Big data and sustainability reports: The current approach to non-accounting data management

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Abstract
Smart technologies influence the accounting and reporting environment and pose several challenges to academics and practitioners. In this scenario, Big Data (BD) and BD analytics could play a crucial role in improving management control and accounting practices, as well as the accuracy of financial, non-financial and sustainability reporting. This paper is the first to draft the impact of BD and BD analytics in the management of non-financial and sustainable information. It involved a review of the literature connecting BD to sustainability accounting and reporting, using document-based data covering the 2010-2022 period. The paper's main contribution, by applying a qualitative approach, is the mapping of current research on this emerging topic. Elaborating on previous scholarly contributions, it provides a first account of this research area and recommends possible directions for future studies.

Keywords: Sustainability reporting, Big data, Sustainability accounting, Big data analytics.

1. Introduction

The advent of smart technologies is influencing the accounting and reporting environment, posing several challenges for academics and practitioners (Lombardi, Secundo, 2021). In this scenario, the use of Big Data (BD) could be directed to collect, manage and communicate both accounting and

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non-accounting information to draft the current approach for the corporate data management (Montemari, Nielsen, 2021). Thus, this paper aims to investigate the impact of BD in the management of non-financial or sustainable information by companies directed to prepare their sustainability reports (SR).

Interestingly, the increasing number of companies collecting, managing and preparing non-financial information (e.g. environment, human rights, anti-corruption and bribery, social matters, diversity on company boards) to compose mandatory or voluntary annual reports (Demartini *et al*., 2015; Marchi, 2019, 2020) needs to be regarded in the corporate processes and tools applied in the achievement of such results. On one side companies are applying regulations (e.g. EU Directive 95/2014; D.Lgs 254/2016), standards and frameworks (e.g. Guidelines by the Taskforce on climate-related financial disclosures; Global Reporting Initiative, Gruppo di studio per il bilancio sociale, Carbon Disclosure Project, Climate Disclosure Standard Boards) in composing SR (Fornaciari, Pesci, 2018; GRI, 2016); on the other side, the way to collect, manage and visualize sustainability information and data seems almost under investigated (Castellano, Felden, 2021; Sproviero, 2020).

Sustainability accounting and reporting (SAR) has been long criticised for providing poorly conceptualised and prepared baselines for measurements (Tiwari, Khan, 2020), unreliable sources and methods of data collection (Wanner, Janiesch, 2019), following manual or semi-automatic processes affected by delays and human errors and the manipulation of results and analysis to hide the weaknesses in the corporate sustainability performance, prioritizing the dissemination of good Corporate Social Responsibility (CSR) practices and this way improving company's reputation (Barbeito-Caamaño, Chalmeta, 2020; Bini *et al*., 2016; Cinquini *et al*., 2016; Demartini, Paoloni, 2011; Michelon *et al*., 2015).

Thus, there is a need to use technology to "modernize" companies' SAR (Garzella, Fiorentino, 2013) to solve the above-mentioned shortcomings, particularly through the use of BD and BD analysis techniques (Tiwari, Khan, 2021; Wanner, Janiesch, 2019), providing "objective" data free of bias (Asokan *et al.*, 2020) and able to short-timely managing data. However, little is known about employing BD and BD analytics to improve the quality of sustainability reporting (Serag, 2022). Therefore, integrating sustainability reporting with management control systems based on BD technologies need further academic research (Joshi, Li, 2016; Lodhia, 2018), contributing to the growth of this emerging topic and guiding accounting professionals and managers in their decisions-making.

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Following our aims to draft for the first time the impact of BD in the management of non-financial and sustainable information, this paper analyses previous studies connecting BD and BD analytics to company's internal and external SR, through a literature review, suggesting the way for the future research development in this new field of research (Paoloni, Demartini, 2016). We collected data from several sources (e.g. leading Italian academic journals such as *Management Control*, *Financial Reporting*, *Azienda Pubblica* and the *Italian Accounting Review*; Google Scholar) between 2010-2022 building a dataset of documents composed by 16 articles.

Results are interesting and directed to enrich the integration of SR with management control systems based on BD and BD analytics. Contribution and implications are directed to academic and professional communities as well as to decision-makers. Thus, this article drafts the state of the art in the connection between BD and SR, starting for the first time the discussion on this thrilling and under discovered topic.

This article is organized as follow. After the introduction, Section 2 presents the theoretical background. Section 3 shows the methodology. Section 4 proposes results and discussion. Section 5 presents implications, conclusions and future research agenda.

