Article

How artificial intelligence plays a role in achieving sustainable development goals?

Milad Shahvaroughi Farahani[1,*], Ghazal Ghasemi[2]

[1] Department of Finance, Khatam University, 331773 Tehran, Iran

[2] Department of Public Law, Islamic Azad University, Tehran, Iran

* Corresponding author: Milad Shahvaroughi Farahani, m.shahvaroughi@khatam.ac.ir

Abstract: Artificial Intelligence (AI) is increasingly recognized as a key enabler in achieving Sustainable Development Goals (SDGs) due to its transformative potential across various sectors. This paper explores the intersection of AI and SDGs, highlighting the significant role AI plays in accelerating progress towards sustainability. AI technologies such as machine learning, natural language processing, and computer vision have been instrumental in enhancing efficiency, decision-making, and resource management in areas such as healthcare, agriculture, education, and climate change mitigation. By analyzing vast amounts of data, AI can provide valuable insights and predictive models to inform policy-making, optimize resource allocation, and enhance monitoring and evaluation processes. Furthermore, AI empowers developing countries to leapfrog traditional developmental barriers by offering innovative solutions that are cost-effective and scalable. Through initiatives like precision agriculture, telemedicine, and smart energy systems, AI enables inclusive growth while reducing inequalities and enhancing resilience to environmental challenges. While AI brings immense opportunities for sustainable development, challenges such as data privacy, bias, and ethical concerns must be addressed to ensure that AI technologies are deployed responsibly and equitably. Collaborative efforts between governments, industry, and civil society are essential to harness the full potential of AI in achieving the SDGs and creating a more inclusive and sustainable future for all.

Keywords: artificial intelligence; sustainable development goals; swot analysis; education; agriculture

JEL Classification: D63; E2; I2; I30; J2

1. Introduction

Artificial Intelligence (AI) has emerged as a transformative force with the potential to significantly contribute to the achievement of Sustainable Development Goals (SDGs) set forth by the United Nations. This comprehensive analysis explores the multifaceted role of AI in advancing sustainable development across various sectors and domains.

At its core, AI offers powerful tools and technologies that can enhance decision-making, optimize resource allocation, and drive innovation in support of sustainable development objectives [1]. In the realm of environmental sustainability, AI-enabled solutions such as predictive analytics, remote sensing, and natural language processing facilitate more accurate monitoring of environmental indicators, enabling early detection of environmental risks, biodiversity conservation, and climate change mitigation efforts [2].

In the realm of healthcare, AI applications such as medical imaging analysis, predictive modeling, and personalized medicine hold the potential to improve healthcare delivery, increase access to quality healthcare services, and reduce healthcare disparities [3]. By leveraging AI-driven insights, healthcare practitioners can enhance disease diagnosis and treatment outcomes, optimize healthcare resource utilization, and promote preventive care initiatives, ultimately contributing to better health outcomes and well-being for individuals and communities.

Moreover, AI-driven innovations in agriculture, food security, and supply chain management are instrumental in addressing global food challenges, promoting sustainable agriculture practices, and ensuring equitable access to nutritious food resources. AI-powered agricultural technologies, including precision farming, crop monitoring, and yield prediction, enable farmers to optimize resource use, increase crop yields, and mitigate the adverse effects of climate change on agricultural productivity [4].

In the context of education and skill development, AI-driven adaptive learning platforms, virtual tutoring systems, and personalized learning experiences are revolutionizing education delivery, expanding access to quality education, and fostering lifelong learning opportunities for individuals worldwide. By tailoring educational content and learning experiences to individual learner needs and preferences, AI technologies empower learners to acquire new skills, pursue higher education, and participate more effectively in the knowledge economy [5].

However, alongside the potential benefits, the widespread adoption of AI in sustainable development efforts also raises ethical, social, and regulatory considerations that must be carefully addressed. Concerns related to data privacy, algorithmic bias, digital divide, and technological unemployment require proactive strategies and policy interventions to ensure that AI-driven solutions contribute to inclusive, equitable, and sustainable development outcomes [6].

Overall, this analysis underscores the transformative potential of AI in advancing sustainable development goals and highlights the importance of harnessing AI technologies responsibly and ethically to address pressing global challenges and create a more sustainable and prosperous future for all.

2. The role of artificial intelligence in achieving sustainable development goals

In this paper, we have tried to review how AI can speed up the achievement of sustainable development goals (SDGs). So, this is a kind of scientific promotional article which means our focus is on interconnection between AI and SDGs. As a result, this paper has been divided into two parts:

The first part is dedicated to AI-related concepts, while the second one belongs to SDGs-related concepts.

Finally, we have tried to merge them to obtain the results.

2.1. Concepts connections with artificial intelligence (AI)

Artificial intelligence (AI) is a broad and interdisciplinary field that encompasses various concepts and technologies to create intelligent machines capable of simulating

human-like behavior and cognitive functions [7]. These processes include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions), and self-correction. AI is used in various applications such as natural language processing, speech recognition, image recognition, and machine learning. Here are some key concepts connected with artificial intelligence (see **Table 1**).

