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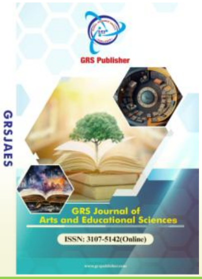


# Investigating the provision of a suitable model for the development of Internet of Things technologies in the field of environmental and energy issues in order to progress and achieve long-term development goals

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**Abstract:** This study investigates the development of Internet of Things (IoT) technologies in the domains of environmental and energy management, with the aim of facilitating progress toward long-term sustainable development goals. To achieve this objective, the research adopted a theory-building strategy with an emergent approach, allowing for systematic collection and analysis of qualitative data.

The study population comprised experts in IoT technologies, and theoretical saturation was reached after conducting 20 semi-structured interviews using purposive sampling. Data were analyzed through Strauss and Corbin's coding framework, encompassing open, axial, and selective coding procedures, to ensure rigorous and structured interpretation of the data.

Based on the analysis, the study proposes a conceptual framework entitled: *"Internet of Things Technology Development Model in the Field of Environmental and Energy Issues to Achieve Sustainable Development Goals."* This framework highlights that existing challenges in energy and environmental sectors act as key drivers for the advancement of IoT technologies.

The application of IoT in environmental sustainability demonstrates multiple benefits, including enhanced agricultural productivity, reduced deforestation, cost savings, and improved quality of life. Furthermore, this model illustrates that IoT technologies can not only mitigate pressing environmental challenges but also support the achievement of sustainable development objectives, particularly within the environmental dimension.

Overall, the findings underscore the critical role of IoT technologies as enablers of sustainable development, offering practical pathways for integrating technological innovation with environmental and energy policy initiatives.

**Keywords:** *Internet of Things, Sustainable Development, IoT Technology Development, Energy, Environment.*

**Cite this Article**

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## Introduction

Organizations have continually sought growth, value creation, and productivity improvement. One of the most effective strategies to achieve these objectives is the establishment of sustainable development practices. Sustainable development provides organizations with numerous competitive advantages, including effective utilization of human resources, workforce retention, cost savings, reduction of waste and losses, and energy conservation. Achieving sustainable development within businesses necessitates the application of technological and innovative solutions (Xiang, 2016; Taleghani, 2005).

Among the most significant technological solutions contributing to sustainable development—particularly in foresight-based technology processes—is the Internet of Things (IoT) (Pour-Ezzat & Abdi, 2018; Nasiri, 2016; Ghasemi et al., 2016). A critical requirement for achieving sustainability is the efficient management of objects and the optimization of energy and resource consumption, which can be facilitated through IoT technologies. The ability to track objects in real time enhances operational efficiency and supports sustainability in practice (Atzori et al., 2010). By intelligentizing systems through IoT, organizations can substantially reduce costs while increasing productivity and efficiency.

The IoT represents a network of physical objects embedded with electronic components, software, sensors, and connectivity, allowing these objects to exchange information with operators, manufacturers, or other devices. Smart objects not only facilitate real-time human interaction but also enable object-to-object communication, forming a pervasive network of devices, humans, and computer systems. By acquiring and analyzing sensor data at the endpoints of connected objects, IoT realizes its value in monitoring, measurement, and smart device creation, delivering benefits to individuals, organizations, and societies (Khetmatgazar, 2015).

In recent decades, IoT has demonstrated diverse applications across industries such as energy and environmental management, healthcare, transportation, and retail (Gubi et al., 2013). Implementing IoT to improve environmental sustainability has been particularly impactful, as it enables the monitoring and reduction of pollutants. For example, pollutant sensors in urban water infrastructures can detect contamination early, thereby mitigating water pollution and increasing water use efficiency. Similarly, IoT applications in agriculture enhance crop yields, reduce deforestation, optimize costs, and improve overall quality of life (Nanko et al., 2016).

