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THE ROLE OF DIGITAL TECHNOLOGIES IN MONITORING AND REDUCING ENVIRONMENTAL IMPACTS IN MODERN INDUSTRIES

Aftab Ahmad[1], Gulfan Ullah[2], Kamran Ullah Khan[3], Muhammed Adil Khan[4], Basmina[5]

[1] *Sustainability Manager, CosmosE, KSA.*
[2] *Sustainability & Environmental Specialist, ROWAD Modern Engineering, KSA.*
[3] *Sustainability Manager, Alfanar, KSA.*
[4] *Environmental Engineer, NESMA, KSA.*
[5] *Botanical & Environmental Researcher, KUST, Kohat, KPK, Pakistan.*

[*] ***Corresponding Author:*** (aftab.bhittani1@gmail.com)

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Article Info

Abstract

Introduction: Modern industries have become deeply concerned by environmental sustainability because of the rising rates of pollution, depletion of resources, and environmental degradation. Through industrial activities, the impacts on the environment are very pronounced, and this is the reason why there is the necessity to have an effective monitoring system and sustainable management practices. Digital technologies like the Internet of Things, artificial intelligence, and big data analytics offer new possibilities to industries to monitor environmental conditions and enhance environmental performance using the help of data-driven decision-making.

Aim: This research is intended to analyze how digital technologies can be used to monitor and decrease environmental effects of contemporary industries. The research question explores the potential of the acquisition of digital technologies to enhance environmental monitoring systems and promote environmental sustainability.

Methodology: The research design used in this study was quantitative. The structured questionnaire was the means by which primary data were collected through distributing the survey to professionals operating in the industrial sectors, including manufacturing, energy, and logistics. A mean score of 150 valid responses was performed in terms of descriptive statistics, correlation analysis and regression analysis to ascertain the relationship between digital technology adoption and reduction of environmental impact.

Results: According to the findings, digital technologies are very applicable in increasing environmental monitoring abilities and add to environmental sustainability. Internet of Things monitoring systems exert the biggest impacts in reduction of the environmental impact, followed by artificial intelligence and big data analytics.

Conclusion: The paper comes to a conclusion that digital technologies in the industrial processes can enhance environmental monitoring and lessen the effects on the environment. Development of a sustainable industrial system and the improvement of practical environmental management can be, therefore, supported with the adoption of the newest digital technologies.

Keywords: *digital technologies, environmental monitoring, industrial sustainability, Internet of Things, artificial intelligence, big data analytics.*

Introduction

One of the most impressive challenges of the twenty-first century in the global arena is environmental degradation. There has been a huge increase in environmental pressures, such as greenhouse gas emissions, water pollution, deforestation, and loss of biodiversity due to rapid industrialization, urbanization and the rise in natural resource demand. The industrial processes are commonly known to have significant impact on the environmental degradation caused by excessive use of resources, pollution, and energy usage. Due to this, a number of governments, international organizations and environmental agencies are putting more focus on the necessity of sustainable industrial development that not only meets the needs of economic growth but also puts the environment first. In this regard, industries are being challenged to embrace novel measures and technological interventions that would be in a position to regulate environmental effects and minimize pollution and waste of resources.

Environmental monitoring is important in appreciating the level of environmental degradation and finding practical solutions of using the environment to ensure sustainable management. The conventional environmental monitoring tools are usually manual methods of data collection and laboratory tests, and regular environmental evaluations. The methods are usually time-consuming, costly, and not that effective to detect changes in the environment in real-time despite yielding meaningful information. Therefore, the solution lies in industries becoming more inclined to the usage of digital technologies to boost environmental monitoring and reach the efficiency of environmental management strategies. The occurrence of digital technologies gives the high potential of gathering, assessing and interpreting environmental data in real time as a way of enabling industries to identify environmental risks, and take preventive actions.

The advent of digital transformation and the idea of Industry 4.0 have altered industrial processes and environmental management practices greatly. Industry 4.0 denotes the combination of digital technologies (artificial intelligence (AI), the Internet of Things (IoT), big data analysis, blockchain, and cyber-physical systems) in industry. The technologies allow machines, sensors, and digital platforms to interact with each other and exchange information automatically, forming smart and interconnected industrial networks. These technologies can be integrated to enable industries to run their operations smoothly, effectively use resources, and minimize the effects on the environment as it would be possible to monitor and control industrial processes more accurately (Javaid et al., 2022; Shabur et al., 2024).

Among the digital technologies that have made the most considerable contribution to environmental sustainability, one can mention the creation of sophisticated environmental monitoring systems. Digital monitoring is a method that employs sensors, communication infrastructure, and analytical tools in executing cumulative tracking of the environment and transmitting the information to analyze the situations. These systems enable industries to monitor important environmental parameters of air including air quality, water pollution, temperature, energy use and greenhouse gases emissions on-the-fly. Continuous data collection on the capacity will enable industries to detect abnormalities in the atmosphere promptly and take necessary actions on any probable threat to the environment before it transforms into a significant crisis (Lala, 2025).

The Internet of Things (IoT) is one of the digital technologies that have been and continue to be used to monitor the environment. IoT comprises a system of interdependent devices, where the devices are sensitized and implanted with communication technologies, to automatically gather and send information. The IoT sensors in the industrial setting may be configured to be deployed in the factories, power plants and manufacturing plants to detect the environmental factors like air pollution, water quality and energy use. These sensors facilitate uninterrupted monitoring in the environment and produce huge data sets that can be studied to enhance the practice of environmental management. Monitoring systems that are based on IoT can deliver correct, extendable, and computerized environmental data that can dramatically execute the capacity of industries in identifying and reducing environmental hazards (Lanfranchi, 2025; Lala, 2025).

