IMPACT OF INDUSTRY 4.0 ON ACHIEVING ARTIFICIAL INTELLIGENCE-ENABLED SUSTAINABLE DEVELOPMENT GOALS: ECONOMIC AND SOCIAL DIMENSIONS

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ABSTRACT
This study aims to examine the effects of the fourth industrial revolution, defined as artificial intelligence (AI) and Industry 4.0 (I4.0), in economic and social dimensions in order to achieve the Sustainable Development Goals (SDGs) determined by the United Nations. It has been observed that this issue has started to attract attention in research in recent years. Therefore, in the study, a structure has been created by addressing the integration of artificial intelligence and Industry 4.0 in terms of increasing efficiency in production processes and reducing resource consumption in the economic dimension. At the same time, the positive effects of the use of these technologies on economic growth, creating new job opportunities and production resources will be emphasized. In the social dimension, the potential of artificial intelligence to increase justice in areas such as education and health, the impact of the use of digital technologies on social inequalities and the difficulties that may arise in the labor market will be discussed. In particular, it is emphasized in the study that digitalization and automation processes can lead to job losses and that social justice should be ensured in this transformation. First of all, the study will include an introductory section where sustainable development goals, industry 4.0 and artificial intelligence are briefly defined. In the first part, the role of artificial intelligence and industry 4.0 in achieving the SDGs and the potential of digitalization in achieving the SDGs will be discussed. In the third part, the focus will be on economic and social dimensions. In the fourth part, the impact of artificial intelligence and Industry 4.0 on the SDGs will be explained with practical examples. Finally, the study will be concluded with the conclusion and recommendations section.
Keywords: Industry 4.0, Artificial Intelligence, Sustainable Development Goals, Economic and Social Dimensions

INTRODUCTION
The contributions of artificial intelligence (AI) and Industry 4.0 (I4.0) technologies in economic and social dimensions to achieve the 17 targets defined as Sustainable Development Goals (SDGs) determined by the United Nations have been a subject of interest for researchers in recent years. In this study, the opportunities offered by Artificial Intelligence and Industry 4.0 technologies in the areas of increasing efficiency in production processes and reducing resource use will be discussed.

Industry 4.0 or the fourth industrial revolution is seen to lead to serious changes in many areas, especially from increasing the individual skills of people to facilitating production and long-term strategic planning of states. It has been determined that these changes have attracted great interest from academics due to their potential impact in different fields of study. In academic literature, Industry 4.0 has many advantages such as efficiency, flexibility and speed in the context of facilitating production, as well as disadvantages such as environmental and social risks. Therefore, it needs to be evaluated in line with sustainability goals in order to reduce or eliminate the risks that will arise with this level of technological advancement and to benefit more from the opportunities provided by Industry 4.0 (Anuşlu and Fırat).

Artificial intelligence (AI) is generally defined as the science and engineering of developing the ability of machines, especially computer programs, to imitate functions specific to human intelligence (Russell & Norvig, 2010). Today, artificial intelligence has the power to transform all kinds of data, from the way we access information to the production of products and services, from information collection methods to human interactions. Especially in developing economies, AI technologies reduce production costs and market entry barriers for businesses, enabling the formation of more innovative entrepreneurial activities than traditional methods. The role of technology-based solutions in economic development is increasing; global goals such as reducing poverty and increasing shared prosperity are becoming dependent on the effective use of the opportunities offered by AI (Strusani and Houngbonon, 2019).

The concept of sustainable development is used in many places in the literature today, but it was first defined in 1987 by the World Commission on Environment and Development in a report called Our Common Future. The report defined sustainable development as a development process that meets the needs of current generations without jeopardizing the ability of future generations to meet their own needs. The report emphasized that the effects of technological developments and human activities on environmental resources could be managed by taking into account the self-renewal capacity of the biosphere and that this approach would be effective in combating many global problems, especially poverty (WCED, 1987).

In this context, the 2030 Agenda for Sustainable Development was adopted by the United Nations in 2015. The accepted Sustainable Development Goals (SDGs) consist of 17 goals and 169 sub-goals with the aim of increasing global welfare, preventing environmental degradation and ensuring inclusive economic growth. The determined goals include ending poverty in the world, quality education, reducing social inequalities, bringing peace and prosperity for all, promoting sustainable industry and innovation, climate action for environmental protection and protecting terrestrial life (United Nations, 2015). Today, the development of Industry 4.0 and artificial intelligence technologies in line with these goals is of great importance not only in terms of economic growth but also in terms of ensuring environmental and social sustainability.

