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Digital circular economy and artificial intelligence: Pathways to sustainable development in the United Arab Emirates

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Abstract---This article aims to explore the relationship between the digital circular economy and artificial intelligence as key tools to support sustainable development in the United Arab Emirates. It outlines how the digital circular economy—focused on reducing waste and improving resource efficiency—can be integrated with artificial intelligence technologies that optimize production and service processes through data analysis and intelligent decision-making. The paper reviews national strategies and policies that encourage innovation in these fields, as well as major projects and initiatives aimed at transforming the UAE's economy into a sustainable, low-carbon model. These initiatives highlight the opportunities presented by modern technologies to stimulate sustainable economic growth and achieve environmental and social goals. The study concludes that combining the digital circular economy with artificial intelligence can significantly enhance sustainability in the UAE by improving the use of natural resources and supporting economic diversification.

Keywords---Digital Circular Economy, Artificial Intelligence, Sustainable Development.

Introduction

In today's world, the global economy faces major environmental challenges—from air and water pollution to the depletion of natural resources. In response, there is a growing need to adopt new economic models that are both efficient and sustainable. The circular economy offers a promising solution. It focuses on reducing waste, increasing recycling, and using resources more effectively, in contrast to traditional models based on consumption and disposal.

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With the rise of digital technologies, digital applications have become a vital part of circular economy strategies. This development has given rise to the digital circular economy, which relies on digital transformation in resource management. It helps reduce waste and increase efficiency across different sectors.

At the same time, artificial intelligence has become a powerful tool that is transforming many industries. AI makes it possible to analyze large amounts of data and make informed decisions based on patterns, which boosts productivity, reduces costs, and promotes sustainability. Through automation and precise analysis, AI plays a key role in driving innovation in areas such as the economy, energy, services, and the environment.

The United Arab Emirates is one of the leading countries in adopting advanced technologies to promote sustainable development and achieve digital transformation. The UAE government has launched ambitious strategies to encourage innovation in the fields of digital economy and artificial intelligence. Notable among these are the UAE Vision 2021 and the Artificial Intelligence Strategy 2031, which aim to improve government performance and enhance the efficiency of economic sectors in line with environmental and social goals. One of the most recent trends in the UAE is the integration of the digital circular economy and artificial intelligence to create a sustainable economic model that supports both environmental and social progress.

1. Problem Statement

This article is based on a central research question: How can the integration of the digital circular economy and artificial intelligence contribute to advancing sustainable development in the United Arab Emirates?
This question is of key importance because it involves economic, environmental, and technological dimensions that must be studied carefully to understand how they interact.

2. Sub-Questions

Several related questions emerge from the main research problem :

- What is the impact of the digital circular economy on the efficient use of natural resources in the UAE ?
- How can artificial intelligence improve production and distribution processes within the circular economy sector ?
- To what extent do government policies support innovation in the fields of digital circular economy and artificial intelligence?
- What opportunities and challenges does the UAE face in combining these technologies to achieve environmental and social objectives ?

3. Hypotheses

To answer the above questions, the following hypotheses are proposed :

- The digital circular economy can play an effective role in improving resource management and reducing waste across various economic sectors in the UAE ;
- The use of artificial intelligence in the circular economy sector can enhance production efficiency and reduce the environmental impacts of manufacturing and transportation ;
- UAE government policies directly encourage innovation in both digital circular economy and artificial intelligence, thus strengthening the country's global competitiveness ;

- The UAE faces both opportunities and challenges in integrating the digital circular economy and artificial intelligence. Positive outcomes can be achieved, but this requires strengthening digital infrastructure and increasing cooperation between the public and private sectors.

4. Significance of the Study

This study holds particular significance in light of the rapid transformations taking place in the United Arab Emirates in the fields of digital transformation and environmental sustainability. It highlights how modern technologies can be used to improve resource efficiency and support sustainable economic growth. In addition, the study offers practical and applicable insights for officials and decision-makers on how to integrate the digital circular economy and artificial intelligence into national development strategies.

5. Objectives of the Study

This study aims to:

- Examine the role of the digital circular economy in achieving sustainable development in the United Arab Emirates;
- Analyze how artificial intelligence technologies can contribute to improving economic and service processes in line with environmental sustainability;
- Evaluate Emirati policies and strategies that support innovation in the fields of the digital circular economy and artificial intelligence;
- Provide strategic recommendations to support the integration of these technologies in achieving national goals related to sustainable development.

6. Methodology

This study adopts a descriptive analytical approach that seeks to explore and explain the relationship between the digital circular economy and artificial intelligence in the United Arab Emirates. Data will be collected from secondary sources, including government reports, academic research, and previous studies focused on the digital circular economy and artificial intelligence. The data will be analyzed by examining the tools and initiatives implemented in the UAE, with a focus on how these technologies impact the sustainability of economic and environmental resources. In addition, case studies of local projects that integrate the digital circular economy and artificial intelligence will be analyzed to understand how they contribute to environmental and social objectives. This methodology aims to provide a deep understanding of the mechanisms, opportunities, and challenges related to the application of these technologies within the Emirati context.

First: Theoretical Framework of the Study

1. Conceptual Framework of the Circular Economy and the Digital Circular Economy

A. The Concept of the Circular Economy

The term "circular economy" first appeared in 1989 with the publication of the book Natural Resource and Environmental Economics by David Pearce and R. Kerry Turner, published by Johns Hopkins University Press. The book explores the connection between the economy, natural resources, and the environment. It explains how the ecological and economic systems interact and identifies key environmental imbalances and their economic effects.

The authors distinguish between two economic models. The first is the linear economy, where resource consumption follows an open-ended path. The second is the circular economy, which aims to rebuild

capital—whether financial, industrial, human, social, or natural—and to enhance the return on resources. This is done by recycling products, components, and raw materials at all stages, thus ensuring a continuous flow of both technical and biological materials.
The circular economy is defined as : A system of production, exchange, and consumption that aims to improve the use of resources at all stages of a product or service life cycle, within a circular model, while reducing the environmental footprint and contributing to individual and community well-being[1]

The circular economy is also defined as: A dynamic economic model that seeks to change the way we live by promoting development and innovation in both production and consumption. The circular economy offers many opportunities to support long-term sustainability and growth. It focuses on reducing waste by lowering dependence on raw material imports, increasing resource productivity, creating a more competitive economy, ensuring sustainable resource use, generating more job opportunities, and reducing environmental impacts[2]

It is also defined as: An economy that aims to preserve the value of products, materials, and resources for as long as possible. It helps decouple growth in manufacturing, production, and consumption from the use of natural resources. This model promises economic, social, and environmental benefits. The international community's intention to shift toward a circular economy by 2030 is also reflected in the Sustainable Development Goals. These goals seek a systemic transformation in several interrelated areas, including sustainable production and consumption (Goal 12), economic growth (Goal 8), climate action (Goal 13), and sustainable cities and communities (Goal 11). The circular economy approach will support the achievement of these important goals.

The concept of the circular economy is based on several pillars. These include recycling, attention to the environmental impact of industrial processes, a focus on industrial integration, and interest in regenerative design. It also involves shifts in consumption patterns and a growing emphasis on services rather than goods and physical products[3].

The circular economy is considered an innovative approach to creating long-term value and prosperity. It seeks to extend the life of products by improving design and service quality. It also redirects waste from the end of the supply chain back to the beginning, based on repeated and efficient use of resources rather than one-time consumption.
At its core, the circular economy focuses on three main activities:

- Product-level reuse (such as repair or refurbishment);
- Component-level reuse (such as remanufacturing);
- Material-level reuse (such as recycling).

From this perspective, the circular economy can be understood as an economic model that aims to achieve sustainability by reducing waste and maximizing the use of resources. This is done through reuse, repair, refurbishment, and recycling within a closed-loop system of production and consumption. The model works to extend product life and reduce reliance on non-renewable natural resources. It promotes the design of recyclable and repairable products and transforms waste into new resources. This helps reduce environmental impact and supports greater economic efficiency. This concept can be illustrated in the following figure:

1 Fatima Zahra Kandouz, Requirements for the Transition from a Linear Economy to a Circular Economy for Environmental Protection, Journal of Commercial Sciences, Vol. 17, No. 01, 2018, p. 06.

2 Nachida Ahtattash, The Role of Waste Management in the Sustainability of the Circular Economy to Achieve Green Sustainable Development : A Case Study of Algeria, Al-Bashaer Economic Journal, Vol. 07, No. 02, 2021, p. 770.

3 Kafia Chenafi and Ahmed Ghabouli, Household Waste Recycling within the Framework of the Circular Economy and Its Role in Achieving Sustainable Development – A Case Study of Setif Province, Journal of Economic Studies, Vol. 11, No. 01, 2024, p. 337.