The other revolutionary technological advancement is artificial intelligence, which is rapidly finding application in the area of environmental surveillance and sustainability programs. The AI is able to study the complicated data of the environment and pinpoint the patterns that are hard to notice in humans. With the help of machine learning and predictive analytics, AI systems can predict trends in pollution, identify sources of pollution, and forecast environmental hazards such as industrial pollution, or chemical spills. Environmental monitoring systems that are produced with the help of AI can also be automated at every stage of decision-making so that the industry could improve its reaction to environmental changes and limit its impact on the environment. Studies have shown that artificial intelligence applications can be of great utility in pollution control, disaster management, and mitigation to environmental risks in various industries (Olawade et al., 2024; Popescu et al., 2024).

Digital environmental monitoring systems are also assisted with the help of big data analytics. Machines, sensors and operational systems have enormous amounts of data produced by the industrial processes. Big data technologies provide industries with the means to process and analyze these large datasets in search of the inefficiencies and environmental effects in the industrial operations. Using the insights provided by the data, industries will be able to use their resources more efficiently, use less energy, and generate less waste. As an example, data analytics may determine habits of unhealthy energy consumption in manufacturing facilities and suggest changes that help to achieve efficiency and less carbon emission. Large-scale analysis of environmental data contributes to making better decisions and practicing sustainable industries.

Other digital technologies (blockchain and digital twins) are also playing a role in environmental sustainability with the help of AI and IoT, not to mention big data analytics. Blockchain technology enhances visibility and accessibility of supply chains through the maintenance of reliable and impervious accounts of environmental information and responsiveness. This enables industries to check compliance with the environment and trace resource consumption in their complex world supply chains. Instead, digital twins establish virtual or replica versions of physical industrial systems, thus enabling industries to model situations in the environment and optimally operate such system before making changes in reality. Taken together, these technologies increase the capacity of industries to track the impact their activities have on the environment and take efficient measures to make the process sustainable.

Another way digital technologies help to sustain the environment is by enhancing the energy management and facilitating the process of reduction to low-carbon economies. As an illustration, the digital systems would have the ability to track the consumption of energy in factories and find areas to cut on their energy wastage. Developed energy management systems based on AI and IoT allow industries to describe energy consumption, accept renewable energy resources, and minimize greenhouse gases release. The global digital economy research states that digital technologies can play a critical role in meeting climate objectives by actively enhancing efficiency and lowering emission levels in various fields of the economy (OECD, 2024).

Even though such prospects are rather high, it is apparent that the adoption of digital technologies in environmental monitoring does have a number of challenges. Adoption of advanced digital systems can be quite costly in terms of money as well as technical set up and also in terms of technical manpower that can operate very complicated technological systems. Additionally, the fast growth of digital technologies can also present new environmental concerns like the consumption of more energy by data centers and the growth of electronic dumping. Thus, industries, and policymakers should strive to make sure that digital overhaul policies are formulated in a sustainable way that both enhances as much as possible the environmental benefits and reduces harmful others (Goel, 2024).

Overall, to conclude on the matter of digital technologies, it is becoming significant in the context of assisting the modern industries to keep track of and mitigate their environmental effects. The incorporation of technologies, like IoT, artificial intelligence, big data analytics, blockchain, and digital twins has reinvented the conventional environmental monitoring as it led to the possibility to collect data in real-time, predictively analyze them, and make better decisions. These technologies will enhance sustainable development of industries since they enhance efficiency in resources, curb pollution, and enhance environmentally responsible production activities. With the industries persistently implementing digital transformation strategies, digital technologies are likely to be the required tools in the implementation process of global environmental sustainability.

2. Literature Review

2.1 Theoretical Framework

The growing widespread adoption of digital technologies in industrial processes has been a popular topic in the work of the theory of sustainability and technological innovation. The concept of Industry 4.0 can be considered one of the most notable theoretical approaches applied to explaining the adoption of digital technologies in the field of environmental management. Industry 4.0 focuses on linking cyber-physical structures, computer networks, mechanization, and smart data analysis in industrial processes. Theoretically, Industry 4.0 facilitates efficient production and better management of resources and less adverse effects on the environment with the help of digital monitoring and making decisions based on data (Lasi et al., 2014). The framework implies that both economic and environmental gains should be realized as a result of introducing digital technologies into the production systems in industries.

The other school of thought that can be considered in this study is the Resource-Based View (RBV) of the firm. According to the RBV, competitive advantage of organizations can be achieved by using valuable, rare, and imitable resources successfully. Artificial intelligence, IoT systems, and data analytics platforms are some of the digital technologies that can be regarded as a strategic organizational resource in the context of environmental sustainability. When the firms properly incorporate such technologies, they would be able to achieve efficiency in their operations even as they mitigate the effect that they have on the environment (Hart, 1995). This school of thought emphasizes the role of technological capabilities in creating sustainable competitive advantage and environmental performance.

The ecological modernization theory is also instrumental in offering a theoretical basis in the study of the role of technology in preserving the environment. This theory states that the environmental enhancement is possible not by only economical restrictions but by technological invention and modernization. This school of thought suggests that technological innovation empowers industries to increase their efficiency to cut down on pollution, as well as, to use more economical methods of production without hurting their economic growth (Mol & Spaargaren, 2000). Digital technologies are thus critical in facilitating industrial growth that is sustainable to the environment.

