

IOT-BASED LEGAL POLICY IN CO₂ EMISSION SAFETY CONTROL TO SUPPORT GREEN TRANSPORTATION

Trias Hernanda¹, Soma Setiawan Ponco Nugroho¹, Tazkiya Isya Izzati¹, Firda Khoirun Nisa¹,
Widya Cholid Wahyudin¹, Eko Nuriyatman²

¹ Muhammadiyah University of Kudus, Jawa Tengah, Indonesia

² Jambi University, Jambi, Indonesia

Corresponding author email: triashernanda@umkudus.ac.id

Article Info

Received: Jun 03, 2025

Revised: Aug 08, 2025

Accepted: Sep 25, 2025

OnlineVersion: Oct 12, 2025

Abstract

Religious tourism areas in Kudus Regency, Indonesia particularly the Tomb of Sunan Muria and the Tomb of Sunan Kudus are visited by thousands of pilgrims every day, creating significant transportation flows and contributing to air pollution. This study aims to evaluate the environmental quality and legal implications of air pollution caused by transportation activities in these two religious tourism sites. Using an empirical legal research design with a qualitative approach, primary data were collected through interviews and supported by results from Internet of Things (IoT) based air pollution detection devices that measured oxygen (O₂), temperature, and carbon dioxide (CO₂) levels. The results were then analyzed using the mean formula. The findings reveal differing environmental conditions between the two locations. The highland area of Sunan Muria generally shows air quality levels within Indonesia's permissible standards, while the urban environment of Sunan Kudus records higher CO₂ and temperature levels exceeding the national air pollution threshold. These findings indicate that urban religious tourism faces more severe environmental challenges. The discussion emphasizes the urgent need for legal and policy reform toward a green transportation framework in Kudus Regency. This research contributes to demonstrating how IoT-based monitoring can serve as an empirical foundation for evidence-based environmental policymaking in Indonesia's tourism sector.

Keywords: Green Transportation, IoT, Legal Policy.



© 2025 by the author(s)

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

INTRODUCTION

The issues of climate change, global warming and sustainable development are interdimensional. In fact, the discussion of these three issues continues to develop into an annual agenda that is always emphasized to all countries contributing to the problem of climate change (Wibisana, 2017; Yamasaki, 2022) an One of the countries in the center of the spotlight in the study of climate change is Indonesia (Raihan et al., 2023; Ramadhan et al., 2024). In response to the spotlight, Indonesia continues to create

or ratify programs related to climate change issues. In President Prabowo's vision and mission, it is written that Indonesia supports a sustainable energy transition (Sekarintias et al., 2023; Propana Okionomus Ali, 2024)

This vision and mission continues to provide space and legal policy support for the industrialization of electric cars and electric motors in Indonesia. Another goal is to phase out fossil fuel production and leave large reserves untouched, which is important for achieving the Paris Agreement targets (van Asselt, 2021). However, the policy has become an internal debate between the government and the public, as the government is perceived as closing one eye but leaving the other open. The parallels are that the government is opening up energy downstream in the field of VE (vehicle electric) but not limiting fossil-fueled motorcycles or cars (Sandifer et al., 2015; Ariyani et al., 2025). One aspect of the problem that arises and cannot support the president's vision and mission towards downstream energy is the tourism sector. The sector provides support to the problem of carbon emission contributors. Because in Indonesia some tourism does not have access to carbon emission reduction (Andrasari et al., 2024). The concept of sustainable tourism has not been implemented properly and the support of the concept of green transportation in several tourism sites is a study that has not been seriously touched (Pan et al., 2018).

The concept of green transportation is important because it can support the reduction of carbon emissions arising from the excessive use of fossil fuels by vehicles (Setiyo, 2023). On the other hand, the concept of green transportation is part of the 2030 SDGs, which Indonesia has ratified. In this study, the research team will conduct empirical research on one of the religious tourism sites in Kudus Regency. The name of religious tourism in Kudus Regency is Sunan Muria Tourism and Sunan Kudus Tourism (Suprapti, 2014). The reason for choosing these tourist attractions is the large number of tourists who visit and also the use of motorbikes in supporting the course of tourism, besides that the majority of the people of Kudus Regency use fossil fuel motorbikes and cars in carrying out their daily routines. Many studies have examined air pollution in urban areas, but few have explored its legal implications within the context of religious tourism zones. For instance, Abderahman Rejeb conducted research on the Internet of Things (IoT) that primarily focused on major cities (Rejeb et al., 2022), while Matteo Palmaccio applied IoT in his study related to corporate business models (Palmaccio, 2021). In contrast, in Indonesia, there has been no specific scholarly work discussing the use of IoT within religious tourism areas. Moreover, when synchronized with the concept of green transportation, previous research on this topic is also lacking. Therefore, this study on the legal policy of IoT in supporting the green transportation concept in Kudus Regency serves as a foundational work that can guide future research, both at the regional and national levels.

