

The Role of Green Digital Transformation in Environmental Protection and Achieving Sustainable Development in Algeria

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Abstract

This study provides a general and specialized framework on green digital transformation as an application of the principle of integrating technology into environmental protection mechanisms and achieving sustainable development, while highlighting its potential contributions and the reality of Algeria and its national experience. This is addressed through the following research problem: How has the Algerian legislator adopted green digital transformation, and what are the main challenges facing its implementation?

Accordingly, the research problem was addressed through two sections, the first theoretical and the second practical. The study ultimately observed that Algeria has adopted digital transformation as a general approach to improving public services and facilitating administrative, financial, and economic operations. However, it remains limited in the field of environmental protection, which leads to the recommendation that specific legislation and executive mechanisms for green digital transformation should be established.

Keywords: Environment; Sustainable Development; Digitization; Digital Transformation; Clean Technology.

Introduction

The issue of environmental protection and the achievement of sustainable development occupies a highly important position in the life of individuals and societies, as both contribute to achieving quality of life and human well-being and enhancing human rights by improving economic and social conditions. Consequently, this reality has driven continuous efforts to identify mechanisms capable of protecting and preserving the various living and non-living components of the environment in order to achieve sustainable development. This has become increasingly urgent due to the rapid spread of environmental damage and the accumulation of its risks.

This approach is partially achieved through the use of various means, including the adoption of clean technologies, support for innovation, and reliance on green digital transformation. This gives the present study considerable importance, particularly in terms of:

1. Helping to define the concept of green digital transformation and demonstrate its impact on environmental protection and the fight against pollution, particularly through the collection of environmental information, anticipation of risks, and rationalization of environmental decision-making.
2. Working to strengthen the application of the principle of integrating technology into environmental protection and ensuring its sustainability as an internationally recognized principle.
3. Opening the door to discussing the challenges facing Algeria in its pursuit of green digital transformation and providing proposals concerning them.

Accordingly, the main research problem of this study is formulated as follows: *To what extent has the Algerian legislator dedicated efforts toward digital transformation for the purpose of protecting the environment and achieving sustainable development, and to what extent have the desired results been achieved in light of the existing challenges?*

The study relies on the descriptive-analytical method with regard to the concept of digital transformation and the examination of the available legal framework, means, and tools, with the aim of developing more effective proposals.

Section One: The Theoretical Framework of the Environment and Digital Transformation: An Overview

Digital transformation has brought about a modern transformation in management, administration, and service delivery. Interest in it has increased with the spread of technology and its widespread use across various economic, social, scientific, and humanitarian sectors to enhance performance. Therefore, before addressing the research problem, it is necessary to establish the concept of the environment as the subject of protection and green digital transformation as a mechanism for such protection.

Subsection One: The Theoretical Framework of the Environment as a Subject of Legal Protection

The environment and its various components have supported human existence since ancient times. It constitutes the living framework and a source of resources, and it represents a subject of various branches of natural and human scientific studies.

First Branch: The Concept of the Environment

After the environment became a subject of legal protection at both the international and national levels, protection instruments suited to its particular characteristics were established. Accordingly, it became necessary to precisely define its legal concept in a manner that would contribute to providing such protection.

First: Definition of the Environment

The term “environment” refers to the surrounding conditions in which living organisms exist, encompassing both natural and human-made elements. It includes components such as air, water, soil, and biodiversity, which are essential for sustaining life.[1]

Scholars suggested that the environment is the sum of those phenomena that enter a reaction system of the organism or otherwise directly impinge upon it to affect its mode of life at any

time throughout its life cycle as ordered by the demands of the ontogeny of the organism or as ordered by any other condition of the organism that alters its environmental demand.[2]

The Algerian legislator also defined it through its components pursuant to Article 4 of Law No. 03/10 of 19 July 2003 relating to the protection of the environment within the framework of sustainable development, according to which the term means:

“Abiotic and biotic natural resources, including air, the atmosphere, water, soil and subsoil, fauna and flora, including genetic heritage, the interactions among the aforementioned resources; as well as natural sites, landscapes, and natural monuments.”