The other theoretical framework that justifies the use of digital technologies in the monitoring of the environment is the technology-organization-environment (TOE) framework. The TOE framework presents the manner in which technological adoption in the organizations is affected by the technological capabilities, organizational preparedness, and the external environmental pressures. Considering environmental sustainability, regulatory expectations, stakeholders' expectations, and environmental policies in most cases compel industries to implement digital monitoring technologies which enhance transparency and compliance (Tornatzky and Fleischer, 1990). This framework gives a detailed insight on the way industries incorporate environmental monitoring technologies into the more global technological setting as well as regulatory setting.

The sustainable development theory is also significant in the explanation of the integration of digital technologies in the contemporary industries. Sustainable development implies the necessity to promote economic development, environmental stewardship, and social welfare levels. This balance can be facilitated using digital technologies as the resources can be used more efficiently, waste to the environment will decrease, and the monitoring system that will safeguard the natural ecosystems will be more developed (Elkington, 1998). The industries can also be able to come up with economical yet eco-friendly production systems through the use of sophisticated technologies.

More so, the concept of the circular economy gives more theoretical approaches to digital environmental monitoring. The round economy focuses on creating less waste, reuse, and recycling of materials in the production cycles. Circular models of production are supported by the use of such digital technologies as smart sensors, data analytics platforms, and digital tracking systems that enhance the management of resources and the monitoring of material flows in industrial systems (Geissdoerfer et al., 2017). Consequently, industries will be able to leave the use of linear production models and transition into systems that are more sustainable and utilize resources with less consumption.

Besides these frameworks, the environmental management theory emphasizes the role of the monitoring systems in mitigating the environmental risks. Sound management of the environment entails proper and timely information regarding the level of pollution, consumption of resources and the effects of the ecosystems. The digital monitoring technology also allows industries to acquire real time environmental data, which allows organizations to adopt proactive environmental management actions (Daily & Huang, 2001). All these theoretical views can be summarized by the reason why digital technologies are emerging as the center of environmental monitoring stages and sustainability programs in the contemporary industries.

2.2 Empirical Studies

There has been an increasing number of empirical studies that have investigated the aspects of the role played by digital technologies in environmental monitoring and sustainability within industrial industries. Numerous literary works prove the role of advanced digital technologies in enhancing environmental performance through real-time monitoring, predictive analytics, and enhanced decision making.

Various empirical investigations indicate the importance of the use of the IoT technologies in monitoring the environment. Sensors that are linked via IoT can be used to monitor the environmental situation, i.e. air quality, water pollution and industrial emissions continuously. A study by Gubbi et al. (2013) showed that environmental monitoring systems based on IoT can present users with precise real-time information that assists industries in understanding threats to the environment at earlier stages and acting effectively to rectify the situation. On the same note, Zanella et al. (2014) also discovered that IoT networks contribute to better monitoring of the environment by allowing them to collect data in large amounts and enhance communication among monitoring devices.

Artificial intelligence has also been broadly researched in the context of its relevance in terms of enhancing environmental sustainability. The AI algorithms can examine extensive environmental data and determine a pattern that can be used to predict environmental management. Vinuesa et al. (2020) conducted a study revealing that AI applications can be used to help accomplish various sustainability objectives due to their proficiency in resource utilization, pollution tracking, and environmental risk forecasting. A different empirical study by Rolnick et al. (2019) proved that machine learning technologies could enhance climate predictions, make energy systems more efficient, and identify any anomalies in the environment related to industrial processes.

The other field that has been highly considered in empirical research based on environmental monitoring is big data analytics. Several data volumes can be generated in industrial systems and analyzed to determine inefficiencies as well as environmental risks. A study by Wang et al. (2016) established that big data analytics enhances the performance of the environment since it allows industries to optimize energy consumption and minimize waste generation. Likewise, in another study, Dubey et al. (2019) investigated the role of big data analytics in enhancing sustainable supply chain management and discovered that data-focused decision making can enhance environmental efficiency to a great extent.

The use of digital technologies has been examined as well in relation to smart manufacturing and sustainable production systems. Research by Stock and Seliger (2016) indicate that the Industry 4.0 technologies can increase the efficiency of resources because they can be used to monitor the production process and conduct the predictive maintenance of industrial equipment in advance. Predictive maintenance decreases the failures of the equipment and minimizes wastage of energy, which enhances environmental sustainability.

Empirical studies also show that digital technologies will enhance environmental transparency in the supply chains. According to Kshetri (2018), blockchain technologies have the power to provide reliable monitoring of the environmental data and enhance the transparency in sustainable supply chain management. When environmental performance data is stored in the immutable digital registers, it is possible to audit the compliance of the organization with environmental standards and sustainability certifications.

Moreover, digital monitoring technologies were found to advance environmental regulation and control adherence. A research study conducted by Zhang et al. (2021) indicated that digital environmental monitoring systems are useful in ensuring that industries adhere to environmental laws by creating true and clear environmental information. Policymakers and regulation bodies use these monitoring systems to determine the environmental performance in industries.

Although these findings are positive, there are also a few problems with digital environmental monitoring outlined in some empirical research. A study conducted by Hilty and Aebischer (2015) discloses that data centers and digital infrastructures could enhance energy consumption because of digital technologies. Thus, the industries have to exercise great care in the environmental footprint of digital technologies themselves in order to use them to enhance environmental sustainability.

