standards, which are involved in the innovation process. Starting from evidence in the literature on how I4.0 DTs impacted SDGs (Bai et al., 2023; Beier et al., 2021; Mabkhot et al., 2021; Oláh et al., 2020; Bonilla et al., 2018), and the GRI Guideline that links SDGs with informative economic, social and environmental GRI Disclosures (GRI, 2022a), the proposed DTs - SDGs Progress framework has been developed to connects I4.0 DTs to the SDGs, and thus identify those GRI Disclosures that better allow companies to measure and monitor economic, social, and environmental performances as well as monitor the managerial areas (activities and workers, governance, strategy, policies and practices, and stakeholder engagement), influenced by the adopted I4.0 innovations. This research is primarily grounded in the TBL theory, which provides a comprehensive framework for evaluating the economic, environmental, and social dimensions of sustainability (Braccini & Margherita, 2018). This theory is particularly relevant as it aligns closely with the multifaceted SDGs (Khan et al., 2023). Additionally, this study draws on legitimacy and stakeholder theory, dealing with the importance of aligning corporate actions with stakeholder expectations towards sustainable development (Michelon & Parbonetti, 2012). By combining TBL and stakeholder theories, the proposed framework offers a robust analytical lens to explore how I4.0 DTs can be integrated into innovative business practices and innovation strategies intended to achieve sustainability goals, as it makes explicit the link between the technologies and SDG progress, while also enhancing transparency and accountability through sustainability reporting, particularly via the GRI standards. Among the existing I4.0 DTs, the validation stage of the proposed framework focuses on Artificial Intelligence (AI) that emerges as largely related to SDG (Peng, 2023; Chutcheva et al., 2022; Isabelle et al., 2022; Sætra, 2021; Vinuesa et al., 2020; Ghallab, 2019). The validation procedure follows a systematic multi-step content analysis process (Hsieh & Shannon, 2005) applied to a set of GRI sustainability reports of the Boston Consulting Group's 2023 Most Innovative Companies operating in the electronics sector.

The remainder of the paper is structured as follows. In Section 2 the methodology is presented as the research flow of the study. The DTs - SDGs Progress framework is provided in Section 3. An illustrative application with AI reporting by innovative companies is conducted in Section 4 to validate the framework. Finally, the managerial implications are discussed, and the conclusions together with future developments.

2. Methodology

The research methodology encompasses three phases and five stages (Table 1). The phases are (i) exploratory; (ii) framework conceptualization; and (iii) validation. Aligned with these phases, the stages refer to the literature gap identification and the research problem definition (first phase); the literature review and the development of the DTs - SDGs Progress framework (second phase); data selection and method (third phase). Table 1 shows the research flow used to conduct the research.

Table 1: The research flow of the study.

Exploratory Phase	**Literature Gap Identification:** State of scientific research and identification of research gaps and unsolved problems concerning measurement and analysis of DTs impacts on SDGs
	Research problem Definition: Develop a conceptual framework that explains the impact of I4.0 DTs on the SDGs progress directly linked to an enhanced company's economic, environmental, and social performance
Conceptual Framework Phase	**Literature Review**: Conduct a comprehensive review of existing literature to identify how I4.0 DTs impact SDGs. Focus on key DTs such as AI, Big Data, blockchain, Internet of Things (IoT), and Additive Manufacturing (AM)

	Development of the DTs - SDGs Progress framework: Selecting Industry 4.0 DTs with a recognized impact on SDGS and linking DTs-impacted SDGs with informative GRI Disclosures, according to the GRI guidelines (GRI, 2022a). The GRI disclosures allow for the differentiation of the impact of DTs on TBL in terms of sustainability performance (economic, environmental, and social) or managerial areas influenced by the adopted I4.0 innovations
Validation Phase	**Data selection and method** **1. I4.0 DT and Industry Selection** 1.1 Identification of AI keywords from literature to perform quantitative content analysis 1.2 Among the Boston Consulting Group's 2023 ranking of the most innovative companies, select those operating in the electronics sector **2. Sustainability report selection** Collection of sustainability reports based on the selection criterion: compliance with GRI Standards **3. Quantitative content analysis** Identification of sentences that mention AI and cross-referencing theme with the GRI Disclosures listed in the GRI Index section of the sustainability reports **4. Qualitative content analysis** Analysis and interpretation of information involving three experts that independently analysed the AI-related sentences to determine whether AI solutions relate to the sustainability performance or managerial areas (activities and workers, governance, strategy, policies and practices, and stakeholder engagement) explained by the GRI Disclosures

3. DTs - SDGs Progress Framework

The proposed DTs - SDGs Progress framework (Table 2) shows the main studies on how a single I4.0 DT or multiple I4.0 DTs contribute to SDGs (Varriale et al., 2024; Bai et al., 2023; Mabkhot et al., 2021). Then, the GRI-based key performance indicators that allow for capturing the impacts of companies' activities and operations on SDGs are provided, taking into consideration the GRI Guideline (GRI, 2022a). These indicators - the so-called GRI Disclosures, are categorized into different dimensions of sustainability performance (i.e. economic, social, and environmental), and managerial practice (i.e. activities and workers, governance, strategy, policies and practices, and stakeholder engagement) which clarify how I4.0 influences management areas and explicitly contributes to SDG progress (GRI, 2022b; Fonseca et al., 2014). As emerges from the literature, I4.0 DTs impact all the SDGs (Table 2). The proposed framework highlights the dimensions of sustainability performance and managerial areas directly linked to each SDG (GRI, 2022a). For instance, achieving gender equality (SDG5) relates to the economic and social company's performance, as well as to the company's governance. Therefore, the potential I4.0 contribution to SDG5 can be explained through those economic GRI Disclosures (202-1, 203-1) or social (401-1, 401-1-a, 401-2, 401-3, 404-3-a, 405-1, 405-2-a, 406-1, 408-1-a, 409-1-a, 414-1-a, 414-2) or Governance (2-9-c, 2-10).