2. Theoretical background

2.1 How Big Data are reshaping accounting landscape

Traditionally the main source of data for businesses, representing the heart of accounting and reporting, has always been the Enterprise Resource Planning system, however, with the diffusion of smart technologies (e.g. IoT, AI, cloud computing) and the advent of Industry 4.0 revolution, new types and volumes of data became available from different sources (e.g. smartphones, social media, websites) increasing the quality and volume of data to be used for accounting, reporting and decision-making processes (Arnaboldi *et al.*, 2017; Cockcroft, Russell, 2018; Lombardi, Secundo, 2021). This new type of data is known as BD and includes financial and non-financial data, as well as quantitative and qualitative data, which are available in big amounts, real-time and different formats (e.g. video recordings, voice messages, images, sensor recordings) (Capurro *et al*., 2018; Blazquez, Domenech, 2018).

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There is not a generally accepted definition of BD, however scholars agreed that the most important characteristics are (Bhimani, Willcocks, 2014; McAfee, Brynjolfsson, 2012; Moffitt, Vasarhelyi, 2013):

1. "Volume", which refers to a massive quantity of data which is keeping to increase because of ICTs development;
2. "Velocity", which refers to that BD can be generated and processed at a very high speed enabling the reaching of relevant data or information in real-time and timely updates;
3. "Variety", which refers to a wide range of data sources and formats (unstructured, semi-structured and structured data) which integrates traditional tools.

Scholars are arguing that BD can provide more accurate, complete and real-time large amounts of data (i.e. high-quality data), which may also improve management control and accounting practice (Cupertino *et al*., 2018; Montemari, Nielsen, 2021; Warren *et al*., 2015), financial accounting (Moffitt, Vasarhelyi, 2013), auditing process (De Santis, 2018; Marcello, 2020; Rakipi *et al*., 2021) as well as the accuracy of financial, non-financial and sustainability reporting (Janvrin, Watson, 2017; Wanner, Janiesch, 2019). Indeed, using BD analytics techniques (i.e. innovative algorithms and statistical tools) companies can collect and process great volumes of financial and non-financial data, both structured or unstructured and internal or external, giving insights in real-time to stakeholders and decision-makers and enabling a flexible, interactive and up-to-date corporate reporting.

Therefore, BD can increase both transparency and data quality of corporate reporting systems, decreasing information asymmetry (*Agency Theory* – Pratt, Zeckhauser, 1985) and improving corporate image thanks to a better perceived credibility of financial and sustainability reports (Wanner, Janiesch, 2019) thus maximizing the benefits for all stakeholders (*Stakeholder Theory* - Freeman, 1984).

To date, various studies have been investigating the relationship between BD and corporate reporting and accounting, mainly focusing on financial reporting and adopting conceptual approaches with little empirical findings, as well as on the impact of BD on accounting profession (Al-Htaybat, von Alberti-Alhtaybat, 2017; Bhimani, Willcocks, 2014; Griffin, Wright, 2015; Quattrone, 2016).

Thus, the use of BD seems a promising lever also to enhance company's sustainability (Cupertino *et al*., 2018; Etzion, Aragon-Correa, 2016; Montemari, Nielsen, 2021) with "unbiased", more accurate, high quality, real-time and external SR.

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2.2 Sustainability reporting

Social responsibility and sustainability have become crucial in business and organization discourses due to the potential impact of their decision and activities on the society and the environment (Buscarini *et al*., 2021; Fadda *et al*., 2021; Gray, 2010; Marchi, 2019), also affecting company's profitability in the long run (Gao, Zhang, 2006).

Consequently, transparency became a new paradigm for conducting business and corporate non-financial reporting gained recognition and interest among stakeholders (GRI, 2020; Mazzola, Contrafatto, 2019). Companies traditionally more concerned with financial reporting are increasingly aware that measurement and tracking of non-financial data and information improves their decision-making process, allowing them to identify threats and opportunities which can heavily affect their capacity to generate and preserve long-term value (Bellucci *et al*., 2019; Lombardi *et al*., 2021a; Marchi, 2020; Milne, Gray, 2013; Molinari *et al*., 2021). Whether it's driven by CSR, transparency demands or long-term company's vision, an increasing number of organizations are starting to consider sustainability reporting at the same level of standard financial reporting processes.

According to Global Reporting Initiative (2006), which provides a global reporting framework for SAR, the expression "sustainability report" describe the communication of the economic, environmental, and social impacts, that is, Triple Bottom Line (TBL) (Milne, Gray, 2013), corporate social and/or environmental reports and SR among others. Particularly, SR represent an essential tool enabling companies to assess and disclose their social and environmental impacts. Additionally, the European Union issued a proposal of Directive on Sustainability Report also fostering digitalization (www.ec.europa.eu).