Given the limitations of land for waste disposal and the negative consequences of landfill-based methods on public health and the environment, optimal waste management remains a crucial goal for both developed and developing societies. According to the World Commission on Environment and Development (1987), sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Gonzalez et al., 2017). Sustainable development is comprehensive, encompassing social, economic, cultural, environmental, and other human needs (Brady & Gates, 1994).

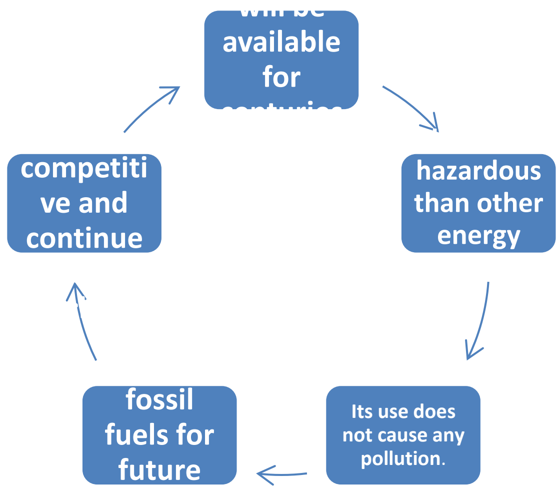
Globally, sustainable development is conceptualized around three primary dimensions: economic, social, and environmental sustainability (Garbie, 2014; Bardi et al., 2015). These dimensions also serve as a framework for evaluating and reporting organizational performance (Azmat, 2013). Figure 1 illustrates the three dimensions of sustainable development.


Social Dimension: Social sustainability emphasizes people-centered development. It encompasses institutions, policies, and mechanisms that allow all members of society to achieve optimal health, safety, participation, and access to economic benefits. It aims to foster social cohesion through equitable income distribution and equal access to resources and services (Bardi et al., 2015). Social development also involves public awareness and legal protection, particularly in environmental health, and encourages community participation in environmental protection initiatives (Garbieh, 2014).

Economic Dimension: Economic sustainability focuses on maintaining and enhancing current economic conditions without depleting natural resources. It addresses critical aspects such as income generation, employment, energy consumption, and urban infrastructure development, all while promoting justice and efficiency. Economic development, viewed as a process to improve quality of life, includes improvements in healthcare access, literacy, poverty reduction, and unemployment management (Bardi et al., 2015; Frommatt, 2013). This dimension emphasizes evaluating economic efficiency at a macro level rather than purely microeconomic business profitability.

Environmental Dimension: Environmental sustainability centers on ecosystem protection, air quality, and resource conservation. It encompasses policies and practices that ensure efficient resource management, reducing pollution, promoting renewable resource utilization, and enhancing adaptive capacity to environmental change. Environmental sustainability involves responsible water usage, carbon neutrality, waste reduction, recycling, and the use of eco-friendly materials. Notable examples include Chicago's smart rodent control system, Hamburg's urban traffic management plan, and Copenhagen's carbon neutrality initiative targeted for 2031 (Zenalo et al., 2014).

Sustainable development, therefore, relies heavily on science and technology, with IoT serving as a pivotal tool in achieving these objectives. Figure 2 illustrates the role of IoT technology in sustainable development.




Despite its growing importance, IoT is still an emerging area with limited research. A few notable studies have explored its potential for sustainability. For instance, a Finnish study titled "The IoT as an Enabler in Innovation for Creating Sustainability" employed a qualitative case study to examine the link between IoT and sustainability. The study highlighted IoT's role in energy reduction, early disaster detection, pollution control, and improving circular economy performance (Nasiri, 2016).

Similarly, Wirtz et al. (2019) proposed a general integrated framework for IoT in smart governance, incorporating four strategic layers: public value creation, public demand, technological infrastructure, and business-oriented approaches. In Uzbekistan, Zarei et al. (2016) quantitatively demonstrated that IoT acts as a catalyst for sustainable development across industries, including healthcare, energy, smart homes, transportation, and retail, offering policy guidance for promoting IoT adoption.