Second: The Environment as a Jurisprudential and Regulatory Concept

The environment has not remained a dry concept isolated from other concepts. Rather, it has enriched other concepts and has become part of political, legal, and social reality. It also contributes to consolidating the jurisprudential framework of certain concepts firmly established in today's world, including the following:

1. The Environment as a Human Right

The environment has become an integral part of the human rights framework. On 28 July 2022, the United Nations General Assembly adopted a landmark resolution recognizing the human right to a healthy environment. Guided by the Charter of the United Nations, reaffirming the Universal Declaration of Human Rights and the Vienna Declaration and Programme of Action, recalling the Declaration on the Right to Development, the Stockholm Declaration of 1972 and the Rio Declaration of 1992, and relevant international human rights treaties and other relevant regional human rights instruments, it also recognized that a vast majority of States have recognized the right to a clean, healthy and sustainable environment through international agreements, their national constitutions, legislation, laws, or policies.[3]

The environmental right is generally understood to include substantive elements such as clean air, a safe and stable climate, access to safe water and adequate sanitation, healthy and sustainably produced food, non-toxic environments in which to live, work, study and play, and healthy biodiversity and ecosystems. The procedural elements include access to information, the right to participate in decision-making, and access to justice and effective remedies.[4]

2. The Environment as a Pillar of the Concept of Sustainable Development

The concept of sustainable development achieves several balances, whether through achieving economic development and meeting public needs, or through benefiting from such development in a manner that preserves environmental protection and contributes to ensuring the rational exploitation of its renewable and non-renewable resources.

The term “sustainable development” has been included in the Rio framework to denote the need to balance environmental and development considerations. The original articulation of the principle is found in the Brundtland Report, which stated that sustainable development means development that satisfies the needs of present generations without jeopardizing the ability of future generations to meet their own needs, and has three pillars, namely: economic development, social development, and environmental protection.[5]

The Algerian legislator provided for it in Article 04 of the aforementioned Law No. 03/10 as follows:

“A concept that seeks to reconcile sustainable socio-economic development with environmental protection, that is, the integration of the environmental dimension into a development process aimed at meeting the needs of present and future generations.”

But this has been criticized by some as being devoid of content, as a concept used to express different and often disparate worldviews, whereas developing countries have used the principle to buttress their right to development.[6]

Second Branch: The Theoretical Framework of Green Digital Transformation

The rapid development of technology has led to qualitative transformations in societies and fundamental changes in lifestyles. This calls for an examination of the general concept of digital transformation, followed by the specific concept related to environmental protection, as well as an explanation of the main areas in which it can be applied.

First: Definition of Digital Transformation

Digital transformation refers to the integration of digital technologies into various aspects of an organization, industry, or society, fundamentally changing operations, value creation, and user experiences. It encompasses advancements such as artificial intelligence, the Internet of Things (IoT), big data analytics, and blockchain, which streamline processes, enable data-driven decision-making, and improve operational efficiency.[7]

It should be noted that there are two closely related concepts that are often used interchangeably across a wide range of literature. The first is digitization, which refers to the process of digitizing, that is, the conversion of analog data (e.g., images, video, text) into digital format. Digitization is also defined as the material process of converting individual analog streams of information into digital bits. The second is digitalization, which is related to the acceptance or increased use of digital technology by organizations, industries, and countries.[8]

Second: The Emergence of Green Digital Transformation as a Specialized Concept

Green digital transformation generally refers to the use of digital technologies and innovations to promote sustainability and environmental responsibility. This concept encompasses various strategies and practices that leverage digital tools to reduce the environmental impact of human activities and contribute to the overall goal of a more sustainable future.[9]

Accordingly, the concept aims to use all that technology has achieved in terms of computing equipment, digital tools, and application software to ensure environmental protection and sustainability through data collection, risk monitoring, and the optimal selection of intervention methods.

Subsection Two: Areas of Application of Green Digital Transformation

Green digital transformation has various applications in the field of environmental protection aimed at achieving sustainable development and improving methods of dealing with environmental issues. This is manifested in numerous environmental fields, as presented below.