Figure 01: Mechanism of the Circular Economy
Source: Circular Economy… Preserving Resources and Creating Value, published on September 1, 2022. Accessed on April 8, 2025. Available online at :
https://almostathmir.dz/الاقتصاد-الدائري-للحفاظ-على-الموارد-و/

B. The Importance of the Circular Economy

The importance of the circular economy can be attributed to the following reasons :[4]

- **Environmental protection :** It reduces emissions that worsen the effects of climate change. It lowers the consumption of natural resources. It also reduces waste generation and the loss of biodiversity.
- **Economic benefit to the local economy :** It promotes models based on the reuse of local waste as raw materials.
- **Employment growth :** It supports the development of a new industrial model that is more innovative and competitive. This leads to economic growth and an increase in job opportunities.
- **Resource independence :** The reuse of local resources can reduce reliance on imported raw materials.
- **Social welfare and equity :** It improves access to goods and services, contributing to social well-being and justice.
- **Technological innovation and sustainable design:** It encourages the development of new technologies and the design of more efficient, repairable, and recyclable products.
- **Lower long-term production and operating costs :** It minimizes the need for new raw materials and enhances the efficient use of available resources.
- **Greater adaptability of companies :** It improves the ability of firms to respond to market changes and environmental regulations, giving them a competitive edge in global markets.
- **Improved quality of life :** It reduces pollution and improves community health by lowering waste and harmful emissions.
- **Cross-sector collaboration :** It fosters cooperation between various industrial sectors by creating networks for material recycling and shared resource use between businesses and communities.
- **Restoration of natural capital.**

4 Kafia Chenafi and Ahmed Ghabouli, Op. Cit, p. 337.

C. Principles of the Circular Economy: The circular economy is built on a set of principles, outlined as follows:[5]

- **Organizing Reverse Cycles :** Resources should move in circular flows. To achieve closed-loop resource use, systems for collection and processing must be established to recover value from expired products. These systems include processes such as refurbishment and recycling, which return resources to the value chain. In this way, the output (waste) of one process becomes the input (feedstock) for another, effectively eliminating the concept of waste.
- **Resource Efficiency :** The circular economy aims to increase the efficiency of resource use across the economy. At its core, resource efficiency means using materials to their fullest potential to create a positive impact. This refers to the desired outcome, rather than settling for lesser or unintended results.
- **Systems Thinking :** Systems are composed of many interconnected parts. The behavior of each part affects the performance of the whole system. Systems thinking is a method used to understand how components interact and how they relate to the system overall. The circular economy seeks to improve the performance of the full system, not just individual parts.
- **Prioritizing the Future :** All types of institutions strive to remain competitive and to grow. This requires adapting to environmental changes. Some organizations even shape those changes. In doing so, they must assess and predict risks. This process is a key driver for transitioning from the linear economy's challenges to circular economy solutions. The circular model offers a fundamentally different approach to today's dominant economic and industrial practices.
- **Creating Mutual Benefit :** The circular economy meets society's needs for products and development. Basic market principles such as supply and demand remain in place. However, the ways in which resources are used and value is created are different. When these methods change, activities must be organized in a way that generates mutual benefit for all stakeholders.
- **Eliminating Waste and Pollution :** In the linear economic model, production depends on extracting raw materials from the earth, using them in manufacturing, and then disposing of them as waste in landfills or incinerators. This leads to the loss of valuable resources. The circular economy seeks to eliminate this waste through recycling and reuse.
- **Regenerating Nature :** Transitioning from a linear model of "take, make, waste" to a circular model helps support natural systems. It creates space for ecosystems to flourish. The shift is from extraction to regeneration.
- **Circulating Products and Materials at Their Highest Value :** This involves keeping materials in use as long as possible—whether as products, components, or raw materials. It prevents waste and preserves the inherent value of both materials and goods. Figure 02, known as the "Butterfly Diagram," shows the continuous flow of materials in the circular economy. It includes two main cycles: the technical cycle and the biological cycle.

On the right side is the technical cycle, which focuses on products that are used rather than consumed. On the left side is the biological cycle, which includes materials that can safely return to the environment through natural degradation. This cycle mainly involves consumable goods, such as food. However, some biodegradable materials may eventually move from the technical to the biological cycle when they degrade beyond reuse. These principles are illustrated in the following diagram:

5 Hout, Niek Benjamin. **Developing a dedicated tool to support the development of domestic boilers for a Circular Economy**. À Master thesis, Department of Design, Production and Management, Faculty of Engineering Technology, University of Twente- Netherlands, 2017, p- p 53-56.

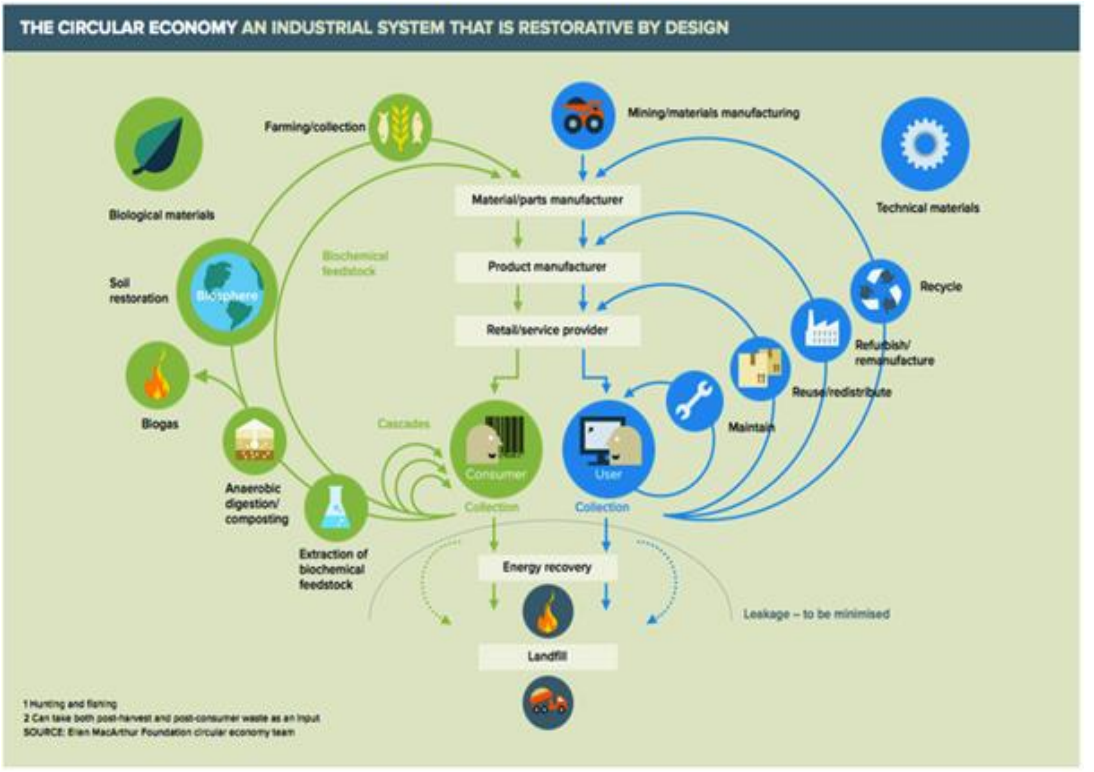

Figure 02: Circular Economy System Diagram
Source : Lamis Al-Arabi, The Fifth Industrial Revolution: The Circular Economy as a New System Offering Sustainability Opportunities, published on September 8, 2023. Accessed on April 8, 2025. Available online:
https://futureuae.com/ar-AE/Mainpage/Item/8590/الثورة-الصناعية-الخامسة-الاقتصاد-الدائري-نظام-جديد-يحمل-فرص-الاستدامة

D. Definition of the Digital Circular Economy: The digital circular economy is an economic model that combines the principles of the circular economy—such as reuse, recycling, and waste reduction—with digital technologies like Artificial Intelligence (AI), Blockchain, and the Internet of Things (IoT). This model aims to increase resource efficiency, improve material tracking, and support sustainable business models. It does so through big data analysis, automation, and smart systems.

This approach plays a key role in advancing sustainable development goals. It helps convert waste into resources, improves transparency in supply chains, and reduces the environmental footprint of industries[6]
It is also defined as: "An integrated framework that brings together advanced digital technologies and the principles of the circular economy to create more efficient and sustainable systems of production and consumption."
This model relies on technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and Blockchain. These tools support closed-loop material flows, enhance resource tracking, and maximize reuse and recycling[7]

6 International Labour Organization ILO, World Employment and Social Outllok 2021 : The Role of Digital Labour Platforms in Transforming the World of Work, International Labour Office, Geneva, 2021, URL : https://www.ilo.org/publications/flagship-reports/role-digital-labour-platforms-transforming-world-work.

It is also defined as: "An integrated techno-economic model that uses digital solutions to optimize and manage the flow of materials and energy within a closed circular system."
It relies on digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and Cloud Computing to enable:[8]

- Smart tracking of resources across value chains ;
- Real-time optimization of industrial processes ;
- Extension of product lifespan through predictive maintenance ;
- Creation of efficient markets for secondary resources.

From the above, it can be concluded that the **digital circular economy** is an extension of the traditional circular economy. It does not differ in its definition, importance, or core principles. Both models aim to reduce waste, maximize resource use, and extend product life cycles through reuse, repair, refurbishment, and recycling.

However, the digital circular economy adds a technological dimension. It integrates digital technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Blockchain, and Big Data. These tools support efficient resource tracking, improve supply chain performance, enhance transparency across the product life cycle, and enable more intelligent and sustainable business models. Thus, the digital circular economy is a complementary development. It strengthens the effectiveness of the circular economy and expands its applications through the tools of the digital age.

