ARTIFICIAL INTELLIGENCE FOR SUSTAINABILITY: 
A SYSTEMATIC LITERATURE REVIEW IN INFORMATION SYSTEMS

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ABSTRACT

Objective: It is vital to investigate how technologies benefit or impair sustainable development. This review aimed to provide updated literature on Artificial Intelligence (AI), in explicit connection with sustainability.

Theoretical Framework: This article performs a systematic literature review of information systems (IS) journals on AI employment in promoting sustainable development (SD).

Method: Among 331 articles, 97 have been identified in the Scopus and Web of Science databases from 2017 to 2022 focusing on the AI use for environmental, economic, legal political, organizational, and social development.

Results and Discussion: According to the findings, the identified areas of interest and respective papers were associated with the corresponding concepts and summarized. These studies point to the role of AI in supporting decision-making and reveal research avenues in information and communication technologies (ICTs) and SD. The authors also propose a framework correlating the concepts with the 17 Sustainable Development Goals (SDGs).

Research Implications: The practical and theoretical implications of this research were discussed, providing insights into how the results can be applied or influence practices in the field of ICTs and SD.

Originality/Value: The relevance and value of this research are evidenced by highlighting the contributions research in the IS field has made regarding AI for SD since 2017. As a step forward in this literature review, the authors suggest a research agenda for the IS field.

Keywords: Artificial Intelligence, Sustainable Development, SDGs, Literature Review

INTELIGÊNCIA ARTIFICIAL PARA A SUSTENTABILIDADE: 
UMA REVISÃO SISTEMÁTICA DA LITERATURA EM SISTEMAS DE INFORMAÇÃO

RESUMO:

Objetivo: É vital investigar como as tecnologias beneficiam ou prejudicam o desenvolvimento sustentável. Esta revisão teve como objetivo fornecer literatura atualizada sobre Inteligência Artificial (IA), em relação explícita com a sustentabilidade.

Referencial Teórico: Este artigo realiza uma revisão sistemática da literatura de periódicos de sistemas de informação (SI) sobre o emprego da IA na promoção do desenvolvimento sustentável (DS).

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Método: Dentre 331 artigos, 97 foram identificados nas bases de dados Scopus e Web of Science no período de 2017 a 2022 com foco no uso da IA para o desenvolvimento ambiental, econômico, jurídico político, organizacional e social.

Resultados e Discussão: De acordo com os achados, as áreas de interesse identificadas e os respectivos artigos foram associados aos conceitos correspondentes e resumidos. Esses estudos apontam para o papel da IA no apoio à tomada de decisão e revelam caminhos de pesquisa em tecnologias da informação e comunicação (TICs) e DS. Os autores também propõem um framework correlacionando os conceitos com os 17 Objetivos de Desenvolvimento Sustentável (ODS).

Implicações da Pesquisa: As implicações práticas e teóricas desta pesquisa foram discutidas, fornecendo insights sobre como os resultados podem ser aplicados ou influenciar práticas no campo das TICs e DS.

Originalidade/Valor: A relevância e o valor desta pesquisa são evidenciados ao destacar as contribuições que a pesquisa na área de SI fez em relação à IA para DS desde 2017. Como um passo à frente nesta revisão de literatura, os autores sugerem uma agenda de pesquisa para o campo de SI.

Palavras-chave: Inteligência Artificial, Desenvolvimento Sustentável, ODS, Revisão de Literatura.
1 INTRODUCTION

Information and communication technologies (ICTs) are ubiquitous. The use of these technologies has become unconscious in performing everyday tasks, with widespread availability and acceptance. Artificial intelligence (AI) has been gaining prominence and deserves attention from researchers in obtaining competitive advantage in sustainable development, generation of new products, services, and knowledge with positive impacts on society and the environment (Hsu et al., 2018) inclusive sustainable, responsible, and social innovations (Bailey and Osei-Bryson, 2018).

It is critical to draw attention to the connection between AI and sustainability as a growing theme today (IA Sustainable Development Summit, 2019; Sustainable AI, 2021; International Conference on Sustainable Technology and Development, 2021). This connection is vital, given the application of AI in scenarios involving smart cities (Arfanuzzaman, 2021), food production (Eashwar and Chawla, 2021), education (Galés and Gallon, 2019), living economy (Modgil Gupta and Bhushan, 2020), crisis response and natural disasters (Ojo, 2019), health (Singh, 2019), Green IS (Nishant et al., 2020) and sustainability itself comprehensively (Schoormann et al., 2021).