4. Validation Through AI Reporting by Innovative Companies

The proposed DTs - SDGs progress framework is validated through a content analysis of the selected reports, to quantify and analyse the presence, meanings, and relationships of words, themes, or concepts related to AI. As emerges from the literature (Table 2) AI has a relevant impact on SDG achievement while improving a company's performance and practice is a suitable technology for validation purposes. Content analysis is a research method used to systematically and objectively analyse the content of various forms of data to extract meaningful insights, patterns, and relationships (Gao et al., 2021). Qualitative-quantitative content analysis combines qualitative and quantitative approaches to analyse data. By integrating both qualitative and quantitative elements, researchers gain a deeper understanding of the data under study (Hsieh & Shannon, 2005). The present study employs a qualitative-quantitative-combined content analysis to uncover evidence of the impact of companies' adoption of AI on the company's contribution to SDGs as conceived in the proposed DTs - SDGs progress framework (Table 2).

Table 2: Conceptual framework

Main References	I4.0 DTs	SDGs	GRI Disclosures
Bai et al., 2023; Mabkhot et al., 2021	Multiple DT	1 - No Poverty	Economic Performance: 202-1, 203-2, 207-1, 207-2, 207-3, 207-4 Social Performance: 413-2-a
Sætra, 2021; Vinuesa et al., 2020	AI		
Alami et al., 2024; Muth et al., 2023	AM		
López-Vargas et al., 2020	IoT		
Chandan et al., 2023	Blockchain		
Bai et al., 2023; Mabkhot et al., 2021	Multiple DT	2 - Zero Hunger	Social Performance: 411-1, 413-2-a
Vinuesa et al., 2020; Ghallab, 2019	AI		
Alami et al., 2024	AM		
López-Vargas et al., 2020	IoT		
Chandan et al., 2023	Blockchain		
Giordano et al., 2023	Robotics		
Bai et al., 2023; Mabkhot et al., 2021	Multiple DT	3 - Good Health and Well-being	Economic Performance: 203-2 Environmental Performance: 305-1, 305-2, 305-3, 305-6-a, 305-7, 306-1, 306-2-a, 306-2-b, 306-2-c, 306-3-a, 306-3-b, 306-3-c, 306-4-a, 306-4-b, 306-4-c, 306-4-d, 306-5-a, 306-5-b, 306-5-c, 306-5-d Social Performance: 401-2-a, 403-6-a, 403-6-b, 403-9-a, 403-9-b, 403-9-c, 403-10
Vinuesa et al., 2020; Ghallab, 2019	AI		
Alami et al., 2024; Muth et al., 2023	AM		
López-Vargas et al., 2020	IoT		
Chandan et al., 2023	Blockchain		
Giordano et al., 2023	Robotics		
Bai et al, 2023	Multiple DT	4 - Quality Education	Social Performance: 404-1-a
Sætra, 2021; Vinuesa et al., 2020	AI		
Muth et al., 2023	AM		
López-Vargas et al., 2020	IoT		
Bai et al., 2023	Multiple DT	5 - Gender Equality	Governance: 2-9-c, 2-10 Economic Performance: 202-1, 203-1 Social Performance: 401-1, 401-1-a, 401-2, 401-3, 404-3-a, 405-1, 405-2-a, 406-1, 408-1-a, 409-1-a, 414-1-a, 414-2
Vinuesa et al., 2020	AI		
López-Vargas et al., 2020	IoT		
Bai et al, 2023; Mabkhot et al., 2021	Multiple DT	6 - Clean Water and Sanitation	Environmental Performance: 303-1-a, 303-1-c, 303-2-a, 303-3-c, 303-4, 303-5-a, 303-5-b, 304-1-a, 304-2, 304-3-a, 304-3-b, 304-4-a, 306-1, 306-1-a, 306-2-a, 306-2-b, 306-2-c, 306-3-a, 306-3-b, 306-3-c, 306-5-a
Sætra, 2021; Vinuesa et al., 2020; Ghallab, 2019	AI		
Parmentola et al., 2021	Blockchain		
López-Vargas et al., 2020	IoT		
Giordano et al., 2023	Robotics		

Bai et al., 2023; Mabkhot et al., 2021; Modgil et al., 2020; Oláh et al., 2020; Bonilla et al., 2018	Multiple DT	7 - Affordable and Clean Energy	Environmental Performance: 302-1, 302-2, 302-2-a, 302-3-a, 302-4-a, 302-5-a
Varriale et al., 2024; Chutcheva et al., 2022; Sætra, 2021; Vinuesa et al., 2020	AI		
Alami et al., 2024	AM		
Parmentola et al., 2021	Blockchain		
López-Vargas et al., 2020	IoT		
Giordano et al., 2023	Robotics		
Bai et al., 2023; Beier et al., 2021; Mabkhot et al., 2021; Modgil et al., 2020; Oláh et al., 2020	Multiple DT	8 - Decent Work and Economic Growth	Activities and workers: 2-7-a, 2-7-b, 2-8-a Stakeholder engagement: 2-30 Economic Performance: 201-1, 202-1, 202-2-a, 203-2, 204-1-a Environmental Performance: 301-1-a, 301-2-a, 301-3, 302-1, 302-2-a, 302-3-a, 302-4-a, 302-5-a, 306-2-a Social Performance: 401-1, 401-2-a, 401-3, 402-1, 403-1-a, 403-1-b, 403-2-a, 403-2-b, 403-2-c, 403-2-d, 403-3-a, 403-4-a, 403-4-b, 403-5-a, 403-7-a, 403-8, 403-9, 403-10, 404-1-a, 404-2, 404-3-a, 405-1, 405-2-b, 406-1, 407-1, 408-1, 409-1, 409-1-b, 414-1-a, 414-2
Peng, 2023; Chutcheva et al., 2022; Sætra, 2021; Vinuesa et al., 2020	AI		
Alami et al., 2024	AM		
López-Vargas et al, 2020	IoT		
Giordano et al., 2023	Robotics		
Bai et al., 2023; Beier et al., 2021; Mabkhot et al., 2021; Modgil et al., 2020; Bonilla et al., 2018	Multiple DT	9 - Industry, Innovation and Infrastructur e	Economic Performance: 201-1, 203-1
Peng, 2023; Sætra, 2021; Vinuesa et al., 2020; Ghallab, 2019	AI		
Parmentola et al., 2021	Blockchain		
Muth et al., 2023	AM		
López-Vargas et al., 2020	IoT		
Giordano et al., 2023	Robotics		
Bai et al., 2023; Mabkhot et al., 2021; Modgil et al., 2020	Multiple DT	10 - Reduced Inequality	Activities and workers: 2-7-a, 2-7-b Economic Performance: 207-1, 207-2, 207-3, 207-4 Social Performance: 401-1, 404-1-a, 404-3-a, 405-2-a
Vinuesa et al., 2020	AI		
López-Vargas et al., 2020	IoT		
Bai et al., 2023; Mabkhot et al., 2021; Modgil et al., 2020	Multiple DT	11 - Sustainable Cities and Communities	Economic Performance: 203-1 Environmental Performance: 306-1, 306-2-a, 306-2-b, 306-2-c, 306-3-a, 306-4-a, 306-4-b, 306-4-c, 306-4-d, 306-5-a, 306-5-b, 306-5-c, 306-5-d
Sætra, 2021; Vinuesa et al., 2020	AI		
Alami et al., 2024	AM		
Parmentola et al., 2021	Blockchain		
López-Vargas et al., 2020	IoT		
Giordano et al., 2023	Robotics		

