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Emerging underwater survey technologies: A review and future outlook

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Abstract

Emerging underwater survey technologies are revolutionizing the way we explore and understand the underwater world. This review examines the latest advancements in underwater survey equipment, highlighting their operational benefits and potential areas for future development. Recent developments in underwater survey technologies have led to significant improvements in accuracy, efficiency, and data quality. Advanced sonar systems, such as multibeam and sidescan sonars, provide high-resolution images of the seafloor, allowing for detailed mapping of underwater features. Autonomous underwater vehicles (AUVs) equipped with sophisticated sensors and cameras enable precise data collection in challenging environments, such as deep-sea areas or complex underwater structures. The operational benefits of these technologies are vast. They allow for faster surveying, reduced costs, and improved safety for personnel. Additionally, the high-quality data obtained from these surveys can lead to better decision-making in various industries, including offshore energy, marine research, and underwater archaeology. Looking ahead, the future of underwater survey technologies is promising. There is a growing interest in developing integrated systems that combine multiple sensors and data processing capabilities to provide a more comprehensive view of underwater environments. Artificial intelligence and machine learning algorithms are also being increasingly utilized to analyze large datasets and extract valuable insights. However, several challenges remain, such as the need for better underwater communication systems, improved battery life for autonomous vehicles, and enhanced data processing capabilities. Addressing these challenges will be crucial for the continued advancement of underwater survey technologies. In conclusion, the latest advancements in underwater survey technologies offer exciting opportunities for enhancing our understanding of the underwater world. By leveraging these technologies and addressing key challenges, we can unlock new possibilities for underwater exploration and research.

Keywords: Future Outlook; Underwater; Technologies; Survey; Emerging

1. Introduction

The exploration of the underwater world has always presented unique challenges due to the inherent difficulties of conducting surveys in aquatic environments (Biu, et. al., 2024, Eboigbe, et. al., 2023). However, recent advancements in underwater survey technologies have significantly improved our ability to explore and understand the depths of our oceans, lakes, and rivers (Chemisky, et. al., 2021, Mohsan, et. al., 2022). This review aims to analyze the latest advancements in underwater survey equipment, including their operational benefits and potential areas for future development.

Underwater survey technologies encompass a wide range of equipment and techniques used to map and explore underwater environments (Sodiya, et. al., 2024, Sonko, et. al., 2024). These technologies include advanced sonar systems, autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and specialized cameras and sensors. Each of these tools plays a crucial role in helping researchers, scientists, and engineers study and document

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underwater ecosystems, map the ocean floor, and assess underwater structures (Atadoga, et. al., 2024, Dada, et. al., 2024).

The importance of advancements in underwater survey equipment cannot be overstated. These advancements not only improve our understanding of the underwater world but also have practical applications in various industries. For example, in offshore energy exploration, accurate underwater surveys are essential for locating and assessing potential oil and gas reserves (Adekanmbi, et. al., 2024, Nwokediegwu, et. al., 2024). In marine biology, underwater surveys help researchers study marine life and ecosystems, leading to conservation efforts and the protection of marine biodiversity.

This review will analyze the latest advancements in underwater survey equipment, focusing on their operational benefits and potential areas for future development. By examining the latest technologies and their applications, we can gain insights into how these advancements are shaping the future of underwater exploration and research.

Advancements in underwater survey technologies have not only expanded our knowledge of the underwater world but also revolutionized industries such as offshore energy, marine research, and underwater archaeology (Adeleke, et. al., 2024, Etukudoh, et. al., 2024). These technologies have enabled us to conduct detailed surveys and mapping of underwater environments with unprecedented accuracy and efficiency. The operational benefits of these advancements are far-reaching, leading to cost savings, improved safety, and enhanced environmental protection measures.

Despite these advancements, there are still areas for improvement and further development in underwater survey equipment (Ayorinde, et. al., 2024, Hamdan, et. al., 2024). This review will explore the latest advancements in underwater survey technologies, including their operational benefits and potential areas for future development. By analyzing these advancements, we can gain a deeper understanding of the current state of underwater survey technologies and identify opportunities for future innovation.

2. Advanced Sonar Systems

Advanced sonar systems are at the forefront of emerging underwater survey technologies, offering significant advancements in underwater mapping and exploration (Dada, et. al., 2024, Ebirim, et. al., 2024). This review examines two key types of sonar systems - multibeam sonar and sidescan sonar - analyzing their operational benefits and potential areas for future development.

Multibeam sonar systems have revolutionized underwater surveying with their ability to generate detailed, high-resolution maps of the seafloor (Adekanmbi, et. al., 2024, Obiuto, et. al., 2024). These systems emit multiple sonar beams simultaneously, allowing for rapid and accurate mapping of large areas. The operational benefits of multibeam sonar. Multibeam sonar systems can generate detailed 3D maps of the seafloor, providing valuable information for offshore infrastructure development, environmental monitoring, and marine research.

The ability to map large areas quickly and accurately reduces surveying time and costs, making multibeam sonar an attractive option for industries such as offshore oil and gas exploration, underwater archaeology, and marine resource management (Aderibigbe, et. al., 2023, Nwokediegwu, et. al., 2024). Applications of multibeam sonar in underwater surveying are vast and varied, including: Multibeam sonar is used to map the seafloor and identify potential drilling sites, helping to reduce exploration risks and optimize resource extraction. Multibeam sonar can be used to map underwater habitats, providing valuable information for conservation efforts and ecosystem management.

Sidescan sonar systems are another essential tool in underwater surveying, offering detailed imaging of the seafloor and underwater structures (Ohalete, et. al., 2023, Oke, et. al., 2024). Unlike multibeam sonar, which provides depth information, sidescan sonar generates detailed images of the seafloor's surface (Al-Hamad, et. al., 2023, Ogedengbe, et. al., 2023). Sidescan sonar systems can capture detailed images of underwater features, including shipwrecks, pipelines, and geological formations, aiding in archaeological surveys and infrastructure inspections. Sidescan sonar can be deployed from surface vessels or towed behind boats, making it a flexible tool for a wide range of underwater surveying applications (Sonko, et. al., 2024, Umoga, et. al., 2024).

Sidescan sonar is used to locate and map shipwrecks, providing valuable insights into maritime history and archaeology. Sidescan sonar can be used to inspect underwater pipelines and cables for damage or leaks, ensuring the integrity of critical infrastructure (Ani, et. al., 2024, Ibekwe, et. al., 2024). In conclusion, multibeam and sidescan sonar systems are integral components of advanced underwater survey technologies, offering enhanced mapping capabilities and operational efficiencies. Future developments in these technologies are likely to focus on improving resolution, increasing mapping speeds, and enhancing data processing capabilities, further advancing our ability to explore and understand the underwater world (Nwokediegwu, et. al., 2024, Obaigbena, et. al., 2024).

Despite its many benefits, multibeam sonar technology continues to evolve, with ongoing research and development aimed at further improving its capabilities (Sodiya, et. al., 2024, Uwaoma, et. al., 2024). Researchers are working on enhancing the resolution of multibeam sonar systems to provide even more detailed maps of the seafloor (Alahira, et. al., 2024, Etukudoh, et. al., 2024). This could be achieved through advancements in sensor technology and signal processing algorithms. There is a growing interest in developing real-time data processing capabilities for multibeam sonar systems. This would allow surveyors to obtain immediate feedback on survey results, enabling faster decision-making and more efficient survey operations (Obiuto, et. al., 2024, Ohalete, et. al., 2024). Future multibeam sonar systems may be integrated with other sensors, such as cameras and magnetometers, to provide a more comprehensive view of underwater environments. This integrated approach could improve the accuracy and reliability of survey data.