2. The Conceptual Framework of Artificial Intelligence

A. The Concept of Artificial Intelligence

–The Emergence of Artificial Intelligence : The first ideas about artificial intelligence appeared in the 1940s. However, the French philosopher **Paul Valéry** was among the earliest to speak meaningfully about the future of machines and their coexistence with humans. In the early 19th century, he stated: "Every human is in the process of becoming a machine, and in truth, it is the machine that is evolving to become human.
He envisioned that the development of artificial intelligence could eventually lead to a replacement of human intelligence. This idea is echoed in a quote attributed to Albert Einstein: "The speaking, moving robot will replace Albert Einstein."
It is important to note that artificial intelligence is not a recent invention. Its origins trace back to the second half of the twentieth century. The development of AI can be studied through three key phases, as outlined below:[9]
First Phase (1940–1960): During this period, researchers used mathematical analysis to build systems capable of analyzing data and making decisions. In 1956, the first conference on artificial intelligence was held at Dartmouth College in the United States. At that event, **John McCarthy, Marvin Minsky, Herbert Simon, and Allen Newell** introduced the term Artificial Intelligence and began developing programs that used mathematical data analysis.
Second Phase (1961–2000): This stage is known for the rise of neural networks. Academic and professional efforts moved in parallel to explore new technologies. Researchers focused on studying

7 Julian Kirchherr, Denise Reike, Marko Hekkert, Conceptualizing the Circular Economy : An Analysis of 114 Definitions, Resources, Conservation and Recycling, Issu 127, 2017, Elsevier, p 232.
8 Maria Antikainen, Teuvo Uusitalo, Paivi Kivikyto-Reponen, Digitalisation as an Enabler of Circular Economy, Journal Procedia CIRP, 8th Cirp Conference on Industrial Product-Service Systems, Volume 73, Elsevier B.V, 2018, p 48.
9 Saleh Mahdi Al-Amiri and Hassan Jamal Al-Yudawi, Analyzing the Effects of Artificial Intelligence on the Future of Work in the Global Economic Environment, Al-Ghari Journal for Economic and Administrative Sciences, Vol. 20, Special Issue – Proceedings of the Seventh Scientific Conference of the College of Administration and Economics : The Integration of Administrative and Economic Sciences in Light of the Digital Transformation of Business Models and Innovation Challenges, 2024, p. 48.

how the human brain functions and building computer models inspired by those processes. In 1980, **David Rumelhart**, an American scientist, developed the concept of "neural networks." Today, these networks are considered among the core technologies in AI. During this phase, practical applications of artificial intelligence began to appear.

Third Phase (2001–present): This phase marked the emergence of new technologies such as deep learning, natural language processing, and advanced image and voice recognition. These advances were made possible by improvements in computing power, the evolution of neural networks, and the development of deep learning methods. Since then, AI technologies have become more advanced and diverse than ever before. Comprehensive applications of AI began to spread across multiple sectors, including **big data analysis, autonomous vehicles, medical image interpretation, machine translation, robotics control, cybersecurity, e-commerce**, and **government operations**. Military applications also emerged, including the use of smart machines in warfare and security operations, such as **drones, guided missiles, and unmanned vehicles**.

–Definition of Artificial Intelligence : As mentioned earlier, the term Artificial Intelligence was first introduced in 1956. It originally referred to the idea that "if machines could solve problems that only humans could solve," then they could be called intelligent. However, this early vision proved to be overly optimistic. Despite some localized breakthroughs from time to time, it became clear that artificial intelligence was far more complex than initially thought.

Most researchers eventually chose to avoid the term "artificial intelligence" and instead used phrases like expert systems or neural networks. The term AI only regained interest in 2012, with the emergence of what became known as the ImageNet Challenge, which marked a turning point in the modern development of AI technologies[10]

Artificial Intelligence is defined as "the study of intellectual abilities through the use of computational models that aim to simulate human thinking." It is also described as a technology used to build machines capable of imitating human thought, forming opinions, making judgments, and developing the ability to learn and evolve.

Copeland & Proudfoot define artificial intelligence as "the process of developing computer systems that can perform tasks which typically require human intelligence, such as visual perception, speech recognition, decision-making, and translation."

Ray Kurzweil, one of the most well-known researchers in the field, defines it as "the art of creating machines that can perform tasks requiring intelligence when done by humans"

Another definition describes AI as "a form of intelligence that machines can acquire through software that enables them to behave as if they have a mind capable of mimicking human cognitive abilities."

According to Oracle, AI refers to "systems or devices that mimic human intelligence to perform various tasks, and that can also improve themselves based on the data they collect. These systems are characterized by advanced reasoning and data analysis capabilities"[11]

Artificial Intelligence is defined as a branch of computer science that focuses on developing systems capable of learning, decision-making, and prediction within specific fields.

In its simplest form, artificial intelligence takes data and applies mathematical rules or algorithms to it. Based on this, the system either makes a decision or predicts an outcome.

For example, the data may consist of images of handwritten words, letters, or numbers. The algorithm is a computer program written by a human and contains rules, such as common letter shapes and the spacing between words. These rules allow the computer to analyze scanned images of handwritten text, apply the rules, and predict the letters, numbers, and words shown in the image.

This enables machines to recognize handwriting. One example of this type of artificial intelligence is its use by the United States Postal Service, which has relied on it to automatically read addresses on mail since 1997[12]

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10 Fahd Al-Hazmi and Victor Sahab, Artificial Intelligence : Its Technologies, Evolution, and Promises, Al-Qafilah Journal, Vol. 66, No. 01, 2017, p. 37.

11 Majed Abu Al-Naga Al-Sharqawi, The Economic Dimensions of Artificial Intelligence: Assessing the Readiness of the Egyptian Economy, Journal of Legal and Economic Studies, Vol. 09, No. 01, 2023, pp. 288–289.

Computing power plays a vital role in supporting artificial intelligence (AI), big data, and cloud computing. These technologies support a wide range of functions, from ride-hailing services to daily business operations and chatbot systems.

Generative AI, for instance, can produce content that is often indistinguishable from human-created work. Among the most notable examples is ChatGPT, which represents one of the key drivers of the **Fourth Industrial Revolution**. Alongside digital transformation and the Internet of Things, AI stands at the core of the technological change shaping the world today.[13]

Based on the above, we can conclude that **Artificial Intelligence (AI)** is a branch of computer science concerned with designing and developing systems and software that can simulate intelligent human behavior.

AI enables machines to learn, reason, plan, understand language, and solve problems using data and algorithms. It includes a range of technologies such as **machine learning**, **artificial neural networks**, **natural language processing (NLP)**, and **computer vision**. These technologies aim to help systems acquire knowledge through experience and interact with complex environments in an independent and efficient manner.

Today, artificial intelligence is used in many fields, including **healthcare**, **industry**, **finance**, and **education**. This makes it one of the most influential scientific and technological trends of the modern era.

–Key Characteristics of Artificial Intelligence : The main features of artificial intelligence, based on the definitions presented above, include :[14]

- **Learning Ability:** Artificial intelligence possesses the capacity to learn from available data and adapt to changing conditions. This enables AI systems to improve their performance over time. Devices powered by AI can develop patterns and make predictions based on experiences.
- **Analytical and Interpretive Capability:** AI can analyze vast amounts of data and extract hidden patterns . This skill makes AI valuable for processing big data and making informed decisions based on the insights derived.
- **Autonomy:** Some AI systems can make decisions independently without human intervention. In advanced applications such as self-driving cars, AI contributes to making decisions autonomously based on the data it receives.
- **Natural Language Processing:** AI is capable of understanding and processing human language. This technology is used in applications like voice assistants, including Siri and Alexa, which comprehend and analyze language to provide accurate responses.
- **Pattern Recognition:** AI excels at identifying patterns within data. This capability finds use in various applications such as facial recognition in images and forecasting future trends in financial markets. In addition to the above characteristics, there are other features that include:[15]
- **Contextual Awareness:** Advanced artificial intelligence can understand the surrounding context—such as location, time, and user—and make appropriate decisions based on it, rather than merely reacting to random data.
- **Continuous Adaptation:** Instead of one-time learning, intelligent systems keep learning and evolving through daily use, allowing their performance to improve with new data and experiences.

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12 Bernard Ward, translated by Aisha Yaken, *Applications* of Artificial Intelligence: How 50 Successful Companies Used AI and Machine Learning to Solve Problems, Obeikan Publishing and Distribution, Riyadh, Kingdom of Saudi Arabia, 2022, p. 23.

13 Nozad Abdulrahman Mohammed Saleh, Abdulrahman Al-Hiti, Artificial Intelligence: Its Economic Indicators and Its Impact on Labor Markets, Lubab Journal for Strategic Studies, Issue 20, Doha, Qatar, 2023, p. 91.

14 Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, 1st Edition, MIT Press, Cambridge, United States, 2016, pp 29-30.

15 S**tuart J. Russell & Peter Norvig**, *Artificial Intelligence : A Modern Approach,* 4th Ed., Prentice Hall, Engelwood Cliffs, NJ, USA, 2020, pp. 42–47.

- **Scalability:** Advanced AI systems can be deployed on a large scale via cloud services. They can handle millions of users and vast amounts of data without compromising performance.
- **Speed and Accuracy:** AI systems process complex tasks and large datasets faster and with fewer errors compared to humans, as seen in fields like medical diagnosis.
- **Explainability:** There is a growing focus on building models that can clarify the rationale behind their decisions, thereby enhancing transparency and trust. These models are known as Explainable AI (XAI).
- **Rationality and Resilience:** Beyond logical reasoning, research efforts such as "AIR5" are advancing AI systems' abilities to justify actions, withstand challenges, and cope with failure and disruption. According to the previous definitions, artificial intelligence also possesses numerous key features and advantages, most notably the following:[16]
- **Knowledge Representation Capability :** Unlike statistical software, artificial intelligence programs employ a specialized structure to represent knowledge. This structure includes facts, the relationships between them, and the governing rules. The aim is to provide a knowledge base that offers as much relevant information as possible about the problem to be solved.
- **Use of an Optimistic Experimental Approach :** A key characteristic of AI is its ability to tackle problems without known solutions. This means that such programs do not follow a fixed sequence of steps leading to a guaranteed solution. Instead, they select an approach that appears promising, while keeping open the possibility of changing this method if it proves less effective than an alternative for reaching a faster solution.
- **Ability to Handle Incomplete Information :** Another notable feature of AI programs is their capacity to propose partial solutions even when the available information is incomplete.
- **Reasoning Ability :** This refers to the capacity to infer possible solutions for a specific problem based on known data and prior experience, especially for issues where traditional methods are insufficient. This capability is realized through computers that store potential solutions, logical rules, and inference mechanisms.