Bai et al., 2023; Beier et al., 2021; Mabkhot et al., 2021; Oláh et al., 2020; Bonilla et al., 2018	Multiple DT	12 - Responsible Consumption and Production	Environmental Performance: 301-1-a, 301-2-a, 301-3-a, 302-1, 302-2-a, 302-3-a, 302-4-a, 302-5-a, 303-1-a, 303-1-c, 305-1, 305-2, 305-3, 305-6-a, 305-7, 306-1, 306-2-a, 306-2-b, 306-2-c, 306-3-a, 306-3-b, 306-3-c, 306-4-a, 306-4-b, 306-4-c, 306-4-d, 306-5-a, 306-5-b, 306-5-c, 306-5-d Social Performance: 417-1
Varriale et al., 2024; Isabelle et al., 2022; Di Vaio et al., 2020; Vinuesa et al., 2020; Ghallab, 2019	AI		
Varriale et al., 2024; Chandan et al., 2023; Parmentola et al.,	Blockchain		
Alami et al., 2024; Varriale et al., 2024; Muth et al., 2023	AM		
Varriale et al., 2024; López-Vargas et al., 2020	IoT		
Giordano et al., 2023	Robotics		
Bai et al., 2023; Mabkhot et al., 2021; Oláh et al., 2020; Bonilla et al., 2018	Multiple DT	13 - Climate Action	Economic Performance: 201-2-a Environmental Performance: 302-1, 302-2-a, 302-3-a, 302-4-a, 302-5-a, 305-1, 305-2, 305-3, 305-4-a, 305-5-a
Chutcheva et al., 2022; Isabelle et al., 2022; Vinuesa et al., 2020; Ghallab, 2019	AI		
Alami et al., 2024	AM		
Varriale et al., 2024; Chandan et al., 2023; Parmentola et al.,	Blockchain		
López-Vargas et al., 2020	IoT		
Varriale et al., 2024; Giordano et al., 2023	Robotics		
Bai et al., 2023; Mabkhot et al., 2021	Multiple DT	14 - Life Below Water	Environmental Performance: 304-1-a, 304-2, 304-3-a, 304-3-b, 304-4-a, 305-1, 305-2, 305-3, 305-4-a, 305-5-a, 305-7
Isabelle et al., 2022; Sætra, 2021; Vinuesa et al., 2020	AI		
Chandan et al., 2023; Parmentola et al., 2021	Blockchain		
Muth et al., 2023	AM		
López-Vargas et al., 2020	IoT		
Giordano et al., 2023	Robotics		
Bai et al., 2023; Mabkhot et al., 2021	Multiple DT	15 - Life on Land	Environmental Performance: 304-1-a, 304-2, 304-3, 304-4-a, 305-1, 305-2, 305-3, 305-4-a, 305-5-a, 305-7, 306-3-a, 306-3-b, 306-3-c, 306-5-a
Chutcheva et al., 2022; Isabelle et al., 2022; Sætra, 2021; Vinuesa et al., 2020	AI		
Chandan et al., 2023; Parmentola et al., 2021	Blockchain		
López-Vargas et al., 2020	IoT		
Giordano et al., 2023	Robotics		
Bai et al., 2023; Mabkhot et al., 2021	Multiple DT	16 - Peace, Justice and Strong Institutions	Governance: 2-9-c, 2-10, 2-11, 2-12, 2-15 Strategy, policies and practices: 2-23-a, 2-23-b, 2-26 Economic Performance: 205-1, 205-2, 205-3, 206-1 Environmental Performance: 307-1-a Social Performance: 403-4-a, 403-4-b, 403-9-a, 403-9-b, 403-9-c, 403-10, 408-1, 410-1, 414-1-a, 414-2, 415-1-a, 416-2, 417-2, 417-3, 418-1, 419-1-a
Peng, 2023; Vinuesa et al., 2020	AI		
López-Vargas et al., 2020	IoT		
Bai et al., 2023; Mabkhot et al., 2021	Multiple DT	17 - Partnerships for the Goals	Economic Performance: 207-1, 207-2, 207-3, 207-4
Peng, 2023; Ghallab, 2019	AI		
Alami et al., 2024	AM		
López-Vargas et al., 2020	IoT		