Sidescan sonar technology is also undergoing continuous development, with researchers exploring new ways to improve its performance and capabilities (Olu-lawal, et. al., 2024, Umoga, et. al., 2024). Researchers are working on developing new imaging techniques for sidescan sonar systems to improve image quality and resolution (Adeleke, et. al., 2024, Ibeh, et. al., 2024). This could involve advancements in signal processing algorithms and sensor technology. There is growing interest in developing autonomous sidescan sonar systems that can be deployed and operated without human intervention (Nwokediegwu, et. al., 2024, Ogunkeyede, et. al., 2023). This would enable more efficient and cost-effective survey operations, particularly in remote or hazardous environments. Like multibeam sonar, future sidescan sonar systems may be integrated with other sensors to enhance their capabilities. For example, integrating sidescan sonar with bathymetric sensors could provide a more complete picture of underwater topography. In conclusion, multibeam and sidescan sonar systems are key components of advanced underwater survey technologies, offering a range of operational benefits and applications. Continued research and development in these areas are likely to lead to further advancements, improving our ability to explore and understand the underwater world (Obiuto, et. al., 2024, Olajiga, et. al., 2024).

3. Autonomous Underwater Vehicles (AUVs)

Autonomous Underwater Vehicles (AUVs) are revolutionizing underwater surveying and exploration by offering a range of advanced sensor capabilities and operational benefits (Adekanmbi, et. al., 2024, Nwokediegwu, et. al., 2024). This article explores the sensor capabilities of AUVs, including imaging sensors and sonar systems, as well as their operational benefits, such as efficiency in data collection and safety advantages. AUVs are equipped with various imaging sensors, such as cameras and optical scanners, which allow them to capture high-resolution images of the underwater environment. These imaging sensors can provide detailed visual information about underwater structures, marine life, and other features.

AUVs are also equipped with sonar systems, which use sound waves to map the seafloor and detect underwater objects (Abatan, et. al., 2024, Ebirim, et. al., 2024). There are several types of sonar systems used in AUVs, including side-scan sonar and multibeam sonar, which provide detailed images of the seafloor and underwater structures. AUVs are capable of collecting large amounts of data in a short amount of time, making them highly efficient for underwater surveying and exploration. Their autonomous nature allows them to operate for extended periods without human intervention, further increasing their efficiency.

AUVs offer significant safety advantages over manned submersibles and remotely operated vehicles (ROVs). Since they operate autonomously, there is no need for direct human involvement in underwater operations, reducing the risk to human life. Additionally, AUVs can operate in hazardous or hard-to-reach environments, making them ideal for tasks that would be dangerous for humans (Atadoga, et. al., 2024, Ilojianya, et. al., 2024). In conclusion, AUVs are a vital tool in underwater surveying and exploration, offering advanced sensor capabilities and operational benefits. Their ability to collect high-quality data efficiently and safely makes them invaluable for a wide range of applications, from marine research to offshore oil and gas exploration. As technology continues to advance, AUVs are likely to play an even greater role in underwater exploration, expanding our understanding of the underwater world.

AUVs are used extensively in marine research to study oceanography, marine biology, and underwater geology. Their ability to collect data in remote and inaccessible areas makes them invaluable for studying marine ecosystems and underwater phenomena (Afolabi, et. al., 2023, Hamdan, et. al., 2024). AUVs are used for environmental monitoring, including mapping and monitoring of coral reefs, seagrass beds, and other sensitive marine habitats. They can also be used to monitor water quality and detect pollution. In the offshore industry, AUVs are used for a variety of applications, including pipeline and cable inspections, seabed mapping for oil and gas exploration, and offshore infrastructure inspections. Their ability to operate autonomously and collect high-quality data makes them ideal for these tasks (Sodiya, et. al., 2024, Usman, et. al., 2024).

AUVs are used by military and defense agencies for tasks such as mine countermeasures, underwater surveillance, and reconnaissance (Nwokediegwu, et. al., 2024, Ohalete, et. al., 2023). Their ability to operate autonomously and covertly makes them valuable for military applications. Future AUVs are likely to be equipped with more advanced sensor technology, including improved imaging sensors and more sophisticated sonar systems (Aderibigbe, et. al., 2023, Majemite, et. al., 2024). This will allow them to collect even more detailed and accurate data. Future AUVs are expected to become more autonomous, with the ability to make decisions and adapt to changing conditions without human intervention. This will further increase their efficiency and effectiveness in underwater operations.

Future AUVs may be integrated with other technologies, such as artificial intelligence and machine learning, to enhance their capabilities (Adeleke, et. al., 2024, Obaigbena, et. al., 2024). This could include the ability to analyze data in real-time and make decisions based on that analysis. In conclusion, AUVs are a versatile and valuable tool in underwater surveying and exploration, offering advanced sensor capabilities, operational benefits, and a wide range of applications. As technology continues to advance, AUVs are likely to become even more capable and play an increasingly important role in our understanding of the underwater world.

4. Integrated Survey Systems

Integrated survey systems are at the forefront of emerging underwater survey technologies, offering a comprehensive approach to underwater mapping and exploration (Atadoga, et. al., 2024, Dada, et. al., 2024). This review examines the latest advancements in integrated systems, analyzing their operational benefits and potential areas for future development. Integrated survey systems combine multiple sensors and technologies into a single platform, allowing for more comprehensive and efficient data collection. These systems typically include a combination of imaging sensors, such as cameras and sonar systems, as well as navigation and positioning systems (Etukudoh, et. al., 2024, Nwokediegwu, et. al., 2024). By integrating these sensors, integrated survey systems can provide a more detailed and accurate picture of the underwater environment.

By combining multiple sensors, integrated survey systems can provide more accurate and reliable data, leading to better decision-making in underwater operations. Integrated survey systems can streamline data collection processes, reducing the time and resources required for underwater surveys (Ayorinde, et. al., 2024, Obiuto, et. al., 2024). Integrated systems can collect a wide range of data, including bathymetric data, imagery, and environmental data, providing a more complete picture of the underwater environment.

Future integrated survey systems are likely to feature even more advanced sensor integration, combining a wider range of sensors and technologies to provide more comprehensive data collection (Hamdan, et. al., 2024, Ibekwe, et. al., 2024). Future systems may focus on improving data processing capabilities, including real-time data analysis and automated data interpretation, to further enhance efficiency and accuracy. There is growing interest in developing integrated survey systems that can operate autonomously, without the need for human intervention. This would enable more efficient and cost-effective underwater surveys.

In conclusion, integrated survey systems represent a significant advancement in underwater survey technologies, offering enhanced data collection capabilities and operational benefits (Nwokediegwu, et. al., 2024, Olajiga, et. al., 2024). Continued research and development in this area are likely to lead to further advancements, improving our ability to explore and understand the underwater world. Integrated survey systems rely on advanced data fusion techniques to combine data from multiple sensors and sources (Dada, et. al., 2024, Majemite, et. al., 2024, Sodiya, et. al., 2024). These techniques involve algorithms that can integrate data in real-time, taking into account the different characteristics and uncertainties of each sensor. By fusing data from multiple sensors, integrated survey systems can provide a more accurate and reliable picture of the underwater environment.

Future developments in integrated survey systems may involve the integration of multimodal sensors, which can provide a more comprehensive view of the underwater environment. For example, systems that combine imaging sensors with chemical or biological sensors could provide valuable information about underwater ecosystems and habitats (Ebirim, et. al., 2024, Ohalete, et. al., 2024). As technology advances, integrated survey systems are likely to become smaller, lighter, and more portable. This would make them easier to deploy and operate, especially in remote or hard-to-reach areas. Miniaturization could also lead to the development of autonomous underwater vehicles (AUVs) that are equipped with integrated survey systems, further enhancing their capabilities.

Integrated survey systems may incorporate real-time data transmission capabilities, allowing data to be transmitted to the surface or to a control center in real-time (Obiuto, et. al., 2024, Okoli, et. al., 2024). This would enable researchers and operators to monitor survey progress and make decisions based on up-to-date information, improving the efficiency and effectiveness of underwater surveys (Etukudoh, et. al., 2024, Olajiga, et. al., 2024). In conclusion, integrated survey systems are a key area of advancement in underwater survey technologies, offering enhanced data collection capabilities and operational benefits. Continued research and development in this field are likely to lead to further advancements, improving our ability to explore and understand the underwater world.