To date, companies usually prepare their SR annually, comparing data with previous year and communicating the results in a static printed and/or online document. This way, sustainability data remains unrelated to different reports and it's hard to aggregate them in order to give decision-makers useful information (Herremans *et al*., 2016). Moreover, sustainability reporting practices are frequently criticized for non-integration into daily management activities, for not giving a higher quality of information, for lacking credibility and for not progressing sustainability (Abdalmuttaleb, Al-Sartawi, 2021; Burritt, Schaltegger, 2010; Cho et al., 2012; Coombs, Holladay, 2013). Consequently, various scholars have accused SR for contributing to enterprises greenwashing by enlarging the credibility gap (Lock, Seele, 2016; Khan *et al*., 2020; Seele, Gatti, 2017).

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The increasing amount of data now available (BD) represent an enormous potential driver of change in current sustainability reporting practices, making traditional SR progressively losing relevance. In the BD era every aspect of a company's sustainability performance can be processed and analyzed in real-time, giving companies the opportunity to immediately react, predict or pre-emptively counteract sustainability risks even before they take place, and to develop specific non-financial Key Performance Indicators (KPIs) both enhancing their decision-making process as well as SR effectiveness. This way, companies could release SR in shorter periods, providing accurate, transparent and eventually real-time sustainability information to stakeholders.

In addition, the direction of SR could be shaped also by using BD in materiality assessments – e.g. using internal and external tweet, email, reviews – to determine which sustainability issues are the most material (i.e. important) for every stakeholders group and therefore needs to be reported (Balluchi *et al*., 2019; Molinari *et al*., 2021). Consequently, materiality issues could also be the ones enhancing revenues, reducing operational costs and mitigating negative social and environmental impacts. Therefore, BD could transform SR from a centralized and static tool into a decentralized and interactive digital tool, allowing stakeholders to observe company's sustainability through up-to-date information.

Several scholars argued that BD has the potential to advance company's sustainability, environmental and social concerns by "modernizing" SAR practices (Tiwari, Khan, 2021; Wanner, Janiesch, 2019). Therefore, the advantages of integrating SR with management control systems based on BD – such as a better operationalization and communication of sustainability ideals (De Villiers, 2016) – need much research efforts, contributing to the growth of this emerging topic and guiding accounting professionals and managers in their decisions-making.

In the light of the previous considerations, the main research questions addressed in this study are the following:

RQ1: *What is state of the art in the connection between BD and sustainability reports?*

RQ2: *What are the implications for future research agenda analyzing the connection between BD and sustainability reports?*

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3. Research method

We applied a qualitative methodology using the critical/interpretative and document approaches. This paper analyses literature to investigate characteristics, identify patterns and examine the impact of the topic of BD and BD analytics in relation to sustainability reporting over time (Demartini, Paoloni, 2017; Lombardi, Secundo, 2021; Paoloni *et al*., 2019; Tranfield *et al*., 2003).

Following Petticrew and Roberts (2006) we first identified that no prior literature review had summarized the academic research on the topic of SR intersection with BD and BD analytics. Since the research questions are aiming at the interplay between SR and BD we took under consideration two groups of words, the first regarding SR and the relating terms, the second regarding BD and associated terms. Then, we carried out a scoping study on the concept of SR in connection with BD and BD analytics by entering keywords combinations in several databases, obtaining an exploratory overview of the literature on this topic. Lastly, we drafted a review protocol to guide the literature analysis process, as displayed in Figure 1.

The list of keywords found during the scoping study was then complemented with alternative expressions and terms derived also from the JEL Classification Codes Guide provided to conduct social science research. This way we obtained two keyword groups relating to SR and BD. Moreover, wherever possible we used the symbol (*) to capture all related word endings. Afterwards, the search string was created linking the two keyword groups by using Boolean operators (Figure 1).

The aim of this article is to build knowledge on how this research topic is actually evolving both from theoretical and practical perspectives and to define future line of research in this area. We collected data from several sources among which leading Italian academic journals such as Management Control, Financial Reporting, Azienda Pubblica and the Italian Accounting Review and Google Scholar between 2010-2022 building a dataset of documents.