Table 1. AI-related concepts [8].

Row	Terms	Definitions
1	Machine learning (ML)	Machine learning is a subset of AI that focuses on developing algorithms and models that enable computers to learn from data and improve their performance over time without being explicitly programmed. It includes techniques such as supervised learning, unsupervised learning, and reinforcement learning.
2	Deep learning (DL)	Deep learning is a specialized form of machine learning that involves artificial neural networks with multiple layers (deep neural networks). It has been particularly successful in tasks such as image recognition, natural language processing, and speech recognition.
3	Natural Language Processing (NLP)	NLP is a branch of AI that deals with the interaction between computers and human languages. It enables computers to understand, interpret, and generate human language, allowing for applications such as chatbots, language translation, and sentiment analysis.
4	Computer vision	Computer vision involves teaching computers to interpret and understand visual information from the real world. It enables applications such as object detection, image classification, facial recognition, and autonomous driving.
5	Robotics	Robotics combines AI with mechanical engineering to design and develop robots capable of performing tasks autonomously or semi-autonomously. It encompasses areas such as robot perception, motion planning, manipulation, and human-robot interaction.
6	Expert Systems	Expert systems are AI systems designed to mimic the decision-making ability of human experts in specific domains. They use a knowledge base of rules and heuristics to provide recommendations or solutions to problems within their domain of expertise.
7	Reinforcement learning	Reinforcement learning is a type of machine learning where an agent learns to make decisions by interacting with an environment and receiving feedback in the form of rewards or penalties. It is commonly used in applications such as game playing, robotics, and autonomous vehicle control.
8	Ethical AI	Ethical AI focuses on ensuring that AI systems are developed and deployed responsibly and ethically. It involves addressing issues such as bias and fairness, transparency and explainability, accountability, privacy, and the societal impacts of AI technologies.

On the other hand, it is possible to present the subset of AI as follows (see **Figure 1**).
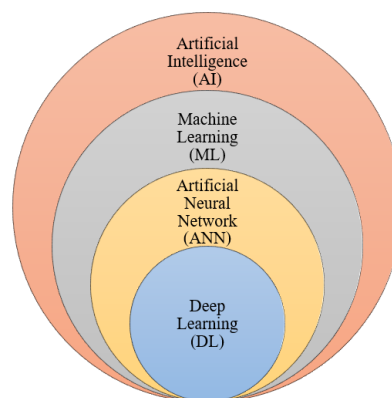

Figure 1. AI subsets [9].

AI encompasses a wide range of capabilities, enabling machines to perform tasks that typically require human intelligence. Some of the key capabilities of AI include [10]:

Machine Learning (ML): ML algorithms enable computers to learn from data and improve their performance over time without being explicitly programmed. This capability powers many AI applications, including predictive analytics, pattern recognition, and decision-making systems.

Natural Language Processing (NLP): NLP enables computers to understand, interpret, and generate human language. This capability allows for applications such as language translation, sentiment analysis, and chatbots.

Computer vision: Computer vision enables machines to interpret and understand visual information from the real world. This capability enables applications such as object detection, image classification, and facial recognition.

Speech recognition: Speech recognition allows computers to transcribe spoken language into text. This capability is used in virtual assistants, voice-controlled devices, and dictation software.

Robotics: Robotics combines AI with mechanical engineering to design and develop robots capable of performing tasks autonomously or semi-autonomously. This capability enables applications such as industrial automation, autonomous vehicles, and robotic surgery.

Planning and optimization: AI algorithms can analyze complex systems and make decisions to optimize outcomes based on predefined objectives. This capability is used in logistics, supply chain management, and resource allocation.

Pattern recognition: AI systems can identify patterns and correlations in large datasets that may not be apparent to humans. This capability is valuable in fields such as healthcare, finance, and marketing for detecting anomalies, predicting trends, and making informed decisions.

Generative modeling: Generative AI models can create new data samples that are similar to the training data they have been exposed to. This capability is used in creative applications such as image generation, music composition, and text generation.

Autonomous systems: AI enables machines to operate autonomously, making decisions and taking actions without human intervention. This capability is essential in autonomous vehicles, drones, and robotic systems deployed in hazardous environments.

Adaptive learning: AI systems can adapt and learn from new data or changing environments, improving their performance over time. This capability enables personalized recommendations, adaptive tutoring systems, and dynamic optimization.

These are just a few examples of the capabilities of AI, which continue to evolve and expand as researchers develop new algorithms and technologies. AI has the potential to revolutionize industries, improve efficiency, and address complex challenges across various domains.

These concepts represent just a few of the many interconnected areas within the broader field of artificial intelligence, highlighting the diverse range of applications and research areas it encompasses. In this article, we have tried to use AI and its impacts on achieving sustainable development goals.