5. Artificial Intelligence and Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) are playing an increasingly important role in underwater surveying, offering advanced capabilities for data analysis, interpretation, and decision-making (Alahira, et. al., 2024, Dada, et. al., 2024). This article explores the role of AI and ML in underwater surveying, their applications, and future prospects.

AI and ML algorithms can process large volumes of data collected by underwater survey equipment, such as sonar systems and imaging sensors, more efficiently than traditional methods. This allows for faster data analysis and interpretation (Adeoye, et. al., 2024, Nwokediegwu, et. al., 2024). AI and ML algorithms can analyze images captured by underwater cameras and sensors to identify objects and features of interest, such as marine life, underwater structures, and geological formations. This helps researchers and operators to better understand the underwater environment.

AI and ML algorithms can be used to develop autonomous underwater vehicles (AUVs) that can navigate underwater environments and conduct surveys without human intervention. These algorithms enable AUVs to make real-time decisions based on environmental data and sensor inputs (Aderibigbe, et. al., 2023, Etukudoh, et. al., 2024). AI and ML algorithms can detect and classify objects in underwater images, such as shipwrecks, pipelines, and marine life, providing valuable information for underwater surveys and research. AI and ML algorithms can be used to plan optimal paths for AUVs to navigate underwater environments, avoiding obstacles and maximizing survey coverage.

AI and ML algorithms can integrate data from multiple sensors and sources to create comprehensive maps and models of underwater environments, improving the accuracy and reliability of survey data (Adeleke, et. al., 2024, Ohalete, 2022). AI and ML algorithms are expected to continue to improve data analysis capabilities, enabling researchers and operators to extract more insights from underwater survey data. AI and ML algorithms will enable AUVs to operate more autonomously and make more sophisticated decisions based on environmental data, leading to more efficient and effective underwater surveys.

AI and ML algorithms are likely to be integrated with other technologies, such as advanced sensors and communication systems, to further enhance underwater survey capabilities (Nwokediegwu, et. al., 2024, Olu-lawal, et. al., 2024). In conclusion, AI and ML are driving significant advancements in underwater surveying, offering new possibilities for data analysis, interpretation, and autonomous operation (Ebirim, et. al., 2024, Ibekwe, et. al., 2024). Continued research and development in this field are expected to lead to further improvements in underwater survey technologies.

AI and ML algorithms can interpret complex data patterns in underwater environments, such as underwater topography, marine life distribution, and geological features. By analyzing these patterns, researchers can gain deeper insights into the underwater ecosystem (Atadoga, et. al., 2024, Ohalete, et. al., 2023). AI and ML can be used to create predictive models for underwater environments, helping to forecast changes in marine habitats, water quality, and underwater infrastructure. These models can assist in decision-making for conservation efforts and resource management.

AI and ML technologies can enhance the efficiency and cost-effectiveness of underwater surveys by automating repetitive tasks, reducing human error, and optimizing survey routes (Nwokediegwu, et. al., 2024, Sodiya, et. al., 2024). This can lead to significant time and cost savings in underwater exploration and research. AI and ML algorithms can enable real-time monitoring of underwater environments, allowing for immediate responses to changes or anomalies. This capability is particularly valuable for environmental monitoring, disaster response, and underwater infrastructure maintenance.

Future developments in AI and ML for underwater surveying may include the integration of advanced sensor technologies, such as hyperspectral imaging and acoustic sensors, to further enhance data collection and analysis capabilities (Abatan, et. al., 2024, Sonko, et. al., 2024). Additionally, advancements in AI and ML algorithms may lead to the development of more autonomous and intelligent underwater vehicles for surveying and exploration. In conclusion, AI and ML technologies are revolutionizing underwater surveying by enhancing data analysis, interpretation, and decision-making capabilities (Ugwuanyi, et. al., 2024, Usman, et. al., 2024). Continued research and innovation in this field are expected to drive further advancements in underwater survey technologies, enabling a deeper understanding of the underwater world and its ecosystems.

6. Challenges and Future Directions

Underwater survey technologies have made significant advancements in recent years, offering improved capabilities for mapping and exploring the underwater world. However, several challenges remain that hinder the full realization of their potential (Ebirim, et. al., 2024, Obiuto, et. al., 2024). This article examines the key challenges facing emerging underwater survey technologies, strategies for overcoming these challenges, and future directions for development.

The underwater environment is often challenging to access, requiring specialized equipment and vehicles (Etukudoh, et. al., 2024, Nwokediegwu, et. al., 2024). This can make it difficult to conduct surveys in remote or deep-sea locations. Collecting accurate and reliable data in underwater environments can be challenging due to factors such as water turbidity, acoustic noise, and signal attenuation. Additionally, interpreting the collected data to extract meaningful information can be complex and time-consuming. Underwater survey equipment and operations can be costly, requiring significant financial resources. This can limit the scope and frequency of surveys, particularly in resource-constrained environments.

The development of advanced sensor technologies, such as high-resolution imaging sensors and multi-beam sonar systems, can improve data collection and accuracy in underwater surveys (Ohalete, et. al., 2024, Sodiya, et. al., 2024). The use of autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs) can improve accessibility and reduce the need for human intervention in underwater surveys. These systems can also be equipped with AI and ML algorithms for real-time data processing and analysis. Collaboration between industry, academia, and government agencies can help pool resources and expertise to overcome challenges in underwater survey technologies (Sonko, et. al., 2024, Uwaoma, et. al., 2024). This can lead to the development of innovative solutions and best practices.

The integration of AI and ML algorithms into underwater survey equipment can enhance data processing and analysis capabilities, leading to more efficient and accurate surveys (Nwokediegwu, et. al., 2024, Olajiga, et. al., 2024). Future underwater survey equipment is likely to become smaller, lighter, and more portable, allowing for easier deployment and operation in remote or challenging environments. There is growing interest in using underwater survey technologies for environmental monitoring, such as tracking changes in marine habitats and monitoring pollution levels. Future developments in this area are expected to focus on improving the accuracy and scope of environmental monitoring efforts (Ray, 2023, Sodiya, et. al., 2024).

while underwater survey technologies face several challenges, there are promising strategies and future directions that can help overcome these challenges and further advance the field (Ibekwe, et. al., 2024, Obaigbena, et. al., 2024). Continued research and development in underwater survey technologies are essential for enhancing our understanding of the underwater world and its ecosystems. Underwater survey equipment must withstand extreme temperatures and pressures, which can affect their performance and longevity. Exposure to saltwater can cause corrosion and fouling on underwater survey equipment, leading to degradation of performance and reliability. Marine organisms can attach to underwater survey equipment, affecting its accuracy and efficiency (Sodiya, et. al., 2024, Uwaoma, et. al., 2024). Developing anti-fouling coatings and cleaning mechanisms can help mitigate this issue.

Using corrosion-resistant materials for underwater survey equipment can help improve durability and performance (Abatan, et. al., 2024, Ebirim, et. al., 2024). Applying protective coatings to equipment can help prevent corrosion and fouling, extending the lifespan of the equipment. Regular inspection and maintenance of underwater survey equipment can help identify and address issues before they become major problems. Future underwater survey equipment may be designed with sustainability in mind, using eco-friendly materials and energy-efficient components (Sonko, et. al., 2024, Ugwuanyi, et. al., 2024). Advances in sensor technologies can enable underwater survey equipment to monitor environmental parameters, such as water quality and marine life, providing valuable data for conservation efforts.

Autonomous underwater vehicles (AUVs) equipped with maintenance capabilities, such as cleaning mechanisms, could help address environmental challenges associated with fouling and corrosion (Nwokediegwu, et. al., 2024, Obiuto, et. al., 2024). In conclusion, addressing environmental challenges and considering sustainability in the design and operation of underwater survey technologies are crucial for the future of underwater exploration and research (Alahira, et. al., 2024, Etukudoh, et. al., 2024). Continued research and development in this area are essential for improving the reliability, efficiency, and sustainability of underwater survey equipment.