***Table (1): Summary of previous studies***

| Row | Source | Parameters studied | Method used | Achievement | Description |
|---|---|---|---|---|---|
| 1 | Shin, D. 2014, Telematics and Informatics | Understand how the Internet of Things evolves and develops and establishes a smart environment | Qualitative (content analysis) | Socio-technical analysis of the development of the Internet of Things | Framework proposal including components of technology, cultural and social issues, government and industry |
| 2 | Huang, Y., Poderi, G.2019. The Internet of Things for Smart Urban Ecosystems | Socio-technical analysis of the development of the Internet of Things in the field of smart electricity energy | Qualitative (literature review and case study) | Providing a data aggregation and analysis platform | Analysis of challenges and socio-technical system approach for the development of the Internet of Things |
| 3 | Abel Riccardo Stefanelli Rodriguez de la Daniele, Concepcion, 2014,Trinchero | Providing an optimized wireless sensor network platform to support sustainable agriculture | Exploratory | Developing sensors and remote monitoring cameras as a solution to improve product quality and production and improve environmental sustainability | ---- |
| 4 | Yifan Bo, Haiyan Wang, 2011 | Application of cloud computing and the Internet of Things in agriculture | Exploratory | Presenting and examining applications such as: monitoring and controlling farm diseases and pests based on the Internet of Things and cloud computing platform | ---- |
| 5 | Jun feng Zhang, Yu Feng Ji-chun, Jian-xin Guo Zhao, 2010 | Study and application of Internet of Things technology in the environment with a sustainable development approach | Design | Investigation of remote monitoring systems by combining Internet of Things technologies and wireless sensors via microcontrollers | Measuring the temperature and humidity of the soil and air through sensors - transferring it to the display using a microcontroller - the user monitors the environmental |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | conditions of the greenhouse through their mobile phone. |
| 6 | Dlodlo. Nomusa & Kalezhai. Josephat ,2015 IEEE, | Internet of Things for Sustainable Rural Development | Literature review | Examining the power of Internet of Things technology to solve problems: transportation, agriculture, education, and health in rural areas | ---- |
| 7 | Nasiri, M.2016, Lappeenranta University of Technology | Discovering the link between IoT technology, sustainability and innovation | Qualitative | Achieving sustainable development in all three dimensions through the use of the Internet of Things | Improving living standards, economic growth, gaining competitive advantages, and reducing pollution |

Table 1 summarizes prior research on IoT applications in environmental and energy sustainability, highlighting the methodologies and key Achievements of each study. Collectively, these studies emphasize the potential of IoT to enhance sustainability across economic, social, and environmental dimensions, providing a robust foundation for further research.

## Materials and Methods

The present study is descriptive in terms of its research methodology. One of the defining characteristics of descriptive research is that the researcher does not intervene in the position, status, or role of variables, nor manipulates or controls them. Instead, descriptive research observes, describes, and explains phenomena as they naturally occur. Given that this study aims to identify the impact of Internet of Things (IoT) development on environmental and energy issues, it is classified as a descriptive study.

The novelty of IoT technology and the limited existing research in this domain highlight that the effective application of IoT for sustainable development remains an emerging field. This novelty justifies the adoption of the grounded theory approach, which is commonly used to explore new phenomena or to investigate existing phenomena in novel contexts (Strauss & Corbin, 1998). The study employs an emergent approach to theory development. Despite its challenges, this approach fosters creativity in data analysis and offers high flexibility, allowing the researcher to explore and interpret complex phenomena comprehensively.

Following Strauss and Corbin's methodology, data analysis occurs in three stages: open coding, axial coding, and selective (central) coding:

1. Open Coding: The initial stage involves careful examination of raw data, such as interview transcripts and field notes. Codes are extracted from the data, with the aim of identifying concepts and potential categories. Rather than merely describing events, the researcher seeks to understand the underlying concepts and processes (Glaser & Strauss, 1967).
2. Axial Coding: In this stage, subcategories are related to main categories, establishing relationships and creating a structured classification. Axial coding revolves around central categories and often utilizes the paradigm model to determine causal relationships, conditions, and consequences (Strauss et al., 1967).
3. Selective (Central) Coding: The final stage involves identifying a core category around which the emerging theory is structured. Relationships between the core category and other categories are interpreted and visualized in a conceptual model. This stage enables the development of a comprehensive theory through continuous comparison of codes, concepts, and categories until theoretical saturation is achieved (Ali Ahmadi & Saravi, 2019).