Research Problem

Industry 4.0 and the rapid development of artificial intelligence technologies are causing radical changes in many areas, from people's individual skills to the change of production possibilities in the industrial sector. However, it has been determined from the studies that it is still not fully clear how these technological advances will be compatible with sustainable development goals. It has been seen that artificial intelligence applications, in addition to supporting economic growth, contain both opportunities and risks in areas such as reducing social inequalities and ensuring fair economic development. In this context, the main research problem in this study is to understand how artificial intelligence technologies can be used effectively and responsibly to achieve sustainable development goals.

Purpose of the Research

The main purpose of this study is to analyze the contribution of Industry 4.0 and artificial intelligence technologies to achieve sustainable development goals and to contribute to the gaps identified in the literature in this direction. In the literature study on the subject conducted by Kamble, Gunasekaran, and Gawankar (2018), it was revealed that the issue of sustainability is not sufficiently covered in the current Industry 4.0 literature.

However, it has been emphasized that in order for researchers to overcome this deficiency, advanced technologies such as artificial intelligence should be used in line with sustainability goals. In this context, the evaluation of artificial intelligence-supported Industry 4.0 applications together with their economic and social sustainability dimensions emerges as a critical need both in academic and practical terms. In the study, the opportunities offered by artificial intelligence in economic and social dimensions and the risks that may be encountered will be analyzed and how these technologies can be optimized within the framework of a sustainable development vision will be discussed. In addition, it is aimed to develop suggestions on how artificial intelligence-supported solutions can be used effectively in development processes in developing countries.

Literature summary

In their study, Anuşlu and Fırat (2020) evaluated the effects of the basic components of Industry 4.0 on sustainable development and environmental performance. In order to carry out the analysis of the study, they used the 2018 data of 116 countries regarding the indexes, taking into account the Global Innovation Index, Sustainable Development Goals (SDGs) and Environmental Performance Index (EPI) indicators. 17 Sustainable Development Goals were included in the analysis by reducing the dimension with Factor Analysis. In the method section of the study, regression analysis was performed and some models were created showing the effects of innovation on sustainable development and environmental performance. As a result, it was revealed that some indicators representing Industry 4.0 positively affect sustainable development; while some indicators have negative effects on sustainable development. This situation was interpreted depending on whether the partial correlation coefficients are positive or negative.

Kasa (2020) examined the development stages of innovative countries that successfully implemented the Industry 4.0 process in this process and investigated how these countries affected economic growth in the Industry 4.0 transformation. In the analysis, the System GMM model was used for the effect of R&D expenditures, high-tech product exports, human capital index, foreign direct investment and patent applications of the 16 countries on GDP per capita. As a result of the analysis, it was determined that especially high-tech exports and foreign direct investment have positive and significant effects on economic growth; In this context, the determining role of technology and capital-oriented strategies in the adaptation process to Industry 4.0 was emphasized.

In his study, Mhlanga (2021) examined the impact of AI on poverty reduction (SDG 1) and industry, innovation and infrastructure development (SDG 9) targets in developing economies using the content analysis method. From the findings, it was determined that AI plays an effective role in increasing the reliability of transportation infrastructure, supporting economic growth and reducing poverty. It was stated that AI improves data collection processes through poverty mapping; It will help especially marginalized groups to participate in the economy by increasing access to agricultural education and financial services. Finally, it was determined that sustainable development efforts in developing economies are supported through the contributions of AI to the education and finance sectors.

Javaid et al. (2022) conducted a study based on literature review to examine in detail the role of AI in Industry 4.0 applications and to reveal the function of AI in the technological transformation of production systems. In the study, the technological features of AI, application areas and encountered difficulties were discussed in detail; a detailed analysis was made that could guide researchers, sector employees and students.