7. Conclusion

In conclusion, the review of emerging underwater survey technologies highlights significant advancements that are transforming the field of underwater exploration and research. Key advancements include the development of advanced sonar systems, autonomous underwater vehicles (AUVs), integrated survey systems, and the integration of artificial intelligence (AI) and machine learning (ML). These advancements offer operational benefits such as improved data quality, efficiency, and safety in underwater surveys.

The future of underwater survey technologies looks promising, with ongoing research and development focusing on addressing key challenges and exploring new possibilities. Strategies for overcoming challenges include the development of advanced sensor technologies, autonomous systems, and collaboration between industry, academia, and government agencies. Future directions for development include the integration of AI and ML, miniaturization and portability of equipment, and environmental monitoring.

To further advance underwater survey technologies, continued research and development are recommended. This includes exploring new sensor technologies, enhancing autonomous capabilities, and improving environmental monitoring capabilities. Collaboration between researchers, industry partners, and government agencies will be key to driving innovation and ensuring the sustainable development of underwater survey technologies. In conclusion, the future of underwater survey technologies is promising, with advancements in equipment and techniques enhancing our ability to explore and understand the underwater world. Continued research and development will be essential to unlock the full potential of underwater survey technologies and ensure their effective and sustainable use in the future.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Abatan, A., Adeyinka, M. A., Sodiya, E. O., Jacks, B. S., Ugwuanyi, E. D., Daraojimba, O. H., & Lottu, O. A. (2024). The role of IT in sustainable environmental management: A global perspective review. *International Journal of Science and Research Archive*, *11*(1), 1874-1886.

[2] Abatan, A., Jacks, B. S., Ugwuanyi, E. D., Nwokediegwu, Z. Q. S., Obaigbena, A., Daraojimba, A. I., & Lottu, O. A. (2024). THE ROLE OF ENVIRONMENTAL HEALTH AND SAFETY PRACTICES IN THE AUTOMOTIVE MANUFACTURING INDUSTRY. *Engineering Science & Technology Journal*, *5*(2), 531-542.

[3] Abatan, A., Obaigbena, A., Ugwuanyi, E. D., Jacks, B. S., Umoga, U. J., Daraojimba, O. H., & Lottu, O. A. (2024). INTEGRATED SIMULATION FRAMEWORKS FOR ASSESSING THE ENVIRONMENTAL IMPACT OF CHEMICAL POLLUTANTS IN AQUATIC SYSTEMS. *Engineering Science & Technology Journal*, *5*(2), 543-554.

[4] Adekanmbi, A. O., Ani, E. C., Abatan, A., Izuka, U., Ninduwezuor-Ehiobu, N., & Obaigbena, A. (2024). Assessing the environmental and health impacts of plastic production and recycling. *World Journal of Biology Pharmacy and Health Sciences*, *17*(2), 232-241.

[5] Adekanmbi, A. O., Ninduwezuor-Ehiobu, N., Abatan, A., Izuka, U., Ani, E. C., & Obaigbena, A. (2024). Implementing health and safety standards in Offshore Wind Farms.

[6] Adekanmbi, A. O., Ninduwezuor-Ehiobu, N., Izuka, U., Abatan, A., Ani, E. C., & Obaigbena, A. (2024). Assessing the environmental health and safety risks of solar energy production. *World Journal of Biology Pharmacy and Health Sciences*, *17*(2), 225-231.

[7] Adeleke, A. K., Montero, D. J. P., Ani, E. C., Olu-lawal, K. A., & Olajiga, O. K. (2024). ADVANCES IN ULTRAPRECISION DIAMOND TURNING: TECHNIQUES, APPLICATIONS, AND FUTURE TRENDS. *Engineering Science & Technology Journal*, *5*(3), 740-749.

[8] Adeleke, A. K., Montero, D. J. P., Lottu, O. A., Ninduwezuor-Ehiobu, N., & Ani, E. C. (2024). 3D printing in aerospace and defense: A review of technological breakthroughs and applications.

[9] Adeleke, A. K., Montero, D. J. P., Olajiga, O. K., Ani, E. C., & Olu-lawal, K. A. (2024). Evaluating the impact of precision engineering education on industry standards and practices. *International Journal of Science and Research Archive*, *11*(1), 2336-2345.

[10] Adeleke, A. K., Olu-lawal, K. A., Montero, D. J. P., Olajiga, O. K., & Ani, E. C. (2024). The intersection of mechatronics and precision engineering: Synergies and future directions. *International Journal of Science and Research Archive*, *11*(1), 2356-2364.

[11] Adeoye, O. B., Chigozie, A. E., Nwakamma, N. E., Danny, J. M., Usman, F. O., & Olu-Lawal, K. A. (2024). A conceptual framework for data-driven sustainable finance in green energy transition.

[12] Aderibigbe, A. O., Ani, E. C., Ohenhen, P. E., Ohalete, N. C., & Daraojimba, D. O. (2023). Enhancing energy efficiency with ai: a review of machine learning models in electricity demand forecasting. *Engineering Science & Technology Journal*, *4*(6), 341-356.

[13] Aderibigbe, A. O., Ohenhen, P. E., Nwaobia, N. K., Gidiagba, J. O., & Ani, E. C. (2023). Advanced sensing techniques in electro-mechanical systems: surveying the rise of smart sensors and their implications for system robustness. *Engineering Science & Technology Journal*, *4*(6), 323-340.

[14] Aderibigbe, A. O., Ohenhen, P. E., Nwaobia, N. K., Gidiagba, J. O., & Ani, E. C. (2023). ARTIFICIAL INTELLIGENCE IN DEVELOPING COUNTRIES: BRIDGING THE GAP BETWEEN POTENTIAL AND IMPLEMENTATION. *Computer Science & IT Research Journal*, *4*(3), 185-199.

[15] Afolabi, J. O. A., Olatoye, F. O., Eboigbe, E. O., Abdul, A. A., & Daraojimba, H. O. (2023). REVOLUTIONIZING RETAIL: HR TACTICS FOR IMPROVED EMPLOYEE AND CUSTOMER ENGAGEMENT. *International Journal of Applied Research in Social Sciences*, *5*(10), 487-514.

[16] Alahira, J., Ani, E. C., Ninduwezuor-Ehiobu, N., Olu-lawal, K. A., & Ejibe, I. (2024). THE ROLE OF FINE ARTS IN PROMOTING SUSTAINABILITY WITHIN INDUSTRIAL AND GRAPHIC DESIGN: A CROSS-DISCIPLINARY APPROACH. *International Journal of Applied Research in Social Sciences*, *6*(3), 326-336.

[17] Alahira, J., Ninduwezuor-Ehiobu, N., Olu-lawal, K. A., Ani, E. C., & Ejibe, I. (2024). ECO-INNOVATIVE GRAPHIC DESIGN PRACTICES: LEVERAGING FINE ARTS TO ENHANCE SUSTAINABILITY IN INDUSTRIAL DESIGN. *Engineering Science & Technology Journal*, *5*(3), 783-793.

[18] Alahira, J., Nwokediegwu, Z. Q. S., Obaigbena, A., Ugwuanyi, E. D., & Daraojimba, O. D. (2024). Integrating sustainability into graphic and industrial design education: A fine arts perspective. *International Journal of Science and Research Archive*, *11*(1), 2206-2213.

[19] Al-Hamad, N., Oladapo, O. J., Afolabi, J. O. A., & Olatundun, F. (2023). Enhancing educational outcomes through strategic human resources (hr) initiatives: Emphasizing faculty development, diversity, and leadership excellence. *Education*, 1-11.

[20] Ani, E. C., Olajiga, O. K., Sikhakane, Z. Q., & Olatunde, T. M. (2024). RENEWABLE ENERGY INTEGRATION FOR WATER SUPPLY: A COMPARATIVE REVIEW OF AFRICAN AND US INITIATIVES. *Engineering Science & Technology Journal*, *5*(3), 1086-1096.