The statistical population of this research consisted of experts and specialists with experience and knowledge in IoT technology and sustainable development. The study employed purposive sampling, followed by the snowball method, where initial interviewees introduced additional experts. Data collection continued until theoretical saturation was reached, which occurred after 20 semi-structured interviews.

This methodological approach ensures that the resulting conceptual model of IoT development in environmental and energy sectors is grounded in empirical evidence and reflects both expert insights and systematic data analysis.

## Research Findings

The data obtained from the interviews were analyzed using Strauss and Corbin's paradigm model along with the constant comparative method during the coding process. As outlined in the Strauss and Corbin approach, coding proceeds in three main stages:

1. Open Coding
2. Axial Coding
3. Selective Coding

Data coding was performed using MAXQDA qualitative analysis software to ensure systematic organization and analysis of the interview data. The steps in each coding stage are detailed below:

**a. Open Coding**

In this stage, interviews were carefully and thoroughly examined without imposing restrictions, following the principles of the Strauss and Corbin paradigm model. The primary objective was to identify emerging concepts from the raw data.

From this analysis, 60 initial codes were extracted from the interviews. Through the processes of constant comparison and questioning, these codes were further consolidated into seven main concepts. To define these concepts, codes with similar meaning were grouped together, and careful examination and analysis of each group allowed the extraction of meaningful concepts directly grounded in the interview data.

**b. Axial Coding**

Axial coding is so named because it centers on a core category. In this stage, subcategories are related to the main categories to establish connections and determine causal and contextual relationships in accordance with the paradigm model (Strauss et al., 1967).

Following axial coding, the resulting codes and concepts from the interview analysis were organized under relevant categories. These are presented in Tables 2, 3, 4, and 5, where only the titles of the codes are listed. These codes reflect the insights and perspectives expressed by the experts during the interviews.

***Table (2): Codes and concepts of the central category in selective coding***

| **Category (Pivotal): The phenomenon of the development of the Internet of Things** | | | **Frequency of category codes: 15** |
|---|---|---|---|
| Row | Code | Concept | Class |
| **1** | Market-driven nature of IoT development | Market-driven natureCategory-driven | Central category |
| **2** | Stimulating the market for the development of IoT application | | |
| **1** | Competitiveness and dynamism of companies in the field of IoT development | Need-based nature. | |
| **2** | The IoT's role in facilitating immediate and long-term decision-making. | | |
| **3** | The facilitating nature of technology in solving crises | | |
| **4** | Society's willingness to adopt technological solutions | | |
| **1** | The non-transitory nature of the development of IoT technology. | The non-transitory nature. | |
| **2** | Valid predictions of the growth of IoT technology in the coming years. | | |
| **1** | The central role of telecommunications in everyday life | The inevitable nature | |
| **2** | The increasing number of devices that can be connected to the Internet | | |
| **3** | The increasing number of smartphones | | |
| **4** | The increasing number of SIM cards | | |

***Table (3): Codes and concepts of causal conditions in selective coding***

| **Category of issues requiring intelligence** | | **Frequency of category codes: 10** | |
|---|---|---|---|
| **Row** | **Code** | **Concept** | **Class** |
| **1** | The existence of numerous environmental challenges in air and water | | |

| | | | |
|---|---|---|---|
| **2** | Water shortage crisis and high water consumption rates | Environmental and energy issues | Causal conditions |
| **3** | Forest fires and serious environmental damage | | |
| **4** | Uneven distribution of electricity in the provinces and the need for Internet of Things technology | | |