As a result, the gradual but decisive role of AI in reaching the goals of Industry 4.0 was mentioned and it was reported that awareness of the automation solutions that stakeholders need to adapt to this new production process may be needed.
Tuğaç (2023) discussed the positive effects of AI on SDGs in his study and also examined the risks encountered, especially ethical problems, in detail. In this context, the necessity of developing human, administrative and legal capacity was revealed as a result; and drew attention to the balanced, sustainable and inclusive implementation of AI solutions in line with the basic principles of SDGs.
Filho et al. (2024) examined the contribution of artificial intelligence (AI) to sustainable urbanization within the scope of goal 11 of the Sustainable Development Goals (SDG 11) based on literature review and various case studies. The case studies supported by the findings obtained from the literature showed that AI supports urban sustainability with functions such as increasing energy efficiency, improving waste management, optimizing traffic flow and contributing to overall environmental sustainability.
Mukhopadhyay, Singh and Jain (2024) evaluated the power of artificial intelligence (AI) to improve marketing skills in the fast-moving consumer goods (FMCG) sector in India in the context of dynamic capabilities (DC). Within the scope of the research, in-depth interviews were conducted with 26 experienced employees with different duties in the field examined. The obtained data were analyzed using open, axial and selective coding techniques. As a result of the analysis, it was determined that AI strengthens marketing practices in four main areas such as personalization, consumer engagement, marketing automation and achieving strategic goals. In this context, it has been emphasized that when AI technologies are correctly understood and used by companies, marketing efficiency and effectiveness will increase, thus achieving a competitive advantage.

CHAPTERS

1. INDUSTRY 4.0 AND ARTIFICIAL INTELLIGENCE (AI) INTEGRATION

With Industry 4.0 or the 4th Industrial Revolution, the acceleration of digitalization in the production and service sectors has made it necessary to integrate smart factories, big data analytics, autonomous systems and artificial intelligence applications into processes, thus significantly increasing the speed of industrial transformation.
Industry 4.0 can be defined as the use of advanced knowledge and new production technologies in industries. In its most common sense, Industry 4.0 is also used to refer to digital transformation in industry. The basic components of Industry 4.0 include technologies such as artificial intelligence, cyber systems, the Internet of Things (IoT), cloud computing and machine learning. All these components allow for intelligent analysis of data in production processes, enabling dynamic improvement of processes. By quickly processing the data collected during production, better processes can be developed and outputs can be continuously optimized. This transformation not only establishes a stronger connection between processes, but also makes production activities more flexible and efficient. Industry 4.0 enables the rapid spread of digitalization in industrial production, causing a radical change in business processes through artificial intelligence and machine learning applications (Jagatheesaperumal et al., 2021).
Industry 4.0 was first announced to the world as a new industrial revolution, defined at the Hannover 2011 Fair by giving the name to the German Federal Government's project on digitization of manufacturing. Industry 4.0 is an approach that aims to further increase the use of computer technologies in the manufacturing industry and to make production processes compatible with advanced technologies.

In this direction, three main objectives stand out: reducing human labor in production processes, reducing human-related errors, providing a high level of flexibility in production, and enabling the production of consumer-specific products, and increasing production speed (Mahfi Eğilmez, 2017). With the announcement and spread of Industry 4.0 by the German government to the whole world, the need for economical, safe and sustainable smart production has increased, which has led to an increase in the use of new technologies such as artificial intelligence (AI) and big data in industries (Jagatheesaperumal et al., 2021). The concept of Industry 4.0 is the adaptation of advanced information and production technologies to industrial sectors. This term is generally used to describe the digital transformation in the industry and includes technologies such as artificial intelligence, cyber-physical systems, the Internet of Things (IoT), cloud computing and machine learning. These technologies offer the opportunity to intelligently analyze the data obtained in production processes and continuously improve the processes (Javaid, et al., 2022).