B. The Importance of Artificial Intelligence : Several aspects highlight the broad importance of artificial intelligence across various fields and disciplines, including :[17]

- Artificial intelligence contributes to preserving accumulated human expertise by transferring it to intelligent machines ;
- It enables humans to interact with machines using natural language instead of computer programming languages. This makes advanced machines accessible to all segments of society, whereas previously their use was limited to specialists and experts;
- AI plays a vital role in many sensitive fields, including assisting in disease diagnosis and prescription, providing legal and professional consultations, supporting interactive education, enhancing security and military applications, among other areas;
- Intelligent systems contribute significantly to decision-making processes. These systems possess autonomy, accuracy, and objectivity. As a result, their decisions are free from errors, biases, racism, prejudgments, or external and personal interference;
- Intelligent machines relieve humans from many risks and psychological pressures. They allow individuals to focus on more important and humane tasks, while managing time more effectively;
- The application of artificial intelligence will contribute to achieving sustainable development goals, specifically Goal 7 (Affordable and Clean Energy), Goal 13 (Climate Action), Goal 14 (Life Below Water), and Goal 15 (Life on Land).[18]

16 Geisel A, The current and future impact of artificial intelligence on business, International Journal of Scientific and Technology Research, Vol 07, No 05,2018, pp 116-122.

17 Souria Chenibi, Implementing a Railway Transport Development Strategy in Algeria Using Intelligent Transport Systems as an Application of Artificial Intelligence, Journal of Financial and Accounting Studies, Issue 07, El Oued University, Algeria, 2016, pp. 157–158 .

Artificial intelligence has also gained significant importance alongside the evolving economy and job markets in the context of the Fourth Industrial Revolution. This is evident in the following aspects:[19]

- It enables humans to interact with machines using natural language instead of computer programming languages. This accessibility extends to all individuals, including those with disabilities, whereas previously, operating advanced machines was limited to specialists;
- It plays a crucial role in many sensitive fields, such as assisting in disease diagnosis, prescribing medication, performing surgical procedures, conducting hazardous experiments, providing legal and professional consultations, and supporting interactive education like pilot or driver training. It is also significant in security, defense, and other domains;
- Its importance is especially notable in decision-making areas, due to its autonomy, accuracy, and objectivity. As a result, its decisions tend to be free from errors, biases, racism, preconceived judgments, or external and personal influences.

Artificial intelligence has contributed positively by improving various sectors. It has enhanced productivity in both manufacturing and service industries. Moreover, it has helped prevent crimes, particularly cybercrimes, and has advanced education and healthcare services, especially during crisis periods such as the COVID-19 pandemic. Additionally, AI has played a key role in the development of smart cities and digital governments.

C. Types of Artificial Intelligence: The types of artificial intelligence can be categorized as follow[20]:

- **Weak Artificial Intelligence (Narrow AI) :** This type of artificial intelligence has limited learning capabilities. It is designed to perform specific tasks only, without the ability to learn or understand beyond its initial programming. This form of AI is considered restricted and relies entirely on the primary programming it receives. Although it can execute programmed tasks efficiently, it lacks adaptability to new contexts or the capacity to learn from new data. Weak AI is useful in scenarios requiring repetitive and consistent task execution but is ineffective in dynamic environments that demand continuous learning and adaptation to new challenges.
- **Strong Artificial Intelligence :** This type of AI is intended to possess the ability to understand and process information similarly to human intelligence. Strong AI remains under development and is not yet available.
- **Super Artificial Intelligence :** This advanced form of AI is a subject of concern globally due to fears it might surpass human capabilities and potentially replace humans in the future. This type is still hypothetical and not yet realized. It is designed to exceed human intelligence in all fields, including creativity, problem-solving, and decision-making.

Artificial intelligence influences the future of every industrial sector and every person on the planet. It serves as the primary driver behind emerging technologies such as big data collection, robotics, and the Internet of Things. AI is expected to play an increasingly significant role in the coming years.

D. Applications of Artificial Intelligence: The year 2023 witnessed considerable advancements in AI technologies accessible to the public. These technologies can be utilized to enhance everyday skills such as internet research, editing, writing, and even fostering a healthier lifestyle. These applications include:[21]

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18 Mohammed bin Rashid Al Maktoum Foundation for Knowledge and the Regional Bureau for Arab States, United Nations Development Programme, The Future of Knowledge : A Foresight Report, Al Ghurair Printing and Publishing, Dubai, United Arab Emirates, 2018, p. 10.

19 Ibtisam Nasser Huwaimel, Khawla Abdullah Al-Mufaiz, Artificial Intelligence : The Future of Human Resource Management, Obeikan Publishing and Distribution, Riyadh, Kingdom of Saudi Arabia, 2022, pp. 58–59.

20 Samir Tabour, Ben Ali Qrijij, Digital Transformation Technologies and Artificial Intelligence in Addressing and Predicting Economic Crises, Al-Riyada Journal of Business Economics, Vol. 11, No. 11, 2025, pp. 164–165.

21 Samir Tabour, Ben Ali Qrijij, Previously Cited Source, pp. 165–166.

- **ChatGPT Application :** This application ranks among the most widely used tools by individuals and businesses. It is one of the most popular generative artificial intelligence tools. It operates as a chatbot that provides users with a platform for discussion and dialogue. The uses of this application are diverse, including education, offering advice, and organizing data according to the priorities of the user.
- **BARD Application :** Developed by Google, BARD is an AI-powered chatbot designed to deliver simplified and well-organized information to users through conversational AI technology. Unlike its competitor ChatGPT, BARD allows users to access the latest information available on the internet. It features a search capability called "Google it" and can verify sources, including checking published data on platforms such as Wikipedia.
- **Perplexity AI Application :** Considered one of the best tools for research, this app functions as a conversational search engine powered by AI. It provides users with answers to their questions by utilizing language programming models. Several specialized reports highlight the effectiveness of this engine in scientific and research-oriented contexts.
- **DALL-E Application :** This system is a language model developed by the American company OpenAI. It is capable of generating realistic images and paintings based on descriptions provided in natural language. This development follows OpenAI's research in artificial intelligence, the same organization that introduced the ChatGPT tool.
- **WOMBO Dream Application :** This AI system is user-friendly and suitable for all ages. It offers affordable subscription plans for advanced paid services with extended durations. The application converts written text into images using natural language processing.
- **Socratic Application :** An educational AI app available for mobile download. It assists students with their homework by providing diverse educational resources, including videos, questions and answers, and topic-related links. The app offers a variety of learning materials to help students complete assignments more effectively.
- **ELSA Application :** Designed for individuals and institutions focused on learning English, this app enhances pronunciation, writing, and language skills through AI technologies. It relies on voice data from speakers with various English dialects.
- **Fooducate Application :** This app aims to help users lose weight by providing reliable information grounded in AI techniques. It offers methods for identifying healthy foods and understanding their components, alongside comprehensive and up-to-date guidance on appropriate nutrition strategies. The app uses AI algorithms to scan and analyze nutritional needs tailored to each user. It also offers advice on suitable food types and nutritional values necessary to meet personal health goals.

Additional AI applications exist that can complement the ones listed above, including:[22]

- **Voice Assistant Programs :** Voice assistant programs are AI-based systems designed to understand spoken commands and perform various tasks. These systems have been developed by major companies such as Apple (Siri), Amazon (Alexa), Microsoft (Cortana), Google (Google Assistant), Facebook (Jarvis), and Nokia (Viki). Each program has its strengths; for example, Google Assistant excels in location services, Siri in reading messages, and Alexa in online shopping. However, no single program outperforms the others comprehensively.
- **Search Result Control and News Recommendations :** Internet platforms rely on AI algorithms to analyze user behavior and preferences. These algorithms customize the content displayed, such as tweets, videos, advertisements, and friend suggestions. They recommend content similar to the user's previous searches, like suggesting videos on YouTube or search results on Google. This personalization makes browsing experiences better aligned with individual interests.
- **Automated Customer Inquiry Response Systems :** These AI systems handle customer inquiries through live chat without human intervention. They analyze user questions and provide accurate and prompt responses, as implemented by some major technology companies. This approach

22 Ahmed Deqqa, Ahmed Hneish, The Impact of Artificial Intelligence on Economic Development in Developed and Developing Countries (A Study of the Algerian Case), Journal of Quantitative Economic Studies, Vol. 11, No. 01, 2025, pp. 181–182.

improves customer satisfaction while users often remain unaware they are interacting with an automated system rather than a human representative.

- **Comprehensive Monitoring and Surveillance :** Relying solely on human operators to monitor surveillance camera feeds may not suffice to ensure security, especially in public spaces. Security algorithms, however, can perform this task efficiently. They can detect suspicious movements, anticipate threats, trigger alarms, and even recognize faces and identities of individuals on site.
- **Expert Systems Component :** Expert systems are computer programs that collect specialized knowledge from experts in a particular field. They use this knowledge to solve problems and make decisions quickly and efficiently. These systems simulate human expertise, offering suitable solutions and automating routine tasks, while leaving the final decision to human judgment[23]
- **The Intelligent Agents Component :** Intelligent agents are systems that use sensors to gather information from their surrounding environment. They then decide how to act based on the situation, allowing them to make smart and independent decisions when dealing with different circumstances.