2.3 Research Gap

Even though the available literature indicates that digital technologies have been crucial in the context of environmental monitoring, as well as sustainability, there are a number of research gaps. To begin with, the scientific literature concentrates on each of the technologies (i.e., IoT, artificial intelligence, or big data analytics) individually, but not on how these technologies can be interconnected within a single integrated system of environmental monitoring. It is yet to be understood in a more detailed way how the various digital technologies can function effectively in the industrial setting.

Second, most of the available empirical studies are concentrated in the developed economies where the digital infrastructure and technological resources are highly distributed. Little evidence has been conducted to address the use of digital environmental monitoring technologies within the developing economies where industries can be limited by the financial, technological and institutional resources available. The role of digital technologies to promote the sustainability of the environment in developing countries is thus a significant area of study.

Third, although most literature highlights the environmental advantage of digital technologies, the literature that evaluates the possible environmental expenses of digital transformation is comparatively less. The consumption of energy by digital infrastructure, e-waste, and data center environmental footprint are issues that need to be researched more.

Last but not least, the research on the opportunity of digital technologies to benefit long-term adoption of the environmental policy and sustainable industrial government is limited. Further research should be on how environmental monitoring systems that are digital can be incorporated with environmental policies, regulatory frameworks, and corporate sustainability strategies in an attempt to broaden the environmental goals.

These research gaps need to be addressed to come up with a more holistic picture of how digital technologies may be successfully used to provide effective environmental monitoring and minimize the adverse effects of modern industries on the environment.

3. Methodology

3.1 Research Design

The research design used in this study is quantitative research design that explores the role of digital technologies in monitoring and reducing environmental footprint in contemporary industries. The study will use quantitative research since this will enable the researcher to quantify relationships between variables and then analyze the pattern using statistical tests. The research aims to learn the impact of the implementation of digital technologies on the environment observation and sustainability performance of industrial companies. The research uses numerical data gathered through respondents and employed in the industrial sector in order to assess the contribution of technologies like artificial intelligence, Internet of Things systems and technologies as well as digital monitoring toward the management of the environment.

The cross-sectional research design was employed, which involved gathering of data at a point in time among respondents. This design enables the researcher to study prevailing trends in the industries in terms of practices and attitudes to digital technologies and environmental monitoring. The method is appropriate in ascertaining trends and relationships between rates of technological usage and environmental performance of various industries. Another way in which the research design helps the study to generate empirical evidence is the concern of effectiveness of digital technologies in reducing the effects on the environment.

3.2 Population and Sampling

Professionals in the modern industries, which make use of digital technologies in their work, are the target population in this study. Such professionals are the environmental managers, sustainability officers, production managers, engineers and workers with information technology in the manufacturing, energy, logistics and industrial production industries. These people are regarded as the right respondents as they are directly engaged in the implementation of digital technologies and environmental monitoring systems in their organizations.

The purposive sampling technique was used to select a sample of this population. The purposive sampling will enable the researcher to come up with relevant respondents with knowledge and experience to the digital technologies and environmental management. In this research, we have chosen 150 respondents who were working in different industrial organizations. Such a size of sample can be discussed as sufficient to be analyzed quantitatively and to provide good confirmation that gathered data reflects various attitudes of professionals dealing with industrial environmental monitoring.

3.3 Data Collection Method

The structured questionnaire was used to gather primary data in order to establish the correlation between the adoption of digital technology and the effectiveness of environmental monitoring. There were two major sections of the questionnaire. The former section entailed gathering demographic data regarding the respondents such as their occupation, tenure, and business sector. The second part consisted of the statements about the use of digital technologies, environmental monitoring arrangements, and performance in their organizations in the environmental terms.

The respondents were expected to grade their level of agreement with these statements on a five-point Likert scale of strongly disagree to strongly agree. By utilizing the electronic medium, email and online survey methods, the questionnaire was availed to professionals in the identified industries. This method will enable the researcher to get the responses effectively with accessibility to respondents who are in other organizations and regions.

3.4 Data Analysis Technique

The analysis of the data collected was done through the methods of statistical analysis. Demographic information was summarized with the help of descriptive statistics and gave a general overview of the perception of respondents on digital technologies and environmental monitoring practices. Mean values and standard deviations have been used to understand the general trends in the data.

Moreover, the inferential statistical analysis was also carried out to determine the connections between digital technology adoption and reduced environmental impacts. The correlation analysis and regression analysis statistical tools were applied to identify how the use of digital monitoring technologies can substantially affect the environmental performance in industrial organizations. Such statistical tools enable the study to give empirical data with respect to the efficacy of digital technologies to enhance environmental sustainability.

3.5 Ethical Considerations

The study was conducted in a manner that adhered to ethical standards in order to guarantee the integrity and reliability of the study. The survey was voluntary and the respondents were notified on the aim of the research and proceeded in filling the questionnaire. Respondents were ensured their personal and organizational information was not exposed by ensuring that confidentiality and anonymity of the respondents would keep their information confidential. The obtained data were also not given to any third party and were utilized academically. These ethics prevented the unethical conduct of the research and made sure that the study was done in a responsible manner and in agreement with accepted academic research ethics.