Artificial intelligence applications make it possible to make very fast and data-based decisions in industrial processes, facilitate production processes, reduce all costs of the company, including production costs, and improve customer service (Dal Mas et al., 2019). Smart facilities compatible with artificial intelligence are taking production processes to an unprecedented level of efficiency, reducing costs and increasing customer satisfaction. In the context of Industry 4.0, artificial intelligence contributes to the more efficient production systems by integrating various technologies that enable software and machines to perceive, comprehend, act and learn human operations. The manufacturing sector is showing a continuous growth trend thanks to artificial intelligence technologies that progress parallel to Industry 4.0. Artificial intelligence is one of the basic technologies developed to increase efficiency, improve product quality and reduce operational costs. Smart factories, created by hyper-connected production processes, realize a digital transformation through machines that communicate with each other and provide significant advantages in quality control, standardization and maintenance (Zhang and Lu, 2021). Artificial intelligence-supported systems produce faster and more accurate results with less human intervention, thus transforming the digital transformation of Industry 4.0 into a more intelligent and productive structure. In addition, developments in artificial intelligence enable computing systems to gain capabilities such as vision, hearing, and learning, and lead to the development of new generation innovative platforms (Javaid, et al., 2022).

2. OVERVIEW OF SUSTAINABLE DEVELOPMENT GOALS

The United Nations aimed to solve the main problems faced by people all over the world by declaring the 2030 Sustainable Development Goals (SDG 2030), which consists of 17 interrelated basic goals and 169 related targets. The Sustainable Development Goals aim to end poverty, protect the environment, take precautions against the climate crisis, and achieve world peace and prosperity for everyone (United Nation). The determined goals draw attention to the issue of sustainability as the main source of development in the world, and are shaped in three dimensions: economic, environmental and social, and are declared to be a common problem of humanity (Tıraş, 2017):

The economic dimension is based on the effective and efficient use of scarce resources in production factors. An economically sustainable system can be defined as a structure that produces goods and services on a continuous basis, avoids sectoral imbalances that harm production in agricultural and industrial production, and ensures sustainable management of domestic and foreign debts.

The social dimension refers to a human-centered approach. A socially sustainable system is defined as a system that provides individuals with fair and adequate access to basic social services such as education and health, supports gender equality, and encourages political participation and social responsibility.
The environmental dimension aims to maintain the balance of biological and physical systems and to ensure that ecosystems adapt to changing environmental conditions. In this context, environmental sustainability is a system that aims to protect natural resources, maintain biodiversity, and prevent environmental degradation. Addressing these three dimensions together is of critical importance in terms of implementing sustainable development from a holistic perspective.
When we look at all the complementary purposes of the sustainable development goals, it is possible to say that the goals are not only evaluated with the economy-environment duo, but also with multidimensional elements such as basic human needs, climate change, environmental protection, peace, democracy and fundamental rights and freedoms. Today, the world aims to shape the sustainable development discourse in line with the vision of "A Better World by 2030" (Peşkircioğlu, 2016). The Sustainable Development Goals (SDGs), declared by the United Nations (2015), aim to increase global welfare within a broad framework from the elimination of poverty to the provision of environmental sustainability. These goals can be summarized as follows (United Nation):
Goal 1: No Poverty, Eliminating all forms of poverty everywhere in the world.
Goal 2: No Hunger, Ending hunger, ensuring food security, improving nutritional quality and promoting sustainable agricultural practices.
Goal 3: Health and Quality Life, Ensuring that individuals live a healthy life at all ages and supporting their well-being.
Goal 4: Quality Education, Ensuring inclusive, equal and quality education for all and increasing lifelong learning opportunities.
Goal 5: Gender Inequality, Achieve gender equality and empower women and girls.
Goal 6: Clean Water and Sanitation, Ensure sustainable access to clean water and sanitation for all.
Goal 7: Affordable and Clean Energy, Ensure availability of safe, sustainable, accessible and modern energy sources for all.
Goal 8: Decent Work and Economic Growth, Promote inclusive and sustainable economic growth, promote full and productive employment and decent work opportunities.
Goal 9: Industry - Innovation and Infrastructure, Build resilient infrastructures, support sustainable industrialization and increase innovation capacity.
Goal 10: Reduce Inequalities, Reduce inequalities within and between countries.
Goal 11: Sustainable Cities and Communities, Make cities and human settlements inclusive, safe, resilient and sustainable.
Goal 12: Responsible Production and Consumption, Develop sustainable consumption and production patterns.
Goal 13: Climate action, Take urgent action to combat climate change and its impacts.
Goal 14: Life below water, Protect and ensure sustainable use of oceans, seas and marine resources.
Goal 15: Life on land, Protect terrestrial ecosystems, ensure sustainable forest management, combat desertification and prevent biodiversity loss.
Goal 16: Peace, Justice and Strong Institutions, Promote peaceful and inclusive societies, ensure access to justice for all and build effective, accountable and inclusive institutions.
Goal 17: Partnerships for the Goals, Strengthen global partnerships and develop effective collaborations for sustainable development.