The validation procedure follows a systematic multi-step process of content analysis applied to a set of GRI sustainability reports. The recent sustainability reports compliant with GRI Standards of companies operating in the electronics sector ranked in the BCG's 2023 Most Innovative Companies (Manly et al., 2023) were considered. The BCG ranking was selected on the assumption that highly innovative companies should have thoroughly and extensively implemented the innovations introduced by I4.0 (Piccarozzi et al., 2023). Consequently, they should also be capable of critically assessing their contribution to environmental, economic, and social sustainability goals, making the selected set of companies suitable for the DTs - SDGs Progress framework validation purpose. Furthermore, the electronics sector was chosen due to its reputation as a high-velocity environment, where demand, competition, and technology are constantly and rapidly evolving (Sánchez et al., 2011). Initially, a quantitative content analysis was conducted, searching for AI-related keywords based on the terms proposed by Li et al. (2023), and herein reported in Table 3. Nevertheless, the keywords of further I4.0 DTs under analysis can be taken into account, for example, those present in the literature (Varriale et al., 2024). This search was performed within the sustainability reports of the four companies in our sample: Apple (2022), Samsung (2022), Xiaomi (2022), and Sony (2022). The goal was to identify sentences mentioning AI and to cross-reference these with the GRI Disclosures listed in the GRI Index section of the sustainability reports, according to the proposed DTs - SDGs Progress framework (Table 2). Following this, a qualitative content analysis was carried out by a research team of three coders. An example of AI sentence aligned with GRI Disclosures and the corresponding SDGs is shown in Table 4 in order to clarify the coding process. Indeed, Table 5 synthesizes the output of the coding process, with the first and second columns showing the connections of AI technologies with the specific GRI Disclosure in the company's sustainability report. Moreover, Table 5 illustrates the application of the proposed framework, where the bullets represent the connection among GRI Disclosures and SDGs. The bullets' colours show the sustainability performance (i.e. economic in purple, environmental in green and social in orange) or management practices (black) impacted by the adoption of AI technology.

Table 3: AI-Related Keywords Used in the Search for Sustainability Reports.

Reference	AI-keywords
Li et al., 2023	Artificial intelligence (AI), business intelligence, computer vision, investment decision assistance systems, intelligent robots, expert system, machine learning, semantic search, biometrics, face recognition, Identity verification, unmanned driving, autonomous driving, electronic design automation, natural language processing (NLP), customer relationship management, manufacturing resource management system, enterprise resource management, production information management System, Digital Control, Office Automation, Product Lifecycle Management, Robotic Process Automation, Enterprise Resource Management Software System, Financial System, Financial Management System, Kingdee, UFIDA, intelligent, intelligent office, intelligent technology, intelligent identification, intelligent manufacturing, intelligent terminal, robot, automatic control, intelligent equipment, intelligent workshop, intelligent factory, intelligent decision making, flexibility, integration, numerical control industrialization, fine management, industrial intelligence, intelligent system, intelligent operation and maintenance, intelligent warehousing.

Before starting, a comprehensive understanding of the GRI Disclosures, which compose GRI Standards, is essential for the effective application of the DTs – SDGs Progress framework. The GRI Standards are freely accessible at the following link, https://www.globalreporting.org/standards/.

Each coder independently analysed the AI-related sentences to determine whether they conveyed that AI contributed to the GRI Disclosures. Each coder reviewed and verified the documents initially analysed by their peers to ensure accuracy and consistency throughout the process (Curtó-Pagès et al., 2021). Discrepancies among coders were discussed and resolved to uphold reliability and Krippendorff's Alpha was used to measure Inter Coder Reliability (Krippendorff, 2018). The resulting high alpha value indicates strong agreement among the coders, thereby confirming the robustness and reliability of the analysis. Nonetheless, in order to allow an unambiguous categorization of the AI sentences (i.e., the sentences in the report in which a keyword among those listed in Table 3 appears) in terms of assignment of a GRI Disclosure, it was necessary to proceed with a comparison between the coders which led to a univocal assignment.

Table 4: Example of AI sentences aligned with GRI Disclosures and their corresponding SDGs.

GRI Disclosure – AI sentence	GRI disclosure	Impacted SDGs
"Samsung Innovation Campus operates a range of curricula, from programming to AI, in different countries. In cooperation with the local ministry of education, schools, and NGOs, we work to adapt the program to the local educational environment and conditions. The program contributes to nurturing workplace capabilities in youth by offering theoretical and hands-on IT training for programming, AI, IoT, and big data. [...] A total of 39,182 students in 28 countries received technological training in 2021. In Turkey, in particular, 86% of Samsung Innovation Campus graduates succeeded in being recruited, and some started their own businesses." Samsung 2022 SR, p. 43	203-2 Significant indirect economic impacts (GRI, 2022a)	1, 3, 8

Table 5: Coding process.

AI Sentence	GRI Disclosure	Sustainable Development Goals (SDGs) Impact																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Apple SR 2022, p.27	404-2 Programs for upgrading employee skills and transition assistance programs								●									
Apple SR 2022, pp.51,52, 54	403-7 Prevention and mitigation of occupational health and safety impacts directly linked by business relationships								●									
Apple SR 2022, p.68	201-1 Direct economic value generated and distributed								●	●								
Apple SR 2022, p.68	203-2 Significant indirect economic impacts	●		●					●									
Samsung SR 2022, p.27	302-4 Reduction of energy consumption							●	●				●	●				
Samsung SR 2022, p.29	302-5 Reductions in energy requirements of products and services							●	●				●	●				
Samsung SR 2022, pp.42-43	203-1 Infrastructure investments and services supported					●				●		●						
Samsung SR 2022, pp.42, 43	203-2 Significant indirect economic impacts	●		●					●									
Samsung SR 2022, pp.73	404-2 Programs for upgrading employee skills and transition assistance programs								●									
Xiaomi SR 2022, p.113	302-5 Reductions in energy requirements of products and services							●	●				●	●				
Xiaomi SR 2022, p.117	201-2 Financial implications and other risks and opportunities due to climate change													●				
Xiaomi SR 2022, pp. 121, 148	203-2 Significant indirect economic impacts	●		●					●									