The Legal instruments that underlie sustainable tourism, green transportation and carbon emission reduction at the national level actually exist, but at the district level they do not yet exist, such as Kudus District, which still lacks regulations that have substance in supporting the concept of green transportation, sustainable tourism and even SDGs 2030. Therefore, the problems related to the increase in carbon emissions cannot be solved using laws or regulations. A legal or regulatory void results in government action becoming unbalanced and an imbalance is born in the realm of law enforcement (Mulwafu & Kamchedzera, 2024). The law will function if the rules and implementation go together. Law can also be used as social engineering in society when referring to the opinion of Roscoe Pound. On the other hand, the law also needs help in carrying out its role. In the Indonesian legal system, the determination of sanctions can be carried out when fulfilling the elements of proof and testimony. These obstacles can result in the fulfillment of the 17 Goals of the SDGs that have been implemented in Indonesia being inhibited.

Therefore, to support law enforcement that aims to carry out the government's vision-mission in reducing carbon emissions and implementing SDGs 2030 at the regional level, it is necessary to prove it by using a IoT (Internet of Things) tools that can detect the amount of carbon CO₂ produced by humans. The tool used is an air quality monitoring system made by the author's research team, the IoT tool can detect air quality from the elements of carbon and carbon dioxide. The purpose of this research is to show the state of air quality being faced by Kudus Regency in the religious tourism area and encourage the birth of a new policy to optimize the air quality produced by visitors to the tourist area who visit. It is expected that the data obtained and then analyzed will have an impact on further research to obtain the strength of the substance of the legal policy to be formed. Pemilihan metode IoT karena metode tersebut bisa menerjemahkan hasil data real dilapangan yang kemudian ditampilkan dengan bentuk data realtime (Rawat, et al., 2025)

RESEARCH METHOD

This research is an empirical legal study employing a qualitative approach, supported by air pollution data analyzed using the mean PM2.5 formula. The study integrates legal and environmental perspectives to examine the relationship between transportation activities and air quality in religious tourism areas of Kudus Regency. Primary data were collected through field observations and interviews with key stakeholders, including officials from the Department of Environment (PKPLH) and the Department of Culture and Tourism of Kudus Regency. Meanwhile, IoT-based air quality monitoring devices were installed at several points around the Tomb of Sunan Muria and the Tomb of Sunan Kudus to measure levels of oxygen (O₂), carbon dioxide (CO₂), and temperature. The collected data were then interpreted through qualitative analysis to identify legal gaps and policy implications concerning the implementation of green transportation and sustainable tourism frameworks in Kudus Regency

In order to strengthen this research, we will write down the location of the tourist areas that we studied, namely the Sunan Kudus Religious tourism area which is located at the coordinates of 6°48'12"S 110°49'59"E and the Sunan Muria tourist area which is located at the coordinates of 6°40' 3.51" Longitude: 110° 54' 34.37" E. the two tours are located far apart. Sunan Kudus Tourism is located at the point of location in the city center of Kudus Regency while Sunan Muria religious tourism is in the Muria mountain area, which is in the northern region of Kudus Regency. Meanwhile, Kudus Regency is a regency located in the northern region of Java Island Indonesia, which borders Demak Regency, Jepara Regency and Pati Regency (Sari & Mardiansjah, 2025). The reason the two religious tours were chosen as research material was because the two tours had the largest number of visitors, namely in 2024 the visitors who attended the sunan kudus tour amounted to 616077 people while Sunan Muria had 575629 visitors.

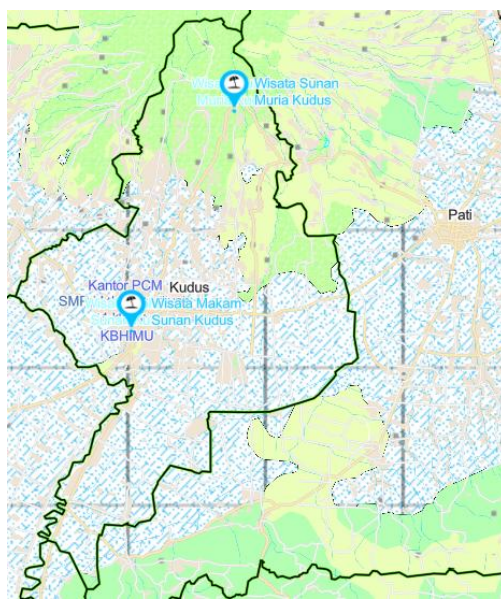


Figure 1. map of the location of the Sunan Kudus and Sunan Muria Religious tourism