2.2. Concepts connected with sustainable development goals (SDGs)

Concepts connected with Sustainable Development Goals (SDGs) encompass a wide range of principles, strategies, and initiatives aimed at achieving sustainable development across economic, social, and environmental dimensions. Sustainable development goals (SDGs) are a collection of 17 global goals set by the United Nations in 2015 to address social, economic, and environmental challenges faced by countries all around the world [11]. These goals aim to create a better and more sustainable future for all by tackling issues such as poverty, inequality, climate change, environmental degradation, peach, and justice. The SDGs are a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by the year 2030.

Here are some key concepts closely linked to SDGs (see **Table 2**):

Table 2. SDGS-related concepts [12].

Row	Terms	Explanations
1	Sustainability	Sustainability refers to meeting the needs of the present without compromising the ability of future generations to meet their own needs. It involves balancing economic growth, social equity, and environmental protection to ensure long-term well-being.
2	Triple Bottom Line	The triple bottom line (TBL) is a framework that evaluates organizational performance based on three interconnected pillars: people, planet, and profit. It emphasizes the importance of considering social, environmental, and economic factors in decision-making.
3	Environmental Stewardship	Environmental stewardship involves responsibly managing and conserving natural resources to minimize negative impacts on ecosystems and biodiversity. It includes practices such as sustainable resource use, pollution prevention, and habitat preservation.
4	Social Equity	Social equity focuses on promoting fairness, justice, and equality in society, ensuring that all individuals have access to opportunities, resources, and basic human rights. It involves addressing issues such as poverty, inequality, discrimination, and social exclusion.
5	Climate Action	Climate action aims to mitigate and adapt to climate change by reducing greenhouse gas emissions, promoting renewable energy, and enhancing resilience to climate-related risks. It aligns with SDG 13: Climate Action, which calls for urgent action to combat climate change and its impacts.
6	Circular Economy	The circular economy is an economic model that aims to minimize waste and maximize resource efficiency by keeping products, materials, and resources in use for as long as possible through reuse, recycling, and regeneration. It supports SDG 12: Responsible Consumption and Production.
7	Partnerships for the Goals	SDG 17 emphasizes the importance of collaboration and partnerships among governments, businesses, civil society, and other stakeholders to achieve the SDGs. It encourages multi-stakeholder partnerships, knowledge sharing, and capacity-building initiatives.
8	Resilience	Resilience refers to the ability of individuals, communities, and systems to withstand and recover from shocks and stresses, such as natural disasters, economic crises, and social disruptions. Building resilience is crucial for achieving sustainable development in the face of uncertainty and challenges.
9	Inclusive Growth	Inclusive growth aims to ensure that economic development benefits all segments of society, particularly marginalized and vulnerable groups. It involves creating opportunities for employment, education, healthcare, and entrepreneurship to reduce poverty and inequality.
10	Biodiversity Conservation	Biodiversity conservation involves protecting and preserving the variety of life on Earth, including species, ecosystems, and genetic diversity. It contributes to SDG 15: Life on Land, which seeks to sustainably manage forests, combat desertification, halt biodiversity loss, and protect wildlife.

These concepts are interconnected and provide a holistic framework for addressing the complex challenges of sustainable development and achieving the SDGs. By embracing these principles and taking collective action, stakeholders can work towards building a more sustainable and equitable future for all.

The Sustainable Development Goals (SDGs) encompass a broad set of objectives aimed at addressing global challenges and promoting sustainable development across economic, social, and environmental dimensions. The capabilities of SDGs are multifaceted and include the following [13]:

Comprehensive framework: The SDGs provide a comprehensive framework for addressing interconnected global issues, including poverty, hunger, health, education, gender equality, clean water and sanitation, affordable and clean energy, sustainable cities and communities, climate action, and life below water and on land. With 17 goals and 169 targets, the SDGs cover a wide range of areas critical to human well-being and planetary health.

Universal applicability: The SDGs apply universally to all countries, regardless of their level of development, and aim to mobilize collective action at the global, national, and local levels. By setting common objectives and targets, the SDGs promote international cooperation and solidarity in addressing shared challenges and achieving shared goals.

Integrated approach: The SDGs recognize the interconnectedness of social, economic, and environmental issues and emphasize the need for an integrated approach to sustainable development. By addressing the root causes and interlinkages between different challenges, the SDGs promote holistic and systemic solutions that contribute to long-term sustainability.

Ambitious goals: The SDGs set ambitious targets for addressing pressing global issues and advancing sustainable development. These goals are designed to be aspirational yet achievable with concerted efforts and collaboration among governments, businesses, civil society organizations, and other stakeholders.

Transformative agenda: The SDGs represent a transformative agenda aimed at catalyzing positive change and driving progress toward a more equitable, inclusive, and sustainable future. By promoting innovation, investment, and policy reform, the SDGs seek to create transformative shifts in areas such as poverty reduction, gender equality, clean energy adoption, and sustainable consumption and production patterns.

Measurement and monitoring: The SDGs are accompanied by a robust framework for measurement, monitoring, and reporting progress towards the goals and targets. This includes indicators, data collection mechanisms, and reporting platforms that enable governments and stakeholders to track progress, identify gaps, and take corrective actions to accelerate implementation.