Xiaomi SR 2022, p. 128, 132	2-23 Policy commitments																●	
Xiaomi SR 2022, p. 145	404-2 Programs for upgrading employee skills and transition assistance programs								●									
Xiaomi SR 2022, p. 148	203-1 Infrastructure investments and services supported					●				●		●						
Xiaomi SR 2022, p. 148	403-7 Prevention and mitigation of occupational health and safety impacts directly linked by business relationships								●									
Sony SR 2022, pp.34,47,48	302-4 Reduction of energy consumption							●	●				●	●				
Sony SR 2022, pp.47,48	305-1 Direct GHG emissions			●									●	●	●	●		
Sony SR 2022, pp.47,48	305-2 Energy indirect GHG emissions			●									●	●	●	●		
Sony SR 2022, pp.47,48	305-3 Other indirect GHG emissions			●									●	●	●	●		
Sony SR 2022, pp.47,48	305-4 GHG emissions intensity													●	●	●		
Sony SR 2022, pp.47,48	305-5 Reduction of GHG emissions													●	●	●		
Sony SR 2022, p.67	202-1 Ratios of standard entry level wage by gender compared to local minimum wage	●				●			●									
Sony SR 2022, pp.67-71-72-73	405-1 Diversity of governance bodies and employees					●			●									
Sony SR 2022, p.71-72-73	404-1 Average hours of training per year per employee				●				●		●							
Sony SR 2022, p.71-72-73	404-3 Percentage of employees receiving regular performance and career development reviews					●			●		●							
Sony SR 2022, p.88-89	406-1 Incidents of discrimination and corrective actions taken					●			●									

5. Managerial Implications

The proposed DTs - SDGs Progress framework allows comparisons among companies and their contribution to SDGs. Results are reported in Table 6, showing that AI solutions by innovative companies in the electronics sector influence all the SDGs except for SDGs 2, 6 and 17. In line with the previous literature (Table 2), AI solutions in the electronics sector contribute to SDG 1, SDG 3 and SDG 8 for all the analysed companies. Some SDGs (4, 10, 14, 15, 16) are relevant only for Sony while SDG 16 is only for Xiaomi. It is also possible to observe that Apple has a more focused contribution to some SDGs while Sony explains a more widespread contribution, followed by Xiaomi and Samsung. It emerges that the more innovative the company is, the more the contribution to the SDGs is focused on some SDGs.

Table 6: AI contribution to the SDGs for each company.

Positioning in the BCG ranking	Company	Impacted SDGs																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Apple	•		•					•	•								
7	Samsung	•		•				•	•	•		•	•	•				
29	Xiaomi	•		•		•		•	•	•		•	•	•			•	
31	Sony	•		•	•	•		•	•		•		•	•	•	•		

In addition, the framework allows comparison among the coverage of the AI reporting practices. Table 7 shows, for each company, the number of AI keywords in the sustainability reports, the number of AI sentences containing AI keywords and, finally, how many AI sentences were considered relevant to inform about SDG contribution according to the proposed content process (Table 1). The measure of AI centrality, determined by the ratio between the number of useful AI sentences after applying the coding process (i.e., AI sentences that relate to SDGs) and the total number of AI sentences, indicates that both the most innovative company (Apple) and the least innovative (Sony) report on the adoption of AI more adherent to the GRI disclosures (around 31% and 36.7%). The other companies show a lower level of AI centrality and the same level of reporting adherence (16 and 21%).

Table 7: Comparative analysis of AI reporting.

Company	Apple	Samsung	Xiaomi	Sony
Positioning in the BCG ranking	1	7	29	31
# AI keywords	5	7	9	8
# AI sentences	13	31	33	30
# AI sentences that relate to SDGs	4	5	7	11

Additional comparisons can be considered in terms of dimensions of sustainability performance that drive AI solutions towards SDG achievement. The impact of AI on the sustainability performances of the overall set of companies shows a balanced contribution in the three dimensions (Figure 1): economic 30.8%, environmental 34.6%, and social 34.6%.

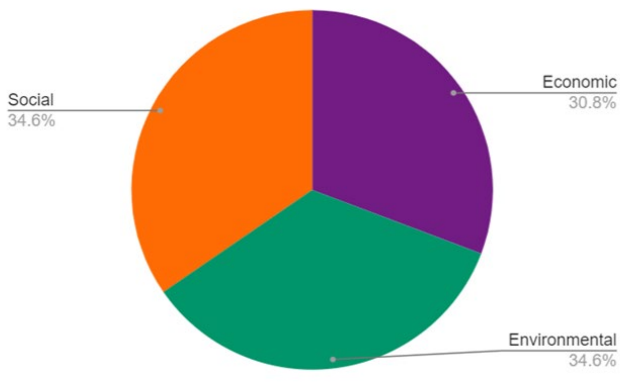

Figure 1: Impact of AI on sustainability performances in the electronics sector, overall set of companies.

However, the most innovative company does not present environmental reporting of the adopted AI solutions (Table 8). The AI contribution to the relevant SDGs (4 SDGs in the case of Apple) is reported in terms of economic and social performance through 4 GRI Disclosures (201-1, 203-2, 402-4, 403-7, see Table 5). The other companies report on all the dimensions of sustainability performance although with different percentages of presence. The relevance of the social dimensions is indirectly linked to the innovativeness of the company: Sony presents the highest level of social reporting (36%). On the other hand, it emerges that only in the case of one company (Xiaomi), AI contribution to SDG is explained in terms of managerial practice (strategy, policies, and practices) by means of the GRI Disclosure “2-23 Policy commitments” (see Table 5).

Table 8: AI contribution to the sustainability performance of each company.

Positioning in the BCG ranking	Company	Total Sustainability Performance GRI Disclosures related to AI	Total impacted SDGs	AI impact on sustainability performance
1	Apple	4	4	Economic (50%), Social (50%)
7	Samsung	5	9	Economic (40%), Environmental (40%), Social (20%)
29	Xiaomi	6	10	Economic (50%), Environmental (17%), Social (33%)
31	Sony	11	11	Economic (9%), Environmental (55%), Social (36%)