Regarding elements such as (artificial neural networks), (genetic algorithms), and (machine learning), these are not applications but rather techniques or branches within artificial intelligence. On the other hand, (drones), (robots), and (3D printers) are conditional applications; they become AI applications only when integrated with intelligent algorithms.

3. The Theoretical Framework of Sustainable Development:

A. Definition of Sustainable Development: The definitions associated with this concept have varied since its emergence in the early 1980s. Among the most important and widely referenced definitions is the one provided by the World Commission on Environment and Sustainable Development in 1978, which states: "Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs[24]

Accordingly, sustainable development can be defined as a developmental process aimed at meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. It is based on achieving a balanced integration between the economic, social, and environmental dimensions of development. Sustainable development relies on the utilization of natural and human resources in a way that preserves their continuity and minimizes negative environmental impacts, while promoting social justice and improving the quality of life. It is a comprehensive framework that requires long-term planning and strategies to ensure inclusive and balanced development that safeguards both human well-being and the environment simultaneously.

B. Dimensions of Sustainable Development: The dimensions of sustainable development are characterized by their interrelatedness and integration; they are interconnected and cannot be separated from one another: [25]

- **Economic Dimension :** This dimension refers to improving the quality of life for members of society by meeting their needs for goods and services. The key elements of the economic dimension of sustainable development include achieving sustainable economic growth, ensuring efficiency in capital use, and changing consumption patterns that threaten biodiversity to prevent the depletion of natural resources. It also involves considering the individual's share of natural resource consumption, the responsibility of developed countries for pollution and its mitigation, reducing the

23 Imad Takwasht, The Role of Artificial Intelligence in Accelerating the Transition to a Circular Economy, Al-Aseel Journal for Economic and Administrative Research, Vol. 07, No. 02, 2023, pp. 465–466.

24 Nawal Al-Ahawel, The Role of the Circular Economy in Achieving Sustainable Development through Household Waste Recycling in Algeria, Journal of Economic Problem and Development, Vol. 02, No. 01, 2023, p. 46.

25 Al-Sadiq Zouwin, The Shift Toward a Circular Economy to Achieve Sustainable Development in Algeria, Ma'arif Journal of Legal and Economic Sciences, Vol. 02, No. 01, 2021, pp. 33–34.

dependency of developing countries, dedicating natural resources to continuously improve living standards, reducing income disparities, and striving for equitable distribution of resources.

- **Social Dimension :** The concept of sustainable development centers on reducing extreme poverty, hunger, and unemployment while narrowing the significant gap between the rich and the poor. The social dimension is crucial in achieving sustainable development through social equality.
- **Environmental Dimension :** The environment is a fundamental and necessary condition for human activity. Hence, sustainable development includes elements under this dimension aimed at preserving the environment and its components, ensuring their safe transfer to future generations.
- **Cultural Dimension :** Attention to this dimension is essential in the development process, as it represents the developmental efforts that allow the formulation of policies and strategies. These enable the improvement or transformation of the cultural context in which individuals and groups operate, alongside enhancing their living standards and capacity for participation.

4. The Relationship Between Digital Circular Economy, Artificial Intelligence, and Sustainable Development:

It is understood that the relationship between the digital circular economy, artificial intelligence (AI), and sustainable development cannot be explained collectively in a single view. Instead, it is clearer when examined from multiple angles. Previously, we defined the digital circular economy as a traditional circular economy that employs various technologies, including AI. From this, we conclude first that AI is an important, supportive, and necessary element for the existence of the digital circular economy. Amid growing environmental challenges and increasing pressure on natural resources, adopting the circular economy model becomes an urgent necessity to achieve sustainable development. This model aims to reduce waste and maximize resource use through reuse, recycling, and long-lasting design.
In this context, AI emerges as an effective tool supporting the circular economy's objectives. AI's ability to analyze big data, predict needs, and improve production and logistics processes makes it essential. It enables the development of smart solutions that allow companies to make informed decisions, design sustainable products, and enhance environmental efficiency at all levels.

A. The Role of Artificial Intelligence in Enhancing the Status of the Digital Circular Economy:

The world has witnessed significant economic system development in recent years. However, the global economic system must continue evolving to adapt to ongoing changes without allowing negative impacts on the environment and society to prevail. Thanks to AI's vital capabilities, it facilitates the transition toward applying the circular economy by enabling faster and better handling of processes. AI strengthens the position of the circular economy in three main ways:[26]

- **Circular Design, Product Development, and Maintenance Using Artificial Intelligence :** Artificial intelligence is employed to design sustainable products that meet the standards of the circular economy. This is achieved by analyzing usage and waste data to develop materials and products that are easy to maintain, disassemble, and reuse. AI also supports the design of long-lasting, recyclable products. Moreover, it helps monitor product condition and maintenance through Internet of Things (IoT) sensors to enhance performance and extend product lifespan.
- **Facilitating Circular Business Models :** AI promotes the development of innovative circular business models. Examples include data-driven dynamic pricing, increased product circulation, and intelligent inventory management. These advancements support business sustainability and improve operational efficiency.
- **Improving Circular Infrastructure :** Artificial intelligence contributes to enhancing reverse logistics infrastructure. This includes optimizing processes such as product sorting, disassembly, and remanufacturing of components. The goal is to "close the loop" in the circular lifecycle of products and materials.

26 Imad Takwasht, Previously Cited Source, pp. 471–472.

- **Data Analysis to Enhance Efficiency :** AI analyzes vast amounts of data to understand consumption and production patterns. This aids in better resource management, demand forecasting, inventory control, and cost reduction.
- **Recycling and Waste Management Improvement :** AI plays a vital role in advancing recycling processes by employing computer vision and robotics to accurately sort waste and disassemble electronic products for component reuse. This reduces environmental impact.
- **Predictive Maintenance :** AI systems can predict failures before they occur. This capability enables proactive maintenance, which extends product life and minimizes waste.
- **Enabling Innovation in Business Models :** Artificial intelligence supports the creation of innovative circular business models that rely on resource sharing and reuse. Examples include sharing economy platforms and product exchange systems between companies to enhance sustainability.
- **Transparent Supply Chains Using Artificial Intelligence :** AI enhances transparency in circular economy supply chains by tracking materials and products throughout their lifecycle stages. Utilizing technologies like the Internet of Things (IoT) and blockchain, each product or material can be linked to a digital record detailing its origin, manufacturing processes, and sustainability status. AI uses this data to analyze environmental performance and ensure supplier compliance with sustainability standards. This transparency empowers companies and consumers to make environmentally responsible decisions. It also supports recycling efforts, waste reduction, and improved resource efficiency across supply chains[27]

B. Ethics of Applying Artificial Intelligence in the Digital Circular Economy:

A set of ethical guidelines governs the use of artificial intelligence within the digital circular economy. These guidelines include the following key principles:[28]

- **Bias and Discrimination :** Artificial intelligence systems may reflect unfair biases due to skewed or unrepresentative training data. This can result in discriminatory outcomes in fields such as recruitment or lending. Addressing such issues requires regulatory oversight to minimize these unfair practices.
- **Transparency and Accountability :** Many AI systems lack transparency due to their technical complexity. This makes it difficult to interpret their decisions or determine who is responsible when errors occur. Ongoing efforts aim to design more interpretable and explainable AI models to address these challenges.
- **Creativity and Ownership :** The use of AI in generating creative content raises legal and ethical questions about intellectual property. It remains unclear who owns the resulting work and who has the right to commercialize it. Regulatory bodies continue to explore appropriate frameworks to govern these emerging issues.
- **Manipulation and Misinformation :** AI technologies can be used to spread false information and manipulate public opinion. Deepfake tools, in particular, pose significant risks. These developments highlight the need for monitoring systems to prevent the misuse of AI in ways that threaten social and political stability.
- **Privacy, Security, and Surveillance :** AI often relies on vast amounts of personal data. This reliance raises concerns about data privacy and individual rights, especially in systems like facial recognition. Strong data protection measures are essential to ensure individual freedoms and the ethical use of such technologies.
- **Job Displacement :** While AI may replace certain human roles, it also presents opportunities for new types of employment. This transition requires reskilling and training programs to support workers whose jobs are at risk and to promote equitable adaptation in the labor market.

27 Accenture, Circular Advantage : Innovative Business Models and Technologies to Create Value in a World without Limits to Growth, 1 st Edition, Accenture Strategy, New York, United States, 2015, p 26.

28 Imad Takwasht, Previously Cited Source, pp. 471–472.

- **Autonomous Weapons :** The development of autonomous AI-based weapons presents ethical concerns regarding control and responsibility. These risks call for the establishment of international agreements to regulate the military use of such technologies and ensure human oversight.