Local action and ownership: While the SDGs are global in scope, their implementation relies on local action and ownership. National governments, local authorities, communities, and individuals play crucial roles in implementing and adapting the SDGs to local contexts, priorities, and challenges.

Partnerships and collaboration: Achieving the SDGs requires collaborative partnerships among governments, businesses, civil society organizations, academia, and other stakeholders. The SDGs provide a platform for fostering multi-stakeholder partnerships, knowledge sharing, and capacity-building initiatives to leverage resources, expertise, and innovations towards common objectives.

Overall, the capabilities of the SDGs lie in their ability to mobilize collective action, drive systemic change, and promote sustainable development that benefits people, the planet, and prosperity, both now and in the future.

3. Artificial intelligence (AI) and sustainable development goals (SDGs)

Artificial Intelligence (AI) can significantly accelerate the achievement of Sustainable Development Goals (SDGs) through various mechanisms.

In **Table 3**, you can see the interconnection of AI with SDGs:

Table 3. SDGs in connection with AI. [9-14]

No	Goals	Connections with AI
1	No poverty	Poverty reduction by using content analysis including improving agriculture soil cultivation for raising crops and livestock. Collecting data via poverty maps to improve agriculture and education and revolutionize the financial systems as well [15].
2	Zero hunger	Using AI-based early warning systems to help decision makers avert situations such as malnutrition (food shortages). AI can transform existing food and agricultural systems including crop management, crop quality, and yield which can maximize crop productivity and efficiency [16].
3	Good health and well-being	Using response adaptive randomization in eye health which can determine how service delivery can be optimized in a resource-limited setting and considering several keys such as developing analytics, ethics abilities, working collaboratively and adopting a fast-fail culture [17].
4	Quality education	Working on developing virtual tutors, automating textbook creation, and developing personalized learning paths [18].
5	Gender equality	AI can mimic the racial, ethnic, cultural and linguistic similarities of a suspect. AI benefits a wide range of situations. [19].
6	Clean water and sanitation	AI in delivering clean water and sanitation. AI can be used to develop water-intensive industries. Predictive control by using AI operations in wastewater treatment process. Optimizing aeration, waste digestion, membrane cleaning, membrane bioreactor cleaning, and chemical dosing by using AI technologies [20].
7	Affordable and clean energy	Enable smart grids, monitoring devices, and IoT devices for communicate using AI technologies. Using AI in power system, productivity, visibility and the usage of RE system including forecasting, reducing emissions, cost minimization, rigorous and smooth control, demanded quality without variation, environmental awareness, enhanced power management [21].
8	Decent work and economic growth	Mapping AI's influence on growth by using AI technologies such as ML, NN, industrial robots, analytic tools, data science, 3d printers etc. [22].
9	Industry, innovation, and infrastructure	Using content analysis for determining the presence of specific words, topics, or concepts within a given descriptive statistical text or data [23].
10	Reduced inequality	AI can help to achieve economic growth and impact to achieve reduced inequality [24].
11	Sustainable cities and communities	By optimizing services and addressing several social, environmental, and economic aspects of the city, machine learning approaches are providing to be critical to a smart and sustainable future including the management of waste, air quality, disaster response and transportation [25].
12	Responsible consumption and production	AI can cut global greenhouse emissions by around 4 percent by 2030. AI can be helpful to promote supply and demand side sustainability effort. Using the food waste app Karma ML-based algorithms to predict and prevent food waste [26].
13	Climate action	AI can reduce emissions by leveraging ML algorithms and big data [27].
14	Life below water	Monitoring illegal, unreported, and unregulated fisheries to reduce waste in supply chains as well as identifying illegal, unregulated, and unreported catches by leveraging AI and ML approaches [28].
15	Life on land	Analyzing deforestation, land degradation, and desertification by using advanced machine learning models and deep learning techniques [29].
16	Peace and justice strong institutions	AI can enhance a law enforcement's ability to make better decisions, make citizens safer, and make institutions more accountable if its advantages are utilized [30].
17	Partnerships to achieve the goal	It emphasizes the importance of multi-stakeholder partnerships in fostering and sharing knowledge, expertise, technology, data, and relationships, to achieve the goals throughout the world [31].

Artificial Intelligence has the potential to play a significant role in achieving Sustainable Development Goals (SDGs). Here are some ways AI can contribute to the SDGs [14]:

- Poverty and Hunger: AI can help in optimizing agricultural processes, predicting crop yields, and improving resource allocation to reduce poverty and hunger.
- Healthcare: AI can enhance healthcare systems by enabling early disease diagnosis, personalized treatment plans, and remote monitoring, thereby improving healthcare access and outcomes.
- Education: AI can personalize learning experiences for students, provide access to quality education in remote areas, and facilitate continuous learning opportunities for all.
- Gender equality: AI applications can help in identifying and addressing biases in hiring practices, promoting diversity in workplaces, and ensuring equal opportunities for all genders.
- Clean energy: AI can optimize energy consumption, improve grid management, and facilitate the integration of renewable energy sources, thus contributing to sustainable energy practices.
- Climate action: AI can analyze climate data, predict natural disasters, and offer insights for mitigating environmental impacts, aiding in climate change adaptation and mitigation efforts.
- Sustainable cities: AI can optimize urban planning, transportation systems, and resource management to create more sustainable and livable cities for all residents.
- Partnerships: AI can foster collaboration and partnership among stakeholders by facilitating data sharing, decision-making processes, and resource allocation for achieving the SDGs.