***Table (4): Codes and concepts of strategies and solutions in selective coding***

| **Category: Internet of Things Applications** | | **Frequency of Category Codes: 15** | |
|---|---|---|---|
| **Row** | **Code** | **Concept** | **Class** |
| **1** | Application of the Internet of Things in Smart Water Systems | Environment and Energy Sector | Strategies and Solutions |
| **2** | Application of the Internet of Things in Power Plant Facilities | | |
| **3** | Application of the Internet of Things in Smart Water Well Motors | | |
| **4** | Application of the Internet of Things in monitoring the energy consumption of household appliances | | |
| **5** | Application of the Internet of Things in monitoring the exchange of distributed electricity | | |
| **6** | Application of the Internet of Things in reducing the forest fire crisis | | |

***Table (5): Codes and concepts of outcomes in selective coding***

| **Category Consequences of the Development of the Internet of Things** | | **Frequency of Category Codes: 20** | |
|---|---|---|---|
| **Row** | **Code** | **Concept** | **Class** |
| **1** | Protection of environmental assets | | |
| **2** | Traffic balancing by making the urban control system smart | Environmental consequences | Consequences |
| **3** | Reducing pollutants from cars by making urban transportation smart | | |
| **4** | Optimizing household water consumption to deal with the water crisis | | |
| **5** | Reducing losses and controlling energy consumption by developing smart homes | | |

## c. Selective Coding

Selective coding represents the **final stage of the coding process**, in which a **central category** is identified and a theory emerging from the research is developed around it. This theory is typically presented in the form of a **visual model**, which illustrates the relationships between the central category and other categories derived from the data. Interpretation and articulation of these relationships follow the structure of the research model.

In this study, the **central category** identified is the **"development of Internet of Things (IoT) technology in the field of environmental and energy issues for sustainable development."** Figure 3 illustrates the conceptual model derived from the analysis of the interviews.