C. The Role of the Digital Circular Economy in Advancing Sustainable Development :

The digital circular economy presents a modern approach that actively supports the achievement of the Sustainable Development Goals (SDGs). It integrates circular economy principles with advanced digital technologies such as artificial intelligence, the Internet of Things (IoT), and big data analytics.
The United Nations has identified a set of key goals—**Goals 7, 8, 11, 12, 13, 14, and 15**—where the digital circular economy can make significant contributions. It provides practical, integrated solutions that align technological advancement with environmental and economic priorities.[29]

- **Goal 7 – Affordable and Clean Energy :** This goal aims to ensure access to modern, reliable, and sustainable energy services for all. While renewable energy and energy efficiency address approximately 45% of global emissions, the digital circular economy offers solutions for the remaining 55%. Through redesign and improved use of products, emissions can be further reduced. Applying digital strategies across five major sectors—**cement, aluminum, steel, plastics, and food**—could cut around **9.3 billion tons of CO_2** by 2050. This figure is equivalent to reducing transport emissions to net zero.
- **Goal 8 – Decent Work and Economic Growth :** This goal promotes inclusive economic growth and decent employment. The digital circular economy supports this by improving resource efficiency and reducing waste, while also creating new green jobs. Technology-driven circular business models offer significant economic potential. In the European Union, it is estimated that such models could generate **€1.8 trillion in net annual benefits** by 2030, reflecting the global potential of this approach.
- **Goal 11 – Sustainable Cities and Communities :** By 2050, nearly three-quarters of the global population will live in urban areas. Transitioning to a **digitally supported circular economy** is critical to mitigate the environmental impacts of urbanization. Digital tools enable the design of flexible buildings that consume fewer resources and support reuse. These innovations improve urban infrastructure efficiency and help provide affordable housing for low-income groups, making cities more sustainable and resilient.
- **Goal 12 – Responsible Consumption and Production :** This goal focuses on reducing pressure on natural resources and balancing growth with environmental impact. The digital circular economy enables the tracking and analysis of value chains to identify environmental hotspots and optimize system-wide performance. Key practices include water and waste management, sustainable products, and smart supply chains. Circular principles such as **redesign**, **repair**, and **remanufacturing** support pollution reduction and guide production toward sustainable outcomes.
- **Goal 13 – Climate Action :** Current climate measures often prioritize renewable energy, but the digital circular economy plays a complementary and vital role. It supports emission reduction, especially in product manufacturing. If digital circular practices are applied in **four major industrial sectors**—cement, steel, plastics, and aluminum—**emissions could be reduced by 40% by 2050**, and by **49% in food systems**. Together, these reductions could bring the world **45% closer to net-zero targets**.
- **Goal 14 – Life Below Water :** The digital circular economy helps protect oceans by preventing waste from reaching marine environments. Smart technologies improve waste and resource management, and enable nutrient recovery from wastewater before it enters the sea. These efforts limit ocean acidification and reduce stress on marine ecosystems, contributing to long-term sustainability.

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29 Mohammed Hameed Mohammed, The Circular Economy and Its Role in Achieving Sustainable Development, Al-Riyada Journal for Finance and Business, Vol. 02, No. 03, 2021, pp. 165–166.

– **Goal 15 – Life on Land :** This goal aims to preserve terrestrial ecosystems and biodiversity. The digital circular economy contributes to this through sustainable agriculture and data-driven agroforestry. It enables the return of biological materials to the soil as nutrients, which improves soil health and supports the recovery of biodiversity and degraded ecosystems.

Integrating artificial intelligence into the digital circular economy supports sustainable development by enhancing resource use and minimizing waste. Economically, it helps reduce costs and create green jobs. Socially, it improves quality of life and increases access to essential resources. Environmentally, it reduces emissions and pollution while protecting ecosystems.
Artificial intelligence thus serves as a powerful tool to balance economic growth with environmental protection and social well-being.

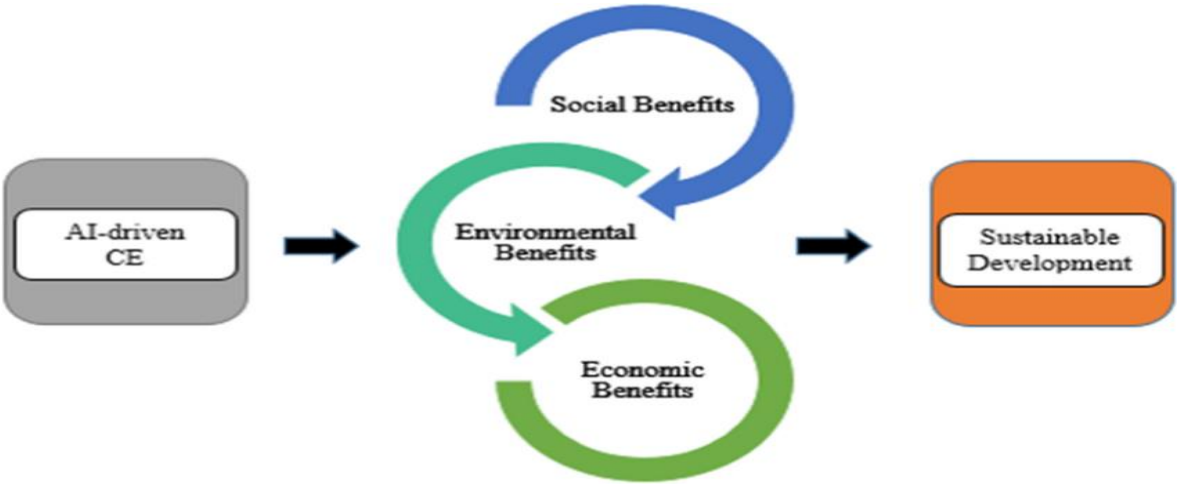

Figure 03 : The relationship between the digital circular economy and artificial intelligence in advancing sustainable development
Source : Ali, Z. A., Zain, M., et al. (2023). Contributions of Artificial Intelligence for Circular Economy Transition Leading Toward Sustainability: An Explorative Study in Agriculture and Food Industries of Pakistan. Environment, Development and Sustainability. Retrieved from https://www.researchgate.net/publication/371573036

Secondly: Applied Framework of the Study: Case Study of the United Arab Emirates

This section presents an in-depth analysis of the integration between artificial intelligence and the digital circular economy in the United Arab Emirates. This integration is examined as an innovative approach to achieving the goals of sustainable development.
The applied aspect of the study draws upon an analysis of national policies, such as the **UAE Circular Economy Policy 2021–2031** and the **UAE Artificial Intelligence Strategy 2031**. The analysis explores the mechanisms of integration between these two key developmental pillars.
In addition, the study offers practical examples of how AI applications support the circular economy in sectors such as **transport, energy, waste management, and sustainable agriculture**. It also addresses the challenges involved and presents proposed solutions to maximize the benefits of this technological and environmental synergy.

Before delving into this integration, it is essential to review both strategies:
1. The UAE Circular Economy Policy 2021–2031
The circular economy policy forms an essential part of the **UAE Vision 2031**. It aims to shift from a traditional economic model to one that promotes both environmental and economic sustainability.

The policy seeks to reduce reliance on non-renewable natural resources and encourages reuse and recycling practices. The main features of this strategy are summarized in the following table :

Table 01 : The United Arab Emirates Circular Economy Policy 2021–2031

Item	description
Strategic Objectives	**Reduce waste:** Reduce waste generated by industrial processes and develop effective waste management strategies. **Promoting recycling:** Increasing the proportion of recycled materials in various sectors, which contributes to reducing the need for new resources. **Supporting innovation:** Encouraging research and development in the fields of green technology and sustainable practices. **Achieving sustainable economic growth:** Working to strengthen the national economy by investing resources more efficiently.
Key areas	**Industry:** Encourage companies to adopt circular economic practices such as the use of sustainable materials. **-Construction:** Develop standards for green building and improve the efficiency of resource use in construction projects. **Transport:** Promote the use of sustainable transport and reduce carbon emissions. **Agriculture:** Introducing sustainable farming techniques and increasing the efficiency of water resource use. **Tourism:** Developing sustainable tourism that enhances environmental and cultural experiences.
Key Directions	**Green Infrastructure Development:** Creating infrastructure that supports sustainability, such as renewable energy and waste management systems. **Promoting research and innovation:** Supporting innovative projects that contribute to the circular economy through funding and technical assistance. **Promoting public-private collaboration:** Encourage government-private partnerships to achieve environmental goals.
Initiatives	**- Establishing awareness programs:** Organizing workshops and awareness campaigns to enhance the community's understanding of the concepts of circular economy. **Development of new technologies:** Support research into waste reduction techniques and improve resource efficiency. **Supporting environmental innovation projects:** Providing grants and funding for projects that contribute to achieving the objectives of the circular economy.
International Cooperation	Strengthen partnerships with other countries to share knowledge and experiences, including participation in global conferences and joint programs.
Evaluation and follow-up	Develop performance evaluation mechanisms, including indicators to measure the success of initiatives, and update policies based on the results obtained to ensure effective implementation.
Challenges	**Community acceptance:** the need to change community behavior towards more sustainable practices. **Significant investments:** The need for huge investments in new technology and innovations to ensure the successful transition to a circular economy.
Expected results	**-Improving the environment:** reducing the carbon footprint and improving the quality of life. **Strengthening the national economy:** by creating new job opportunities in sustainable sectors. **Providing new job opportunities:** in the fields of innovation and green technologies.

Source : UAE Circular Economy Policy 2021–2031, Government of the United Arab Emirates. Available at : https://u.ae/ar-ae/about-the-uae/strategies-initiatives-and-awards/policies/economy/uae-circular-economy-policy (Accessed : 8 April 2025).

In **Table 01**, we summarize the **UAE Circular Economy Policy (2021–2031)**. It outlines a comprehensive plan designed to reduce waste, strengthen recycling practices, and support innovation to achieve sustainable economic growth. The policy targets five key sectors : **industry, construction, transport, agriculture, and tourism**.

It also seeks to develop green infrastructure, build both local and international partnerships, and promote awareness and innovation. However, the policy faces challenges. These include the need for changes in social behavior and greater investment in technology. Despite this, the UAE aims to achieve both environmental and economic gains through the circular economy model.