6. Conclusions

This study contributes to the existing body of knowledge by providing new TBL-based analytical perspectives on the impacts of I4.0 DTs on SDGs through a framework that leverages the recognized linkage between SDGs and GRI Standards. While several studies, such as Varriale et al. (2024) and Mabkhot et al. (2021), explore the impact of I4.0 DTs on SDGs, and Narula et al. (2021) show how I4.0 DTs influence GRI Standards adoption, the present study shifts attention to managerial practices. By adopting the GRI Standard Disclosures, the proposed DTs - SDGs Progress framework enables the quantification of sustainability performance across TBL dimensions, as well as the influence of I4.0 innovations on managerial areas. Additionally, the focus on AI in the electronics sector offers new insights into how companies in the field contribute to SDGs through AI-based innovations. The framework allows companies to evaluate and track the impact of adopted Industry 4.0 solutions towards SDGs while explaining sustainability performance achieved and how the innovative AI solution relates to managerial areas (activities and workers, governance, strategy, policies and practices, and stakeholder engagement). Through a multi-step content analysis of sustainability reports by BCG’s 2023 Most Innovative Companies operating in the electronics sector, the study shows the practical application of the DTs - SDGs progress framework. The framework allows comparisons among the company’s contributions to SDGs. By focusing on AI, the application case reveals that AI solutions mainly influence SDG 1 (No Poverty), SDG 3 (Good Health and Well-being) and SDG 8 (Decent Work and Economic Growth) but also contributions emerge for SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), SDG 10 (Reduced Inequality), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 15 (Life on Land), SDG 16 (Peace, Justice and Strong Institutions). The impact of AI on the sustainability performances of the overall set of companies shows a balanced contribution in the three dimensions (economic 30.8%, environmental 34.6% and social 34.6%) although some differences among the selected companies emerge. The company’s innovativeness does not imply environmental reporting of the adopted AI solutions while the relevance of the social dimensions is indirectly linked to the innovativeness of the company. The coverage of the AI reporting practices also shows that the AI centrality in reports is not directly linked to the company’s innovativeness. By leveraging the GRI Standards, the proposed framework is useful to improve the reliability and transparency of the company’s reported information (Watts, 2014). The framework allows comparability among companies and facilitates communication with stakeholders (Adams, 2022). Communicating how digital innovation contributes to SDG progress allows companies to improve their reputation and build stronger relationships with stakeholders who prioritize sustainability issues, such as investors or customers (Hamidi et al., 2023; Menichini & Salierno, 2023). Managers can use the proposed framework to obtain clearer and consistent information on the company’s sustainability efforts, making it easier for stakeholders to evaluate and compare the company’s practices and performance. Indeed, transparency about the company’s impacts on sustainable development is crucial to maintaining the social license to operate and achieve long-term business success (Băndoi et al., 2021; Calabrese et al., 2020). Although the proposed framework is designed to be applicable to companies of any size and sector, as it is based on the GRI Standards (Halkos & Nomikos, 2021), the application in this study is specifically focused on the electronics sector and AI technologies. Another limitation of this study consists of the framework based on contributions from the existing scientific literature, which means not all potential applications and case studies may have been captured, as some opportunities related to achieving the SDGs might not yet have been explored by researchers. Furthermore, the study concentrates exclusively on the positive impacts of digital technologies, potentially leading to a partial view and introducing bias into the research. Future research should broaden the scope of the analysis to include a broader range of sectors and a more diverse set of I4.0 DTs. This will provide a more comprehensive understanding of how I4.0 enables the private sector to contribute to sustainable development. Additionally, longitudinal studies analyzing trends over multiple years, including subsequent reports of the most innovative companies ranked in future BCG Most Innovative Companies reports, will be essential. Moreover, future analysis could consider how specific technologies from different sectors contribute to the achievement of specific SDGs in those sectors. This extended analysis will validate the framework in various contexts, improving its robustness by considering sector-specific practices and technological advances. In this way, the framework will remain adaptable and relevant, addressing both its strengths and potential limitations. This approach will ensure a comprehensive understanding of the interaction between I4.0 technologies and sustainability in different sectors, contributing to the broader goal of sustainable development.

References

Adams, C.A., Alhamood, A.M. and He, X., 2022. The development and implementation of GRI standards: practice and policy issues. In *Handbook of accounting and sustainability* (pp. 26-43). Edward Elgar Publishing.

Alami, A.H., Olabi, A.G., Alashkar, A., Alasad, S., Aljaghoub, H., Rezk, H. and Abdelkareem, M.A., 2023. Additive manufacturing in the aerospace and automotive industries: Recent trends and role in achieving sustainable development goals. *Ain Shams Engineering Journal*, *14*(11), p.102516.

Alami, A.H., Olabi, A.G., Khuri, S., Aljaghoub, H., Alasad, S., Ramadan, M. and Abdelkareem, M.A., 2023. 3D printing in the food industry: Recent progress and role in achieving sustainable development goals. *Ain Shams Engineering Journal*, p.102386.

Alhammadi, A., Alsyouf, I., Semeraro, C. and Obaideen, K., 2024. The role of industry 4.0 in advancing sustainability development: A focus review in the United Arab Emirates. *Cleaner Engineering and Technology*, p.100708.

Apple, 2022. Sustainability report. Available at: https://s2.q4cdn.com/470004039/files/doc_downloads/2022/08/2022_Apple_ESG_Report.pdf and https://s2.q4cdn.com/470004039/files/doc_downloads/Apple-ESG-Index.pdf

Bai, C., Zhou, H. and Sarkis, J., 2023. Evaluating Industry 4.0 technology and sustainable development goals–a social perspective. *International Journal of Production Research*, *61*(23), pp.8094-8114.

Băndoi, A., Bocean, C.G., Del Baldo, M., Mandache, L., Mănescu, L.G. and Sitnikov, C.S., 2021. Including sustainable reporting practices in corporate management reports: Assessing the impact of transparency on economic performance. *Sustainability*, *13*(2), p.940.

Beier, G., Niehoff, S. and Hoffmann, M., 2021. Industry 4.0: a step towards achieving the SDGs? A critical literature review. *Discover sustainability*, *2*(1), p.22.

Bennett, M. and James, P., 2017. Key themes in environmental, social and sustainability performance evaluation and reporting. In *Sustainable measures* (pp. 29-74). Routledge.

Bonilla, S.H., Silva, H.R., Terra da Silva, M., Franco Gonçalves, R. and Sacomano, J.B., 2018. Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, *10*(10), p.3740.