3. THE ROLE OF ARTIFICIAL INTELLIGENCE AND INDUSTRY 4.0 IN ACHIEVEMENT OF SDGs

Artificial intelligence (AI) stands out as a critical technology in terms of its potential to improve the well-being and quality of life of individuals, contribute to sustainable global economic activities, promote innovation and productivity, and provide solutions to fundamental global problems (UNESCO, 2021). Artificial intelligence (AI) and Industry 4.0 not only accelerate economic growth, but also play an important role in solving social and environmental problems. The 17 Sustainable Development Goals (SDGs) determined by the United Nations cover a wide range of areas, from reducing poverty to quality education, from access to health services to combating climate change. AI-supported systems, which are one of the basic components of Industry 4.0, are a driving force for achieving these goals. Especially in areas such as health and education, eliminating inequalities, reducing environmental impacts with AI-supported solutions in areas such as agriculture and climate change, increasing resource efficiency, delivering services to wider audiences, and enabling faster and more accurate decision-making processes (Vinuesa et al., 2020).

It is accepted that artificial intelligence (AI) can have different effects on societies and economies. Artificial intelligence applications especially change economic structures, transformations in employment, deepening digital inequalities, data privacy, threats to human rights and democratic values, etc. It also creates some risks such as (Jobin, Ienca & Vayena, 2019).

In order to avoid these risks, these systems must be used effectively, therefore, the existence and collection of accurate, up-to-date and sufficient data is of great importance.

Therefore, the primary condition for the use of artificial intelligence to support the achievement of the Sustainable Development Goals (SDGs) is to provide access to appropriate data (Palomares et al., 2021; UN, 2022a: 6). However, for AI to provide a fair and inclusive contribution, it requires that it adhere to principles such as ethics, transparency and data security. In cases where these are not taken into account, it can be said that AI carries the risk of increasing social inequalities. In addition, the violation of the privacy of individuals and sectors by big data used in artificial intelligence systems leads to ethical problems and poses the risk of damaging individual rights. In this context, it is emphasized that the traditional environmental, economic and social dimensions of the SDGs, as well as the technological and individual rights dimensions, should also be taken into account (Tuğaç., 2023). On the other hand, reliability is the most important element of digital transformation processes. Since it is not known what kind of impact the use of AI technologies will have in the future, reliability is a determining factor in the process of adopting artificial intelligence technologies by society. In order to effectively evaluate the benefits that technology offers to societies and states and to manage potential risks, it is of great importance to establish a comprehensive, well-informed and transparent strategy throughout society (Floridi et al., 2018). It is important for artificial intelligence to be more reliable, to support people's own skills, to include less represented groups in the process, to reduce economic and social inequalities and to protect the environment. In this context, the participation of all stakeholders in the process will strengthen the role of artificial intelligence in achieving inclusive growth, sustainable development and environmental sustainability goals (OECD, 2019).

As a result, it is possible to say that if technologies are to be designed and used in every field in order to maximize the contribution of artificial intelligence to sustainable development, it is necessary to prioritize ethical values, social inclusiveness and environmental awareness at every stage.

3.1. Economic Dimensions

Artificial Intelligence (AI) and Industry 4.0 technologies have become a driving force of economic growth today, increasing production efficiency, reducing costs, and accelerating innovation by creating new business models. This transformation both strengthens the competitive advantage of businesses at the micro level and increases the economic growth potential of countries at the macro level (Your Artificial Intelligence Guide). Thus, artificial intelligence technologies are considered as an important element in supporting sustainable development by both the state and the private sector. AI technologies transform economic structures for states, and provide optimization in business processes for the private sector, while increasing the interactions between different sectors, thus providing businesses with a competitive advantage on a global scale.

In this context, it is seen that the use of artificial intelligence can be directly associated with the relevant targets of the Sustainable Development Goals. In particular, SDG 8: Decent Work and Economic Growth, SDG 9: Industry, Innovation and Infrastructure, and SDG 12: Responsible Production and Consumption targets overlap with the economic contributions of AI (United Nations, 2015).

