

Opinion

Digital transformation for sustainable development

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Abstract: This study aims to explore how digital transformation can promote sustainable development. Specifically, this paper makes an in-depth analysis from the perspective of theory and practice, in order to provide a solid theoretical basis and effective practical guidance for sustainable development, and help the coordinated progress of economy, society and environment. The primary characteristics of digital transformation include being data-driven, real-time interconnected, automated and intelligent, and customer-oriented. Digital transformation can contribute to sustainable development across various industries, ranging from industrial manufacturing to agriculture, energy, and urban development, all of which have seen practical outcomes. In the industrial manufacturing sector, digital transformation can enhance production efficiency, reduce energy consumption, and minimize waste emissions. In agriculture, it can enable precision farming and smart agriculture, thereby improving agricultural productivity and sustainability. In the energy sector, digital transformation can achieve clean, efficient, and renewable energy production. In urban development, it can facilitate the construction of smart and sustainable cities, improving urban environmental quality and residents' quality of life. Government, businesses, and society all play crucial roles in driving digital transformation forward.

Keywords: digital transformation; industry development; manufacturing development; agriculture development; energy development; urban development

1. Introduction

Digital transformation and sustainable development are two highly discussed topics in today's society. Digital transformation refers to the process of deeply restructuring and innovating traditional business models, workflows, and value chains through the use of digital technology and information means. We have made it clear that this process has profoundly affected every aspect of our lives, from the daily way of life to the macro model of the economy, to the complex form of social organization. Digital transformation is not just about simply migrating existing businesses to digital platforms but also involves redesigning business processes, integrating data and technology, and reshaping and innovating business models [1]. The main characteristics of digital transformation include being data-driven, real-time interconnected, automated and intelligent, and customer-oriented. The development of digital technology is evolving rapidly, covering multiple fields such as information technology, communication technology, artificial intelligence, big data, the Internet of Things (IoT), and blockchain, with technologies like cloud computing, big data, artificial intelligence, and IoT being particularly prominent.

Sustainable development, on the other hand, refers to the ability of future generations to meet their own needs while meeting current needs. Around the world, climate change, resource shortage, environmental pollution and other problems are becoming increasingly serious, and the attention and call for sustainable development

are growing. How to combine it with sustainable development and give full play to the huge potential of digital transformation in promoting the sustainable development of economy, society and environment is still an important topic that needs to be further explored and solved.

After extensive and in-depth research on digital transformation and sustainable development, the empirical research results by Zhang and Jin show that digital transformation can significantly promote the sustainable development of enterprises [2]. Lu et al. found that digital transformation is the promoter of enterprise sustainable innovation and performance based on the dual perspective of information processing and innovation [3]. Qing and Jin have confirmed the positive impact of digital transformation on the sustainable development of enterprises [4]. Zhang et al. found that digital transformation has a significant positive impact on the sustainable development of enterprises [5]. Li and Xu proposed that the digital transformation of enterprises is the key driving force for the sustainable development of urban economy [6]. In the past research, experts and scholars mostly put the impact of digital transformation on sustainable development in the enterprise perspective, but lack of macro related research. Different from previous studies, this paper focuses on the sustainable development of digital transformation in many different fields, and expounds the important role of digital transformation on the sustainable development of industrial manufacturing, agriculture, energy and urban development.

This study aims to provide theoretical support and practical guidance for the global promotion of sustainable development through digital transformation. In this paper, through the use of multidimensional, systematic analysis method, reveals the close connection between the digital transformation and sustainable development, analyze the digital transformation in promoting the development of all walks of life can hold positive effect and mechanism, and put forward to enhance the synergistic effect between the digital and sustainable development of targeted Suggestions. This study has certain theoretical significance and practical value. From the theoretical perspective, it is helpful to further enrich and improve the relevant theoretical system of digital transformation and sustainable development, provide a more solid foundation and a broader vision for the in-depth research of academic circles in this field, and promote the continuous innovation and development of related theories. From a practical perspective, this study can provide targeted and operational guidance and suggestions for enterprises in developing digital transformation strategies and fulfilling social responsibilities. At the same time, it provides a scientific basis for the government to formulate relevant policies and regulations, guides the rational allocation of social resources, and promotes the coordinated development of the economy, society and the environment.