4. Results

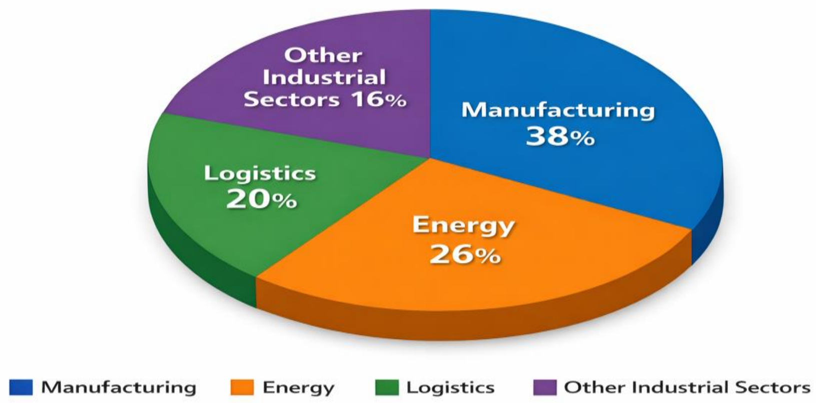
4.1 Demographic Profile of Respondents

This part gives the demographic features of the respondents who took part in the survey. Knowing the background of respondents matters since it means that the gathered data represents educated views of people working on the industry level and being familiar with industrial technologies and environmental control systems. Table 4.1 shows the distribution of the respondents based on their professional roles. The statistics indicate that the highest number of respondents was made up of production managers as they represented 21.3 percent of the entire sample. The industrial engineers took 20 percent, and the environmental managers were 18.7 percent of the respondents. Information technology specialists had 17.3 percent of the sample and that of sustainability officers was 14.7 and operations managers was 8 percent.

Table 4.1 Demographic Characteristics of Respondents (Professional Role)

Professional Role	Frequency (n)	Percentage (%)
Environmental Managers	28	18.7
Production Managers	32	21.3
Industrial Engineers	30	20.0
IT Specialists	26	17.3
Sustainability Officers	22	14.7
Operations Managers	12	8.0
Total	150	100

Figure 4.1 Industrial Sector Distribution of Respondents



The findings suggest that the research obtained the responses of people who actively participate in the technological activities, environmental practices and decision-making process in the industrial organizations. The involvement of the profession ensuring the diversity in the involvement of various professionals makes sure that its findings represent a wide range of opinion on the adoption of digital technologies and their impact on practices of environmental monitoring.

Table 4.2 presents the distribution of respondents with respect to their experience in the profession in terms of year of experience. The findings indicate that the majority of the respondents were in the 7-10 years of experience range and this was the 30.7-percent sample of individuals. Respondents who had four years to six years of experience constituted 25.3 percent and respondents who had 11 to fifteen years' experience constituted 18.7 percent. Those with one to three years' experience formed 16 percent of the respondents and those professionals with over fifteen years' experience formed 9.3 percent of the sample.

Table 4.2 Respondents' Years of Professional Experience

Years of Experience	Frequency (n)	Percentage (%)
1–3 years	24	16.0
4–6 years	38	25.3
7–10 years	46	30.7
11–15 years	28	18.7
More than 15 years	14	9.3
Total	150	100

Such results show that most of the respondents had extensive professional experience in an industrial setting. This is to imply that the responses gathered will be founded on the work knowledge and personal experience with digital technologies and environmental surveillance machinery, which is being implemented in the contemporary industries. The proportion of the respondents to various industrial sectors is pictorially depicted by the Figure 4.1 that demonstrates that the manufacturing industries constitute the highest percentage of the sample with energy and logistics sectors that come next. The availability of the representatives of different industrial fields augments the reliability and generalizability of the results.

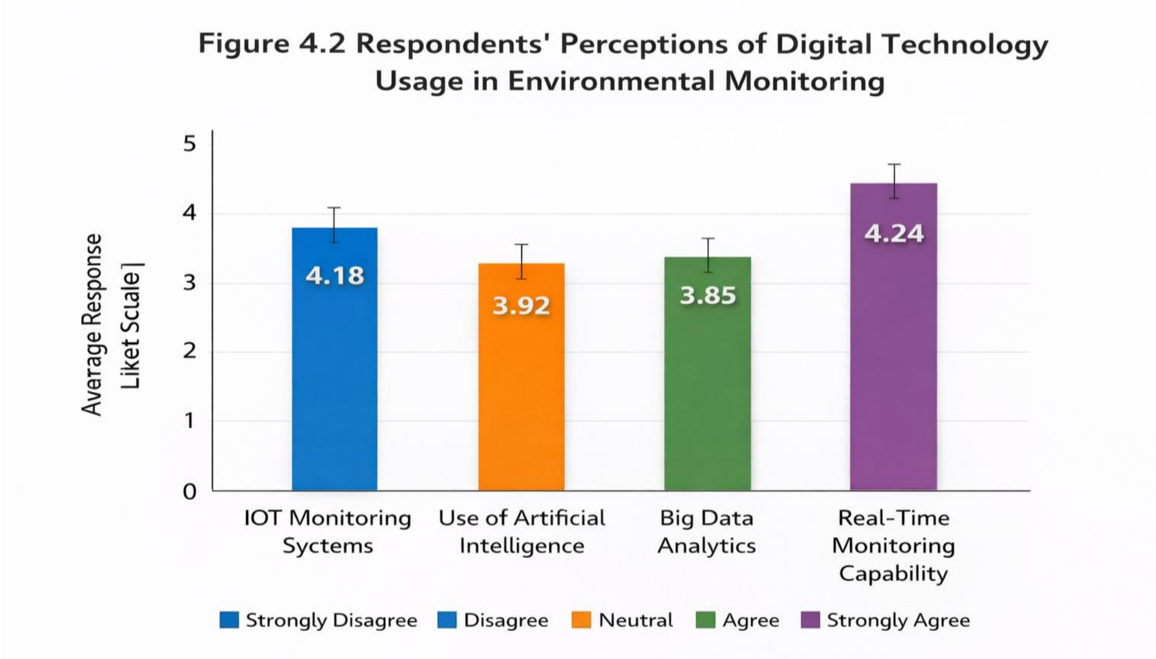
4.2 Descriptive Statistics of Digital Technology Adoption