The main contributions of artificial intelligence technologies to the economy in the context of sustainable development goals can be explained as follows:

• *Increased Productivity and Cost Reduction:* Smart automation systems supported by AI contribute to the reduction of costs by ensuring that goods and services are more efficient in production processes and by using production resources more effectively (Bughin et al., 2018). Industry 4.0 aims to reduce waste by reducing labor-related errors in production stages with the advanced technologies it uses. Products produced using smart machines play an important role in the digital transformation of the production process. These technological products collect and process big data and can interact with the industrial environment. Therefore, they can collect information without human intervention throughout the entire life cycle. These technologies reduce costs by increasing efficiency and create more effective production processes (Terzi, 2021). By associating this situation with supporting the development of more efficient production and consumption models in line with the SDG12 target, we can talk about the impact of artificial intelligence on this goal.

• *Innovation and Competitive Advantage:* It is seen that artificial intelligence technologies strengthen the innovation capacity of businesses in R&D activities and allow companies to quickly adapt to the changing conditions of the market (OECD, 2021). Industry 4.0 offers significant innovations and opportunities not only for large enterprises but also for SMEs. Advantages such as high competitiveness, increased productivity and increased income are the main benefits offered by Industry 4.0 for SMEs. In addition, the activation of resource management with technologies such as the Internet of Things (IoT), the optimization of production processes and the development of new technologies are among the elements that will enable SMEs to gain competitive advantage. These developments also lead to improvements in customer services and increased employment opportunities, thus ensuring and strengthening the innovation and competitiveness of SMEs (Gilchrist, 2016). This contribution serves the establishment of sustainable industrialization and innovative infrastructures within the scope of SDG9.

• *Transformation of Employment and New Job Opportunities:* Along with the use of AI technologies, the automation of some professions in the labor market increases the risk of job loss, and also enables the emergence of new professions and different job fields (Chui et al., 2018). The rapid development of artificial intelligence and autonomous robot technologies will increase the demand for individuals with high technical skills in order to update, improve and ensure the sustainability of existing technological structures.

Although these technologies are expected to negatively affect employment in some sectors, new job opportunities and opportunities will emerge for individuals who can adapt to technology and integrate into changing working conditions (Murat, 2023). This process offers opportunities for the creation of more inclusive and decent job opportunities within the framework of SDG8.

• *Fast and Data-Based Decision-Making Ability:* The fact that AI works in harmony with big data analytics enables fast and accurate decisions to be made in decision-making processes. This situation provides an advantage especially in terms of effective management of resources and improvement of development projects in the public sector (Floridi, 2019). This feature supports economic and technological development by allowing fast and accurate decisions to be made with artificial intelligence and data analytics in the context of SDG9, innovative solutions to be produced in the industry and infrastructure to be improved. The benefits of artificial intelligence technologies brought by Industry 4.0 to economic growth and development provide a significant advantage for the realization of SDGs. In order to effectively benefit from these advantages provided by artificial intelligence, AI applications should also be addressed from the perspectives of inclusiveness, ethical principles, data privacy and human rights (UNESCO, 2021).

3.2 Social Dimensions

Artificial intelligence (AI) is not only a technological transformation in the economic dimension for the realization of the sustainable development goals (SDGs) but also an important factor for the transformation in the social dimension. Especially in the context of SDG1 (elimination of poverty), SDG3 (healthy and quality life), SDG4 (quality education) goals that define the social dimensions of the sustainable development goals, the contribution of AI directly contributes to the reduction of social inequalities by ensuring fair and equal access to basic services all over the world. The use of AI also has the capacity to improve the quality of life of disadvantaged individuals in many areas.

• *Eradicating poverty:* Artificial intelligence (AI) and Industry 4.0 technologies make significant contributions to the primary goal of the Sustainable Development Goals (SDGs), which is to eradicate poverty (SDG1). These technologies offer innovative solutions in the fields of agriculture, finance and education, increasing economic inclusion, especially in developing countries, and thus enabling low-income individuals to participate more actively in the economic system. Digital technologies within the scope of Industry 4.0 accelerate structural transformations by supporting new business areas with the potential to create employment, and contribute to the integration of low-income groups into the digital economy. However, in order for this process to take place in an inclusive and fair manner, digital infrastructure needs to be strengthened and education and skills development programs need to be expanded (UNDP, 2021). Therefore, when supported by the right policies, AI and Industry 4.0 technologies become a powerful tool for reducing poverty.