The literature search was conducted on Sept. 2021, and updated in Apr. 2022, yielding 139 search results in the timespan 2010-2022. We used 2010 as the starting year of the analysis since in this period the first studies investigating the potential of BD for enterprises were published as a result of a growing awareness about BD and related analytics tools. As mentioned, the literature on this topic is still at its infancy and we aimed to cover the entire range, thus we did not excluded studies on the basis of their quality.

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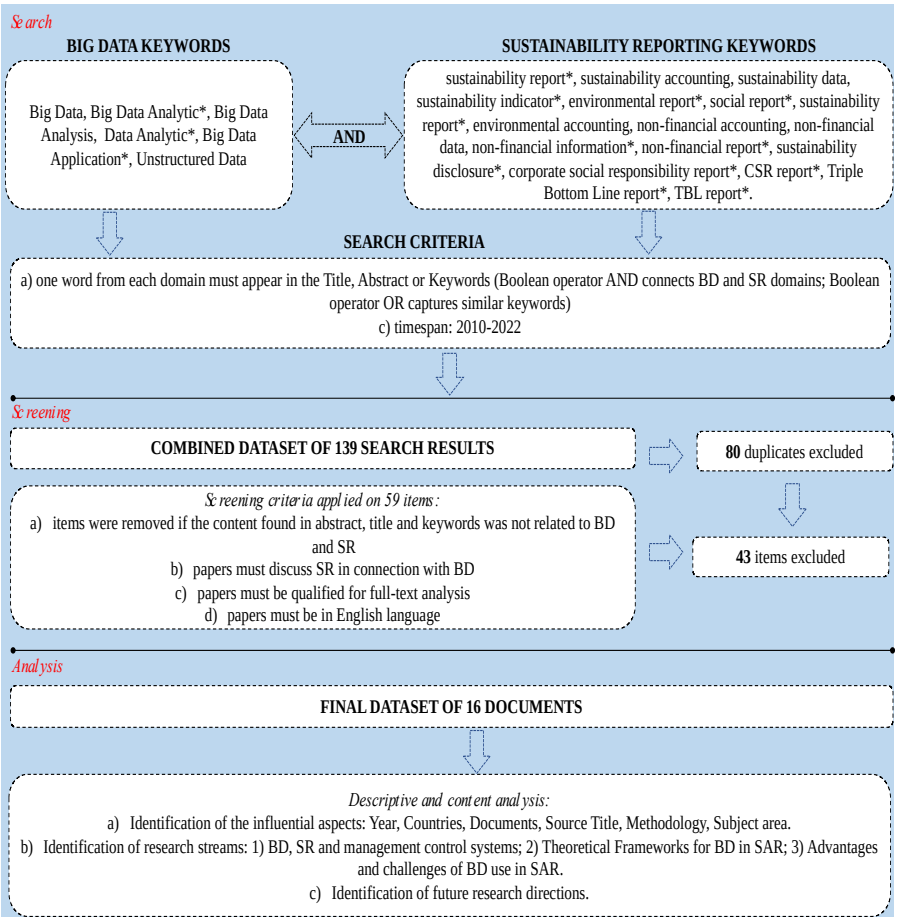
Figure 1 - *Methodological process*



Source: *authors' elaboration*

Publications in languages other than English were excluded to avoid a language bias. After the elimination of duplicated documents and a discussion of the outcomes among authors, 123 documents have been excluded from the initial dataset, resulting in a final dataset of 16 publications (Table 1).

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Table 1 - *Dataset*

Authors	Year	Title	Source title
Serag, M.A.	2022	Enhancing Quality of Sustainability Reporting by Using Big Data Analytics: A Conceptual Framework Based on Stakeholder Engagement.	*Proceedings of the International Conference On Global Economic Revolutions*
Cappelli A., Cavallini I.	2021	The potential of big data analysis in the shipbuilding industry: a way of increasing competitiveness.	*Management Control*
da Costa Tavares M.D. C., do Carmo Azevedo G.M.	2021	Society 5.0 as a contribution to the sustainable development report.	*Smart Innovation, Systems and Technology*
Dicuonzo G., Dell'Atti V., Fusco A., Donofrio F.	2021	Big data and artificial intelligence for health system sustainability: The case of Veneto Region.	*Management Control*
Lombardi R., Trequattrini R., Schimperna F., Cano-Rubio M.	2021	The Impact of Smart Technologies on the Management and Strategic Control: A Structured Literature Review.	*Management Control*
Tiwari K., Khan M.S.	2021	Role of Industry 4.0 Technologies in Sustainability Accounting and Reporting-Research Opportunities in India and Other Emerging Economies	*Lecture Notes in Mechanical Engineering*
Asokan V.A., Yarime M., Onuki M.	2020	A review of data-intensive approaches for sustainability: methodology, epistemology, normativity, and ontology.	*Sustainability Science*
Brunelli S., Ranalli F.	2020	SDGs achievement: commitment, channels of action and the role of integrated reporting in the disclosure mechanisms.	*Accounting, Finance, Sustainability, Governance and Fraud*
Sproviero A.F.	2020	Integrated reporting and the epistemic authority of Big Data: an exploratory study from the banking industry.	*Financial Reporting*
Tiwari K., Khan M.S.	2020	Sustainability accounting and reporting in the industry 4.0.	*Journal of Cleaner Production*
Hämäläinen E., Inkinen T.	2019	Industrial applications of big data in disruptive innovations supporting environmental reporting.	*Journal of Industrial Information Integration*
Wanner J., Janiesch C.	2019	Big data analytics in sustainability reports: an analysis based on the perceived credibility of corporate published information.	*Business Research*