To test the perceptions of the respondents on the use of digital technologies to monitor the environment in industrial organizations, the descriptive statistical analysis was implemented. Table 4.3 that represents the descriptive statistics of the main variables of the study includes digital technology adoption and environmental monitoring practices mean values and standard deviations.

Table 4.3 Descriptive Statistics of Digital Technology Adoption and Environmental Monitoring

Variable	Mean	Standard Deviation	Minimum	Maximum
Adoption of IoT Monitoring Systems	4.18	0.64	2.00	5.00
Use of Artificial Intelligence in Environmental Analysis	3.92	0.71	2.00	5.00
Big Data Analytics for Environmental Data	3.85	0.76	1.00	5.00
Real-Time Environmental Monitoring Capability	4.24	0.58	2.00	5.00
Reduction in Industrial Environmental Impact	4.07	0.69	2.00	5.00

The findings indicate that the highest mean score of 4.24 was on the real time environmental monitoring capability and this means that respondents strongly agree that digital technologies can be used to monitor environmental conditions in real-time. The Simultaneous adoption of IoT monitoring systems also had a high mean score of 4.18 indicating that the industries are deploying sensor-based monitoring technologies at a higher rate to monitor environmental indicators like emissions, air quality and energy consumption.



Environmental analysis using artificial intelligence had a mean score of 3.92, whereas the big data analytics mean score was 3.85. These results show that despite strong awareness of the fact that advanced digital technologies are able to enhance the environmental monitoring rates, the rates of their use could be different in various industries. The graphical display of the perception that the respondents had on the usage of digital technology is presented in Figure 4.2, showing the relative agreement rates among respondents to each of the technological tools used in the monitoring of the environmental conditions.

On the whole, the descriptive analysis allows concluding that in fact the respondents think that digital technologies are effective means to enhance environmental monitoring systems and increase the sustainability performance in contemporary industries.

4.3 Correlation Analysis

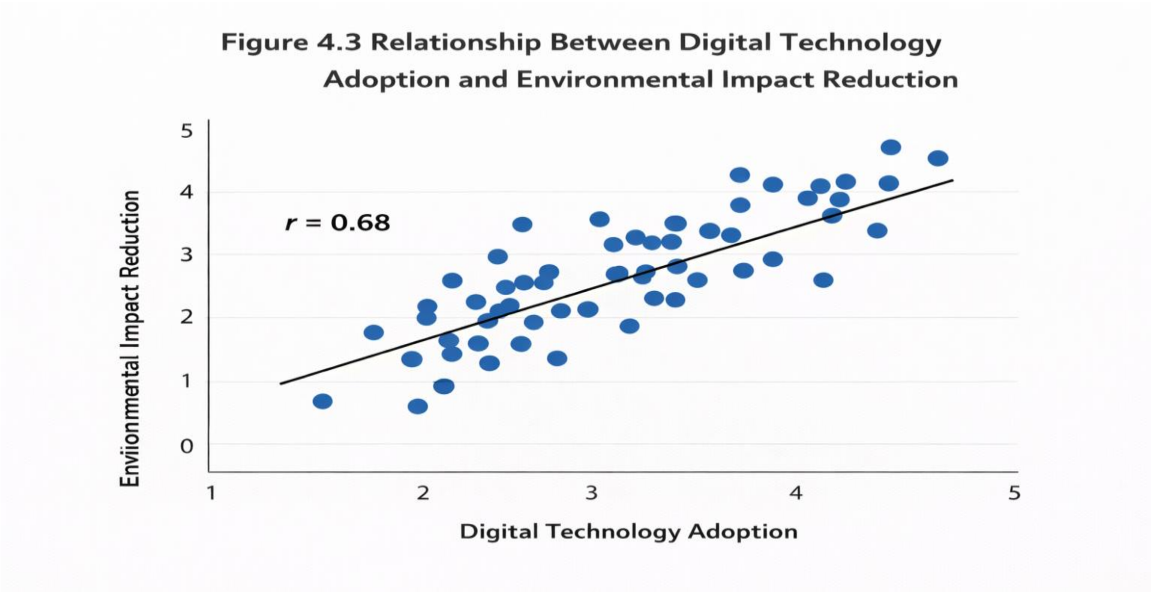
The correlation analysis was used to determine the correlation between the adoption of digital technology and reduction in environmental impact. The findings of the correlation test appear in Table 4.4 that demonstrates the correlation coefficients of the most significant variables of the study.