First Branch: Combating Pollution and Preserving Natural Resources

Digital technologies have revolutionized environmental monitoring, providing tools for real-time data collection, analysis, and reporting. These technologies enable more accurate and comprehensive monitoring of environmental parameters such as air and water quality, deforestation, and wildlife populations, as well as monitoring deforestation, land-use changes, and the health of ecosystems.[10]

This is achieved through early warning, which is defined as a system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems and processes that enable individuals, communities, governments, businesses, and others to take timely action to reduce disaster risks in advance of hazardous events. It may include four interrelated key elements: (1) disaster risk knowledge; (2) detection, monitoring, analysis, and forecasting of hazards and possible consequences; (3) dissemination and communication of timely, accurate, and actionable warnings; and (4) preparedness at all levels to respond to the warnings received.[11]

Second Branch: Promoting the Green Economy

The UNEP defines the green economy as “the process of reconfiguring businesses and infrastructure to deliver better returns on natural, human and economic capital investments, while at the same time reducing greenhouse gas emissions, extracting and using less natural resources, creating less waste and reducing social disparities,” and the main tenets of this green economy initiative are: investing in natural capital; decarbonizing the economy; and creating green jobs.[12]

Thus, digital transformation is referred to as the use of new digital technologies to enable major business improvements in operations and markets, such as enhancing customer experience, streamlining operations, or creating new business models. Others defined digital transformation as a process of evolution where digital technologies and digital capabilities create value by stimulating business models, customer experiences, and operations.[13]

Third Branch: Supporting the Right to Environmental Participation

The right to participation allows people to be part of the decision-making process through consultation and comments, and to have their opinions heard. Participation enables participating communities to hold public authorities accountable for implementation and improves the efficiency and credibility of government processes. Commonly used participatory tools include public hearings, notice and consultation, citizen ombudsmen, and judicial review mechanisms. The right to participation needs to be supported by a right to information that is accurate, accessible, timely, and comprehensive.[14]

Accordingly, the function of digital transformation is to strengthen processes for obtaining environmental information and participation by accelerating the process and disseminating the greatest possible amount of information on a wider scale, particularly when it takes a digital form.

Section Two: Green Digital Transformation in Algeria: Between the Imperative of Implementation and Challenges

The expansion of environmental risks and the need for rapid and continuous intervention have made digital transformation a tool capable of ensuring proactive monitoring and addressing of threats. Like most countries in the world, Algeria has undertaken a commitment to employ technology and digital transformation across various productive and service sectors and others. Accordingly, this section will attempt to assess the extent to which green digital transformation is recognized as a legal instrument, and then examine the experiences of different countries and the main challenges that exist.

Subsection One: Legal Recognition of Green Digital Transformation

The integration of green technologies, including green digital transformation, has received attention since the early stages of the adoption of international environmental instruments, which subsequently paved the way for the development of national environmental legislation in various countries around the world, including Algeria.

First Branch: International Legal Recognition of Green Digital Transformation

International documents and agreements contain numerous references that directly encourage the adoption of technology as a means of achieving environmental protection, among which digital transformation may be included. These include:

1. Stockholm Declaration (1972)

Principle 20 emphasizes the importance of promoting scientific research and technological development to address environmental challenges, particularly in developing countries. It calls for the free exchange of up-to-date scientific knowledge, the sharing of expertise, and the transfer of environmentally sound technologies under fair conditions that encourage their widespread adoption without imposing an economic burden on developing nations.

2. Rio Declaration on Environment and Development (1992)

The Rio Declaration also provides, through **Principle 9**, that States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion, and transfer of technologies, including new and innovative technologies.

We also find numerous practical and field-level details within Agenda 21 resulting from the Conference, particularly through Chapter 34 on the transfer of environmentally sound technologies and Chapter 40 on information for decision-making, including databases and environmental monitoring.

3. United Nations Framework Convention on Climate Change (1992)

Among the obligations established to combat climate change are those set out in Article 4, paragraph (...) of the Agreement:

(g) Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system...

(h) Promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information related to the climate system and climate change, and to the economic and social consequences of various response strategies.