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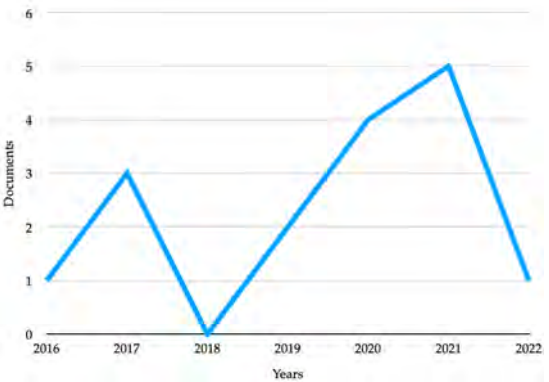
Hämäläinen E., Inkinen T.	2017	How to generate economic and sustainability reports from Big Data? Qualifications of process industry.	*Processes*
Rezaee Z., Homayoun S., Mora M.	2017	Integration of Real-time Analysis of Big Data into Sustainability Attributes.	*CEUR Workshop Proceedings 2017*
Wong E., Wines T., Li S.	2017	Sustainable data analytics for environmental performance monitoring in dynamic supply chain infrastructure.	*Management Science*
Seele P.	2016	Envisioning the digital sustainability panopticon: a thought experiment of how big data may help advancing sustainability in the digital age.	*Sustainability Science*

Source: *authors' elaboration*

4. Results

This section presents the results of this study answering to our research questions. The analysis starts with the displaying of descriptive statistics based on general information of 16 articles. We assume that scholars only recently began to investigate the topic of BD in connection to SAR. The emerging nature of the topic is revealed in Figure 2, where the oldest article is published in 2016, while we highlight that the number of articles published is increasing since 2019. The number of articles for 2022 could be incomplete because the data collection ended at the beginning of April. The most of documents in the sample are article published in scientific journals (11 out of 16), other documents represent conference proceedings and book chapters.

Figure 2 - *Publication trends*



Source: *authors' elaboration*

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Table 2 summarize the research methods applied in the sample papers. According to existing taxonomy (Coyne *et al*., 2010; Paoloni, Demartini, 2016), we grouped research methods in four main categories (i.e. analytical, archival, experimental, and other) and into qualitative versus quantitative methods.

Table 2 - *Research methodology: summary of count*

Authors	*Methodology*	*Qualitative*	*Quantitative*
Serag M.A.	Other-Framework	x	
Cavallini I., Cappelli A.	Other-Framework	x	
da Costa Tavares M.D.C., do Carmo Azevedo G.M.	Other-Framework	x	
Dicuonzo G., Dell'Atti V., Fusco A., Donofrio F.	Other-Case study and interview	x	
Lombardi R., Trequattrini R., Schimperna F., Cano-Rubio M.	Other-Review	x	
Tiwari K., Khan M.S.	Other-Framework	x	
Asokan V.A., Yarime M., Onuki M.	Other-Review	x	
Brunelli S., Ranalli F.	Other-Descriptive	x	
Sproviero A.F.	Other-Descriptive	x	
Tiwari K., Khan M.S.	Other-Focus groups and interview	x	
Hämäläinen E., Inkinen T.	Other-Case study	x	
Wanner J., Janiesch C.	Experimental		x
Hämäläinen E., Inkinen T.	Other-Descriptive	x	
Rezaee Z., Homayoun S., Mora M.	Other-Framework	x	
Wong E., Wines T., Li S.	Other-Case study	x	
Seele P.	Other-Framework	x	
Total		**15**	**1**