[21] Atadoga, A., Sodiya, E. O., Umoga, U. J., & Amoo, O. O. (2024). A comprehensive review of machine learning's role in enhancing network security and threat detection. *World Journal of Advanced Research and Reviews*, *21*(2), 877-886.

[22] Atadoga, A., Umoga, U. J., Lottu, O. A., & Sodiy, E. O. (2024). Tools, techniques, and trends in sustainable software engineering: A critical review of current practices and future directions. *World Journal of Advanced Engineering Technology and Sciences*, *11*(1), 231-239.

[23] Atadoga, A., Umoga, U. J., Lottu, O. A., & Sodiya, E. O. (2024). Advancing green computing: Practices, strategies, and impact in modern software development for environmental sustainability. *World Journal of Advanced Engineering Technology and Sciences*, *11*(1), 220-230.

[24] Atadoga, A., Umoga, U. J., Lottu, O. A., & Sodiya, E. O. (2024). Evaluating the impact of cloud computing on accounting firms: A review of efficiency, scalability, and data security. *Global Journal of Engineering and Technology Advances*, *18*(02), 065-074.

[25] Ayorinde, O. B., Daudu, C. D., Etukudoh, E. A., Adefemi, A., Adekoya, O. O., & Okoli, C. E. (2024). CLIMATE RISK ASSESSMENT IN PETROLEUM OPERATIONS: A REVIEW OF CSR PRACTICES FOR SUSTAINABLE RESILIENCE IN THE UNITED STATES AND AFRICA. *Engineering Science & Technology Journal*, *5*(2), 385-401.

[26] Ayorinde, O. B., Etukudoh, E. A., Nwokediegwu, Z. Q. S., Ibekwe, K. I., Umoh, A. A., & Hamdan, A. (2024). Renewable energy projects in Africa: A review of climate finance strategies. *International Journal of Science and Research Archive*, *11*(1), 923-932.

[27] Biu, P. W., Nwokediegwu, Z. Q. S., Daraojimba, O. H., Majemite, M. T., & Obaigben, A. (2024). Advancements in geo-data analytics: Implications for US energy policy and business investment. *World Journal of Advanced Research and Reviews*, *21*(1), 1422-1439.

[28] Chemisky, B., Menna, F., Nocerino, E., & Drap, P. (2021). Underwater survey for oil and gas industry: A review of close range optical methods. *Remote Sensing*, *13*(14), 2789.

[29] Dada, M. A., Majemite, M. T., Obaigbena, A., Daraojimba, O. H., Oliha, J. S., & Nwokediegwu, Z. Q. S. (2024). Review of smart water management: IoT and AI in water and wastewater treatment. *World Journal of Advanced Research and Reviews*, *21*(1), 1373-1382.

[30] Dada, M. A., Majemite, M. T., Obaigbena, A., Oliha, J. S., & Biu, P. W. (2024). Zero-waste initiatives and circular economy in the US: A review: Exploring strategies, outcomes, and challenges in moving towards a more sustainable consumption model.

[31] Dada, M. A., Obaigbena, A., Majemite, M. T., Oliha, J. S., & Biu, P. W. (2024). INNOVATIVE APPROACHES TO WASTE RESOURCE MANAGEMENT: IMPLICATIONS FOR ENVIRONMENTAL SUSTAINABILITY AND POLICY. *Engineering Science & Technology Journal*, *5*(1), 115-127.

[32] Dada, M. A., Oliha, J. S., Majemite, M. T., Obaigbena, A., & Biu, P. W. (2024). A REVIEW OF PREDICTIVE ANALYTICS IN THE EXPLORATION AND MANAGEMENT OF US GEOLOGICAL RESOURCES. *Engineering Science & Technology Journal*, *5*(2), 313-337.

[33] Dada, M. A., Oliha, J. S., Majemite, M. T., Obaigbena, A., Nwokediegwu, Z. Q. S., & Daraojimba, O. H. (2024). Review of nanotechnology in water treatment: Adoption in the USA and Prospects for Africa. *World Journal of Advanced Research and Reviews*, *21*(1), 1412-1421.

[34] Ebirim, W., Montero, D. J. P., Ani, E. C., Ninduwezuor-Ehiobu, N., Usman, F. O., & Olu-lawal, K. A. (2024). THE ROLE OF AGILE PROJECT MANAGEMENT IN DRIVING INNOVATION IN ENERGY-EFFICIENT HVAC SOLUTIONS. *Engineering Science & Technology Journal*, *5*(3), 662-673.

[35] Ebirim, W., Ninduwezuor-Ehiobu, N., Usman, F. O., Olu-lawal, K. A., Ani, E. C., & Montero, D. J. P. (2024). PROJECT MANAGEMENT STRATEGIES FOR ACCELERATING ENERGY EFFICIENCY IN HVAC SYSTEMS AMIDST CLIMATE CHANGE. *International Journal of Management & Entrepreneurship Research*, *6*(3), 512-525.

[36] Ebirim, W., Olu-lawal, K. A., Ninduwezuor-Ehiobu, N., Montero, D. J. P., Usman, F. O., & Ani, E. C. (2024). LEVERAGING PROJECT MANAGEMENT TOOLS FOR ENERGY EFFICIENCY IN HVAC OPERATIONS: A PATH TO CLIMATE RESILIENCE. *Engineering Science & Technology Journal*, *5*(3), 653-661.

[37] Ebirim, W., Usman, F. O., Montero, D. J. P., Ninduwezuor-Ehiobu, N., Ani, E. C., & Olu-lawal, K. A. (2024). ASSESSING THE IMPACT OF CLIMATE CHANGE ON HVAC SYSTEM DESIGN AND PROJECT MANAGEMENT. *International Journal of Applied Research in Social Sciences*, *6*(3), 173-184.

[38] Ebirim, W., Usman, F. O., Montero, D. J. P., Ninduwezuor-Ehiobu, N., Olu-lawal, K. A., & Ani, E. C. (2024). Project management strategies for implementing energy-efficient cooling solutions in emerging data center markets. *World Journal of Advanced Research and Reviews*, *21*(2), 1802-1809.

[39] Ebirim, W., Usman, F. O., Olu-lawal, K. A., Ninduwesuor-Ehiobu, N., Ani, E. C., & Montero, D. J. P. (2024). Optimizing energy efficiency in data center cooling towers through predictive maintenance and project management. *World Journal of Advanced Research and Reviews*, *21*(2), 1782-1790.

[40] Eboigbe, E. O., Farayola, O. A., Olatoye, F. O., Nnabugwu, O. C., & Daraojimba, C. (2023). Business intelligence transformation through AI and data analytics. *Engineering Science & Technology Journal*, *4*(5), 285-307.

[41] Etukudoh, E. A. (2024). THEORETICAL FRAMEWORKS OF ECOPFM PREDICTIVE MAINTENANCE (ECOPFM) PREDICTIVE MAINTENANCE SYSTEM. *Engineering Science & Technology Journal*, *5*(3), 913-923.

[42] Etukudoh, E. A., Adefemi, A., Ilojianya, V. I., Umoh, A. A., Ibekwe, K. I., & Nwokediegwu, Z. Q. S. (2024). A Review of sustainable transportation solutions: Innovations, challenges, and future directions. *World Journal of Advanced Research and Reviews*, *21*(1), 1440-1452.

[43] Etukudoh, E. A., Fabuyide, A., Ibekwe, K. I., Sonko, S., & Ilojianya, V. I. (2024). ELECTRICAL ENGINEERING IN RENEWABLE ENERGY SYSTEMS: A REVIEW OF DESIGN AND INTEGRATION CHALLENGES. *Engineering Science & Technology Journal*, *5*(1), 231-244.

[44] Etukudoh, E. A., Hamdan, A., Ilojianya, V. I., Daudu, C. D., & Fabuyide, A. (2024). ELECTRIC VEHICLE CHARGING INFRASTRUCTURE: A COMPARATIVE REVIEW IN CANADA, USA, AND AFRICA. *Engineering Science & Technology Journal*, *5*(1), 245-258.

