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Identifying and Prioritizing the Infrastructure Indicators in the Internet of Energy Learning in the Fourth Industrial Revolution

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ABSTRACT

The main goal of this research is to identify and prioritize the basic indicators of Internet energy in the context of the fourth industrial revolution. This research examines the subject literature and utilizes past researches, and with the help of experts in this field, it has identified a number of factors affecting the internet of energy in the fourth industry. At first, Delphi technique was used to identify effective factors. At this stage, related articles were reviewed. In the first stage, the criteria were extracted with a comparative (quantitative) approach and the options were ranked using the critical model. The results of this research showed that, despite the implementation of a wide range of researches related to the factors affecting internet energy in the past and present, this category can be examined more carefully and thoughtfully. This research, relying on theoretical foundations, has tried to fill the scientific and practical gap of knowing the options effective on the Internet of Energy. 8 criteria were identified. The criteria identified are laws and regulations, individual and human factors, financing, technological infrastructure, cultural and social factors, security factors, technological resources and knowledge resources. The technological infrastructure index is the first priority and the financing index is the second priority. **©authors**

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1. Introduction

Given the numerous problems caused by the use of fossil fuels, many researchers have now emphasized the use of energy management as an effective solution to solve current problems (Ahmadi et al., 2014). Its establishment and application involves optimizing consumption and means choosing the correct and practical model of the right policies in energy consumption, which, in addition to being a guarantee of continued economic growth, reduce the destruction of energy resources and reduce the adverse effects of its improper use on the environment and society (Hebal et al., 2021).

Energy management is the process of collecting information about where, when, how and why energy is consumed in an organization, and with its help, efficiency can be increased, costs can be reduced, and the environment can be protected (Sharma & Garg, 2020). This process usually begins with the collection of accurate and real-time energy consumption data obtained by IoT sensors or programmable logic controllers, and then analyzes this data with the help of software to identify inefficient areas and take action based on the results of the analysis. Energy management projects can save significant costs by identifying inefficient areas and taking the necessary actions.

This reduces the total amount of energy used in a building, site or company by more than 35%, and consequently reduces costs and environmental impacts (Kalaichelv & Gayathri, 2023). With the increase in research in the field of energy management on the one hand and with the development of information technology and the Internet of Things, a new concept called the Internet of Energy has been proposed today. The Internet of Energy combines the features of the smart grid and the Internet of Things, and the combination of the advantages of the two leads to better energy management. The Internet of Things is referred to as an Internet-based structure that facilitates the exchange of services, information and data among billions of smart objects (Shafik & Tufail, 2023). The Internet of Things can be widely used in various sectors such as smart grid monitoring, power distribution, telemetric services, military applications and weather forecasting, (Paukstadt & Becker, 2023).

In contrast, a smart grid can communicate It provides a two-way interface between a grid and an energy management system, and controls and monitors energy generating units. Therefore, IOE is increasingly being used in buildings, electric vehicles, distributed energy sources, and domestic and industrial sectors. The Internet can be used to monitor and control energy networks (Liu, 2020) Similar to information routing on the Internet, energy is transferred from a source to a destination as needed. With IoE technology, the way energy is transferred and consumed is carefully managed (XUE, 2015).

The Internet of Energy is defined as a dynamic network infrastructure that connects the energy network via the Internet, so that energy units (which are locally generated, stored, and transmitted) can be transmitted whenever and wherever needed. Related data or information follows the energy flows, so that essential information is exchanged with the energy transfer. In smart cities, the Internet of Energy has many applications, examples of which are the intelligence of buildings and facilities (Pradeep Reddy, & Pavan Kumar, 2023). Energy saving is the main goal of Internet of Energy-based systems. The application of Internet of Energy-based systems is divided into two main techniques, namely: It depends on existing buildings and the construction of new buildings. Compared to the construction of new buildings, the renovation of existing buildings can save energy, more materials and reduce emissions and waste. Therefore, retrofitting existing buildings is the preferred method for energy internet-based systems because it reduces the problems of climate change for environmental purposes (Amarnath & Sujatha, 2020).

The importance of the Internet of Energy in particular and energy management in general has become even more important in the contemporary era, which is the world's fourth industrial revolution. The Fourth Industrial Revolution is the fourth major era since the beginning of the Industrial Revolution. The Fourth Industrial Revolution can be seen as the emergence of cyber-physical systems that include entirely new capabilities for people and machines (Sun et al., 2018).

While these capabilities depend on the technologies and infrastructure of the Third Industrial Revolution, the Fourth Industrial Revolution represents entirely new ways in which technology is embedded in societies and even human bodies. Examples include genome editing, new forms of machine intelligence, breakthrough materials, and governance approaches that rely on cryptographic methods such as blockchain (Fadlullah et al., 2018). In other words, by using the Internet of Energy, the use of energy resources can be significantly reduced, which will save a lot of energy supply resources (Thilakarathne et al., 2022).