Development of the Iot support system for Air Pollution Monitoring

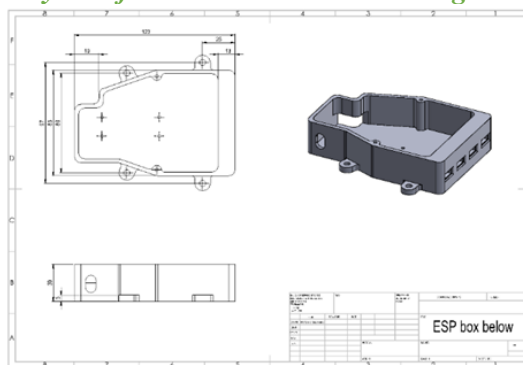


Figure 2. Protective box for monitoring air pollution

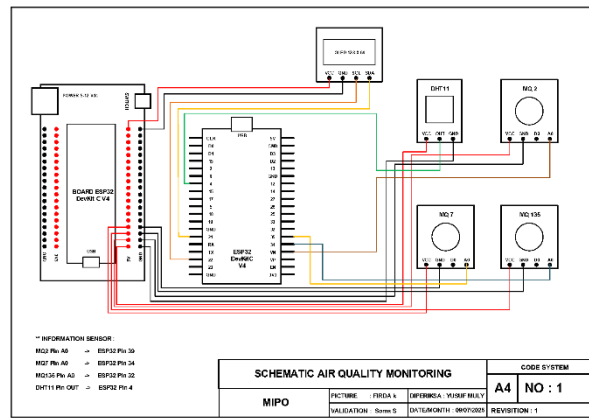


Figure 3. circuit of air pollution monitoring station

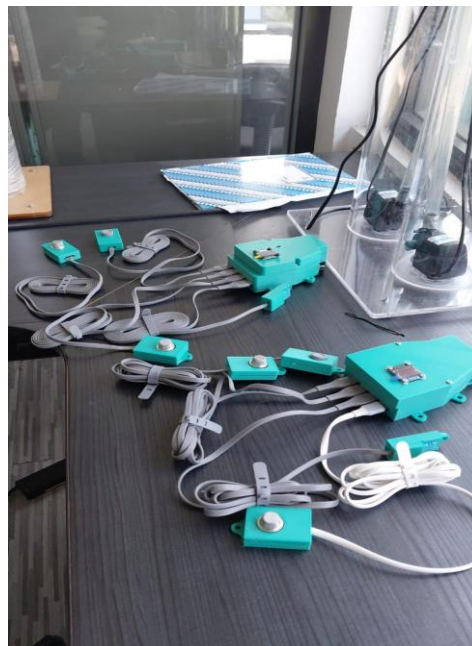


Figure 4. perfect view of the assembled air pollution sensor device

The design, fabrication, installation, and analysis structure of the IoT Air Quality Sensing Mode are described in this section. This model is planned to consist of a number of different air monitoring sensors and is assembled at the SNUMA Menara Manufacturing Laboratory. Furthermore, figure number 3 above is the detailed structure of the Air Pollution Monitoring device that explains the circuit structure and the sensors used are the MQ 7, MQ 136, MQ 2 and DHT 11 sensors. Figures number 2 and 4 above are the protective boxes of the IoT Air Pollution Monitoring device that are specially made using 3D printing tools. The installation of this device in the religious tourism area is only placed at several crucial points. These points are selected based on air humidity, hot temperatures and the number of vehicles gathered in the tourist area. After the device is installed, the device will be turned on and wait for the calibration process of the calculation sensor values that begin to calculate the temperature, CO and CO2 values that enter. The calculation values captured by the sensor will be sent in real-time to the appropriate server. Data collection was carried out for 30 minutes in 3 different places, namely tourist attractions, large vehicle parking areas and motorbike parking areas and was carried out at 09.00, 12.00 and 14.00.

RESULTS AND DISCUSSION

The table above is the average result taken from three different locations, because these religious tourist attractions have rules between the distance of tourist attractions and tourist parking locations that must have a long distance.

Table 1. The calculation value that appears from the IoT Sunan Kudus

No	Sunan Kudus Tourism	CO (Mean)	Co2 (Mean)	Temperature (Mean)
1	Location 1	177.54	70.89	45.97
2	Location 2	43.82	36.57	40.71
3	Location 3	40.30	29.08	37.88

Table 2. The calculation value that appears from the IoT Sunan Muria

No	Sunan Muria Tourism	CO (Mean)	Co2 (Mean)	Temperature (Mean)
1	Location 1	45.94	103.07	26.86
2	Location 2	34.32	83.45	29.01
3	Location 3	29.99	83.08	21.88

The table calculations above are taken from the formula, $Mean = \frac{\sum X_i}{n}$. The table above presents the results obtained from three different locations at each religious tourism site. The data shown represent the average values calculated using the following formula:

$$Mean = (\sum X_i) / n$$

Explanation:

X_i = the value of the i-th data point

n = the total number of data points

These averages illustrate specific environmental situations and conditions observed directly in the field. The findings will later be confirmed through interviews with relevant stakeholders, such as the Environmental Agency (PKPLH) and the Tourism Office. The results in the table also reflect the environmental conditions of religious tourism areas in Kudus Regency, which show two distinct patterns in their final outcomes. These differences are influenced by several factors, including humidity and environmental conditions affected by surrounding vegetation.