By leveraging the power of AI in these areas, we can accelerate progress towards achieving the SDGs and building a more sustainable and equitable world for future generations.

Examples of AI solutions improving sustainable development goals

Artificial Intelligence (AI) solutions are increasingly being deployed to address various challenges and contribute to the achievement of Sustainable Development Goals (SDGs) across different sectors. Here are some examples of AI solutions that are improving sustainable development outcomes [32,33]:

- Environmental conservation:
  1) Wildlife protection: AI-powered image recognition and drones are used to monitor and protect endangered species, detect poaching activities, and track animal populations in remote areas.
  2) Deforestation prevention: AI algorithms analyze satellite imagery to identify deforestation hotspots, track illegal logging activities, and monitor forest cover changes in real-time.
  3) Climate modeling: AI-driven climate models simulate complex environmental processes, predict climate change impacts, and inform policy

decisions to mitigate greenhouse gas emissions and adapt to climate variability.

- Healthcare:
  1) Disease diagnosis: AI algorithms analyze medical images, genomic data, and patient records to assist healthcare professionals in diagnosing diseases such as cancer, tuberculosis, and diabetic retinopathy with higher accuracy and speed.
  2) Drug discovery: AI-driven drug discovery platforms accelerate the identification of novel drug candidates, predict drug interactions, and optimize drug formulations, leading to the development of more effective and affordable treatments for diseases.
  3) Personalized medicine: AI-based predictive analytics tailor treatment plans and interventions to individual patient characteristics, preferences, and genetic profiles, improving treatment outcomes and reducing adverse drug reactions.

- Education:
  1) Personalized Learning: AI-powered adaptive learning platforms deliver customized educational content and activities based on students' learning styles, abilities, and progress, enhancing engagement and retention.
  2) Tutoring and Mentorship: AI chatbots and virtual assistants provide personalized tutoring, feedback, and mentorship to students, facilitating self-directed learning and supporting learners in mastering complex concepts and skills.
  3) Language Translation: AI-powered language translation tools break down language barriers, enable access to educational resources in multiple languages, and promote cross-cultural exchange and collaboration among students and educators worldwide.

- Agriculture:
  1) Precision Farming: AI-based agricultural drones, sensors, and IoT devices collect data on soil health, crop growth, and weather conditions to optimize farming practices, minimize resource use, and increase crop yields while reducing environmental impact.
  2) Crop Monitoring: AI algorithms analyze satellite imagery and sensor data to monitor crop health, detect pest infestations, and identify irrigation needs, enabling farmers to make data-driven decisions and manage agricultural operations more efficiently.
  3) Supply Chain Optimization: AI-driven analytics optimize supply chain logistics, crop distribution, and food storage to reduce food waste, improve food security, and ensure access to nutritious food for communities worldwide.

- Financial inclusion:
  1) Microfinance and credit scoring: AI-powered credit scoring models leverage alternative data sources such as mobile phone usage and social media activity to assess creditworthiness, expand access to financial services, and

support entrepreneurship and economic empowerment among underserved populations.

2) Digital payments and remittances: AI-driven mobile banking apps and payment platforms enable secure and convenient digital transactions, lower transaction costs, and facilitate access to financial services for unbanked and underbanked individuals in remote areas.

These examples illustrate the diverse ways in which AI solutions are driving progress towards sustainable development goals by leveraging data-driven insights, automation, and predictive analytics to address complex challenges and create positive social and environmental impact. However, it is essential to ensure that AI technologies are deployed ethically, responsibly, and inclusively to maximize their benefits and minimize potential risks for society.

It is possible to present the impact of AI on achieving SDGs in other ways based on multiple steps:

Step 1: Identify sustainable development goals (SDGs):
- Identify the specific SDGs you want to focus on, such as poverty alleviation, quality education, climate action, or gender equality.

Step 2: AI Applications for sustainable development:
- Data Analysis: Use AI for analyzing large datasets to identify trends, patterns, and insights related to the chosen SDGs.
- Predictive Analytics: Utilize AI algorithms to predict future trends and outcomes, helping in strategic planning and decision-making.
- Resource Optimization: Implement AI systems for optimizing resource use, energy efficiency, and waste reduction to promote sustainable practices.
- Smart Agriculture: Deploy AI for precision agriculture, crop monitoring, and predictive analytics to increase agricultural productivity and food security.
- Healthcare: Apply AI in healthcare for disease diagnosis, treatment optimization, and improving healthcare access in underserved regions.
- Renewable Energy: Utilize AI in optimizing renewable energy sources, energy distribution, and grid management for sustainable energy solutions.
- Education: Implement AI for personalized learning, educational content delivery, and improving access to quality education for all.