Academic research is required to understand benefits and impact of AI for sustainability in the field of Information Systems (IS), including economic, environmental, political, organizational, and social perspectives (ICT4D) going beyond problems traditionally focused on by IS researchers (Pozzebon and Diniz, 2012). The search for term "artificial intelligence" in Google Scholar has brought over 866,000 references since 2017. When comparing these results with the analyzed articles it is obvious that DS research is only a small part of the scope of AI revealing many research possibilities. This is reinforced by literature review by Dwived et al. (2021), demonstrating a research gap in AI studies. Thus, this review aimed to update literature on AI, in explicit connection with sustainability, raising the following research question: how has the literature seen the relationship between AI and sustainable development?

This article presents a systematic literature review on the benefits and impacts of AI for DS based on 97 articles from the Scopus and Web of Science (WoS) databases, relevant bases in the field of IS, until April 2022. This review aimed to provide updated literature on AI, in explicit connection with sustainability. The research is based on the definition of AI by Goodfellow et al. (2016), covering current theories such as ML, DL, and NN. In addition, in a broad view of sustainability, considering the interdisciplinary aspects. Subsequently, the results are different from other reviews in essence, given the classification in concepts and unit of
analysis, as recommended by Webster and Watson (2014). Essentially, the use of these approaches sought to further refine the understanding of AI for sustainable development, reflecting the state of the art. The research provides answers to understand how and to what extent AI technologies can help solve key global challenges. This introduction is followed by the methodology used, results and discussion, and conclusions.

2 METHODOLOGY

A review creates a firm foundation for the advancement of knowledge, as well as promoting the development of theory, and helping to unravel or host fields of knowledge (Webster and Watson, 2002). AI is a mature topic with an accumulated body of research, but it still requires analysis and synthesis.

There is no consensus on the definition of AI (Samoili et al., 2020). Goodfellow et al. (2016) summarize AI as a discipline surrounding machine learning (ML), representation learning (RL) and deep learning (DL), and a specific type of machine learning, as neural networks (NN). Regarding sustainable development (SD) conceptualization, Daly (2006) defines it as the physical approach, in which entropy flows through the economy and back to nature, and does not decay, while Jabareen (2008) proposes a conceptual approach that includes an interdisciplinary view of economics (natural capital), business (integrative management), sociology (utopia and equity), ecology (ecological form) and politics (global agenda).

Thus, this article presents a comprehensive literature review, based on systematic research of full articles in the areas of Computer Science, and Business, Management, and Accounting at Scopus, and Computer Science and IS at WoS. Keyword research considered the period from 2017 to April 2022 and resulted in 331 articles. The search in the title, abstract, or keywords used the string: “Sustainable development” OR “SDG” OR “ICT4D” AND “Artificial Intelligence” OR “Machine learning” OR “Data mining” OR “Representation learning” OR “Deep learning” OR “Neural networks” OR “Unsupervised learning” OR "Artificially Intelligent” OR "Intelligent systems”. The terms "Artificially Intelligent" and "Intelligent systems" were aggregated, as were "SDG" and "ICT4D", used interchangeably in articles. Also, the term "Data Mining” because it means the process of extracting and analyzing information from databases using a method matrix, including machine learning (Nature, 2022).

In the next step, abstracts and keywords were analyzed to understand the context and main subjects of the articles. At this stage, articles that did not have IA or DS among the main subjects and incomplete articles (search performed via Brazilian Portal de Periódicos,
Institutional signature, and open access) were disregarded. After this step and discounting repeated articles, the research resulted in 256 articles.

In the third stage, the articles were analyzed by reading the introduction, methodology, result, and conclusion. The UN’s 17 SDGs are milestones for multilateralism and international policy, comprising zero hunger, human rights protection, gender equality, planet security (climate, water, land), education, and quality management to create conditions for DS (UNB, 2021). Starting from the detailed reading of the articles, the authors were able to identify main themes of each one and relate them to the 17 SDGs. When analyzing the articles and grouping them around SDGs, some concepts emerged, referenced by the previous literature of Pozzebon and Diniz (2012), and Jabareen (2008): Environmental Development, Economic Development, Legal and Political Development, Organizational Development and Social Development. These concepts were selected due to their importance for the SD and AI presence (Dwivedi et al. 2021).