2. UAE Artificial Intelligence Policy 2031 :

Artificial intelligence is one of the core foundations of the **Fourth Industrial Revolution**. It has broad applications across many domains, including the military, industry, and economy. AI is expected to bring fundamental changes to how people live and work. It will open the door to unlimited innovation, reshaping daily life and work patterns.

The UAE's efforts in this area are outlined in the following summary :

Table 02 : The United Arab Emirates' Artificial Intelligence Policy 2031

Item	description
Strategic Objectives	**Achieving global leadership:** The UAE seeks to be a global leader in the field of artificial intelligence by achieving a set of development goals. **Improving government performance:** Artificial intelligence seeks to improve the efficiency of government performance and promote innovation in service delivery. **Sustainable development:** aims to achieve sustainable development that supports the national economy and enhances the quality of life. **Enabling education and training:** Developing the skills of the local workforce in the field of artificial intelligence through specialized educational programs.
Mechanisms	The UAE relies on several mechanisms to achieve its goals, including: **-Competency Development:** Enhancing the skills of the local workforce in the field of artificial intelligence through specialized training programs. **Organizing training courses:** Providing workshops and educational courses for government employees to enhance their knowledge of artificial intelligence applications. **Community awareness:** Creating a community culture about the importance of artificial intelligence and its positive impact on daily life.
Achievements	The UAE has made remarkable achievements in the field of artificial intelligence, most notably: **Launch of a Ministry of Artificial Intelligence: The** establishment of an independent ministry in 2017 to coordinate government efforts in this field. **Silicon Park Project:** Establishing the first integrated smart city, aimed at integrating artificial intelligence technologies into daily life. **Developing research centers:** Establishing research centers specialized in artificial intelligence to support innovation and technological development.
Future Directions	**Boosting investments:** The UAE seeks to boost investments in artificial intelligence, while supporting initiatives in the private sector. **Innovation in services:** Developing new AI-based services to improve quality of life and increase productivity. **Being a global hub: The** UAE aims to be a global hub for innovation in artificial intelligence by 2030.

Item	description
	Expanding Uses: Increasing the scope of uses of artificial intelligence in various sectors to ensure integration in various sectors to ensure integration between government and private services.
Economic Implications	**High economic growth:** Studies show that the activation of artificial intelligence technologies will lead to high economic growth, as GDP is expected to rise by up to 35% by 2031. **Reduce government costs:** Artificial intelligence will reduce government costs by up to 50%, allowing the state to provide additional resources to invest in new projects. **Improving the quality of services and products:** These technologies are expected to improve the quality of products and services provided, enhancing the country's reputation as a global business hub. **Creating new job opportunities:** With the increasing reliance on artificial intelligence, new job opportunities will be created that require advanced skills, enhancing the country's competitiveness.
Challenges	The UAE faces a number of challenges in implementing AI policies, including: **Restructuring the economy:** The need to modify the economic structure to adapt to the changes resulting from automation. **Confronting unemployment: The** impact of artificial intelligence on the labor market, which may lead to increased unemployment among low-skilled groups. **Income gap: The** need to ensure that the gap between rich and poor does not spread as a result of technological changes. This requires effective strategies to deal with the social and economic impacts of these changes.
Implementation strategies	Implementation strategies include: **Legislating laws:** Establishing a legal framework that ensures the optimal and safe use of artificial intelligence technologies. **Enhancing investments:** Intensifying efforts to attract foreign and local investments in artificial intelligence technologies. **-Providing services:** Providing all government services through artificial intelligence platforms to achieve integration between different sectors. **Education Development:** Introducing specialized educational programs in artificial intelligence in schools and universities to ensure the qualification of future generations.

Source : Ahmad Majid, Artificial Intelligence in the United Arab Emirates, Ministry of Economy, United Arab Emirates, 2018. Online : file:///C:/Users/maison%20xp/Downloads/AI%20Report%202018%20(2).pdf (Accessed: April 8, 2025).

Based on Table 02, the UAE's Artificial Intelligence Strategy 2031 focuses on achieving global leadership. This is pursued through enhancing government performance, promoting sustainable development, and advancing education. The strategy relies on tools such as training and public awareness. Significant achievements include the establishment of the Ministry of Artificial Intelligence and specialized research centers. The country aims to expand AI applications across various sectors. It also seeks to drive economic growth and reduce government expenditures. However, it faces social and economic challenges that require strategic solutions. These include legislative development, education reform, investment incentives, and the digital integration of services.

3. Integration of Digital Circular Economy and Artificial Intelligence to Achieve Sustainable Development : The UAE Experience

In line with the UAE Vision 2031, the country is working to strengthen sustainable development by integrating artificial intelligence with the digital circular economy. This approach represents a fundamental pillar of the future economy, characterized by efficiency, resilience, and sustainability.

A. Practical Models of AI and Circular Economy Integration in the UAE :

– Smart Waste Management : The UAE uses artificial intelligence systems to improve waste sorting and recycling processes, enhancing circular economy efficiency. For example, the Aluminum Recycling Alliance applies machine learning algorithms to analyze the composition of metal waste, which helps optimize sorting operations. This reduces waste and improves the quality of recycled materials. In Dubai, smart waste collection systems rely on predictive data analysis to determine the most efficient routes and schedules. This reduces fuel use and carbon emissions from waste collection trucks. The UAE is also developing multi-level smart classification systems for household and industrial waste. These systems use cameras and computer vision to enable precise sorting at the source.

– AI-Enhanced Sustainable Transport : The UAE has developed an integrated smart transport system based on AI to improve traffic flow and reduce congestion. Key components include :

- **Electric fleet management systems :** that analyze usage patterns to optimize charging station distribution and site planning using real-time data.
- **Intelligent ride-sharing platforms :** that use matching algorithms to enhance vehicle sharing efficiency and reduce individual trips.
- **Predictive maintenance systems :** that analyze vehicle sensor data to detect potential malfunctions in advance, prolonging vehicle lifespan and reducing industrial waste. The UAE is also piloting cooperative AI technologies in vehicle-to-infrastructure and vehicle-to-everything communication (V2I/V2X). These systems reduce idle time at traffic signals and improve traffic flow, directly contributing to emission reductions.

– Smart Green Buildings In the infrastructure sector, AI systems are used for energy management in smart buildings. For instance, the Masdar City project in Abu Dhabi employs advanced machine learning to analyze energy consumption data. It adjusts cooling and air conditioning systems dynamically based on weather conditions and usage patterns. Computer vision technologies are also used to analyze satellite and drone imagery for :

- Accurately identifying construction and demolition waste locations ;
- Assessing their potential for reuse in new projects, supporting principles of redesign and reuse in circular construction. The UAE plans to expand the use of such systems across public and private buildings, integrating them with unified platforms to assess buildings' environmental performance.

– Precision Circular Agriculture : In agriculture, the UAE adopts AI to promote precision and circular farming. Applications include :

- **Smart irrigation systems :** that analyze real-time soil, moisture, and weather data to optimize water use and reduce waste.
- **Food tracking platforms :** that use blockchain and AI to enhance supply chain transparency and improve agricultural resource management.
- **Demand forecasting systems :** in the food retail sector that align production with actual consumption, helping reduce food surplus and waste.
- **AI-powered drones :** that monitor crops, detect pests, and recommend targeted intervention strategies with minimal pesticide use.

B. Governance and Coordination Mechanisms :

– Institutional Frameworks : The UAE has established comprehensive institutional frameworks to coordinate AI and circular economy efforts. These include :

- **UAE Circular Economy Council** : which designs policies and initiatives to ensure efficient resource use and achieve carbon neutrality.
- **UAE Artificial Intelligence Council** : which sets priorities for AI deployment across sectors.
- **Office of Artificial Intelligence and Digital Economy** : the primary coordinating body under the UAE government. It ensures the alignment of the national digital agenda with sustainable development goals.

These frameworks coordinate policies and implement joint projects to ensure a balance between technological progress and environmental sustainability.

– Strategic Partnerships : The UAE has established strategic partnerships with global companies, including :

- **Microsoft and OpenAI**, to develop AI solutions that support the circular economy.
- **Industrial firms such as Emirates Global Aluminium and Nestlé**, in projects focused on recycling and reducing carbon footprints.
- **Support for start-ups** in clean technology and environmental AI through funding programs and government-backed incubators.

These partnerships accelerate innovation and promote the localization of sustainable circular solutions driven by artificial intelligence.

– Ethical and Regulatory Frameworks : The UAE recognizes the need to develop regulatory systems that align with the increasing use of AI, ensuring a balance between innovation and environmental responsibility. Key initiatives include :

- **Principles and Ethics of Artificial Intelligence** : launched by the government, outlining eight core values, including fairness, transparency, sustainability, and environmental responsibility.
- **A Guideline for the Use of Generative AI** : which provides practical applications in areas such as environmental protection, resource management, and big data analysis.
- **Monitoring mechanisms :** for AI impacts, focusing on energy consumption and data volume, to ensure alignment with environmental policy goals.

C. Outcomes of Integrating the Digital Circular Economy and Artificial Intelligence in Achieving Sustainable Development in the UAE

The UAE presents a global model for leveraging artificial intelligence and digital technologies in support of the three pillars of sustainable development : economic, environmental, and social. Continued investments in smart infrastructure, regulatory frameworks, and local capacity building are moving the country steadily toward an efficient, resilient, and environmentally responsible economy that ensures long-term well-being for future generations.