Step 3: Impact assessment:
- Evaluate the impact of AI applications on the chosen SDGs by measuring outcomes, assessing effectiveness, and identifying areas for improvement.

Step 4: Policy implications:
- Consider the policy implications of integrating AI technologies into sustainable development initiatives, including regulations, ethical considerations, and equity issues.

Step 5: Continuous improvement:
- Continuously monitor and evaluate the use of AI in achieving sustainable development goals, adapt strategies as needed, and promote innovation for further advancements.

This flowchart illustrates a high-level overview of how AI can be leveraged to address various sustainable development challenges and contribute to the achievement of the SDGs.

4. Challenges and limitations of AI in achieving SDGs

While Artificial Intelligence (AI) holds great potential for advancing Sustainable Development Goals (SDGs), it also faces several challenges and limitations that must be addressed to maximize its effectiveness. Here are some key challenges and limitations of AI in achieving SDGs [34]:

- Data bias and quality:
  - Challenge: AI algorithms rely heavily on data for training and decision-making. However, biased or incomplete data can lead to biased outcomes, exacerbating existing inequalities and hindering progress towards SDGs.
  - Limitation: Data quality and availability vary across regions and sectors, making it difficult to develop AI solutions that are applicable and effective in diverse contexts. Additionally, data privacy concerns may limit access to critical data sources for AI development.

- Ethical and social implications:
  - Challenge: AI technologies raise complex ethical and social issues related to privacy, transparency, accountability, and fairness. Concerns about algorithmic bias, discrimination, and unintended consequences can undermine trust in AI systems and impede their adoption.
  - Limitation: Ensuring that AI solutions adhere to ethical principles and respect human rights requires clear guidelines, standards, and governance frameworks. However, existing regulatory frameworks may not adequately address the ethical challenges posed by AI, leading to uncertainty and ambiguity.

- Accessibility and affordability:
  - Challenge: Access to AI technologies and expertise is unevenly distributed globally, with developing countries and marginalized communities often lacking the resources and infrastructure needed to benefit from AI-driven solutions.
  - Limitation: The high cost of AI development, implementation, and maintenance can create barriers to adoption for organizations and individuals with limited financial resources. Moreover, the digital divide exacerbates inequalities in access to AI education, training, and employment opportunities.

- Technical limitations:
  - Challenge: AI algorithms have inherent limitations, including susceptibility to adversarial attacks, data overfitting, and lack of robustness in dynamic and uncertain environments. These limitations can affect the reliability, accuracy, and safety of AI systems, particularly in critical domains such as healthcare and transportation.

- Limitation: Overcoming technical challenges in AI development requires ongoing research, innovation, and collaboration across disciplines. However, progress in addressing technical limitations may be hindered by resource constraints, intellectual property issues, and competition among stakeholders.
- Regulatory and policy constraints:
  - Challenge: The rapid pace of AI innovation has outpaced the development of regulatory frameworks and policies to govern its use and mitigate potential risks. As a result, there is a lack of consensus and consistency in regulations related to AI, leading to regulatory uncertainty and compliance challenges.
  - Limitation: Developing effective regulations and policies for AI requires interdisciplinary collaboration, stakeholder engagement, and alignment with international standards and norms. However, the complexity and rapid evolution of AI technologies pose challenges for policymakers and regulators in keeping pace with technological advancements.
- Human-Centric design:
  - Challenge: AI systems must be designed and deployed with human well-being and values in mind to ensure that they contribute positively to achieving SDGs. However, there is a risk of prioritizing technological innovation over human needs and preferences, leading to unintended consequences and societal harm.
  - Limitation: Embedding human-centric design principles into AI development requires a shift in mindset, culture, and organizational practices. It also necessitates interdisciplinary collaboration between technologists, social scientists, ethicists, and other stakeholders to prioritize human values and ethics in AI design and implementation.

Addressing these challenges and limitations requires a coordinated effort from governments, academia, industry, civil society, and international organizations. By addressing ethical, technical, regulatory, and social concerns, AI can be harnessed as a powerful tool for advancing sustainable development and creating a more inclusive and equitable future.

4.1. SWOT analysis of AI in achieving SDGs

SWOT analysis is a strategic planning tool used to assess the strengths, weaknesses, opportunities, and threats of a project, initiative, or organization. It helps organizations identify internal strengths and weaknesses that they can leverage or address, as well as external opportunities and threats that they can capitalize on or mitigate. It provides valuable insights for strategic planning, decision-making, and risk management, guiding organizations in maximizing their strengths, minimizing their weaknesses, seizing opportunities, and addressing threats to achieve their objectives effectively.

A SWOT analysis of Artificial Intelligence (AI) in achieving Sustainable Development Goals (SDGs) provides insights into its strengths, weaknesses, opportunities, and threats in advancing global sustainability efforts [35].