[45] Etukudoh, E. A., Ilojianya, V. I., Ayorinde, O. B., Daudu, C. D., Adefemi, A., & Hamdan, A. (2024). Review of climate change impact on water availability in the USA and Africa. *International Journal of Science and Research Archive*, *11*(1), 942-951.

[46] Etukudoh, E. A., Nwokediegwu, Z. Q. S., Umoh, A. A., Ibekwe, K. I., Ilojianya, V. I., & Adefemi, A. (2024). Solar power integration in Urban areas: A review of design innovations and efficiency enhancements. *World Journal of Advanced Research and Reviews*, *21*(1), 1383-1394.

[47] Etukudoh, E. A., Usman, F. O., Ilojianya, V. I., Daudu, C. D., Umoh, A. A., & Ibekwe, K. I. (2024). Mechanical engineering in automotive innovation: A review of electric vehicles and future trends. *International Journal of Science and Research Archive*, *11*(1), 579-589.

[48] Hamdan, A., Daudu, C. D., Fabuyide, A., Etukudoh, E. A., & Sonko, S. (2024). Next-generation batteries and US energy storage: A comprehensive review: Scrutinizing advancements in battery technology, their role in renewable energy, and grid stability.

[49] Hamdan, A., Ibekwe, K. I., Etukudoh, E. A., Umoh, A. A., & Ilojianya, V. I. (2024). AI and machine learning in climate change research: A review of predictive models and environmental impact.

[50] Hamdan, A., Ibekwe, K. I., Ilojianya, V. I., Sonko, S., & Etukudoh, E. A. (2024). AI in renewable energy: A review of predictive maintenance and energy optimization. *International Journal of Science and Research Archive*, *11*(1), 718-729.

[51] Ibeh, C. V., Awonuga, K. F., Okoli, U. I., Ike, C. U., Ndubuisi, N. L., & Obaigbena, A. (2024). A REVIEW OF AGILE METHODOLOGIES IN PRODUCT LIFECYCLE MANAGEMENT: BRIDGING THEORY AND PRACTICE FOR ENHANCED DIGITAL TECHNOLOGY INTEGRATION. *Engineering Science & Technology Journal*, *5*(2), 448-459.

[52] Ibekwe, K. I., Etukudoh, E. A., Adefemi, A., Nwokediegwu, Z. Q. S., Umoh, A. A., & Usman, F. O. (2024). Software tools in energy management: utilization and impact in Canada, USA, and Africa. *International Journal of Science and Research Archive*, *11*(1), 570-578.

[53] Ibekwe, K. I., Etukudoh, E. A., Nwokediegwu, Z. Q. S., Umoh, A. A., Adefemi, A., & Ilojianya, V. I. (2024). ENERGY SECURITY IN THE GLOBAL CONTEXT: A COMPREHENSIVE REVIEW OF GEOPOLITICAL DYNAMICS AND POLICIES. *Engineering Science & Technology Journal*, *5*(1), 152-168.

[54] Ibekwe, K. I., Fabuyide, A., Hamdan, A., Ilojianya, V. I., & Etukudoh, E. A. (2024). Energy efficiency through variable frequency drives: industrial applications in Canada, USA, and Africa. *International Journal of Science and Research Archive*, *11*(1), 730-736.

[55] Ibekwe, K. I., Umoh, A. A., Nwokediegwu, Z. Q. S., Etukudoh, E. A., Ilojianya, V. I., & Adefemi, A. (2024). ENERGY EFFICIENCY IN INDUSTRIAL SECTORS: A REVIEW OF TECHNOLOGIES AND POLICY MEASURES. *Engineering Science & Technology Journal*, *5*(1), 169-184.

[56] Ilojianya, V. I., Umoh, A. A., Etukudoh, E. A., Ibekwe, K. I., & Hamdan, A. (2024). Renewable energy technologies in engineering: A review of current developments and future prospects. *International Journal of Science and Research Archive*, *11*(1), 952-964.

[57] Majemite, M. T., Dada, M. A., Obaigbena, A., Oliha, J. S., Biu, P. W., & Henry, D. O. (2024). A review of data analytics techniques in enhancing environmental risk assessments in the US Geology Sector.

[58] Majemite, M. T., Obaigbena, A., Dada, M. A., Oliha, J. S., & Biu, P. W. (2024). EVALUATING THE ROLE OF BIG DATA IN US DISASTER MITIGATION AND RESPONSE: A GEOLOGICAL AND BUSINESS PERSPECTIVE. *Engineering Science & Technology Journal*, *5*(2), 338-357.

[59] Mohsan, S. A. H., Mazinani, A., Othman, N. Q. H., & Amjad, H. (2022). Towards the internet of underwater things: A comprehensive survey. *Earth Science Informatics*, *15*(2), 735-764.

[60] Nwokediegwu, Z. Q. S., Adefemi, A., Ayorinde, O. B., Ilojianya, V. I., & Etukudoh, E. A. (2024). REVIEW OF WATER POLICY AND MANAGEMENT: COMPARING THE USA AND AFRICA. *Engineering Science & Technology Journal*, *5*(2), 402-411.

[61] Nwokediegwu, Z. Q. S., Dada, M. A., Daraojimba, O. H., Oliha, J. S., Majemite, M. T., & Obaigbena, A. (2024). A review of advanced wastewater treatment technologies: USA vs. Africa.

[62] Nwokediegwu, Z. Q. S., Daraojimba, O. H., Oliha, J. S., Obaigbena, A., Dada, M. A., & Majemite, M. T. (2024). Review of emerging contaminants in water: USA and African perspectives.

[63] Nwokediegwu, Z. Q. S., Ibekwe, K. I., Ilojianya, V. I., Etukudoh, E. A., & Ayorinde, O. B. (2024). RENEWABLE ENERGY TECHNOLOGIES IN ENGINEERING: A REVIEW OF CURRENT DEVELOPMENTS AND FUTURE PROSPECTS. *Engineering Science & Technology Journal*, *5*(2), 367-384.

[64] Nwokediegwu, Z. Q. S., Ilojianya, V. I., Ibekwe, K. I., Adefemi, A., Etukudoh, E. A., & Umoh, A. A. (2024). ADVANCED MATERIALS FOR SUSTAINABLE CONSTRUCTION: A REVIEW OF INNOVATIONS AND ENVIRONMENTAL BENEFITS. *Engineering Science & Technology Journal*, *5*(1), 201-218.

[65] Nwokediegwu, Z. Q. S., Majemite, M. T., Obaigbena, A., Oliha, J. S., Dada, M. A., & Daraojimba, O. H. (2024). Review of water reuse and recycling: USA successes vs. African challenges.

[66] Nwokediegwu, Z. Q. S., Obaigbena, A., Majemite, M. T., Daraojimba, O. H., Oliha, J. S., & Dada, M. A. (2024). Review of innovative approaches in water infrastructure: Sustainable desalination and public-private partnerships.

[67] Nwokediegwu, Z. Q. S., Ugwuanyi, E. D., Dada, M. A., Majemite, M. T., & Obaigbena, A. (2024). AI-DRIVEN WASTE MANAGEMENT SYSTEMS: A COMPARATIVE REVIEW OF INNOVATIONS IN THE USA AND AFRICA. *Engineering Science & Technology Journal*, *5*(2), 507-516.

[68] Nwokediegwu, Z. Q. S., Ugwuanyi, E. D., Dada, M. A., Majemite, M. T., & Obaigbena, A. (2024). URBAN WATER MANAGEMENT: A REVIEW OF SUSTAINABLE PRACTICES IN THE USA. *Engineering Science & Technology Journal*, *5*(2), 517-530.

[69] Nwokediegwu, Z. Q. S., Ugwuanyi, E. D., Dada, M. A., Majemite, M. T., & Obaigbena, A. (2024). Water-energy nexus: A review of policy and practice in Africa and the USA. *Magna Scientia Advanced Research and Reviews*, *10*(1), 286-293.