4. Convention on Biological Diversity (1992)

The Convention contains several references to green digital transformation efforts, as reflected in the provisions of the following articles: **Article 16: Transfer of Technology; Article 17: Exchange of Information; and Article 18: Scientific and Technical Cooperation.**

5. Paris Agreement (2015)

Article 10(4) on the Technology Framework provides:

“A technology framework is hereby established to provide overarching guidance to the work of the Technology Mechanism in promoting and facilitating enhanced action on technology development...”

In **Article 13**, the Agreement provides for the **Enhanced Transparency Framework, including digital data collection and reporting.**

Second Branch: Algerian National Legal Recognition of Green Digital Transformation

The starting point was Presidential Decree No. 20/05 of 26 January 2020, amended and supplemented by Presidential Decree No. 25/298 of 10 November 2025, concerning the establishment of a national system for the security of information systems. Algeria also established the High Commission for Digitalization, placed under the supervision of the Presidency of the Republic, pursuant to Presidential Decree No. 23/314 of 6 September 2023, amended by Presidential Decree No. 24/63 of 1 February 2024. This body is responsible for leading sectoral digitalization projects and strategic projects in the field of transformation.

Algeria also adopted what is known as the “**National Digital Transformation Strategy**,” which is based on five (05) pillars, each of which includes a set of strategic objectives, such as the digital society, digital economy, digital governance, basic information and communication technology infrastructure, human capital, training, research, and development.[15]

Second: Green Digital Transformation in the Algerian Environmental Protection Law

This is Law No. 03/10 of 19 July 2003 relating to the protection of the environment within the framework of sustainable development. Article 5 provides for a number of environmental management instruments consisting of: an environmental information body; the establishment of environmental standards; planning of environmental activities undertaken by the State; a system for assessing the environmental impacts of development projects; the establishment of special legal regimes and regulatory bodies; and the involvement of individuals and associations in the field of environmental protection.

Article 6 provides for environmental information, whereby a comprehensive environmental information system is established. All of these elements benefit from the advantages of green digital transformation and include the following:

- Networks for collecting environmental information belonging to bodies or persons subject to public or private law.
- Methods for organizing these networks and the conditions for collecting environmental information.
- Procedures and methods for processing and validating environmental data.
- Databases concerning scientific, technical, statistical, financial, and economic environmental information.
- All information elements relating to various environmental aspects at both the national and international levels.

All of this was provided for alongside the right to information available under Articles 07, 08, and 09.

First Branch: Different Experiences of Green Digital Transformation

Many countries and institutions have launched various green digital transformation initiatives that have yielded positive results. One notable example is the implementation of smart grids, which allow for the implementation of demand-response programs, whereby consumers are incentivized to reduce or shift their energy use during peak periods, further decreasing the strain on the grid and reducing emissions. One such example is Florida Power and Light (FPL), which leveraged data from smart meters to monitor and optimize its grid, resulting in USD 30 million

in operational savings. The Amsterdam City-Zen project also optimizes energy consumption and stores excess energy with a smart grid that combines AI with digital twin technologies.[16] As another example, precision farming involves the use of GPS, IoT sensors, and drones to monitor crop health, soil conditions, and weather patterns. These real-time data allow farmers to optimize the use of water, fertilizers, and pesticides, reducing waste and minimizing the environmental impact of farming. For instance, John Deere's "See & Spray" is an AI-driven platform that uses computer vision to identify and treat crops individually. This technology allows for the precise application of herbicides, reducing the overall use of chemicals and optimizing crop yields. Another application is the smart irrigation system, which adjusts water delivery based on soil moisture levels and can reduce water usage by up to 40% compared to traditional irrigation methods.[17]

At the European Union level, there is Copernicus, the Earth observation component of the European Union's Space Programme, which looks at our planet and its environment to benefit all European citizens. It offers information services that draw from **satellite Earth Observation and in-situ (non-space) data**, and the European Commission manages the Programme. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Ocean, the European Environment Agency (EEA), and the Joint Research Centre (JRC).[18]

Second Branch: Challenges of Green Digital Transformation in Algeria

Given the great importance of digital transformation and green digital transformation, which have been established within a legal framework confirming their existence and facilitating their practical implementation, this endeavor has nevertheless not been free from difficulties and challenges that make it difficult to achieve the desired results.