Braccini, A.M. and Margherita, E.G., 2018. Exploring organizational sustainability of industry 4.0 under the triple bottom line: The case of a manufacturing company. *Sustainability*, 11(1), p.36.

Brogi, S. and Menichini, T., 2024. The pathway towards circular economy: Measuring circular advantage of eco-innovations. *Business Strategy and the Environment*, *33*(4), pp.3005-3038.

Bronzetti, G., Rija, M., Sicoli, G. and Ippolito, D., 2023. Disclosure of innovation on sustainability report. *European Journal of Innovation Management*, *26*(3), pp.885-907.

Calabrese, A., Costa, R., Levialdi, N., Menichini, T. and Villazon Montalvan, R.A., 2020. Does more mean better? Exploring the relationship between report completeness and environmental sustainability. *Sustainability*, *12*(24), p.10635.

Chandan, A., John, M. and Potdar, V., 2023. Achieving UN SDGs in food supply chain using blockchain technology. *Sustainability*, *15*(3), p.2109.

Chutcheva, Y.V., Kuprianova, L.M., Seregina, A.A. and Kukushkin, S.N., 2022. Environmental management of companies in the oil and gas markets based on AI for sustainable development: An international review. *Frontiers in Environmental Science*, *10*, p.952102.

Costa, R., Menichini, T. and Salierno, G., 2022. Do SDGs really matter for business? Using GRI sustainability reporting to answer the question. *European Journal of Sustainable Development*, *11*(1), pp.113-113.

Curtó-Pagès, F., Ortega-Rivera, E., Castellón-Durán, M. and Jané-Llopis, E., 2021. Coming in from the cold: A longitudinal analysis of SDG reporting practices by Spanish listed companies since the approval of the 2030 agenda. *Sustainability*, *13*(3), p.1178.

Díaz, J., Pérez, J., Gallardo, C. and González-Prieto, Á., 2023. Applying inter-rater reliability and agreement in collaborative grounded theory studies in software engineering. *Journal of Systems and Software*, 195, p.111520.

Di Vaio, A., Palladino, R., Hassan, R. and Escobar, O., 2020. Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. *Journal of Business Research*, *121*, pp.283-314.

Fonseca, A., McAllister, M.L. and Fitzpatrick, P., 2014. Sustainability reporting among mining corporations: a constructive critique of the GRI approach. *Journal of cleaner production*, *84*, pp.70-83.

Gao, S., Li, L. and Wu, J., 2021. Application Analysis of Data Mining Technology in the Field of Learning Analysis in China-From the Perspective of Content Analysis. *The Educational Review, USA*, *5*(6), pp.155-163.

Ghallab, M., 2019. Responsible AI: requirements and challenges. *AI Perspectives*, *1*(1), pp.1-7.

Ghobakhloo, M., 2020. Industry 4.0, digitization, and opportunities for sustainability. *Journal of cleaner production*, *252*, p.119869.

Ghobakhloo, M., Iranmanesh, M., Grybauskas, A., Vilkas, M. and Petraitė, M., 2021. Industry 4.0, innovation, and sustainable development: A systematic review and a roadmap to sustainable innovation. *Business Strategy and the Environment*, *30*(8), pp.4237-4257.

Giannetti, B.F., Agostinho, F., Almeida, C.M., Liu, G., Contreras, L.E., Vandecasteele, C., Coscieme, L., Sutton, P. and Poveda, C., 2020. Insights on the United Nations Sustainable Development Goals scope: Are they aligned with a 'strong'sustainable development?. *Journal of Cleaner Production*, *252*, p.119574.

Giordano, G., Murali Babu, S.P. and Mazzolai, B., 2023. Soft robotics towards sustainable development goals and climate actions. *Frontiers in Robotics and AI*, *10*, p.1116005.

Global Reporting Initiative (GRI). (2022a). Linking the SDGs and GRI. Global Reporting Initiative. Retrieved from https://www.globalreporting.org/search/?query=Linking+the+SDGs+and+the+GRI+Standards

Global Reporting Initiative (GRI). (2022b). The consolidated set of GRI standards 2022. Global Reporting Initiative.

Halkos, G. and Nomikos, S., 2021. Corporate social responsibility: Trends in global reporting initiative standards. *Economic Analysis and Policy*, 69, pp.106-117.

Hamidi, S.R., Ismail, M.A., Mohamed Shuhidan, S. and Abd Kadir, S., 2023. Corporate reputation in industry 4.0: a systematic literature review and bibliometric analysis. *Sage Open*, *13*(4), p.21582440231200951.

Hsieh, H.F. and Shannon, S.E., 2005. Three approaches to qualitative content analysis. *Qualitative health research*, *15*(9), pp.1277-1288.

Isabelle, D.A. and Westerlund, M., 2022. A review and categorization of artificial intelligence-based opportunities in wildlife, ocean and land conservation. *Sustainability*, *14*(4), p.1979.

Khan, I.S., Ahmad, M.O. and Majava, J., 2023. Industry 4.0 innovations and their implications: An evaluation from sustainable development perspective. *Journal of Cleaner Production*, *405*, p.137006.

KPMG. (2017). The road ahead: KPMG International Survey of Corporate Responsibility Reporting. https://doi.org/10.1038/nnano.2013.238

Krippendorff, K., 2011. Agreement and information in the reliability of coding. *Communication methods and measures*, 5(2), pp.93-112.

Krippendorff, K. (2018). Content analysis: An introduction to its methodology. Sage publications.

Li, C., Long, G. and Li, S., 2023. Research on measurement and disequilibrium of manufacturing digital transformation: Based on the text mining data of A-share listed companies. *Data Sci. Financ. Econ*, *3*, pp.30-54.

Li, Y., Sun, H., Li, D., Song, J. and Ding, R., 2022. Effects of digital technology adoption on sustainability performance in construction projects: The mediating role of stakeholder collaboration. *Journal of Management in Engineering*, *38*(3), p.04022016.

López-Vargas, A., Fuentes, M. and Vivar, M., 2020. Challenges and opportunities of the internet of things for global development to achieve the United Nations sustainable development goals. *IEEE Access*, *8*, pp.37202-37213.