[70] Obaigbena, A., Biu, P. W., Majemite, M. T., Oliha, J. S., & Dada, M. A. (2024). THE INTERSECTION OF GEOLOGY AND BUSINESS SUSTAINABILITY: A DATA-DRIVEN REVIEW OF US CORPORATE ENVIRONMENTAL STRATEGIES. *Engineering Science & Technology Journal*, *5*(2), 288-312.

[71] Obaigbena, A., Lottu, O. A., Ugwuanyi, E. D., Jacks, B. S., Sodiya, E. O., & Daraojimba, O. D. (2024). AI and human-robot interaction: A review of recent advances and challenges. *GSC Advanced Research and Reviews*, *18*(2), 321-330.

[72] Obiuto, N. C., Ebirim, W., Ninduwezuor-Ehiobu, N., Ani, E. C., Olu-lawal, K. A., & Ugwuanyi, E. D. (2024). INTEGRATING SUSTAINABILITY INTO HVAC PROJECT MANAGEMENT: CHALLENGES AND OPPORTUNITIES. *Engineering Science & Technology Journal*, *5*(3), 873-887.

[73] Obiuto, N. C., Ninduwezuor-Ehiobu, N., Ani, E. C., & Andrew, K. Implementing Circular Economy Principles to Enhance Safety and Environmental Sustainability in Manufacturing.

[74] Obiuto, N. C., Ninduwezuor-Ehiobu, N., Ani, E. C., Olu-lawal, K. A., & Ugwuanyi, E. D. (2024). SIMULATION-DRIVEN STRATEGIES FOR ENHANCING WATER TREATMENT PROCESSES IN CHEMICAL ENGINEERING: ADDRESSING ENVIRONMENTAL CHALLENGES. *Engineering Science & Technology Journal*, *5*(3), 854-872.

[75] Obiuto, N. C., Olu-lawal, K. A., Ani, E. C., & Ninduwezuor-Ehiobu, N. (2024). Chemical management in electronics manufacturing: Protecting worker health and the environment. *World Journal of Advanced Research and Reviews*, *21*(3), 010-018.

[76] Obiuto, N. C., Olu-lawal, K. A., Ani, E. C., Ugwuanyi, E. D., & Ninduwezuor-Ehiobu, N. (2024). Chemical engineering and the circular water economy: Simulations for sustainable water management in environmental systems. *World Journal of Advanced Research and Reviews*, *21*(3), 001-009.

[77] Obiuto, N. C., Ugwuanyi, E. D., Ninduwezuor-Ehiobu, N., Ani, E. C., & Olu-lawal, K. A. (2024). Advancing wastewater treatment technologies: The role of chemical engineering simulations in environmental sustainability. *World Journal of Advanced Research and Reviews*, *21*(3), 019-031.

[78] Ogedengbe, D. E., James, O. O., Afolabi, J. O. A., Olatoye, F. O., & Eboigbe, E. O. (2023). Human Resources In The Era of The Fourth Industrial Revolution (4ir): Strategies and Innovations In The Global South. *Engineering Science & Technology Journal*, *4*(5), 308-322.

[79] Ogunkeyede, O. Y., Olatunde, T. M., Ekundayo, O. T., Adenle, J. G., & Komolafe, T. A. (2023). DEVELOPMENT OF A PC SOFTWARE BASED WIRELESS WEATHER MONITORING SYSTEM FOR DATA ACQUISITION.

[80] Ohalete, N. C. (2022). A Study of Online Auction Processes using Functional Data Analysis. Bowling Green State University.

[81] Ohalete, N. C., Aderibigbe, A. O., Ani, E. C., & Efosa, P. (2023). AI-driven solutions in renewable energy: A review of data science applications in solar and wind energy optimization. *World Journal of Advanced Research and Reviews*, *20*(3), 401-417.

[82] Ohalete, N. C., Aderibigbe, A. O., Ani, E. C., Ohenhen, P. E., & Akinoso, A. (2023). Advancements in predictive maintenance in the oil and gas industry: A review of AI and data science applications.

[83] Ohalete, N. C., Aderibigbe, A. O., Ani, E. C., Ohenhen, P. E., & Akinoso, A. E. (2023). DATA SCIENCE IN ENERGY CONSUMPTION ANALYSIS: A REVIEW OF AI TECHNIQUES IN IDENTIFYING PATTERNS AND EFFICIENCY OPPORTUNITIES. *Engineering Science & Technology Journal*, *4*(6), 357-380.

[84] Ohalete, N. C., Aderibigbe, A. O., Ani, E. C., Ohenhen, P. E., & Akinoso, A. (2023). Advancements in predictive maintenance in the oil and gas industry: A review of AI and data science applications.

[85] Ohalete, N. C., Ayo-Farai, O., Olorunsogo, T. O., Maduka, P., & Olorunsogo, T. (2024). AI-DRIVEN ENVIRONMENTAL HEALTH DISEASE MODELING: A REVIEW OF TECHNIQUES AND THEIR IMPACT ON PUBLIC HEALTH IN THE USA AND AFRICAN CONTEXTS. *International Medical Science Research Journal*, *4*(1), 51-73.

[86] Ohalete, N. C., Ayo-Farai, O., Onwumere, C., & Paschal, C. (2024). Navier-stokes equations in biomedical engineering: A critical review of their use in medical device development in the USA and Africa.

[87] Ohalete, N. C., Ayo-Farai, O., Onwumere, C., Maduka, C. P., & Olorunsogo, T. O. (2024). Functional data analysis in health informatics: A comparative review of developments and applications in the USA and Africa.

[88] Oke, A. E., Aliu, J., Ebekozien, A., Akinpelu, T. M., Olatunde, T. M., & Ogunsanya, O. A. (2024). Strategic drivers for the deployment of energy economics principles in the developing construction industry: A Nigerian perspective. *Environmental Progress & Sustainable Energy*, e14351.

[89] Okoli, C. E., Adekoya, O. O., Ilojianya, V. I., Ayorinde, O. B., Etukudoh, E. A., & Hamdan, A. (2024). Sustainable energy transition strategies: A comparative review of CSR and corporate advising in the petroleum industry in the United States and Africa. *International Journal of Science and Research Archive*, *11*(1), 933-941.

[90] Olajiga, O. K., Ani, E. C., Olu-lawal, K. A., Montero, D. J. P., & Adeleke, A. K. (2024). INTELLIGENT MONITORING SYSTEMS IN MANUFACTURING: CURRENT STATE AND FUTURE PERSPECTIVES. *Engineering Science & Technology Journal*, *5*(3), 750-759.

[91] Olajiga, O. K., Ani, E. C., Sikhakane, Z. Q., & Olatunde, T. M. (2024). A COMPREHENSIVE REVIEW OF ENERGY-EFFICIENT LIGHTING TECHNOLOGIES AND TRENDS. *Engineering Science & Technology Journal*, *5*(3), 1097-1111.

[92] Olajiga, O. K., Ani, E. C., Sikhakane, Z. Q., & Olatunde, T. M. (2024). ASSESSING THE POTENTIAL OF ENERGY STORAGE SOLUTIONS FOR GRID EFFICIENCY: A REVIEW. *Engineering Science & Technology Journal*, *5*(3), 1112-1124.

[93] Olu-lawal, K. A., Olajiga, O. K., Adeleke, A. K., Ani, E. C., & Montero, D. J. P. (2024). INNOVATIVE MATERIAL PROCESSING TECHNIQUES IN PRECISION MANUFACTURING: A REVIEW. *International Journal of Applied Research in Social Sciences*, *6*(3), 279-291.

[94] Olu-lawal, K. A., Olajiga, O. K., Ani, E. C., Adeleke, A. K., & Montero, D. J. P. (2024). THE ROLE OF PRECISION METROLOGY IN ENHANCING MANUFACTURING QUALITY: A COMPREHENSIVE REVIEW. *Engineering Science & Technology Journal*, *5*(3), 728-739.

[95] Omole, F. O., Olajiga, O. K., & Olatunde, T. M. (2024). CHALLENGES AND SUCCESSES IN RURAL ELECTRIFICATION: A REVIEW OF GLOBAL POLICIES AND CASE STUDIES. *Engineering Science & Technology Journal*, *5*(3), 1031-1046.