The results are indeed not significant, it appears that the arrival of visitors and also the air temperature that begins to rise during the day has an influence on the value of CO₂ and CO. then that can change the situation around. Religious tourism Sunan Kudus and Sunan Muria have a tendency to have abnormal air at certain times. But there is an interesting discovery, the discovery occurred in the area where the pick-up tour of Sunan Kudus. There is a large tree, where the tree becomes a shelter for everyone who visits and waits for the pick-up motorcycle. The tree is known to have an old age and has a good impact, especially on reducing air temperature and producing fresh air. When collecting data at the pick-up point, the data generated tends to slow down, tends to have a low increase value and does not exceed the limits set by the Indonesian government.

Meanwhile, in front of the religious tourism location of the Sunan Kudus tomb, it tends to experience a significant increase. Laying the tool starts at 10 am until 01.00 pm until 02.00 pm. The results obtained tend to exceed the average value set by the Government of Indonesia. And the increase in the value of temperature, CO and CO₂. These conditions are caused by the number of visitors who come, some smoking cigarettes, motorized vehicles that can drive in front of tourist sites and small food vendors who produce smoke in open locations. The location of Sunan Kudus religious tourism is indeed located in a densely populated settlement and so cannot be free from the activities of local residents, one of which is free from motorized vehicles and free from small food vendors that continue to grow. The next location is the parking lot of large vehicles such as buses and mini buses, the resulting temperature conditions tend not to experience a significant increase, but experience a slowdown in the increase of temperature, CO and CO₂. The location of the parking lot does have several large trees such as trembesi trees and mango trees. Based on the results of research in three different locations in the Sunan Kudus religious tourism area, it is found that the big role of trees planted around the research location has a big impact. The research results presented are the first to be conducted in Kudus Regency, and no previous studies have been carried out on this topic.

The attempt to plant trees around the parking area and pick up passengers for religious tourism is an initiative of the local government to support the concept of sustainable development. Indonesia has

indeed used the 2030 SDGs to serve as a policy footing at the central and regional levels (Odagiri et al., 2020; Herdiansyah & Majesty, 2024). One of the cities that is actively implementing the SDGs 2030 program is Kudus Regency, one of the programs that is intensively implemented is the climate village program (PROKLIM). This program is a government initiative under the Ministry of Environment and Forestry aimed at tackling the climate crisis and mitigating natural disasters (Sufri & Lassa, 2024). Unfortunately for tourist areas, a special policy has not been formed that leads to sustainable tourism in line with the 2030 SDGs (Hernanda et al., 2023).

According to the results of the calculations in the Sunan Muria tourism area, the values do not exceed the limits set by the Indonesian government, both the temperature value, oxygen value and the value of carbon dioxide produced. This condition is because the tourism site of Sunan Muria Kudus tends to be in the highlands and the resulting climate tends to be good. This is supported by the surrounding natural conditions that are still natural. The location of the Sunan Muria tourism area is located on the slopes of Mount Muria (Yoga & Hendri, 2023). The Muria mountain area is an area that will become a biosphere nature reserve area that will be designated by UNESCO. However based on the value obtained in the table above, it is caused by the condition of the number of tourists who tend to be stable, which is around 1000 who come every month. So that the cars and buses that come are also stable.

In addition to buses and cars are motorized vehicles whose job is to pick up passengers and then take them to the Sunan Muria cemetery complex. Every day the number of motorized vehicles entering the Sunan Muria cemetery area can reach 200-300 motorized vehicles every weekend. In our opinion, this is a large number. The observations from this study also emphasize the important role of trees in regulating air temperature and increasing oxygen levels around tourist sites. They further encourage a paradigm shift toward the formulation of green transportation policies, even if only at the regency level. The significance of this research for Kudus Regency lies in its potential to transform efforts in addressing climate change challenges, which are influenced by the lack of green transportation implementation—mainly due to limited community participation in environmental improvement initiatives. Nevertheless, the environmental stability of the Sunan Muria tourism area demonstrates that this site has great potential as an environmentally friendly and healthy religious tourism destination for visitors.