• *Reducing Inequalities:* It is reported that artificial intelligence (AI) technologies have the potential to increase access equity, especially in the fields of education, health and social services. It is observed that AI-supported applications contribute to the reduction of social inequalities by facilitating the access of individuals living in rural and disadvantaged areas to quality services (Vinuesa et al., 2020). However, it is emphasized that technological developments alone will not be sufficient to reduce digital inequalities; digital infrastructure needs to be strengthened, individuals' digital literacy levels need to be increased and public policies based on inclusive digital strategies need to be implemented (UNESCO, 2021).

In this context, it is possible to directly associate the opportunities offered by Industry 4.0 technologies with the fair distribution of all segments of society, especially with the target of Sustainable Development Goals (SDG 10).

• *Social Justice*: Industry 4.0, the spread of digitalization in production systems, and the increased use of automation and artificial intelligence applications increase economic efficiency. However, as a result of the widespread use of these systems in all areas, it also includes opportunities for low-income and disadvantaged groups, as well as some risks. It is predicted that unemployment may occur, and therefore income inequalities may increase, especially as a result of automation systems replacing unskilled labor (ILO, 2021). This situation is directly related to both the targets of Decent Work and Economic Growth (SDG 8) and Reducing Inequalities (SDG 10) from the Sustainable Development Goals.

However, with Industry 4.0, technological opportunities; It also has the potential to reduce socioeconomic disadvantages with digital education platforms, online skill development tools and remote working opportunities. If digital technologies are combined with inclusive policies, the participation of low-income individuals in the digital economy can be increased and new jobs can be created (Schwab, 2016). In this context, the implementation of "just transformation" policies is important. These policies should include strengthening social protection systems, expanding reskilling programs, and making labor markets inclusive (UNIDO, 2020).

• *Health and Quality of Life:* Artificial intelligence (AI) and Industry 4.0 technologies, especially AI-supported health applications, directly contribute to the goal of "Ensuring healthy lives and promoting well-being for everyone at all ages" from the Sustainable Development Goals (SDG3) in terms of early diagnosis, personalized treatment, monitoring of infectious diseases and increasing the efficiency of health systems.

• *Quality education:* Thanks to artificial intelligence (AI), personalization of education processes and development of digital capabilities have recently become one of the most remarkable topics. Learning systems supported by AI in particular provide learning opportunities specific to individuals by investigating their knowledge and skill levels. This increases the individual's learning efficiency and also contributes to increasing digital literacy levels. (UNESCO, 2023). It plays an important role in achieving SDG4 (Quality Education), one of the Sustainable Development Goals.

4. THE EFFECT OF ARTIFICIAL INTELLIGENCE AND INDUSTRY 4.0 ON SUSTAINABLE DEVELOPMENT GOALS WITH APPLIED EXAMPLES

As a result of the gradual decrease in production resources in the last century, the efficient use of resources is important in terms of sustainability in terms of leaving a better world for future generations. For this reason, the relationship between Industry 4.0, which is called the fourth industrial revolution, and sustainable development is one of the issues that should be investigated (Bakkari and Khatory, 2017). It is thought that there will be a 10-30% decrease in critical areas such as production costs and transportation costs in businesses with the conveniences brought by Industry 4.0 (Rojko, 2017). For this reason, business owners will start to implement all kinds of innovations that will reduce production costs. Below, some examples of sectors where the use of artificial intelligence makes human life easier are explained.

Agricultural applications supported by AI in the agricultural sector increase agricultural productivity by providing information such as weather forecasts, crop disease detection and efficient irrigation strategies to small-scale farmers. These applications both increase farmers' income levels and support food security (Vinuesa et al., 2020).

Mobile-based AI solutions and digital finance applications used in the finance sector reduce economic exclusion by facilitating access to financial services and support micro-entrepreneurship (Chui et al., 2018).