[96] Omole, F. O., Olajiga, O. K., & Olatunde, T. M. (2024). HYBRID POWER SYSTEMS IN MINING: REVIEW OF IMPLEMENTATIONS IN CANADA, USA, AND AFRICA. *Engineering Science & Technology Journal*, *5*(3), 1008-1019.

[97] Omole, F. O., Olajiga, O. K., & Olatunde, T. M. (2024). SUSTAINABLE URBAN DESIGN: A REVIEW OF ECO-FRIENDLY BUILDING PRACTICES AND COMMUNITY IMPACT. *Engineering Science & Technology Journal*, *5*(3), 1020-1030.

[98] Ray, P. P. (2023). ChatGPT: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope. *Internet of Things and Cyber-Physical Systems*.

[99] Sodiya, E. O., Amoo, O. O., Umoga, U. J., & Atadoga, A. (2024). AI-driven personalization in web content delivery: A comparative study of user engagement in the USA and the UK. *World Journal of Advanced Research and Reviews*, *21*(2), 887-902.

[100] Sodiya, E. O., Jacks, B. S., Ugwuanyi, E. D., Adeyinka, M. A., Umoga, U. J., Daraojimba, A. I., & Lottu, O. A. (2024). Reviewing the role of AI and machine learning in supply chain analytics. *GSC Advanced Research and Reviews*, *18*(2), 312-320.

[101] Sodiya, E. O., Umoga, U. J., Amoo, O. O., & Atadoga, A. (2024). AI-driven warehouse automation: A comprehensive review of systems. *GSC Advanced Research and Reviews*, *18*(2), 272-282.

[102] Sodiya, E. O., Umoga, U. J., Amoo, O. O., & Atadoga, A. (2024). Quantum computing and its potential impact on US cybersecurity: A review: Scrutinizing the challenges and opportunities presented by quantum technologies in safeguarding digital assets. *Global Journal of Engineering and Technology Advances*, *18*(02), 049-064.

[103] Sodiya, E. O., Umoga, U. J., Obaigbena, A., Jacks, B. S., Ugwuanyi, E. D., Daraojimba, A. I., & Lottu, O. A. (2024). Current state and prospects of edge computing within the Internet of Things (IoT) ecosystem. *International Journal of Science and Research Archive*, *11*(1), 1863-1873.

[104] Sonko, S., Daudu, C. D., Osasona, F., Monebi, A. M., Etukudoh, E. A., & Atadoga, A. (2024). The evolution of embedded systems in automotive industry: A global review. *World Journal of Advanced Research and Reviews*, *21*(2), 096-104.

[105] Sonko, S., Etukudoh, E. A., Ibekwe, K. I., Ilojianya, V. I., & Daudu, C. D. (2024). A comprehensive review of embedded systems in autonomous vehicles: Trends, challenges, and future directions.

[106] Sonko, S., Fabuyide, A., Ibekwe, K. I., Etukudoh, E. A., & Ilojianya, V. I. (2024). Neural interfaces and human-computer interaction: A US review: Delving into the developments, ethical considerations, and future prospects of brain-computer interfaces. *International Journal of Science and Research Archive*, *11*(1), 702-717.

[107] Sonko, S., Ibekwe, K. I., Ilojianya, V. I., Etukudoh, E. A., & Fabuyide, A. (2024). QUANTUM CRYPTOGRAPHY AND US DIGITAL SECURITY: A COMPREHENSIVE REVIEW: INVESTIGATING THE POTENTIAL OF QUANTUM TECHNOLOGIES IN CREATING UNBREAKABLE ENCRYPTION AND THEIR FUTURE IN NATIONAL SECURITY. *Computer Science & IT Research Journal*, *5*(2), 390-414.

[108] Sonko, S., Monebi, A. M., Etukudoh, E. A., Osasona, F., Atadoga, A., & Daudu, C. D. (2024). REVIEWING THE IMPACT OF EMBEDDED SYSTEMS IN MEDICAL DEVICES IN THE USA. *International Medical Science Research Journal*, *4*(2), 158-169.

[109] Ugwuanyi, E. D., Nwokediegwu, Z. Q. S., Dada, M. A., Majemite, M. T., & Obaigbena, A. (2024). Reviewing the potential of anaerobic membrane bioreactors in wastewater treatment. *International Journal of Science and Research Archive*, *11*(1), 1831-1842.

[110] Ugwuanyi, E. D., Nwokediegwu, Z. Q. S., Dada, M. A., Majemite, M. T., & Obaigbena, A. (2024). Advancing wastewater treatment technologies: The role of chemical engineering simulations in environmental sustainability. *International Journal of Science and Research Archive*, *11*(1), 1818-1830.

[111] Umoga, U. J., Sodiya, E. O., Amoo, O. O., & Atadoga, A. (2024). A critical review of emerging cybersecurity threats in financial technologies. *International Journal of Science and Research Archive*, *11*(1), 1810-1817.

[112] Umoga, U. J., Sodiya, E. O., Ugwuanyi, E. D., Jacks, B. S., Lottu, O. A., Daraojimba, O. D., & Obaigbena, A. (2024). Exploring the potential of AI-driven optimization in enhancing network performance and efficiency. *Magna Scientia Advanced Research and Reviews*, *10*(1), 368-378.

[113] Umoh, A. A., Adefemi, A., Ibewe, K. I., Etukudoh, E. A., Ilojianya, V. I., & Nwokediegwu, Z. Q. S. (2024). Green architecture and energy efficiency: a review of innovative design and construction techniques. *Engineering Science & Technology Journal*, *5*(1), 185-200.

[114] Usman, F. O., Ani, E. C., Ebirim, W., Montero, D. J. P., Olu-lawal, K. A., & Ninduwezuor-Ehiobu, N. (2024). INTEGRATING RENEWABLE ENERGY SOLUTIONS IN THE MANUFACTURING INDUSTRY: CHALLENGES AND OPPORTUNITIES: A REVIEW. *Engineering Science & Technology Journal*, *5*(3), 674-703.

[115] Usman, F. O., Eyo-Udo, N. L., Etukudoh, E. A., Odonkor, B., Ibeh, C. V., & Adegbola, A. (2024). A CRITICAL REVIEW OF AI-DRIVEN STRATEGIES FOR ENTREPRENEURIAL SUCCESS. *International Journal of Management & Entrepreneurship Research*, *6*(1), 200-215.

[116] Uwaoma, P. U., Eboigbe, E. O., Eyo-Udo, N. L., Daraojimba, D. O., & Kaggwa, S. (2023). Space commerce and its economic implications for the US: A review: Delving into the commercialization of space, its prospects, challenges, and potential impact on the US economy. *World Journal of Advanced Research and Reviews*, *20*(3), 952-965.

[117] Uwaoma, P. U., Eboigbe, E. O., Eyo-Udo, N. L., Ijiga, A. C., Kaggwa, S., & Daraojimba, A. I. (2023). Mixed reality in US retail: A review: Analyzing the immersive shopping experiences, customer engagement, and potential economic implications. *World Journal of Advanced Research and Reviews*, *20*(3), 966-981.

[118] Uwaoma, P. U., Eboigbe, E. O., Eyo-Udo, N. L., Ijiga, A. C., Kaggwa, S., & Daraojimba, D. O. (2023). THE FOURTH INDUSTRIAL REVOLUTION AND ITS IMPACT ON AGRICULTURAL ECONOMICS: PREPARING FOR THE FUTURE IN DEVELOPING COUNTRIES. *International Journal of Advanced Economics*, *5*(9), 258-270.

[119] Uwaoma, P. U., Eboigbe, E. O., Kaggwa, S., Akinwolemiwa, D. I., & Eloghosa, S. O. (2023). ECOLOGICAL ECONOMICS IN THE AGE OF 4IR: SPOTLIGHT ON SUSTAINABILITY INITIATIVES IN THE GLOBAL SOUTH. *International Journal of Advanced Economics*, *5*(9), 271-284.