Some of the key outcomes of this integration include :

– Accelerated Digital Transition Towards a Low-Carbon Economy : The integration of the digital economy and AI serves as a powerful tool in advancing sustainable development. The contribution of the digital economy to GDP rose to approximately **9.7% in 2024**, with a clear target of reaching **20% by 2031**. This growth is closely linked to improved resource efficiency, reduced reliance on high-carbon activities, and stronger green innovation. These developments support the UAE's broader ambition of achieving **net-zero emissions by 2050**.

– Enhanced Government Performance and Innovation Through AI : AI has contributed significantly to improving public services and strengthening decision-making, particularly in sectors such as **energy, environment, and transport**. Estimates suggest that AI technologies could account for **14% of the national GDP by 2030**, equivalent to nearly **AED 367 billion**. This added value stems

from lower operational costs, more efficient infrastructure, and faster, more accurate data processing—facilitating decision-making based on predictive modeling.

– Improved Natural Resource Management and Waste Reduction : By adopting AI systems to monitor air quality, analyze waste data, and track energy and water use, the UAE has enhanced resource management and reduced environmental waste. Predictive technologies and data analytics have supported environmental initiatives such as **smart recycling**, **reduced water use in agriculture**, and **directing investments toward sustainable projects with positive environmental impacts**. These measures directly support the country's environmental sustainability goals.

– Protecting Ecosystems Through Artificial Intelligence : In a concrete example, the UAE used artificial intelligence to monitor the growth of mangrove forests—one of the most vital coastal ecosystems—through deep learning and remote sensing technologies. The results revealed a **29% increase** in mangrove coverage between 2017 and 2024. These forests also captured approximately **194,000 tons of carbon**. This environmental growth contributes to biodiversity protection, mitigation of climate change impacts, and strengthening the ecosystem's natural carbon absorption capacity. It is a core element of sustainable development.

– Advancing Clean Energy and Smart Cities : Smart city projects and renewable energy initiatives have played a central role in the UAE's environmental transition. By 2024, installed renewable energy capacity exceeded **3,000 megawatts**, and **382 charging stations** for electric vehicles were established. The country has also expanded the use of low-cost solar energy systems (at **1.62 cents per kilowatt-hour**). These advancements support energy independence, reduce reliance on fossil fuels, and help build eco-friendly smart cities that balance urban development with environmental sustainability.

– Supporting the Circular Economy Through Smart Technologies : The integration of AI and the circular economy is a fundamental pillar of sustainable production and consumption. AI technologies are used to track material flows and optimize reuse and recycling. The UAE launched initiatives such as **"Scale 360"**, in partnership with the World Economic Forum, to accelerate the adoption of resource-efficient and circular production models. The goal is to recover **75% of solid waste** and harness digital transformation to improve material efficiency and reduce dependency on raw resources.

– Capacity Building and Knowledge Empowerment for Inclusive Development : Sustainable development is strongly tied to human empowerment and capacity building. The UAE has started integrating AI and sustainability into university curricula. It has also established leading institutions such as the **Mohamed bin Zayed University of Artificial Intelligence**, aiming to train a new generation capable of developing intelligent and sustainable solutions. This investment in human capital enhances local innovation, reduces reliance on foreign expertise, and creates new job opportunities that support inclusive economic growth.

D. Challenges of Integrating the Digital Circular Economy and Artificial Intelligence in the UAE, and Proposed Solutions :

– Key Challenges : Based on the previous tables (1 and 2), the following challenges can be identified :

- **Lack of Integrated Environmental and Industrial Data :** Environmental and industrial data often lack standardization and are scattered across multiple agencies. This fragmentation limits the effectiveness of AI systems, which depend on high-quality, structured, and integrated data to generate accurate forecasts or decisions. The absence of a unified data platform delays AI-driven prediction and planning in environmental and industrial sectors.
- **High Costs of Smart Infrastructure :** AI applications, especially in environmental and industrial analysis, require complex infrastructure. This includes sensors, cloud computing, and data centers. The cost of these systems presents a barrier, particularly for smaller entities such as municipalities or small industries. This limits the large-scale adoption of AI technologies.
- **Shortage of Skilled Talent in Circular AI :** There remains a significant gap in the availability of professionals who possess both technical knowledge of AI and an understanding of circular economy principles. This talent shortage slows the development of localized solutions and increases dependence on international partners, which may affect the country's autonomy in this vital sector.

- **Lack of Detailed Regulatory Frameworks for Some AI Applications :** Although general principles and ethical guidelines exist, certain AI applications—particularly generative AI—still lack detailed regulations. This is especially concerning in areas such as recycling or product design. The absence of clear rules may result in unintended environmental harm or legal risks when these technologies are implemented without sufficient oversight.
- **The Environmental Footprint of Artificial Intelligence Itself :** Artificial intelligence systems, especially large and complex models, consume vast amounts of energy. This consumption may increase carbon emissions. If these effects are not carefully managed, AI technologies could become a source of environmental pollution. This would conflict directly with the goals of the circular economy.

– **Proposed Solutions to Overcome Previous Challenges in the UAE :** Based on the challenges mentioned earlier, the following solutions can help achieve integration :

- **Establishing a Unified National Platform for Environmental and Economic Data :** The UAE can develop a unified digital platform that uses open standards to collect and link environmental and industrial data from various entities. Data unification will improve the accuracy of AI models and enhance decision-makers' ability to forecast trends and develop effective policies based on precise analysis.
- **Encouraging Private Sector Investment in Smart Infrastructure :** Providing financial incentives or tax exemptions to companies investing in low-carbon data centers or sustainable AI solutions will greatly reduce the burden on the government. This approach will accelerate the adoption of such technologies and attract new investments in environmental AI sectors.
- **Building Specialized National Capacities :** It is important to integrate interdisciplinary fields that combine AI, circular economy, and environmental sustainability into university curricula. Additionally, specialized vocational training programs should be established, such as "Environmental AI Systems Engineer" or "Sustainable Algorithm Designer." These initiatives will support the development of a local skilled workforce capable of innovation and advancement within the country.
- **Updating Regulatory Policies to Keep Pace with Technology :** There is an urgent need to issue new and detailed regulatory frameworks addressing emerging technologies, such as generative AI in life cycle analysis and industrial redesign. Such frameworks will reduce legal risks and give companies confidence to adopt innovations without fearing regulatory uncertainty.
- **Achieving Carbon Neutrality in AI Technologies :** Clear sustainability standards must be imposed on companies developing or deploying AI solutions in the UAE. This includes the use of renewable energy in training and operating AI systems. Ensuring this will make AI part of the environmental solution rather than the problem. It aligns with the UAE's vision to achieve climate neutrality.

Conclusion

Based on the analysis of the UAE's experience in integrating the digital circular economy with AI technologies to achieve sustainable development goals, the hypotheses of this article have been confirmed to varying degrees. This confirmation aligns with the national policies and practical initiatives implemented on the ground.

First : Findings :

1. The UAE has made significant progress in applying the digital circular economy to improve resource management and reduce waste. This is evident in areas such as smart waste management, precision agriculture, and green buildings. This supports the first hypothesis that big data and digital platforms enhance efficiency and transparency in supply and consumption chains.

2. The use of AI in circular economy applications—particularly in transportation, energy, and manufacturing—has proven effective in improving operational efficiency and reducing emissions and environmental impacts. This directly supports the second hypothesis.
3. Regarding the third hypothesis, the UAE has adopted a proactive institutional approach to support innovation. This is reflected in advanced policies, legislation, and strategic international partnerships. Such an approach has established a stimulating environment for technological innovation in both the circular economy and AI. This strengthens the UAE's competitive position regionally and internationally.
4. The fourth hypothesis is reflected in the UAE experience, which shows a realistic balance between opportunities and existing challenges. Achievements have been met with challenges in areas like data integration, technology costs, and the need to expand human capacities. This underscores the importance of developing digital infrastructure and enhancing cross-sector partnerships.

Based on these findings, it can be concluded that integrating the digital circular economy with AI will significantly enhance sustainable development in the UAE.

Second: Recommandations

Based on this analysis and considering the achievements in the UAE case, the following recommendations are proposed for other countries, particularly those in the Arab region :

- Invest in developing national digital platforms to integrate data on resources, waste, and energy, linking them with artificial intelligence to enhance environmental efficiency.
- Incorporate concepts of the circular economy and artificial intelligence into national policies for sustainable development and the green economy.
- Encourage partnerships between the public and private sectors to develop technological solutions aimed at smart recycling and reducing the environmental footprint of industries.
- Support universities and research centers in developing interdisciplinary programs that combine artificial intelligence, environmental sustainability, and the circular economy.
- Benefit from pioneering experiences, especially the UAE, in adopting flexible ethical and legislative frameworks that keep pace with emerging technologies.
- Stimulate startups to work in environmental innovation using digital transformation tools.
- Ensure the inclusivity of the circular digital transformation by including small cities and rural areas to guarantee equitable development.
- Develop national mechanisms to measure performance indicators in AI-supported circular economy applications to track progress effectively.
- Direct government and international funding toward AI projects focusing on recycling and renewable energy.
- Launch national open innovation labs to pilot digital circular economy solutions in real-world environments before scaling up.
- Enhance civil society participation in adopting sustainable consumption behaviors through digital awareness campaigns supported by data analytics.
- Prepare national roadmaps for AI technologies that support sustainability, tailored to the specific characteristics of each economic sector.

Finally, The UAE's experience indicates that integrating the digital circular economy with artificial intelligence is not merely a technical process. Rather, it represents a strategic vision to build a modern Arab development model characterized by efficiency, sustainability, and competitiveness.

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