Table 4.4 Correlation Analysis Between Digital Technology Adoption and Environmental Monitoring

Variables	IoT Systems	AI Applications	Big Data Analytics	Environmental Monitoring	Environmental Impact Reduction
IoT Systems	1.000	0.58	0.52	0.63	0.60
AI Applications	0.58	1.000	0.61	0.55	0.57

Big Data Analytics	0.52	0.61	1.000	0.50	0.53
Environmental Monitoring	0.63	0.55	0.50	1.000	0.68
Environmental Impact Reduction	0.60	0.57	0.53	0.68	1.000

These findings demonstrate that there exists a positive correlation between the digital technology adoption and environmental monitoring effectiveness. In that way, IoT monitoring systems were closely related to the environmental monitoring capability, whereas artificial intelligence applications and big data analytics have all illustrated positive moderate associations with the reduction of environmental impact. These data indicate that industries implementing the use of digital technologies have more chances of enhancing their environmental monitoring solutions and decrease the number of environmental risks.



The magnitude and direction of the association between digital technology adoption and the decrease of the environmental impact is visualized in Figure 4.3, which gives a scatter plot with a regression tendency line. Its regression line has positive slope which implies that the more the digital technology is adopted, the more the environmental impacts would be reduced. The correlation coefficient provided in the figure once again supports the fact that there is a significant positive relationship existing between these variables.

4.4 Regression Analysis

The regression analysis was performed to identify the degree to which the digital technologies can be anticipated to predict the decrease in the impact on the environment in industrial organizations. Table 4.5

provides the regression output with the values of beta coefficients, standard errors, t-values, and the level of significance of each of the predictor variables.

Table 4.5 Regression Analysis Results for Digital Technology Adoption and Environmental Sustainability

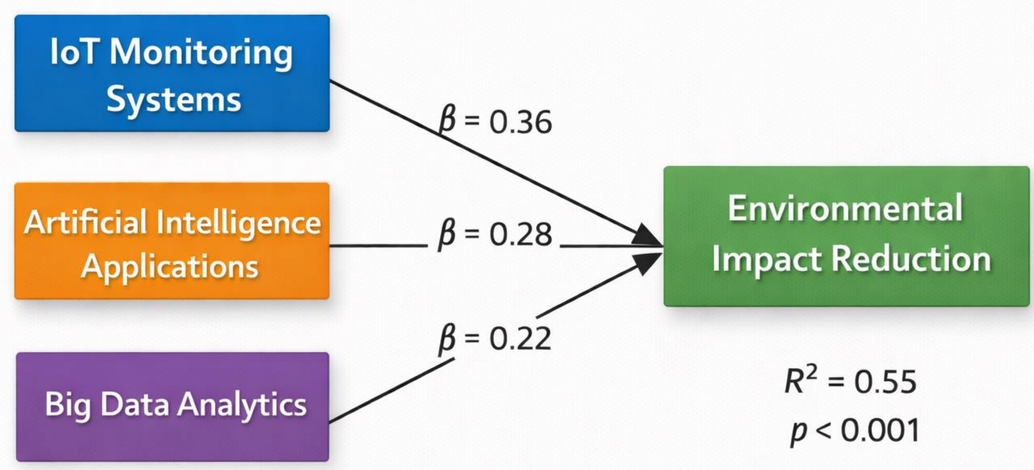
Predictor Variable	Beta Coefficient	Standard Error	t-value	Significance (p)
IoT Monitoring Systems	0.36	0.07	5.14	0.000
Artificial Intelligence Applications	0.28	0.06	4.36	0.000
Big Data Analytics	0.22	0.08	2.75	0.007
Constant	1.12	0.31	3.61	0.001

Model Summary

Statistic	Value
R	0.74
R^2	0.55
Adjusted R^2	0.53
F-value	58.27
Significance	0.000

Results show that the predictive capacity of IoT monitoring systems on environmental impact reduction is the greatest with the beta coefficient value of 0.36 and a statistically significant p-value. The artificial intelligence applications as well exhibit a very high positive impact with a beta coefficient of 0.28 and the big data analytics exhibit a moderate positive impact with a beta coefficient of 0.22.

Figure 4.4 Regression Model of Digital Technology Adoption and Environmental Impact Reduction



The model summary statistics further show that the regression model accounts a significant percentage of variance in environmental impact reduction with the R 2 value of 0.55. This implies that the adoption of digital technologies in the model is useful in explaining the variation in the reduction of environmental impacts by about 55 percent.

Figure 4.4 visually depicts the conceptual relationship between the adoption of digital technology and environmental sustainability by offering the regression model between the use of IoT systems, artificial intelligence applications, and big data analytics and the reduction of the environmental impact. The figure shows how the various technological factors will enhance environmental performance within the industrial organizations.

In sum, the regression analysis indicates that the adoption of digital technology could be important in enhancing the capability to monitor the environment and minimize environmental impacts in the contemporary industries. The identified findings suggest the significance of embracing modern technologies during the industrial processes to aid the sustainability in the industrial production and proper environmental management frameworks.

5. Discussion

The results of the paper indicate a considerable importance of digital technologies in enhancing environmental monitoring and mitigating climate changes in contemporary industries. The findings proved that digital tools including Internet of Things surveillance systems, artificial intelligence applications, and big data analytics affect the monitoring capacity of the environment and the minimization of the environmental impact positively. The results of the regression showed that the most significant effect on the sustainability of the environment is the presence of IoT technologies, then artificial intelligence and big data analytics. These results propose that the industries that are equipped with digital technologies can be more adequately prepared to track the environmental conditions and optimize the use of the resources and minimize the level of pollution.