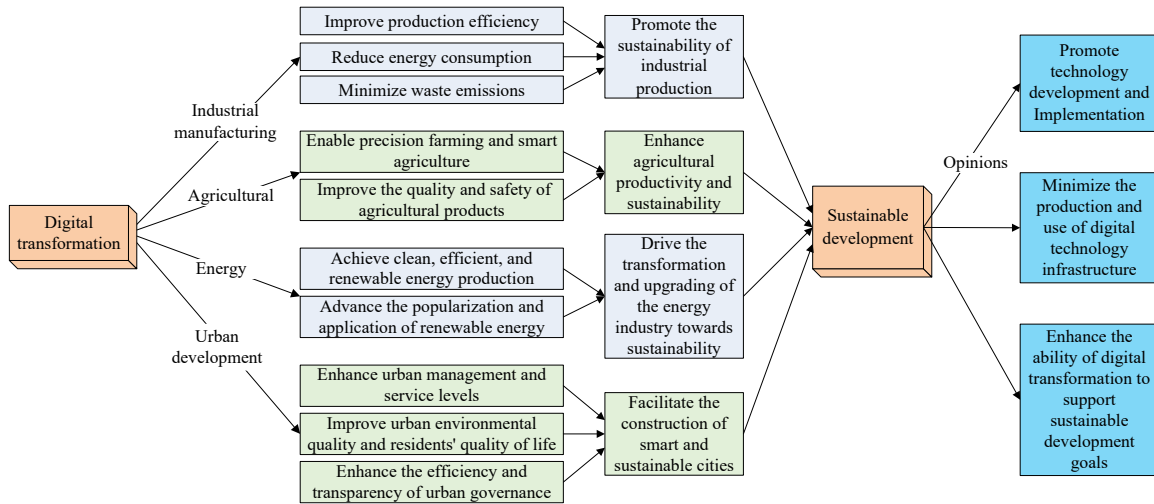


Figure 1. Research framework of digital transformation for sustainable development.

2. Industries of digital transformation for sustainable development

Digital transformation can contribute to sustainable development across various industries, from industrial manufacturing to agriculture, energy, and urban development, all of which have seen practical implementations and outcomes [7]. **Figure 1** illustrates the research framework for digital transformation for sustainable development.

(a) In the industrial manufacturing sector, digital transformation can significantly improve production efficiency, reduce energy consumption, and minimize waste emissions, thereby promoting the sustainability of industrial production. Through technologies like smart manufacturing and industrial Internet, companies can achieve intelligent monitoring and optimization of production processes, reduce energy waste and production costs, and improve product quality and efficiency. For example, big data analytics can help enterprises achieve intelligent production planning and inventory management, thereby shortening production cycles and reducing operating costs. Additionally, the application of artificial intelligence and machine learning can automate repetitive tasks in the production process, improving work efficiency and reducing the need for personnel [8]. Enterprises can adopt clean energy supplies, implement circular economy models, and pay attention to the entire product lifecycle, including design, production, use, and disposal. Businesses can better coordinate suppliers, production, and logistics to respond to market changes. Moreover, new production models such as Rapid Manufacturing (RM) and Custom Manufacturing are continuously evolving to meet the personalized and diverse needs of consumers [9].

(b) In the agricultural sector, digital transformation can enable precision farming and smart agriculture, enhancing agricultural productivity and sustainability. With technologies like IoT, big data, and artificial intelligence, farmers can achieve real-time monitoring and management of farmland, optimize agricultural production schemes, reduce the use of pesticides and fertilizers, and decrease environmental pollution and resource wastage [10]. Furthermore, digital technology can also improve the quality and safety of agricultural products, safeguard farmers' income and living standards, and promote sustainable agricultural development and rural revitalization.