To group and identify concepts and units of analysis, the authors used the dimension of the conceptual matrix (Webster and Watson 2002) classifying the articles by concepts (Environmental, Economic, Legal and Political, Organizational and Social Development), unit of analysis (group, individual or organization) and a summary of the main ideas (added by the authors to the matrix). At the end of this stage, 158 other articles were excluded because they were not related to AI and/or sustainable development, resulting in 97 articles.

As previously mentioned, there is no consensus in the literature on the definition of AI. Therefore, we consider the summarized concept of Goodfellow et al. (2016) to avoid discarding articles that presented successful strategies for using ML or NN tools. This review sought to be transparent in reporting its methods to facilitate the replication of the process (Grant and Booth, 2009) and its validation, following steps similar to Vicent-Saez and Martinez-Fuentes (2018). In addition, the whole process was carried out by two researchers who performed independent reviews and sought consensus in cases of disagreement, with the theory as the guide.

3 RESULTS AND DISCUSSION

The articles analyzed were grouped by similarities in five concepts (Pozzebon and Diniz, 2012; Jabareen, 2008): environmental, economic, legal and political, organizational and social development. According to the findings, the identified areas of interest and respective papers were associated with the corresponding concepts and summarized in table 1.

The concept of environmental development covers issues related to water use, clean and renewable energy, responsible consumption and production, climate, and life. This topic
consists of SDGs 6, 7, 12, 13, 14 and 15. Reviewing the selected articles, some interest areas were identified: (1) Consumption of different forms of energy (Ferreira et al., 2019; Liaqat et al., 2021; Hazem Mohammed et al., 2018; Mori et al., 2018; Parvin et al., 2021); (2) Water consumption and preservation (Shabani et al., 2021; Kalibatiene et al., 2021; Ouyang et al., 2021; Yu et al., 2022; Seo e Lee, 2021; Gambin et al., 2021; Rizwan et al., 2021; Bedi, 2022); (3) Land Use (Chen et al., 2020; Hakim al., et al., 2020; Peng, et al. 2019); (4) Ecosystem analyses (How et al., 2020; Gou and Zhao, 2020; Blas et al., 2020; Chen et al., 2020; Jiang et al., 2019; Duan et al., 2020); (5) Miscellaneous Resources (Fraga-Lamas et al., 2021; Gabbar et al., 2020); (6) Air Pollution (Neto et al., 2021; Shen et al., 2019); (7) Development focused on the ecologically sustainable process (Du et al., 2019; Wan et al., 2019; Amoakoh et al., 2021; Su and Fan, 2019; Wu et al., 2019).

Studies on the environment cover the consumption of natural resources such as water, land, air, and various energy sources that can make up a sustainable alternative for consumption. Water appears in the largest number of studies, with discussions on consumption, access, and preservation. Another important point is the interaction with ecosystems that include forests and biomes and their relationships with people. Finally, the DS processes are highlighted in some studies. Among the 31 articles classified as environmental theme, 28 are analyzed at the group level, one at the individual and two at the organizational level.

<table>
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<tr>
<th>Concepts</th>
<th>Areas of Interest</th>
<th>Authors</th>
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<tr>
<td>Environmental</td>
<td>1. Consumption of different forms of energy</td>
<td>Ferreira et al., 2019; Liaqat et al., 2021; Hazem Mohammed et al., 2018; Mori et al., 2018; Parvin et al., 2021</td>
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<td>2. Water consumption and preservation</td>
<td>Shabani et al., 2021; Kalibatiene et al., 2021; Ouyang et al., 2021; Yu et al., 2022; Seo e Lee, 2021; Gambin et al., 2021; Rizwan et al., 2021; Bedi, 2022</td>
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<td>3. Land Use</td>
<td>Chen et al., 2020; Hakim al., et al., 2020; Peng, et al. 2019</td>
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<td>4. Ecosystem analyses</td>
<td>How et al., 2020; Gou and Zhao, 2020; Blas et al., 2020; Chen et al., 2020; Jiang et al., 2019; Duan et al., 2020</td>
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<td>Du et al., 2019; Wan et al., 2019; Amoakoh et al., 2021; Su and Fan, 2019; Wu et al., 2019</td>
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<tr>
<td>Economic Development</td>
<td>1. Data analysis based on income and non-income indicators to improve resource management</td>
<td>El Katat et al., 2018; XIU and Zhao, 2021; Chen et al., 2021</td>
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<td></td>
<td>2. Actions to make sustainable leisure tourism viable</td>
<td>Wang et al., 2021; Huang et al., 2021</td>
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3. Actions and predictive models to make the use of more efficient resources
   - Cecon et al., 2021; Zhang et al., 2020; Chen et al., 2020; Wang et al., 2021; Chen et al., 2017; Chen et al., 2021; Zhao et al., 2018; Kour et al., 2019; Zgurovsky et al., 2020; Liu, 2021; Bednar et al., 2020; Li et al., 2020; Wu et al., 2022; Sun et al., 2017