Technology-based legal reforms are not only relevant in the context of industry and urbanization (Atmaheni & Adiando, 2024), but also have high urgency in the tourism sector and green transportation sector. In the recent era, tourism has become one of the main destinations for people to end their daily routines and seek serenity. Various tourist destinations offer unique experiences, both natural and spiritual, including religious tourist destinations such as the Tomb of Sunan Kudus and the Tomb of Sunan Muria. Unfortunately, not all tourist areas are able to provide a clean and comfortable environment for visitors, this is because the tourism environment does not always have a point of view towards an environmentally friendly transportation. One of the main problems that arise is air pollution, especially those sourced from motorized vehicles that dominate access to tourist sites. Based on the results of the study, a significant difference was found between the two tourist areas. Sunan Kudus tourism area shows a higher level of air pollution, mainly due to the density of vehicles and the lack of green open spaces that function as air quality neutralizers. Meanwhile, Sunan Muria tourism area, although more stable in terms of air quality because it is located in a mountainous area, still has the potential to be threatened by pollution due to the growth in the number of tourists that is not supported by sustainable transportation management.

This condition indicates that the conventional approach to environmental management in tourist areas is inadequate. Air pollution control efforts require breakthroughs through the use of technology and environmental law reforms that support the digitization of the monitoring system. Technologies such as the Internet of Things (IoT), real-time vehicle emission monitoring systems, and sensor-based air quality mapping have the potential to support emission control policies in tourist areas tambah keunggulan IoT. However, the main obstacle in the implementation of technology to support green transportation is the absence of a specific and detailed legal framework to support its application in the tourism sector (Widyamurti, 2025). Current environmental policies are still dominated by an industrial approach, so the tourism sector, especially spiritual and religious-based tourism, has not received adequate regulatory attention. As well as support from other parties in developing a situation that supports the development of green transportation also does not have enough space (Tias, 2025).

From an intra-generational perspective, the urgency of this reform is relevant to the 2030 Sustainable Development Goals (SDGs) agenda, particularly Sustainable Cities and Settlements, which promotes inclusive, safe, resilient and sustainable cities and communities. Air quality and access to green

transportation are important indicators in these goals. In addition, Addressing Climate Change underscores the importance of rapid action to reduce greenhouse gas emissions and increase environmental resilience. Meanwhile, Health and Wellbeing is also relevant, as air pollution in tourist areas impacts not only on comfort, but also on the health of visitors and local residents.

The answer to this challenge is that a comprehensive legal reformulation is needed. First, legal regulations must be expanded to regulate the use of monitoring technology in tourist areas, including aspects of the legality of digital data and system interoperability between agencies. Second, integration of environmental data in the regional tourism management system is needed, which enables evidence-based planning and rapid response to potential pollution. Third, the implementation of Low Emission Zones in religious tourism areas is one of the strategic solutions, with the reduction of fossil fuel vehicles and the promotion of environmentally friendly vehicles such as electric cars and shuttle buses. In addition, environmental literacy and community participation must be strengthened. Public involvement in air quality reporting, utilization of green transportation, and compliance with clean area policies should be part of the tourism sustainability strategy (Rehman et al., 2025). Green transportation and green technology programs have been implemented by several advanced countries, such as China (Zhang et al., 2024; Wang et al., 2025).

A policy that integrates legal approaches, technology, and the principles of the 2030 SDGs, religious tourism areas such as the Tomb of Sunan Kudus and Sunan Muria can become a model destination that not only honors spiritual values, but also maintains environmental quality, supports public health, and encourages inclusive and technology-based sustainable development. In today's digital era, technology-based environmental law reform is an urgent need, especially in responding to the challenges of air pollution which are increasingly complex and spread across sectors. Internet of Things (IoT) technology is one of the strategic solutions that can be utilized in the process of monitoring, security, verification, and law enforcement at the regional level objectively and efficiently. IoT is not only a passive monitoring tool, but also has great potential to be used as "digital evidence" in the context of administrative law and environmental criminal law.

So far, law enforcement has often been limited by manual methods that are slow, expensive, and vulnerable to data manipulation. Although in several countries the use of technology such as collaboration between AI (Simmler & Canova, 2025) and law enforcement is already underway and collaboration with IoT (Grispos et al., 2024). In this context, IoT comes as a breakthrough that enables real-time and continuous emissions data collection. If sensor systems are installed on vehicles, industrial chimneys, or in densely populated areas, the resulting data can be sent directly to monitoring centers. If regulations give legal recognition to this digital data, the process of investigation and administrative sanctions can take place more quickly and accurately. Several regulations in Kudus Regency related to tourism and transportation still lack the substance that assesses real-time system data. In the Kudus Regency regional regulation number 5 of 2024 concerning the Empowerment of Tourism Villages, there is no mention of green transportation in tourist areas and regional regulation number 7 of 2020 concerning the Implementation of Road Traffic and Transportation also does not discuss in detail about green transportation.