These technologies enable intelligent communication between users and suppliers, suppliers with the energy consumption environment, and monitoring systems. In addition, users' behaviors and consumption patterns can be predicted. Energy Internet technology is capable of detecting appropriate temperature, light, sound, heat, and humidity in the environment, managing energy in a smart environment, reducing carbon dioxide gas, and preventing environmental damage; therefore, users' behaviors and consumption patterns can be predicted and then modified using the empowerment of this technology (Sani et al., 2019; Shrimali et al., 2013).

Although much has been written about the importance of the Internet of Energy as the future approach to energy management in the new century, this concept has not been sufficiently analyzed in the domestic literature and many of its aspects are not well known. On the other hand, there is much unsaid in this regard at the international level. For example, the infrastructure components of the Internet of Things have only been discussed in detail in some articles. In particular, the importance and priority of different Internet of Things infrastructure dimensions have not been well explained. The present study aimed to identify and prioritize the infrastructure indicators of the Internet of Energy in the context of the Fourth Industrial Revolution. The main question of the study is: What are the infrastructure indicators of the Internet of Energy in the context of the Fourth Industrial Revolution and what is the weight and importance of each?

2. Method

This research is applied in terms of purpose and uses a survey and library method. First, 8 criteria and 10 solutions were identified using the Delphi method. Then, the CRITIC method was used to examine and evaluate the criteria. It was used to examine the strategic and economic problems of project progress from the perspective of experts (managers and experts of Hormozgan Province Power Distribution Company). In fact, the population under study consists of experts and senior experts in the field of energy. The company's information technology managers were also used; 20 people were considered as samples based on purposeful sampling. In the first step, the library and Delphi methods were used to identify the underlying factors of the Internet of Energy. In the second step, the Critical method was used to prioritize the identified indicators. For this purpose, a decision matrix was formed and each solution was given a score based on each criterion. Based on the weights calculated in the Critical method, it was converted into a balanced decision matrix and the best solutions were identified. In the Delphi method, a Likert scale questionnaire was used, and in the critical method, a scoring matrix was used.

3. Findings

20 managers and experts of Hormozgan Province Power Distribution Company, 14 men and 6 women with master's degrees in management and industrial engineering, participated in

the Delphi survey to screen the identified criteria. The Delphi questionnaire was designed as a 7-point Likert scale. The arithmetic mean was used to reach consensus. Scores above 4 were accepted.

Table 1. *Screening of identified criteria using the Delphi method*

Source	Identified criteria	Identified criteria	Standard deviation	Average	Mode	X
[1, 4, 17]	Laws and regulations	Laws and regulations	0.258	4.18	4	C01
[10, 14, 16, 18]	Individual and human factors	Individual and human factors	0.236	4.09	4	C02
[1, 5, 16, 17, 19, 21]	Financing	Financing	0.269	4.09	4	C03
[3, 12, 18, 20, 21]	Technological infrastructure	Technological infrastructure	0.214	4.18	4	C04
[6, 8, 10, 19, 20, 21]	Cultural and social factors	Cultural and social factors	0.425	4.18	4	C05
[5, 9, 10, 17, 18, 20]	Security factors	Security factors	0.125	4.63	4	C06
[17, 18, 21]	Technological resources	Technological resources	0.236	4	4	C07
[8, 13, 15, 19, 20]	Knowledge resources	Knowledge resources	0.528	4	4	C08
Kendall coefficient	0.776	0.776	7	231.180	Degrees of freedom	Chi-square statistic

Delphi results indicate the approval of all 8 identified criteria. Also, the Kendall coefficient was 0.776. Therefore, all identified criteria were approved. The following is a prioritization of criteria based on the critical method.

3-1. Weighting of criteria with the critical method

The critical method is the importance of criteria based on the internal correlation of criteria and is a very suitable and practical method for determining the weight of criteria. The critical method uses the same decision matrix and without the need for new data to obtain the weight of criteria. The first step is to form a decision matrix. The decision matrix is a matrix with one option in each row and one criterion in each column. This matrix includes m options and n criteria and is generally written as follows:

Table 2. *Decision-Making Matrix*

X	C01	C02	C03	C04	C05	C06	C07	C08
C01	2.933	3.275	3.475	3.674	3.267	3.549	3.850	3.712
C02	3.667	3.341	3.500	3.667	3.200	3.681	3.800	3.719
C03	3.733	3.462	3.500	3.632	3.933	3.670	3.875	3.750
C04	3.200	3.451	3.800	3.625	3.138	4.031	3.625	3.660
C05	4.067	3.527	3.800	3.674	3.805	4.074	3.700	3.743
C06	4.000	3.495	3.775	3.750	3.801	4.062	3.800	3.813
C07	4.400	3.451	3.775	3.757	4.292	3.914	3.800	3.824
C08	4.067	363/3	3.900	3.766	3.873	3.785	3.750	3.836