4. Use of technology in selective and managerial processes
   - Rab-Kettler and Lehnervp, 2019; Drezewski et al., 2018; Tran-Dang and Kim, 2021

5. Security in financial transactions
   - Huh and Kim, 2020

Legal and Political
1. Policy formulation
   - Hadfi et al., 2021; Baowaly et al., 2019

Organizational
1. Sustainable decision support systems
   - Masood et al., 2021; Abbas et al., 2021
2. Resource optimization
   - Zolbanin et al., 2020

Social Development
1. Use of diverse and integrated smart cities
   - Kuru and Khan, 2020; Laporte et al., 2020; Chen et al., 2020; Li, 2020; Allam et al., 2022

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<th>Concepts, Areas of Interest and Respective Authors Summary (cont.)</th>
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<td><strong>Concepts</strong></td>
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<td>Social Development (cont.)</td>
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The concept of economic development encompasses productive work, properly paid, in conditions of freedom, equity, and security, capable of ensuring a dignified life, and discussions of economic improvement issues for people, communities, organizations, and countries. This topic consists of SDG 8. When reviewing the selected articles, some the interest areas identified were: (1) Data analysis based on income and non-income indicators to improve resource management (El Katat et al., 2018; XIU and Zhao, 2021; Chen et al., 2021); (2) Actions to make sustainable leisure tourism viable (Wang et al., 2021; Huang et al., 2021); (3) Actions...
and predictive models to make the use of more efficient resources, including electricity, gas, oil, water, crops, soil, industry, and others (Ceccon et al., 2021; Zhang et al., 2020; Chen et al., 2020; Wang e Gong, 2021; Chen et al., 2021; Wang e Gong, 2021; Chen et al., 2017; Zhao e Jin, 2018; Kour e Arora, Chen e Wu, 2019; Zgurovsky et al, 2020; Liu, 2021; Bednar e Welch, 2020; Li et al., 2020; Wu et al., 2022; Sun e Xu, 2017); (4) Use of technology in selective and managerial processes (Rab-Kettler and Lehnervp, 2019; Drezewski et al., 2018; Tran-Dang and Kim, 2021); (5) Security in financial transactions (Huh and Kim, 2020).

All these initiatives have economic and sustainable purposes related to society or organizations. The highest concentration of articles arises in the subtopic of actions and predictive models to make use of more efficient resources, including electricity, gas, oil, water, crops, soil, industry, and others. This subtopic is linked to optimized consumption or the most efficient and sustainable use of available resources. This includes the organization, community, and country that is the object of study. Among the 23 articles classified as economic themes, 17 are analyzed at the group level, one at the individual and five at the organizational level.

The concept of legal and political development encompasses partnerships, peace, justice, and institutions. This topic comprises SDGs 16 and 17. When reviewing the selected articles, an area of interest was identified: (1) Policy formulation (Hadfi et al., 2021; Baowaly et al., 2019). This topic has the lowest number of articles evaluated by this study, probably because IS journals do not focus on publications centred on public policies. However, the articles on policymaking in various sectors of government. Among the two articles classified as political and legal, one was analyzed at the group level and one at the individual level.