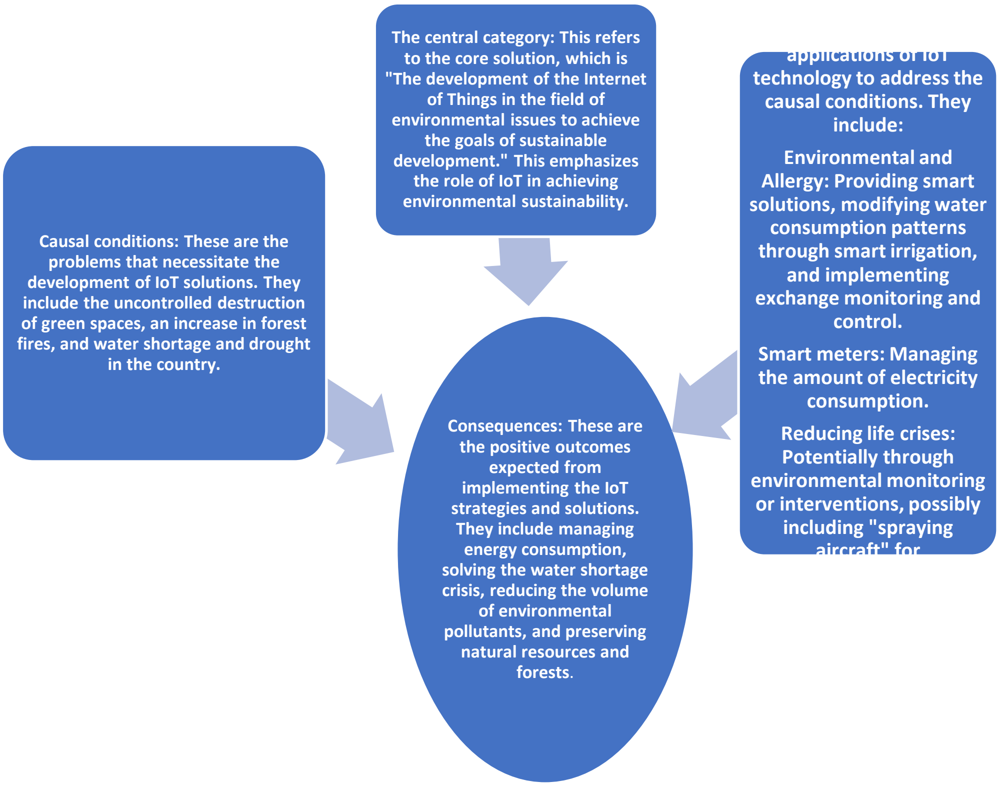



*Figure 3: IoT Technology Development Model in the Field of Environmental and Energy Issues*

## Causal Conditions: Environmental and Energy Issues

Causal conditions represent the reasons and explanations for the emergence of the central category. In this model, environmental and energy challenges were identified as the primary drivers necessitating the development of IoT technology.

According to the research findings, the most critical requirements for the emergence and advancement of IoT technology are linked to environmental and energy domains. Key environmental challenges include:

- Pollution: Air, water, soil, and land pollution remain significant global concerns, including in Iran, with ongoing trends posing serious and potentially irreversible risks.
- Deforestation and green space degradation: Improper management and destruction of forests have exacerbated environmental crises, particularly due to fires affecting biological capital.
- Water scarcity and drought: Water shortages, especially in the agricultural and household sectors, demand strategic interventions and intelligent solutions.

Based on expert insights gathered during the interviews, the development and implementation of IoT technologies can play a crucial role in addressing these environmental and energy challenges, enabling smart monitoring, resource optimization, and sustainable management practices.

## Research Focus: The Phenomenon of Internet of Things Development in the Field of Environmental Issues

The development of Internet of Things (IoT) technology is an inevitable and enduring phenomenon driven by evolving market needs. As a technological and innovative solution, IoT has the potential to address many contemporary environmental and energy crises while contributing to sustainable development.

According to the findings, the phenomenon of IoT development exhibits four defining characteristics: inevitability, permanence, need-based orientation, and market-driven nature.

- Inevitability: The ubiquity of telecommunications and digital connectivity in contemporary life makes the emergence and expansion of IoT technology unavoidable. It has become integral to the daily operations of individuals, organizations, and societies.
- Permanence: IoT is not a transient or faddish technology; rather, it represents a long-term solution in the field of information and communication technology, with sustainable applications that will persist in the coming decades.
- Need-Based: The development of IoT is driven by real-world needs. As organizations and societies encounter environmental and energy challenges, IoT provides practical solutions to address these issues.
- Market-Driven: The creation and expansion of IoT technologies are facilitated through market stimulation, responding to the demand for innovative solutions and fostering opportunities for commercial growth.

### Strategies and Solutions: Energy and Environment

In the proposed model, strategies moderate the relationship between causal conditions (environmental and energy challenges) and the central category (IoT development), as well as between the central category and its consequences. Strategies encompass the practical applications of IoT technologies that not only resolve identified problems but also amplify the positive outcomes of IoT development.

Specifically, in the fields of energy and environmental management, IoT strategies include:

- Smart water systems and optimized water consumption patterns.
- Monitoring and regulating electricity usage.
- Reducing environmental hazards such as forest fires and degradation of green pastures through automated systems, including aerial monitoring and irrigation.

Experts emphasized that IoT technologies in the energy sector can significantly reduce water consumption through smart irrigation practices while mitigating environmental crises such as forest fires and resource depletion.

### Consequences: Environmental Impact

Consequences represent the outcomes resulting from the development and deployment of IoT technologies. Research findings indicate that IoT development in environmental domains produces positive and significant environmental impacts, as affirmed by managers and experts in IoT and sustainable development.

Key environmental outcomes include:

- Improved management of public energy consumption, particularly water and electricity.
- Mitigation of water scarcity crises through precise monitoring and optimization of usage in agriculture and households.
- Enhanced urban environmental quality via smart transportation and traffic management, leading to a reduction in pollutants.
- Preservation of natural resources, forests, and green spaces, thereby preventing crises such as forest fires.