- Strengths:
  - Efficiency and automation: AI technologies enable automation of various processes, enhancing efficiency and productivity in sectors such as agriculture, healthcare, energy, and transportation.
  - Data analysis: AI algorithms can analyze large volumes of data quickly and accurately, providing valuable insights for decision-making and policy formulation to address complex societal challenges.
  - Innovation: AI fosters innovation by facilitating the development of new solutions and technologies to tackle sustainability issues, such as renewable energy systems, smart infrastructure, and conservation initiatives.
  - Precision and optimization: AI enables precision agriculture, resource management, and urban planning, optimizing resource use and minimizing environmental impact.
  - Scalability: AI solutions can be scaled across different regions and contexts, allowing for widespread adoption and impact in achieving SDGs on a global scale.

- Weaknesses:
  - Data bias: AI algorithms may perpetuate biases present in training data, leading to discriminatory outcomes and exacerbating social inequalities.
  - Complexity: The complexity of AI systems and algorithms may pose challenges in understanding and interpreting their outputs, raising concerns about transparency, accountability, and trust.
  - Accessibility: Limited access to AI technologies, expertise, and infrastructure in certain regions and communities may widen the digital divide and hinder progress towards SDGs.
  - Ethical considerations: Ethical dilemmas surrounding AI, such as privacy violations, job displacement, and autonomous decision-making, require careful consideration and regulation to ensure responsible AI deployment.
  - Reliance on technology: Overreliance on AI solutions without considering social, cultural, and environmental factors may lead to unforeseen consequences and unintended negative impacts on sustainability efforts.

- Opportunities:
  - Innovation ecosystem: Collaborative efforts between governments, academia, industry, and civil society can foster an innovation ecosystem for developing AI solutions tailored to address specific SDGs and local contexts.
  - Capacity building: Investment in education, training, and skill development in AI technologies can build capacity and empower individuals and organizations to leverage AI for sustainable development.
  - Partnerships: Strategic partnerships and collaborations between stakeholders can facilitate knowledge sharing, resource mobilization, and collective action towards achieving SDGs.
  - Policy support: Policy frameworks and incentives that promote responsible AI deployment, data governance, and ethical standards can create an enabling environment for AI to contribute effectively to sustainable development.

- Impact assessment: Continuous monitoring, evaluation, and impact assessment of AI interventions can ensure that they align with SDGs and contribute positively to desired outcomes.
- Threats:
  - Job displacement: Automation driven by AI may lead to job displacement and unemployment, particularly in low-skilled and routine occupations, exacerbating socioeconomic inequalities.
  - Data privacy and security: AI applications rely on vast amounts of data, raising concerns about data privacy, security breaches, and misuse of personal information, which could undermine public trust in AI technologies.
  - Regulatory challenges: Inadequate regulations and governance frameworks for AI may fail to address emerging risks and ethical concerns, posing challenges in ensuring responsible AI development and deployment.
  - Bias and discrimination: Biased AI algorithms may perpetuate discrimination and amplify existing social inequalities, leading to unfair treatment and exclusion of marginalized groups.
  - Technological risks: Unintended consequences of AI, such as system failures, algorithmic errors, and unintended side effects, could have detrimental impacts on society and the environment if not properly managed.

Overall, a strategic approach to leveraging AI for achieving SDGs requires addressing its strengths, weaknesses, opportunities, and threats holistically, with a focus on ethical, inclusive, and sustainable development principles. Collaboration, innovation, and responsible governance are key to maximizing the potential of AI while mitigating its risks in advancing global sustainability goals.

4.2. Future prospects of AI and sustainable development goals

The prospects of Artificial Intelligence (AI) in advancing Sustainable Development Goals (SDGs) hold immense promise for addressing complex global challenges and fostering sustainable development across various sectors. Here are some key areas where AI is expected to play a significant role in achieving SDGs [36]:

- Precision agriculture:
  - AI-powered technologies, such as remote sensing, drones, and machine learning algorithms, can optimize agricultural practices and improve crop yields while minimizing resource use and environmental impact.
  - By analyzing vast amounts of data on soil quality, weather patterns, and crop health, AI systems can provide real-time insights and recommendations to farmers, enabling them to make informed decisions and maximize productivity sustainably.
- Healthcare:
  - AI has the potential to revolutionize healthcare delivery by enabling early disease detection, personalized treatment plans, and predictive analytics for public health interventions.
  - Machine learning algorithms can analyze medical images, genomic data, and electronic health records to identify patterns, diagnose diseases, and

> recommend tailored treatments, leading to improved health outcomes and reduced healthcare disparities.

- Environmental conservation:
  - AI-driven monitoring and surveillance systems can enhance environmental conservation efforts by tracking biodiversity, detecting deforestation, and monitoring wildlife populations.
  - By analyzing satellite imagery, sensor data, and other sources, AI algorithms can identify environmental threats, predict ecological trends, and inform conservation strategies to protect natural habitats and biodiversity hotspots.

- Climate change mitigation:
  - AI technologies can facilitate climate change mitigation efforts by optimizing energy consumption, reducing greenhouse gas emissions, and supporting renewable energy deployment.
  - AI-driven models and simulations can optimize energy systems, forecast renewable energy generation, and predict climate impacts, helping policymakers and businesses make informed decisions to transition to a low-carbon economy.