Source: *authors' elaboration*

The category "other" includes the subcategories: case study, focus group and interview, descriptive, review and framework. Two research methodologies are used by the articles published in the dataset under investigation from 2016 to 2022, among which the two dominant techniques are frameworks, case studies and descriptive studies. A noteworthy finding is that only one article adopts the experimental method. The topic is novel and mainly

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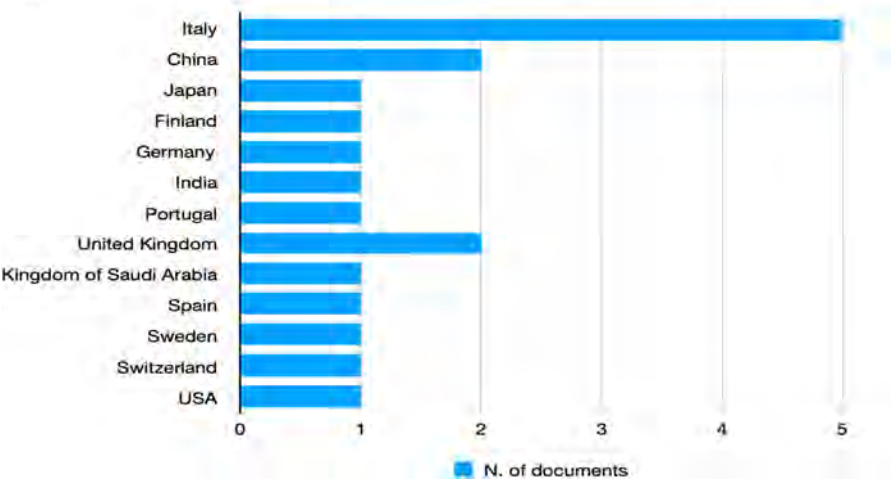
investigated from a theoretical point of view, however, a first empirical analysis conducted in 2021 could indicate that the interest around this research area is now starting to grow among scholars.

Overall, the article sources cover various research domains, revealing how the topic of BD and BD analytics in connection to SR interests multiple research streams and probably favored cross-fertilization of various fields. Among the most relevant areas there is *Business, Management and Accounting* and also *Sustainability Science, Engineering* and *Environmental Science.* Hence, this result is also suggesting the pervasiveness of the investigated topic in social science literature.

The analysis found that there are 28 (out of 32) authors with one article published, thus reflecting that very few scholars are specializing in studying BD and BD analytics in relation to SAR. The authors we are referring to are (1) Hämäläinen; (2) Tiwari; (3) Inkinen; (4) Khan, which research mainly focuses on BD and BD analytics in the context of environmental accounting and reporting and, more generally, SAR. We observed that the entire countries that contributed to the field are 13 countries (Figure 3). Therefore, we highlight that, except for few countries (Italy, Germany, Portugal, Spain, Sweden and Finland), most European countries do not seem to have developed yet a research interest in this field of investigation. Such findings show that the debate on this topic is still in its infancy in the global scientific arena.

Figure 3 - *Documents by country*



Source: *authors' elaboration*

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This study expects that the topic may receive more attention in the near future. Descriptive results revealed that documents in the dataset main concern is the use of BD in relation to company's sustainability issues, accounting and reporting and sustainable development, also in relation to the 17 goals (SDGs) developed by the UN 2030 Agenda. The documents in the sample also investigated sustainability connection with BD in relation to company's decision-making process and the impact of BD use to improve operations sustainability, as well as the implementation of BD analytics in relation to company's SAR.

4.1 Emerging research topics

This section is devoted to discuss all studies composing the dataset, drafting main research paths. We identified three main research paths as reported below.

Research Path 1) Integration of SR with management control systems based on BD and BD analytics.

A first stream of research investigating BD and BD analytics potential in integrating sustainability reporting and management control system is identified. A first contribution is provided by Hämäläinen and Inkinen (2019) who described a novel BD solution replacing traditional and static corporate reporting data-sources with company-wide information based on a BD integrated system. In their view, BD applications for real use in a specific industry is a combination of different categories of data gathered from the cost management system - e.g. sales, production and logistics- to be used to provide monthly and real-time economic reporting, sustainability reporting (especially for emissions) and industrial management simulations. Thus, BD-based reporting system could be used by companies to integrate historic and anticipatory sustainability data together with the business data, simultaneously adopting decision oriented to the development of responsible operation and economic success. Indeed, the authors highlighted that BD could improve production processes and efficiency, lowering production costs and harmful emissions for the environment, thus, improving company's overall sustainability. In a similar direction, Dicuonzo et al. (2021) highlighted that the use of BD allows healthcare organizations to perform real time planning and programming that improves economic sustainability (i.e. time and costs reduction), environmental sustainability (i.e. efficient use of natural resources), and social sustainability (i.e. better accessibility to care, regardless

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of socio-cultural differences). Also, Cappelli and Cavallini (2021) in their study pointed out that BD analytics can help businesses to make processes and operations more cost-effective and be more sustainable and competitive.