Through the integration of sensors, actuators, and data analytics, both individuals and organizations can optimize resource consumption, reduce waste, and contribute to overall environmental sustainability. The application of IoT in these contexts demonstrates the transformative potential of smart technologies in achieving sustainable development goals.

## Research Validation

The rigor of qualitative research is commonly evaluated using four criteria: verifiability, credibility, transferability, and dependability (reliability) (Guba & Lincoln, 1994). In the present study, the reliability and validity of the research were examined from a qualitative perspective. The specific measures taken to meet each criterion are summarized in Table (6).

***Table (6): Research Validation***

| Criteria | Validation |
|---|---|
| **Verifiability** | In this study, verifiability was ensured through careful selection of the sample and the integration of multiple data collection methods. The retention of raw data, interview notes, and all related documents throughout the data collection and analysis process further supports verifiability. This criterion emphasizes enhancing the objectivity of the research, which relies on the researcher's analytical rigor and the accuracy of the data. |
| **Credibility** | Credibility was established by conducting interviews until **theoretical saturation** was achieved, presenting preliminary findings to participants for feedback, performing self-reviews by the researcher, and allocating sufficient time for in-depth interviews. These measures ensure that the results accurately reflect the perspectives of participants. |
| **Transferability** | Transferability was addressed by providing a detailed description of the research context and conditions, enabling readers to assess the applicability of the findings to other populations or settings (Creswell, 2007). This criterion ensures that the research results can be generalized to similar contexts and are relevant beyond the immediate study sample. |
| **Dependability (Reliability)** | Dependability was ensured through careful data analysis and decision-making processes. The researcher-maintained consistency by consulting with the supervisor throughout the data collection and coding process, allowing for verification of the findings and methodological rigor. |

By systematically addressing these four criteria, the study ensures that the qualitative findings are robust, trustworthy, and applicable to the broader field of IoT development in environmental and energy sustainability.

## Discussion and Conclusion

According to the conceptual model presented in Figure (3), the category of "Internet of Things (IoT) development in the field of energy and environmental issues" serves as the central category, surrounded by causal conditions, strategies, and consequences. Each of these categories is described in detail in the research model.

The central category reflects the notion that the development of IoT is neither fleeting nor transitory; rather, it is a phenomenon predicted to occur inevitably over time. It is need-oriented, emerging in response to pressing issues across various application domains, and exhibits a market-oriented nature, being realized through market stimulation and related factors.

The category of causal conditions identifies the challenges and concerns in urban management, energy, and environmental issues as key drivers for the emergence and development of IoT. Environmental pollution, water shortages, inefficient energy consumption, and forest and green space degradation represent pressing problems that necessitate smart solutions through IoT applications.

The strategies and applications category highlights the various ways IoT can address these issues, including smart water management, monitoring electricity consumption, optimizing energy use, and controlling environmental risks. Experts emphasized that IoT technologies can significantly reduce water consumption through smart irrigation and mitigate environmental crises, such as forest fires, using advanced monitoring and early intervention systems.

The consequences category corresponds to the outcomes of IoT development, particularly in achieving sustainable development goals. The research findings indicate that the development of IoT in environmental and energy contexts generates significant environmental benefits, including enhanced resource management, reduced waste, optimized energy consumption, and improved crisis detection and mitigation.

Unlike prior studies, this research presents a theoretical model of IoT development, detailing its strategies and outcomes in environmental and energy domains. Previous studies largely focused on IoT aspects such as security, privacy, or standardization, with limited attention to sustainable development; thus, this study is theoretically innovative.

Among prior research, only Nasiri (2016) qualitatively examined IoT's link to sustainability. The current findings corroborate Nasiri's results across all three dimensions of sustainable development—environmental, social, and economic. Socially, IoT improves living standards, health, safety, and personal security. Economically, it fosters industrial growth, efficiency, and competitive advantages. Environmentally, IoT enables optimized energy control, early detection and mitigation of environmental crises (e.g., fires), pollution reduction, and natural resource preservation. Table (7) illustrates the overlap between IoT applications and sustainable development dimensions based on the current study and previous research.