- Smart cities:
  - AI-powered smart city solutions can enhance urban sustainability by optimizing transportation systems, managing energy use, and improving resource efficiency.
  - Through real-time data analysis and predictive modeling, AI can optimize traffic flow, reduce congestion, and minimize carbon emissions, leading to cleaner, more efficient urban environments.

- Disaster management:
  - AI technologies can enhance disaster preparedness, response, and recovery efforts by providing early warning systems, assessing risk factors, and coordinating emergency response operations.
  - By analyzing historical data, weather patterns, and social media feeds, AI algorithms can predict natural disasters, assess their impact, and coordinate relief efforts to mitigate human suffering and save lives.

While AI holds great promise for advancing SDGs, its widespread adoption and effective implementation depend on addressing various challenges and considerations, including ethical concerns, regulatory frameworks, and societal implications. By harnessing the transformative potential of AI in alignment with sustainable development principles, we can accelerate progress towards achieving the SDGs and building a more prosperous, equitable, and resilient future for all.

5. Recommendations

Accelerating the achievement of Sustainable Development Goals (SDGs) using Artificial Intelligence (AI) requires a strategic approach and concerted efforts from various stakeholders. Here are some recommendations:

Invest in AI research and development: Governments, international organizations, and private sectors should increase investments in AI research and development to

foster innovation and create AI-driven solutions tailored to address specific SDGs. This includes funding for basic research, applied research, and technology transfer initiatives.

Promote data sharing and collaboration: Encourage data sharing and collaboration among governments, academia, businesses, and civil society organizations to leverage diverse datasets for AI applications. This can involve establishing data-sharing frameworks, incentivizing data sharing through public-private partnerships, and promoting open data initiatives.

Build AI capacity and skills: Invest in education and training programs to build AI capacity and skills among policymakers, practitioners, and researchers. This includes offering courses, workshops, and certification programs on AI fundamentals, data science, machine learning, and AI ethics.

Foster ethical AI development: Ensure that AI technologies developed for SDGs adhere to ethical principles, human rights standards, and privacy regulations. Establish guidelines, standards, and certification mechanisms for ethical AI development and deployment, including transparency, fairness, accountability, and inclusivity.

Support AI for good initiatives: Encourage the development and deployment of AI for Good initiatives focused on addressing specific SDGs, such as healthcare, education, climate action, and poverty alleviation. Provide funding, resources, and technical support for projects that leverage AI to tackle global challenges and promote sustainable development.

Facilitate access to AI technologies: Ensure equitable access to AI technologies, tools, and resources, particularly for low- and middle-income countries and underserved communities. This may involve providing financial assistance, technology transfer, and capacity-building support to bridge the digital divide and promote inclusive development.

Strengthen regulatory frameworks: Develop and enforce regulatory frameworks to govern the ethical use of AI in achieving SDGs. This includes legislation, policies, and guidelines to address data privacy, algorithmic bias, cybersecurity, intellectual property rights, and other regulatory issues related to AI deployment.

Promote AI-Enabled innovation hubs: Establish AI-enabled innovation hubs, incubators, and accelerators focused on developing scalable solutions for SDGs. These hubs can bring together multidisciplinary teams of researchers, entrepreneurs, policymakers, and investors to collaborate on AI-driven innovation projects.

Encourage public-private partnerships: Foster collaboration between governments, businesses, academia, and civil society through public-private partnerships (PPPs) to leverage each sector's strengths and resources in advancing SDGs with AI. PPPs can facilitate technology transfer, co-investment, and knowledge sharing to scale up impactful AI solutions.

Monitor and evaluate impact: Implement robust monitoring and evaluation mechanisms to assess the impact of AI-enabled interventions on SDGs. This involves tracking key performance indicators, measuring outcomes, and conducting impact evaluations to ensure that AI investments effectively contribute to sustainable development goals.

By implementing these recommendations, stakeholders can harness the transformative potential of AI to accelerate progress towards achieving the SDGs and create a more inclusive, equitable, and sustainable future for all.

6. Conclusion

In this article, we tried to review the impacts of AI in achieving SDGs. For this purpose, we divided the article into two parts:

The first part is about AI-related concepts, and the second part is about SDGs-related terms. Then these two concepts were merged in the third part. Next, we reviewed the limitations, challenges, and opportunities and a SWOT analysis of applying AI to achieving SDGs.

In conclusion, the role of Artificial Intelligence (AI) in achieving Sustainable Development Goals (SDGs) is pivotal for addressing global challenges and fostering sustainable development across various sectors. AI solutions offer innovative approaches to precision agriculture, healthcare delivery, environmental conservation, climate change mitigation, smart city development, and disaster management, among others, thereby contributing to the advancement of SDGs.

We concluded that we need to leverage technology, innovation, and data science to speed up achieving SDGs. On the other hand, it is necessary to strengthen the infrastructure.

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