(c) In the energy sector, digital transformation can achieve clean, efficient, and

renewable energy production, driving the transformation and upgrading of the energy industry towards sustainability. Through smart grids and intelligent energy management systems, real-time monitoring and scheduling of energy can be achieved, improving energy utilization efficiency and supply reliability while reducing energy consumption and carbon emissions [11]. Moreover, digital technology can promote the development and utilization of clean energy, advance the popularization and application of renewable energy, reduce reliance on traditional fossil fuels, and decrease environmental pollution and the risks of climate change [12].

(d) In the field of urban development, digital transformation can facilitate the construction of smart and sustainable cities, enhancing urban management and service levels, and improving urban environmental quality and residents' quality of life. By building and applying systems like smart transportation, smart energy, and smart environmental protection, urban traffic flow can be optimized, energy resources can be saved, and environmental quality can be improved [13]. Additionally, digital technology can enhance the efficiency and transparency of urban governance, promote the scientific and sustainable planning and development of cities, and drive the green development of urban economies and social harmony and stability.

3. Opinions of digital transformation for sustainable development

To enhance the synergy between digitalization and sustainable development, diverse entities such as governments and enterprises are implementing special policies to elevate the overall digitalization level of the economy and environmental efficiency, thereby improving sustainability.

(1) Digital system innovation requires the development and implementation of various technologies. These technologies must be synchronized with social innovation as well as institutional and behavioral changes. The use of digital technologies must be guided by a comprehensive efficiency strategy, adhering to the principles of purposefulness and minimization. Digitalization efforts should enhance rather than hinder citizens' sovereignty, expanding users' freedom of choice to competently and responsibly use digital media and services. Incentives should promote the use of digital technologies in decentralized business models, reducing dependency on oligopolistic companies for public and private services. Economic and social opportunities in the digital economy must be fair, including providing education opportunities for all to acquire the necessary skills for a digital society and more equitably distributing capital-based income across the population.

(2) The growth in the number of digital devices and services stimulates energy and resource consumption, and their application leads to additional consumption in other industries through various rebound effects. For instance, to meet the energy transition's demand for green technologies, the extraction of minerals like graphite, lithium, and cobalt could increase by 500% by 2050. Each stage of extraction, processing, and disposal of these mineral resources generates waste, significantly impacting land, water, air, and biodiversity. Additionally, the production and operation of digital technologies demand substantial energy and resources, leading to related environmental impacts. Therefore, the environmental footprint of producing and using digital technology infrastructure must be minimized. On one hand, the digital industry

needs to continually leverage new technologies to advance its own energy-saving and low-carbon development. On the other hand, digital innovation needs to systematically and extensively focus on efficiency improvements. Developers should adhere to sustainable software design principles to minimize electricity and resource consumption. For example, Germany's "Blue Angel" label has been incorporated into the evaluation system for energy-efficient data centers.

(3) The support capability of digital transformation for sustainability goals should be enhanced in every aspect. The sustainable digital ecosystem involves supporting environmental change responses through an effectively managed and inclusive data architecture and global digital ecosystem. By utilizing digital tools and non-traditional data sources, including sensors, and artificial intelligence, forming datasets for the public and private sectors can help automatically monitor global, national, and local progress in achieving Sustainable Development Goals and multilateral environmental agreements' key climate, biodiversity, and pollution indicators. Co-building digital transformation partnerships incentives and consumer behavior, using financial technology, e-commerce, social media platforms, and their underlying algorithms and filters to accelerate deep structural changes in markets, value chains, and consumer behavior, thereby steering incentives towards sustainable development. Through various digital innovation-focused hackathons, innovation labs, and similar initiatives, citizen science and open innovation should be encouraged and promoted, particularly supporting the active participation of SMEs, social entrepreneurs, women, and youth.

While digital transformation plays a crucial role in supporting sustainable development, it is a double-edged sword. The novelty, convenience, and functionality of digital technology innovation can provide opportunities for sustainable development. However, we must also be wary of the risks of digitalization being misused and its potential negative social consequences. Therefore, digital transformation must advance in parallel with sustainable development, promoting sustainable development through digital transformation while ensuring the sustainability of digital transformation itself.

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