Imaging systems supported by AI in the health sector contribute greatly to this sector with high accuracy rates in early diagnosis of diseases such as cancer (Topol, 2019). Thanks to the Internet of Things (IoT), one of the basic components of Industry 4.0, it provides the opportunity to monitor patients remotely, wearable health devices and real-time analysis of digital health data, thus improving the quality of life of especially the elderly and chronically ill individuals (Radanliev et al., 2020). The most positive contribution of artificial intelligence in this sector is that even in rural areas where health services cannot be accessed, it becomes possible to reach every individual with digital solutions, thus reducing social inequalities in the field of health. In addition, digital solutions that increase efficiency in health systems contribute to the formation of a sustainable health infrastructure by reducing costs by ensuring the efficient use of resources. In global health crises such as the pandemic crisis experienced in 2019, it has been seen that AI algorithms have been successful in monitoring patients, distributing resources, and increasing the effectiveness of policies implemented regarding public health (Bullock et al., 2020).

In the field of education, the Kira Learning platform founded by Andrew Ng stands out as one of the successful examples in this field with AI-supported teaching assistants that can reduce the workload of teachers and provide one-on-one private tutoring experiences to students (Kira Learning, 2024). Solutions that use technology such as this contribute to the elimination of social inequalities in education by providing equal opportunities, especially for students with different learning speeds and skills. Therefore, artificial intelligence not only improves teaching processes, but also paves the way for inclusive, fair, and quality education for everyone.

Artificial intelligence (AI) makes significant contributions to the creation of circular economy models and the development of smart city applications by ensuring the efficient use of resources. These technologies optimize energy consumption, facilitate waste reduction, and reduce carbon emissions (Ellen MacArthur Foundation, 2019; OECD, 2021). AI-supported solutions such as electric autonomous vehicles, smart meter systems, and demand response technologies make energy use more sustainable and are directly related to SDG 7 (Accessible and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) of the sustainable development goals (IEA, 2021; United Nations, 2015).

DISCUSSION

This study aims to evaluate the potential contributions of Artificial Intelligence (AI) and Industry 4.0 technologies to achieving the Sustainable Development Goals (SDGs) determined by the United Nations within the framework of economic and social dimensions. In this context, as a result of literature reviews and analyses conducted in light of application examples using artificial intelligence in various fields, it has been revealed that AI and Industry 4.0 technologies contribute to social goals such as reducing social inequalities, improving access to education and health services, and building sustainable cities, as well as increasing productivity in production. However, in order to fully benefit from the opportunities provided by AI and Industry 4.0, it is necessary to pay attention to some basic issues. First of all, in order to reach SDGs equally all over the world, it is very important to strengthen the digital infrastructure and increase digital literacy, especially in developing countries. In addition, artificial intelligence systems need to be designed in an ethical, inclusive and reliable manner, and social sensitivity needs to be created on sensitive issues such as data security and privacy.

In addition, considering the effects of technological transformation on employment, it is important to develop reskilling programs, social protection mechanisms and employment policies in line with the principle of "fair transformation". The opportunities offered by AI should be directed in a way that supports the integration of low-income and vulnerable groups into the digital economy.

In this regard, the recommendations can be listed as follows:

At the national and international level, countries need to create roadmaps to develop new policies and strategies for the use of AI and Industry 4.0 technologies in line with the SDGs and should integrate these technologies harmoniously into their sustainable development strategies.

Inclusive education policies should be supported, especially in rural and disadvantaged regions, and digital literacy, artificial intelligence literacy and technical skills training should be expanded in developing countries.

Privacy and security, especially in the use of artificial intelligence, have recently become a topic of discussion. Therefore, legal regulations should be made on ethical rules, data privacy and human rights issues in order for these technologies to be used safely in all areas; the public should be informed about this issue.

Multi-stakeholder platforms should be established with the cooperation of the public, private sector and academia to develop innovative solutions in more areas and to spread the use of inclusive technological applications.

Transparent and data-based monitoring systems should be established to measure the impacts of AI and Industry 4.0 applications on sustainable development.

As a result, AI and Industry 4.0 technologies can serve as powerful tools to achieve the three fundamental dimensions of sustainable development: economic growth, social equality and environmental sustainability, when supported by proper governance, strategic planning and social participation.

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