The findings of this paper agree with other existing studies which underscore the increasing significance of digital transformation, in terms of environmental sustainability. As an example, Bocken and Short (2021) suggest that digital technologies will allow organizations to monitor environmental performance in real-time to implement the environmental decision-making process and sustainability management in industries. On the same note, Li, Dai, and Cui (2020) determined that digital technologies elevate resource management and promote transparency of the environment in industry. The finding of these studies justifies the conclusion that digital monitoring systems could enhance the performance of the industrial environment by giving accurate and timely environmental data.

The results regarding the IoT-based monitoring systems can also be explained by previous works that identify environmental advantages of sensor-based monitoring technology. Kumar, Singh, and Kumar (2021) believe that the introduction of IoT sensors enables industries to constantly monitor the emission level, water use and energy consumption, thus enhancing the efficiency of environmental monitoring systems. In their study, they have proven that real time monitoring of the environment assists the organizations to detect and take corrective actions on the environmental threats that they may face more efficiently. As the findings of the current study would indicate, the adoption of IoT plays a significant role in ensuring the reduction of environmental impacts, which makes the argument of sensor-based monitoring systems as the key method to ensure sustainable industrial functioning.

The positive impact of artificial intelligence was also discovered to be the logical effect on environmental monitoring and sustainability. This finding goes hand in hand with the findings of the past studies indicating that AI technologies enhance environmental forecasting and predictive environmental management. Studies by Dwivedi et al. (2021) have shown that AI-based analytics can compute a high amount of environmental data to establish trends and anticipate environmental hazards to enable industries to take measures before environmental changes take their toll. On the same note, Rai, Constantinides, and Sarker (2019) maintain that AI technologies help in environmental decision-making, since they facilitate the automated calculation of environmental performance indicators. The present paper attests that AI helps to achieve better environmental monitoring and sustainability with respect to industrial environments.

Another result of the study was that big data analytics can also help in abating the effects on the environment, but its impact was slightly less than that of IoT and AI technologies. The results can be compared with the study by Gupta, Kar, and Ilavarasan (2018) to indicate that big data analytics would lead to greater sustainability in the environment because it would help industries to interpret more complicated information about resource usage and the rate of pollution. According to their research, the use of data in the decision-making process enhances better environmental management practices and contributes towards the design of sustainable production systems. The findings of the current research support the notion that big data analytics can assist industries in determining the source of inefficiencies and environmental waste.

The other significant point that the results have revealed is that there is a positive correlation between the use of digital technology and environmental impact minimization. Correlation analysis showed that the effectiveness of environmental monitoring applied by organizations that have a high degree of digital technology use is high. Such a result is related to a study carried out by Bonilla, Silva, and Terra (2020), who have determined that digital technologies play a role in enhancing the nature of environmental governance and sustainability practices in industrial firms. They highlight in their study that monitoring digital platforms contribute to greater environmental responsibility by granting clear data on environmental performance.

Implications of the Study

The results of this paper have critical implications to the industrial professionals and policy makers. In the case of industrial organizations, the findings present the need to have an investment in digital technologies in order to have a greater capacity to monitor the environment and provide a better sustainability performance. Industries can enhance the collection of environmental data, the determination of environmental risks, and the minimization of resource waste by the adoption of such technologies as IoT sensors, artificial intelligence systems, and big data analytics platforms. The technologies have resulted in organizations shifting to reactive environmental management strategies to proactive and predictive sustainability strategies.

To the policymakers, the results indicate that the objectives of facilitating digital transformation of industrial sectors can bear the national and international green agendas. Governments and the regulators can promote the use of digital environmental monitoring initiative by coming up with conducive policies, grants, and investment in the digital infrastructure. Digital innovation towards environmental monitoring can be encouraged to ensure that the industries meet environmental regulations and meet the long-term sustainability goals.

Limitations of the Study

Although it has contributed to it, this study has a number of limitations that must be mentioned. First, the study has been based on survey data obtained with professionals working in industrial organizations, which can also create subjectivity in the answers. In spite of the fact that the respondents had an appropriate working experience, their perceptions might not be reflective of the environmental performance within their organizations.

Second, it could not go beyond a certain population of industrial professionals as a sample group and this could limit the generalizability of the findings to other industries or geographical areas. It might be important that more diverse and larger samples should be used in future investigations to enhance the overall extrapolation of findings across countries and industries.

Third, the research was based on only a few digital technologies, namely, innovative technologies of IoT, artificial intelligence, and big data analytics. Nevertheless, it is also probable that other new technologies like blockchain, digital twins, and cloud-based environmental monitoring systems can have significant implications on environmental sustainability. The effect of these technologies on people should be reviewed by future studies.

Conclusion

To sum up, the present paper has shown that digital technologies have become important in environmental monitoring and minimization of the environmental impacts in contemporary industries. The results indicate that the IoT monitoring systems, artificial intelligence applications, and big data analytics have important positive effects on the environmental monitoring capabilities, and it helps to reduce environmental impact. The findings also reveal that digital technology adopted by organizations has a higher chance of developing effective environmental management strategies and record the attainment of improved sustainability.

The paper is useful in enhancing the existing literature on digital transformation and environmental sustainability as it offers empirical evidence regarding the connection between digital technology implementation and the decrease in negative environmental impact. With growing threats to the environment, the incorporation of the digital world in attaining sustainable development is going to gain more significance in the industries. The investments in new digital monitoring solutions and the advocacy of digital innovation can enhance the performance of industries in terms of environmental performance and sustainable operational efficiency and economic competitiveness.

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