The concept of organizational development covers industry, innovation, and infrastructure. This topic consists of SDG 9. When reviewing the articles, some areas of interest were identified: (1) Sustainable decision support systems (Masood et al., 2021; Abbas et al., 2021); (2) Resource optimization (Zolbanin et al., 2020). This topic also has few articles, because most articles related to organizations and sustainability discuss business sustainability and not the aspect addressed in this study. The articles focused on optimizing the use of resources and supporting sustainable decisions. Among the three articles classified as organizational themes, two are group-level and one individual.

The concept of social development covers issues and implementations that aim to improve people’s lives in cities or societies, reduce poverty, hunger, and inequalities, and improve education and health. This topic consists of SDGs 1, 2, 3, 4, 5, 10 and 11. When reviewing the selected articles, the areas of interest identified were: (1) Use of diverse and integrated smart cities (Kuru and Khan, 2020; Laporte et al., 2020; Chen et al., 2020; Li, 2020;
Allam et al., 2022); (2) Integration of industrialization, informatization, urbanization and agricultural modernization (Xia and Li, 2019); (3) Use of technology to improve mobility (Cao and Xu, 2022; Dlugosch et al., 2020; Wang et al., 2018; Zheng and Huang, 2018; Zheng and Huang, 2020); (4) Use of data to improve life in cities (Broo and Schooling, 2021; Jiang et al., 2017; Liu et al., 2020; Peng et al., 2020; Yin et al., 2020; Qu et al., 2019; Anum et al., 2018; Pirouz et al., 2021; Liu et al., 2021; Chew et al., 2018; Jiang et al., 2021); (5) Use of technologies in health (Xue et al., 2021; Latif et al., 2017; Lopez-Var Gas et al., 2021; Aerts e Bogdan-Martin, 2021; Peng et al., 2021; Ahmad et al., 2021); (6) Use of technologies to improve energy production and consumption (Elijah et al., 2021; Sakib et al., 2020); (7) Use of technology in education (Zhao et al., 2020; Mwitondi et al., 2021; Riekki and Mammela, 2021); (8) Use of technology in food production (Kang and Wang, 2017; Goel et al., 2021; Kumar and Sharma, 2020); (9) Use of technology to make land use more efficient (Zhang et al., 2021; Assarkhaniki et al., 2021); (10) Use of technology in security (Hoffman et al., 2018).

All of these initiatives aim to help improve the sustainability of cities, communities, and people’s lives. The improvement of life in cities using data or even smart city implementations was highlighted. Other topics were also mentioned, such as mobility, health, education, food and energy production and consumption. Among the 38 articles classified as a social theme, 32 are group-level analyses, four are individual-level and two are organizational-level.

As a result, based on the findings (especially in the areas of interest), the authors propose a framework correlating the concepts with the 17 SDGs (Figure 1). The structure is valuable to connect concepts based on a methodology of systematic literature review and essential to understanding how the IS field links the challenges of the SD with the SDGs, benchmarks for multilateralism, and modern international policy. Certainly, this kind of connection should be made to other technologies, which could expand the understanding of the research field.

**Figure 1**

*Five main concepts and the SDGs*
The selection of 97 articles, which were analyzed in more detail and classified according to the central concept, resulted in 38 studies in social development, 31 in environmental development, 23 in economic development, 3 in organizational development, and 2 in legal and political development. In summary, the use of AI to support decision-making deserves to be highlighted, especially in issues involving cities, models, and actions to make use of more efficient resources, with emphasis on water, the most cited natural resource. In addition, we can see the use of artificial intelligence in various areas such as education, health, mobility, food production, efficient use of resources, security, tourism, and leisure, and in the governmental, organizational, and social sectors. Another highlight is the unit of analysis with 80 articles classified as group level, for example: community, city, country, among others.

The possibilities presented in this review demonstrate a great diversity of applications, valuing the role of AI as a practical, transformative, and transversal application technology, considering that analysis in large databases by ML can be replicated for the understanding and prediction of different phenomena. Effectively, based on the findings presented here, a new vision of AI in the face of the challenges of the SDGs is envisaged. In this sense, related research was identified, providing references to theoretical studies, such as the literature review on the application of technologies in the oil and gas sector to press for greener and alternative energy (Elijah et al., 2021) and examples of practical uses of AI to solve real situations, such as the comparative case study using NN to determine CO2 emissions (Ferreira et al., 2019). Considering that every year the United Nations (UN) publishes a report on SDG, it is necessary to better understand whether AI research is considered in these reports and how it could (if still not) improve its indicators. However, not all articles make it explicit which SDGs are being addressed. This tracking is very important to understand what problem is being attacked and the solutions. Also, reports produced by the UN are based on this information described in metadata of major publishing companies such as Elsevier. In this sense, it would be important to have a collective awareness work by the scientific journals, funders, and universities.