1. Pollution Resulting from the Production, Consumption, and Use of Digital Transformation Tools

Digital devices contribute to environmental pollution. However, the share differs significantly between device types. For mains-powered devices, such as desktop personal computers, the relatively high level of power consumption means that more than half of life cycle energy use and emissions can be attributed to the use phase, while for more energy-efficient devices, such as smartphones, the production phase is the dominant source of emissions. The greater the number of devices used around the world, the greater the environmental impact in the production phase and on waste generation at the end of life[1].

The larger the screen of a computer device or monitor, the higher the level of power consumption. In some cases, smartphones have effectively replaced other consumer electronics (e.g., digital cameras, portable music players), reducing the need to manufacture and power a variety of single-function devices. At the same time, growing demand for larger screens for monitors and televisions is offsetting some of the efficiency gains from shifting to more efficient display ("panel") technologies[2].

For instance, in 2017, 1.5 billion smartphones were sold in the world, ten times more than in 2009. Nowadays, smartphone production requires about 9,000 tons of cobalt per year, 10% of the global annual production. This huge and increasing demand for many metals for ICT is not sustainable.

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2/ Challenges in Digital Transformation Infrastructure

If Algeria is taken as an example, it suffers from a clear digital divide between urban and rural areas, where major cities like Algiers and Oran enjoy advanced fibre optic networks and relatively high internet speeds, while rural and remote areas experience weak or nonexistent coverage. According to 2024 data, 75.5% of the population lives in urban areas, leaving a large percentage in less serviced areas, leading to disparities in access to basic digital services such as remote education and electronic health services[3].

Furthermore, the high costs of investing in digital infrastructure. The cost of building and expanding fibre optic networks and 4G and 5G infrastructure is extremely high, especially in areas with low population density. Algeria faces challenges in covering these costs, prompting the government to seek partnerships with the private sector and innovative financing techniques to accelerate the pace of digital coverage. Additionally, the lengthy regulatory procedures and licenses complicate the implementation of projects and increase their costs[4].

4/ Weak Organizational and Human Resources

Technical staff and engineers specialised in information and communication technology form a fundamental pillar for the development and maintenance of digital infrastructure. However, Algeria suffers from a noticeable shortage in this area, which affects the quality of digital services and the ability to adopt modern technologies[5].

5/ Legal and Legislative Challenges:

Current laws and legislation require updating to keep pace with the requirements of the digital age. This includes the protection of personal data, ensuring intellectual property rights, and establishing legal frameworks that support the digital economy.

Cultural Resistance and Reluctance to Adopt: Some entities, particularly in rural areas, face difficulties in accepting digital technology as a result of cultural resistance or a lack of awareness of its importance. This reluctance slows down the pace of digital transformation and limits its spread.

Cybersecurity: Cybersecurity constitutes a major challenge with the increasing risks of cyberattacks. This requires strengthening the digital security infrastructure and developing effective strategies to protect data and information[6].

Conclusion

Environmental law is undergoing significant development in terms of its tools and its institutional and legislative framework, as well as in terms of its subjects aimed at sustainability. Among these means is the integration of clean green technology, which either contributes directly to environmental protection or helps develop traditional methods and provides greater and faster effectiveness.

With regard to the problem raised, the Algerian legislator's adoption of green digital transformation is a broad issue that comes within the context of its move toward the digitalization of various sectors. Accordingly, the following results can be reached:

- Green digital transformation is one of the tools that contribute to environmental protection within the framework of technology integration.

Among the proposals put forward in this regard are:

- The need to work on developing national legal provisions and ensuring the practical integration of green digital transformation alongside technology and capacity building.
- Strengthening the legislative framework with provisions that expressly adopt green digital transformation as a tool, in addition to issuing specific legal provisions concerning environmental information, electronic reporting, and the provision of other environmental services.
- Working to simplify environmental procedures by training workers in the environmental field and enabling civil society and citizens to use green digital transformation tools..

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