However, acknowledgment of digital data will have no legal value without a strong regulatory umbrella. Therefore, legal reforms at the regional level must include updating regulations related to the validity of digital data, standard procedures for device calibration, information security, and cross-sector data governance. This strengthening is very important so that the IoT-based surveillance system is not only a technical tool, but also has legitimacy in the national legal system. Furthermore, the utilization of IoT as a control and law enforcement tool is also closely related to the achievement of the 2030 Sustainable Development Goals (SDGs) ratified by the Indonesian government. especially: First, SDG 13 (Addressing Climate Change): IoT technologies support climate change mitigation actions by providing precise data to monitor and control greenhouse gas emissions. Second, SDG 9 (Infrastructure, Innovation, and Industrialization): The use of IoT reflects the modernization of surveillance systems based on innovation and environmentally friendly technology.

Especially in the transportation sector, the use of IoT opens up opportunities for integration with green transportation, which is a transportation system that is environmentally friendly and has minimal emissions. One of the main sources of air pollution in religious tourism areas such as the Tomb of Sunan Kudus and the Tomb of Sunan Muria comes from fossilized-fuel motorized vehicles that are crowded on certain days (Hernanda et al., 2024). With IoT, air quality in these tourist access points can be monitored in real-time, so that it can be the basis for implementing green zone policies.

The implementation of green zones must be accompanied by the provision of green transportation, such as electric buses, renewable energy-based shuttle vehicles, or pedestrian and bicycle paths supported by adequate infrastructure. Data from IoT can help the government map the time and critical points of pollution, and evaluate the effectiveness of green transportation policies. On the other hand, legal reforms need to include supporting regulations that incentivize the use of low-emission vehicles as well as restrictions on conventional vehicles in religious tourist areas and major cities. As a first step, the Kudus District government can develop a pilot project on the integration of IoT and green transportation in major cities or the Sunan Muria and Sunan Kudus religious tourism areas on a priority list. This model project could involve collaboration between the central government, local governments, the private sector, and academia to design an integrated monitoring system, including an emissions dashboard that is transparent and open to the public. Furthermore, the evaluation results of the pilot project can serve as the basis for developing regional standards for the use of IoT in emissions monitoring, both in the transportation and industrial sectors. The integration of smart technology systems, green transportation, and progressive legal policies will be the main foundation in achieving the goal of effectively and equitably regulated green transportation.

The implementation of green transportation to support the transformation of religious tourism areas also requires the support of cross-stakeholder legal policies. For example, the development of an electric shuttle bus line from the city center to the religious tourism area requires support from the Department of Transportation and Information and the Department of Environment in one coherent policy platform. Without this coordination forum, sectorial approaches will continue to dominate, and the potential for integration between technology, law and ecology will be difficult to realize. Thus, the development of a cross-sector task force to formulate legal policies that support green transportation at the district level is not only relevant, but also urgent, given that the complexity of current environmental and transportation issues demands a collaborative and data-driven approach. Through this shared governance model, the region can strengthen its legal and technological capacity, and become a pioneer in realizing a green transportation system that is safe, orderly, and oriented towards environmental protection and public health.

CONCLUSION

Religious tourism is one of Indonesia's leading tourism sectors, with the tombs of Sunan Muria and Sunan Kudus in Kudus Regency serving as major destinations. Both sites contribute significantly to local economic development but also pose potential threats to air quality due to increased visitor activities. Since these environmental impacts are not easily detectable by human senses, technological monitoring through an Internet of Things (IoT) system is essential to record air pollution levels accurately. This study introduces the concept of IoT-based environmental governance in religious tourism zones, which integrates digital monitoring tools with policy formulation at the local level. The IoT system developed in this research provides empirical data that can guide the Kudus Regency government in formulating sustainable regulations and initiating the transition toward green transportation. The implications of this study extend beyond local governance: it demonstrates how IoT technology can strengthen evidence-based policymaking, promote public awareness, and support the national agenda of sustainable tourism aligned with the 2030 SDGs. Future research should explore policy frameworks that link IoT data utilization with community participation to ensure the long-term success of green transportation initiatives in religious tourism areas.

ACKNOWLEDGMENTS

The researcher would like to thank the Indonesian government and the Ministry of Higher Education for providing research funds under the Beginner Lecturer Research (PDP) Year 2025. In addition, the researcher would also like to thank the Kudus Regency Housing and Environment Office and the Kudus Regency Culture and Tourism Office for providing information through in-depth interviews.