Furthermore, within SDGs and central concepts, there are gaps in Organizational, Legal, and Political Development. Some topics such as general regulation of data protection have not been identified, demonstrating an initial concern more from empirical world than from research, since large technology companies are already using AI tools for this management. Still thinking about these large technology companies, the absence of more articles may be related to intellectual property and patent issues. In the case of public organizations, AI is a tool that is still more in the phases of studies or initial deployment, as in the use of chatbots.
4 RESEARCH AGENDA

The article highlights the contributions research in the IS field has made regarding AI for SD since 2017. As a step forward in this literature review, the authors suggest a research agenda for IS field, because of the importance of the sustainability theme.

It is interesting to point out that, searching for the word “artificial intelligence” in Google Scholar, has brought millions of references, more than 866,000 since 2017. When we compare these results with the ones we have retrieved, it makes clear that research in SD is just a tiny part of AI scope, showing lot of possibilities for research. Based on the findings presented, a new view of AI challenges is envisioned concerning SDGs. In this sense, related research was identified, providing references to theoretical studies, like literature review about application of technologies in oil and gas sector to push for alternative greener energy (Elijah et al., 2021), and examples of practical uses of AI for solving real situations, as the comparative case study using neural network to determine carbon dioxide emissions (Ferreira et al., 2019). Considering that every year the UN publishes the SDG Report, then it is necessary to better understand if AI research is considered in those reports and how it could (if not yet) improve its indicators.

In addition, the articles brought up some interesting ICT that should be more explored in the IS field, such as big data, IoT, and telecommunications. A possible research agenda would be doing a literature review based on those and comparing if the concepts that emerged would be the same. Indeed, there are recent technological developments such as blockchain and 5G, that did not call attention to the list of articles but could bring complementary insights too.

Furthermore, considering the methodology used here, a research agenda for Sustainable Development should be the use of other methods for realizing a literature review, being important in the sense that theories are evolving in the IS field with a range of possibilities. Furthermore, SDG, as a new concern/theme, brings about the need to understand the benefits or setbacks of this application and concerns. Then, we have identified research gaps to be accomplished through design science research, and action science research.

Thinking about these methodologies and other case studies, interesting future research would be analyzing aspects that relate SDGs with the unit of analysis of individuals and organizations. For the individual, one issue that already has literature related is ethics (Vinuesa et al., 2020), especially when linked with AI, and could be more explored at this moment that countries and citizens are more concerned with accessing and sharing personal data. In the organizations, further contributions studies about this change from the sustainable development of the business to Environmental, Social, and Governance (ESG) can be leveraged.
Still, on the SDGs, this article demonstrates that there are researchers of AI focused on solving not only technological issues but also economic, environmental, and social ones, just to stay on those. However, the articles don’t make it all clear what is the SDG related, when mentioning it, and not only in the abstract or keywords for receiving more attention. This tracking is very important to understand which problem is being attacked and solutions for countries and UN reporting based, e.g., on data of big editorial companies such as Elsevier. In this sense, additional research should do interviews with authors of studies, where there is no clarification, to understand the difficulty root to provide better guidelines for future research.

5 FINAL CONSIDERATIONS

The review results allow us to answer the research question, demonstrating that artificial intelligence can be used effectively in the improvement of processes involving human actions aimed at sustainability. In addition, based on the previous theory and methodology used for the systematic literature review, it was possible to link the SDGs with concepts emerging from the 97 articles, resulting in an extensive structure on the various areas of human activity and in different sectors, such as governmental, organizational, and social. The research presents some limitations, such as the use of only two indexing bases for searches, the impossibility of access to all articles, and the articles being focused on the IS field.

Finally, a comprehensive exploration of the database in different areas of artificial intelligence helps define the approach to sustainability of the various areas of human activity and in different sectors such as governmental, organizational, and societal. Furthermore, the article presents a research agenda section, exploring possible future studies related to ICT technologies and sustainable development.

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