Other scholars have pointed out that the integration of external sustainability reporting with management control systems lead to, at least, a better actualization and internal communication of sustainability goals and to a greater stakeholder engagement (Cupertino *et al*., 2018; De Villers *et al*., 2016). In another study published earlier by Hämäläinen and Inkinen (2017) they presented and discussed the building of an integrated system to cover cost management, emission, and economic reporting, introducing ideas on how a solution supporting sustainable production and fully integrated with BD storage works. More recently, Lombardi *et al*. (2021b) in their study underlined a strong connection between BD and the decision-making, planning, and control processes performed by companies, posing key questions and identifying new research directions in this emerging field of study. Lastly, Wong *et al*. (2017) developed a sustainability reporting and BD analytics model to support enterprises' decision-making processes.

Research Path 2) Development of theoretical framework for BD analytics in SAR

Among the literature scrutinized in this study a second research stream could be derived, composed by papers proposing frameworks for BD use in companies' sustainability reporting. Recently, Tiwari and Khan (2021) suggested a framework of Industry 4.0 technologies, particularly focusing on BD and BD analytics, to be adopted by companies - mainly SMEs - to achieve reliable and effective SAR to satisfy the regulatory requirements, investor relations, and achieving the desired level of protection as per the GRI guidelines. In another study, da Costa Tavares and do Carmo Azevedo (2021) developed a framework explaining the impact of Industry 5.0 technologies, including BD and BD analytics, for companies' proactivity in SDGs and its potential implications on SAR. Moreover, Seele (2016) investigated how BD can help advancing sustainability and SR, developing the theoretical concept of "Digital Sustainability Panopticon". Lastly, Serag (2022) proposed a conceptual framework for enhancing sustainability reporting through stakeholder engagement initiatives using BD analytics. The author argued that BD can help enhance the quality of SR information.

Research Path 3) Exploration of potential advantages and challenges regarding BD use for SAR

A third research stream is composed by studies investigating strength and risks of BD in SAR. In this regard, Asokan *et al*. (2020) identified several

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issues that companies have to face when using data-intensive approaches towards sustainable development, such as: data availability, data collection, data interpretation and data presentation, especially among diverse corporate indicators. A major concern is the relevant indicators selection and learning the necessary skills to manage BD. Moreover, Brunelli and Ranalli (2020) underlined the risks taken by accountants who ignore BD generated by social media – such as text, images, voice messages or video collected through Facebook, Instagram or Twitter – since these new forms of data represent nowadays a critical source to control and measure how effectively and successfully their companies are addressing sustainability. However, in their view, managing BD to monitor companies' progress toward sustainability issues pose some challenges for accounting professionals, which will be also asked to: obtain new analytical skills, assess the reliability of data, work with other business functions (e.g. marketing, IT specialists) in order to analyze BD also in terms of expected future performance and cope with privacy matters from a regulatory, customer and employee point of view (Huerta, Jensen, 2017). The authors also state that the best reporting system to account for business sustainability development is the Integrated Report incorporating non-financial or sustainability information in a comprehensive way and in addition to the traditional financial information (see also Behn *et al*., 2019). In this direction, Sproviero (2020) examined BD in corporate reporting by focusing on the Integrated Reporting using an exploratory approach. The author highlighted that Integrated Reporting preparers use BD also to build performance indicators, sustainability indicators or to generally extract new knowledge useful for Integrated Reporting purposes.

In addition, Tiwari and Khan (2020) in their study investigated, using a mixed approach, the potential impact of Industry 4.0 technologies, including real-time data collection and predictive analysis using BD analytics for SAR under the GRI framework. In their view, BD and BD analytics represent a great opportunity for companies to achieve objectives of sustainability, mainly through sensing and actuation, real-time monitoring and control, predictive analytics and automated decision-making. However, they also warn that BD and BD analytics require continual evolution of technical and training programs with the Industry 4.0 maturity for SAR in an organization.