AUTHOR CONTRIBUTIONS

Trias Hernanda (Author 1) was the researcher who compiled the research theme, research framework, compiled the data collection plan and conducted the legal policy data analysis, Soma Setiawan (Author 2) formulated the problem and collected IoT data, Tazkiya Isya Izzati (Author 3) and

Firda Khoirun Nisa (Author 4) conducted the licensing and open data collection, Widya Cholid (Author 5) validated the IoT data and Eko Nuriyatman (Author 6) validated the data law and policy.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

- Andrasari, M., Hasyim, S., Tanjung, A. A., M., S., & Lubis, I. (2024). Carbon emissions In Indonesia viewed from tourism aspects. *Journal of Sustainable Economics*, 2(1), 1–9. <https://doi.org/10.32734/jse.v2i1.15627>.
- Ariyani, L., Aminullah, E., Hermawati, W., Febrianda, R., Rosadi, A. H. Y., & Dinaseviani, A. (2025). The global innovation system view for electric vehicles in Indonesia: Facilitating the transition to electric mobility in society. *Sustainable Futures*, 9(December 2024), 100741. <https://doi.org/10.1016/j.sftr.2025.100741>.
- Atmaheni, A. A., & Adianto, J. (2024). Indonesia's smart city: Does legal framework matter? *International Journal of Built Environment and Scientific Research*, 8(2), 93. <https://doi.org/10.24853/ijbesr.8.2.93-104>.
- Grispos, G., Studiawan, H., Alrabae, S. (2024). Internet of things (IoT) forensics and incident response: The good, the bad, and the unaddressed. *Forensic Science International: Digital Investigation*, 48. <https://doi.org/https://doi.org/10.1016/j.fsidi.2023.301671>.
- Herdiansyah, H., & Majesty, K. I. (2024). Conflict mitigation strategies for sustainable agriculture in palm oil expansion. *International Journal of Sustainable Development and Planning*, 19(5), 1893–1902. <https://doi.org/10.18280/ijstdp.190527>.
- Hernanda, T., Absori, Wardiono, K., Azhari, A. F., Arlinwibowo, J., Azizah, N., & Budiono, A. (2023). The impact of environmental regulation implementation: A Meta-Analysis. *International Journal of Sustainable Development and Planning*, 18(10), 3235–3242. <https://doi.org/10.18280/ijstdp.181023>.
- Hernanda, T., Azizah, N., Syaharani, P. P., & Budiono, A. (2024). Reconstruction of regional regulations on the development of natural tourism and river water tourism in the Muria mountains based on sustainable tourism. *Edelweiss Applied Science and Technology*, 8(5), 978–986. <https://doi.org/10.55214/25768484.v8i5.1798>.
- Kurumi Yamasaki, T. Y. (2022). A framework to assess the local implementation of Sustainable Development Goal 11. *Sustainable Cities and Society*, 84(September 2022). <https://doi.org/10.1016/j.scs.2022.104002>.
- Mulwafu, T., & Kamchedzera, G. (2024). Land degradation neutrality and the weak avoid, reduce and reverse priorities in Malawi's soil laws. *Soil Security*, 14(February), 100134. <https://doi.org/10.1016/j.soisec.2024.100134>.
- Odagiri, M., Cronin, A. A., Thomas, A., Kurniawan, M. A., Zainal, M., Setiabudi, W., Gnilo, M. E., Badloe, C., Virgiyanti, T. D., Nurali, I. A., Wahanudin, L., Mardikanto, A., & Pronyk, P. (2020). Achieving the sustainable development goals for water and sanitation in Indonesia – Results from a five-year (2013–2017) large-scale effectiveness evaluation. *International Journal of Hygiene and Environmental Health*, 230, 113584. <https://doi.org/10.1016/j.ijheh.2020.113584>.
- Pan, S. Y., Gao, M., Kim, H., Shah, K. J., Pei, S. L., & Chiang, P. C. (2018). Advances and challenges in sustainable tourism toward a green economy. *Science of the Total Environment*, 635, 452–469. <https://doi.org/10.1016/j.scitotenv.2018.04.134>.
- Palmaccio, M., Grazia Dicuonzo, Z. S. B. (2021). The internet of things and corporate business models: A systematic literature review. *Journal of Business Research*, 131, 610–618. <https://doi.org/10.1016/j.jbusres.2020.09.069>.
- Propana Okionomus Ali, K. N. K. (2024). Analysis of Indonesia's priority selection: Energy transition, energy-related measures, mining governance, and resource transition using the analytic hierarchy