***Table 7: Overlap of IoT Applications and Sustainable Development Dimensions***

| **Social Dimension** | **Economic Dimension** | **Environmental Dimension** |
|---|---|---|
| Health and treatment: continuous monitoring, disease prevention, increased life expectancy | Agriculture: soil quality monitoring, agricultural product quality | Energy and smart home: optimized water and electricity use |
| Urban management and transportation: standard infrastructure, reduced accidents, crime detection | Manufacturing industries: inventory monitoring, economic prosperity | Urban management: fuel consumption reduction, pollution reduction, waste management |
| Personal applications: wearables, smart clothing, comfort and convenience | — | Natural resource crisis management: forest and resource protection, fire prevention |

Overall, this research demonstrates that IoT development, when applied strategically across industries, not only addresses current environmental and energy challenges but also produces positive outcomes across social, economic, and environmental dimensions, aligning with the principles of sustainable development.

By establishing a network of interconnected objects, IoT facilitates real-time environmental monitoring, predictive crisis management, and intelligent decision-making. For instance, IoT applications can identify fire-prone areas, enable rapid intervention, and optimize urban traffic and energy use. Consequently, the deployment of IoT technologies in smart cities contributes to energy conservation, pollutant reduction, and overall environmental protection, offering a systematic, innovative approach to urban and environmental management.

In conclusion, the findings of this study confirm that the development and strategic application of IoT technologies have the potential to drive sustainable development and address complex environmental challenges, providing both immediate and long-term benefits for society, industry, and the environment.

## Appendix 1. Profile of Interviewees

As described, the experts belong to three groups: university professors (9), government officials (9), and information technology experts (2).

| **Interviewee Code** | **Educational Degree** | **Field of Study** | **Job Title** | **Internet of Things Experience** |
|---|---|---|---|---|
| **P1** | PhD | Software Engineering | Faculty Member | >7 years |
| **P2** | PhD | Software Engineering | Faculty Member | >7 years |
| **P3** | PhD | Computer Engineering | Faculty Member | >7 years |
| **P4** | PhD | Software Engineering | Faculty Member | >7 years |
| **P5** | Master's | Information Technology Engineering | Researcher | >5 years |

| | | | | |
|---|---|---|---|---|
| **P6** | PhD | Software Engineering | Faculty Member | >7 years |
| **P7** | PhD | Electrical Engineering / Control | Smart Energy Solutions Consultant / Faculty Member | >7 years |
| **P8** | Master's | Software Engineering / Management | IT Manager and Consultant | >7 years |
| **P9** | Master's | Software Engineering | CEO of Fava Company | >7 years |
| **P10** | PhD | Computer Engineering | Faculty Member / ICT Consultant | >7 years |
| **P11** | Bachelor's | Software Engineering | IT Manager and Technical Consultant | >7 years |
| **P12** | PhD | Telecommunication Engineering | Faculty Member / Director of ICT | >7 years |
| **P13** | Master's | Information Technology Management | National IoT Project Partner | >5 years |
| **P14** | PhD | Production and Operations Management | Faculty Member / Project Associate, National IoT Project | >5 years |
| **P15** | Master's | Software Engineering / Entrepreneurship Management | Project Partner, National IoT Plan | — |
| **P16** | Master's | Communications Law | Project Partner, National IoT Plan | >5 years |
| **P17** | PhD | Electrical Engineering | Senior IT Manager | >5 years |
| **P18** | PhD | New Technologies Law | Faculty Member / Project Associate, National IoT Plan | >5 years |
| **P19** | Master's | Executive Management / Telecommunications Engineering | FAW Manager and Consultant | >5 years |
| **P20** | Master's | Communications Law | Project Partner, National IoT Plan | >5 years |

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