Lastly, Wanner and Janiesch (2019) conducted the only empirical study in the sample under investigation, analyzing whether innovative information processing capabilities enabled by BD analytics can have a positive impact on data quality of SR. Their findings show that an improvement of the perceived credibility of SR is generally possible with help of BD analytics.

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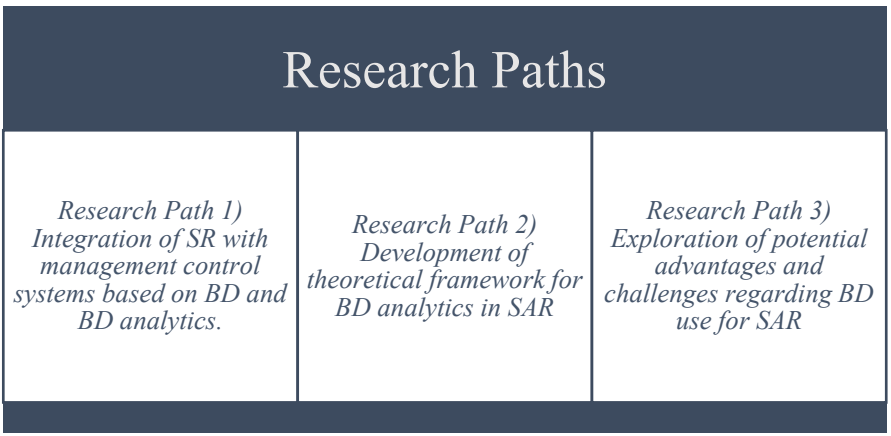
4.2 Implications, Conclusions and Future Research Agenda

This article offers for the first time the analysis of the topic of BD and BD analytics related to SAR, proposing new insights and implications for the future research. Contributing to the literature (Al-Htaybat, von Alberti-Alhtaybat, 2017; Bhimani, Willcocks, 2014; Cupertino *et al*., 2018; Etzion, Aragon-Correa, 2016; Garzella, Fiorentino, 2013; Joshi, Li, 2016; Lodhia, 2018; Lombardi, Secundo, 2021; Montemari, Nielsen, 2021; Serag, 2022; Quattrone, 2016), we identified three main research paths (Figure 4).

Figure 4 - *Research Paths*



Source: *authors' elaboration*

Results shows that there is the need to integrate sustainability reporting with management control systems based on BD and BD analytics (1st emerging research topic), proposing a primary level of analysis and results to academic and practical communities, as well as to decision-makers and corporate management. Other research streams reveal that, due to the lack of scientific knowledge and novelty of the topic, there's a need of building frameworks for effectively BD use in SAR (2nd emerging research topic) and investigate benefits and challenges that BD and BD analytics offer to companies using those techniques in SAR (3rd emerging research topic).

Overall, results show that the current state of research on BD use for SAR stays in an early state, especially in management and accounting area. Studies mainly adopt a theoretical approach, focusing on system frameworks and there is a lack of empirical evidence on the effectiveness of BD for SAR.

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Among the sample analyzed only one research adopted an experimental approach, thus, it is crucial to provide more empirical evidence on suggested arguments about the benefits that companies could obtain adopting BD and BD analytics techniques in terms of improving SAR. Since the interest around the topic is growing, while academic literature is still under development, case studies of real BD adoption for sustainability reporting – which also means business with BD and BD analytics effectively integrated with their IT systems – could help both scholars and practitioners to evaluate BD impact on non-financial and sustainability reporting, comparing evidence before and after the implementation of BD solutions and helping companies to raise the awareness of BD and BD analytics potential in this function. In addition, interviews with managers and adopters could give interesting insights on how and whether company's sustainability reporting and overall sustainability have been improved using BD, in the light of TBL approach, and on accountant's perceptions of BD impact on their role and profession. Lastly, future research could focus on developing unbiased BD-based KPIs to be used to measure the impact of business activities on society and environment (i.e. sustainability issues), as well as measures related to companies' achievement of SDGs based on BD and BD analytics.

Our study show that the use of BD and BD analytics in sustainability reporting could result into improved insight about companies' CSR issues, decision-making, process automation and an increase in sustainability information quality which leads to an improved truth value of SR content, turning into a higher company credibility among stakeholders. We draft some main research topics to be investigated in the future research agenda:
What are challenges concerning BD in SR?;
What are the requirements for accountants, auditors, decision-makers and corporate management to develop new expertise (human capital)?;
Which is the impact of BD in the development of performance measures about societal and environmental impacts of business activities?;
How BD and BD analytics intervene in SR construction?;
How BD and BD analytics improve the credibility among stakeholder in the SR path?.

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