- process (AHP). *Energy for Sustainable Development*, 83. <https://doi.org/https://doi.org/10.1016/j.esd.2024.101559>.
- Raihan, A., Pavel, M. I., Muhtasim, D. A., Farhana, S., Faruk, O., & Paul, A. (2023). The role of renewable energy use, technological innovation, and forest cover toward green development: Evidence from Indonesia. *Innovation and Green Development*, 2(1), 100035. <https://doi.org/10.1016/j.igd.2023.100035>.
- Ramadhan, R., Mon, M. T., Tangparitkul, S., Tansuchat, R., & Agustin, D. A. (2024). Carbon capture, utilization, and storage in Indonesia: An update on storage capacity, current status, economic viability, and policy. *Energy Geoscience*, 5(4), 100335. <https://doi.org/10.1016/j.engeos.2024.100335>.
- Rawat, N., Kumar, P., Hama, S., Natalie Williams, A. Z. (2025). Improving classroom air quality and ventilation with IoT-driven acoustic and visual CO2 feedback system., *Science of the Total Environment*, 980. <https://doi.org/10.1016/j.scitotenv.2025.179543>.
- Rehman, F. U., Noman, A. A., Wu, Y., & Khan, I. (2025). Green transportation – Environmental sustainability within the purview of green energy, green innovation, and institutional quality: New evidence from belt and road initiatives economies an application of quasi-experimental approach. *Sustainable Futures*, 9(October 2024), 100583. <https://doi.org/10.1016/j.sfr.2025.100583>.
- Rejeb, A., Rejeb, K., Simske, S., Treiblmaier, H., & Zailani, S. (2022). The big picture on the internet of things and the smart city: a review of what we know and what we need to know. *Internet of Things (Netherlands)*, 19(July), 100565. <https://doi.org/10.1016/j.iot.2022.100565>.
- Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services*, 12, 1–15. <https://doi.org/10.1016/j.ecoser.2014.12.007>.
- Sari, R. T., & Mardiansjah, F. H. (2025). Characteristics and patterns of urbanization in non-urban regions: The case of Kudus Regency in Central Java Province, Indonesia. *Journal of Regional and City Planning*, 36(1), 1–21. <https://doi.org/10.5614/jpwk.2025.36.1.1>.
- Sekaringtias, A., Verrier, B., & Cronin, J. (2023). Untangling the socio-political knots: A systems view on Indonesia's inclusive energy transitions. *Energy Research and Social Science*, 95(May 2022), 102911. <https://doi.org/10.1016/j.erss.2022.102911>.
- Setiyo, M. (2023). Sustainable transport: The role of clean energy, mass rapid transit, non-motorized mobility, and challenges to achievement. *Automotive Experiences*, 6(1), 1–3. <https://doi.org/10.31603/ae.9108>.
- Simmler, M., & Canova, G. (2025). Facial recognition technology in law enforcement: Regulating data analysis of another kind. *Computer Law and Security Review*, 56(11519), 106092. <https://doi.org/10.1016/j.clsr.2024.106092>.
- Sufri, S., & Lassa, J. A. (2024). Integration of disaster risk reduction and climate change adaptation in Aceh: Progress and challenges after 20 Years of Indian Ocean Tsunamis. *International Journal of Disaster Risk Reduction*, 113(October), 104894. <https://doi.org/10.1016/j.ijdrr.2024.104894>.
- Suprati. (2014). the Tradition of living of muslim community kuduskulon. *Journal of Social Sciences*, 10(2), 63–73. <https://doi.org/10.3844/jssp.2014.63.73>.
- Tias, N. P. (2025). *Interview with the Department of Housing, Residential Areas and Environment of Kudus Regency*.
- van Asselt, H. (2021). Governing fossil fuel production in the age of climate disruption: Towards an international law of 'leaving it in the ground.' *Earth System Governance*, 9, 100118. <https://doi.org/10.1016/j.esg.2021.100118>.
- Wang, Y., Li, C., Yang, S., Long Ye, M. G. (2025). A study on urban residents' intention to choose green transportation modes based on the 2T composite model: A case study of Beijing, China. *Research in Transportation Business & Management*, 60. <https://doi.org/10.1016/j.rtbm.2025.101376>.
- Wibisana, A. G. (2017). Pembangunan berkelanjutan: Status hukum dan pemaknaannya [Sustainable development: Legal status and meaning]. *Jurnal Hukum & Pembangunan*, 43(1), 54. <https://doi.org/10.21143/jhp.vol43.no1.1503>.
- Widyamurti, M. (2025). *Interview With The Tourism Office Of Kudus District*.
- Yoga, D., & Hendri, M. (2023). Strategy for strengthening civic engagement in Muria Forest preservation as an effort to build ecological citizenship through the muria forest protection society association (PMPH). *ANP Journal of Social Sciences and Humanities*, 2(4), 1–7.

<https://doi.org/10.53797/anp.jssh.v4i2.1.2023>.

Zhang, C., Li, W., Huang, W., Wu, H., Skitmore, M., Bo Xia, W. W. (2024). Comprehensive evaluation in urban green transportation development: Evidence from 30 cities in China. *Research in Transportation Business & Management*, 57. <https://doi.org/https://doi.org/10.1016/j.rtbm.2024.101231>.