Mabkhot, M., Ferreira, P., Maffei, A., Podržaj, P., Mądziel, M., Antonelli, D., Lanzetta, M., Barata, J., Boffa, E., Finžgar, M. and Paśko, Ł., 2021. Mapping industry 4.0 enabling technologies into united nations sustainability development goals. *Sustainability*, *13*(5), p.2560.

Manly, J., Ringel, M., MacDougall, A., Cornock, W., Harnoss, J., Apostolatos, K., ... & Izaret, J. M. (2023). *Reaching New Heights in Uncertain Times*. Boston Consulting Group, Boston, Massachusetts, Vereinigte Staaten.

Mansell, P., Philbin, S.P. and Konstantinou, E., 2020. Redefining the use of sustainable development goals at the organisation and project levels—A survey of engineers. *Administrative Sciences*, 10(3), p.55.

Menichini, T., & Salierno, G. (2023). Using Materiality Analysis to Determine Actual and Potential Company Impacts on Sustainable Development. *European Journal of Sustainable Development*, *12*(2), 90-90.

Michelon, G. and Parbonetti, A., 2012. The effect of corporate governance on sustainability disclosure. Journal of management & governance, 16, pp.477-509.

Modgil, S., Gupta, S. and Bhushan, B., 2020. Building a living economy through modern information decision support systems and UN sustainable development goals. *Production Planning & Control*, *31*(11-12), pp.967-987.

Morioka, S.N., Evans, S. and de Carvalho, M.M., 2016. Sustainable business model innovation: exploring evidences in sustainability reporting. *Procedia Cirp*, *40*, pp.659-667.

Muth, J., Klunker, A. and Völlmecke, C., 2023. Putting 3D printing to good use—Additive Manufacturing and the Sustainable Development Goals. *Frontiers in Sustainability*, *4*, p.1196228.

Narula, S., Puppala, H., Kumar, A., Frederico, G.F., Dwivedy, M., Prakash, S. and Talwar, V., 2021. Applicability of industry 4.0 technologies in the adoption of global reporting initiative standards for achieving sustainability. Journal of Cleaner Production, 305, p.127141.

Oláh, J., Aburumman, N., Popp, J., Khan, M.A., Haddad, H. and Kitukutha, N., 2020. Impact of Industry 4.0 on environmental sustainability. *Sustainability*, *12*(11), p.4674.

Parmentola, A., Petrillo, A., Tutore, I. and De Felice, F., 2022. Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of Sustainable Development Goals (SDGs). *Business Strategy and the Environment*, *31*(1), pp.194-217.

Peng, Y., Ahmad, S.F., Ahmad, A.Y.B., Al Shaikh, M.S., Daoud, M.K. and Alhamdi, F.M.H., 2023. Riding the waves of artificial intelligence in advancing accounting and its implications for sustainable development goals. *Sustainability*, *15*(19), p.14165.

Piccarozzi, M., Stefanoni, A., Silvestri, C., & Ioppolo, G. (2024). Industry 4.0 technologies as a lever for sustainability in the communication of large companies to stakeholders. *European Journal of Innovation Management*, 27(6), 2042-2065.

Rashed, A.H. and Shah, A., 2021. The role of private sector in the implementation of sustainable development goals. *Environment, Development and Sustainability*, *23*(3), pp.2931-2948.

Sætra, H.S., 2021. A Framework for Evaluating and Disclosing the ESG Related Impacts of AI with the SDGs. *Sustainability*, *13*(15), p.8503.

Samsung, 2022. Sustainability report. Available at: https://image.samsungsds.com/en/downloads/sustainability-report/__icsFiles/afieldfile/2022/07/22/Samsung-SDS-Sustainability-Report-2022-ENG.pdf?queryString=20231023041239?queryString=20231023041239

Sánchez, A., Lago, A., Ferràs, X. and Ribera, J., 2011. Innovation management practices, strategic adaptation, and business results: evidence from the electronics industry. *Journal of technology management & innovation*, *6*(2), pp.14-39.

Silvestre, B.S. and Ţîrcă, D.M., 2019. Innovations for sustainable development: Moving toward a sustainable future. *Journal of cleaner production*, *208*, pp.325-332.

Sony, 2022. Sustainability report. Available at: https://www.sony.com/en/SonyInfo/csr/library/reports/SustainabilityReport2022_E.pdf

Stranieri, S., Orsi, L., Banterle, A. and Ricci, E.C., 2019. Sustainable development and supply chain coordination: The impact of corporate social responsibility rules in the European Union food industry. *Corporate Social Responsibility and Environmental Management*, *26*(2), pp.481-491.

Sun, Y., Davey, H., Arunachalam, M. and Cao, Y., 2022. Towards a theoretical framework for the innovation in sustainability reporting: An integrated reporting perspective. *Frontiers in Environmental Science*, *10*, p.935899.

Teh, D. and Rana, T., 2023. The use of Internet of Things, Big Data analytics and artificial intelligence for attaining UN's SDGs. In *Handbook of big data and analytics in accounting and auditing* (pp. 235-253). Singapore: Springer Nature Singapore.

Varriale, V., Cammarano, A., Michelino, F. and Caputo, M., 2024. The role of digital technologies in production systems for achieving sustainable development goals. *Sustainable Production and Consumption*.

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., Felländer, A., Langhans, S.D., Tegmark, M. and Fuso Nerini, F., 2020. The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature communications*, *11*(1), pp.1-10.

Watts, S., 2015. Corporate social responsibility reporting platforms: enabling transparency for accountability. *Information Technology and Management*, *16*, pp.19-35.

Xiaomi, 2022. Sustainability report. Available at: https://xiaomi.gcs-web.com/system/files-encrypted/nasdaq_kms/assets/2023/04/26/10-13-04/2022%20ESG%20Report_ENG.pdf

Zadorozhnyy, Z.M., Lyuba, O., Ometsinska, I. and Shesternyak, M., 2023. INTEGRATED REPORTING IN THE MANAGEMENT OF FOREIGN ECONOMIC ACTIVITIES OF ENTERPRISES. *Financial & Credit Activity: Problems of Theory & Practice*, *4*(51).