The second step is to form the correlation matrix. Each element of this matrix is denoted by r_{ij}. Equation (1) is used to measure the correlation of values:

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}$$

Table 3. *Maximum and minimum decision matrix*

Min	2.933	3.275	3.475	3.674	3.267	3.549	3.850	3.660
Max	4.400	3.527	3.900	3.766	3.292	3.074	3.875	3.836

Table 4. *Correlation matrix*

X	C01	C02	C03	C04	C05	C06	C07	C08
C01	0.000	0.000	0.000	0.346	0.111	0.000	0.900	0.294
C02	0.500	0.261	0.059	0.296	0.053	0.251	0.700	0.335
C03	0.545	0.739	0.059	0.049	0.689	0.230	1.000	0.512
C04	0.182	0.696	0.765	0.000	0.000	0.918	0.000	0.000
C05	0.773	1.000	0.765	0.346	0.577	1.000	0.300	0.473
C06	0.727	0.870	0.706	0.889	0.575	0.977	0.700	0.867
C07	1.000	0.696	0.706	0.941	1.000	0.695	0.700	0.930
C08	0.773	0.348	1.000	1.000	0.637	0.449	0.500	1.000
σ	0.332	0.339	0.399	0.403	0.359	0.386	0.325	0.352

The standard deviation of the values of the correlation matrix is calculated. Equation (2) was used to determine the initial weight of the criteria.

$$C_j = \sigma_j \sum_{i=1}^{m} (1 - r_{ij})$$

Table 5. *Calculation of Cj values*

1-R	C01	C02	C03	C04	C05	C06	C07	C08
C01	1.000	1.000	1.000	0.654	0.889	1.000	0.100	0.706
C02	0.005	0.739	0.941	0.704	0.947	0.749	0.300	0.665
C03	0.455	0.261	0.941	0.951	0.311	0.770	0.000	0.488
C04	0.818	0.304	0.235	0.000	1/000	0.082	1/000	1/000
C05	0.227	0.000	0.235	0.654	0.423	0.000	0.700	0.527
C06	0.273	0.130	0.294	0.111	0.425	0.023	0.300	0.133
C07	0.000	0.304	0.294	0.059	0.000	0.305	0.300	0.070
C08	0.227	0.652	0.000	0.000	0.363	0.551	0.500	0.000

Based on the above analysis, it can be concluded that a higher value of C_j provides more information from the given criterion, so the relative importance of the criterion for a decision-making problem is more important. Finally, the final weight of the criteria is determined using the following relationship and in a linear manner.

Relationship (3): Determining the final weight of criteria in the critical method

$$W_j = \frac{C_j}{\sum C_j}$$

Where W_j represents the weight of criterion j and C_j represents the amount of information of the sum of k criteria starting from 1=k and continuing to k=m. C_j is the amount of information extracted from criterion j, which is obtained from the above relationship. According to the above relationships, criteria that have a higher C_j will be assigned a higher weight. Also, in the above relationship, σ_j is the standard deviation of the j_{th} criterion and r_{ij} is the correlation between two criteria i and j.

Table 6. *Prioritization of Criteria*

C08	C07	C06	C05	C04	C03	C02	C01	
0.096	0.079	0.102	0.119	0.127	0.120	0.088	0.089	W

Index C04 with a weight of 0.127 is in the first priority. Index C03 with a weight of 0.120 is in the second priority. Index C05 with a weight of 0.119 is in the third priority. Index C06 with a weight of 0.102 is in the fourth priority. Index C08 with a weight of 0.096 is in the fifth priority. Index C01 with a weight of 0.089 is in the sixth priority. Index C02 with a weight of 0.088 is in the seventh priority. Index C07 with a weight of 0.076 is in the eighth priority.

5. Discussion

The main objective of this research was to identify and prioritize the underlying indicators of the Internet of Energy in the context of the Fourth Industrial Revolution. This research reviews the literature and uses past research, and with the help of experts in this field, it has identified a number of factors affecting the Internet of Energy in the Fourth Industry. Initially, the Delphi technique was used to identify the effective factors. In this stage, relevant articles were reviewed. In the first stage, the criteria were extracted using a quantitative approach and the options were ranked using the critical model.

The results of this research showed that despite the implementation of a large set of research on the factors affecting the Internet of Energy in the past and present, this category can be examined with more precision and reflection.

This research, relying on theoretical foundations, has attempted to fill the scientific and practical gap in understanding the options affecting the Internet of Energy. 8 criteria were identified. The identified criteria are laws and regulations, individual and human factors, financing, technological infrastructure, cultural and social factors, security factors, technological resources and knowledge resources. The technological infrastructure index is given first priority and the financing index is given second priority. Laws and regulations: Includes laws and regulations set by relevant authorities in the field of energy and the Internet. These laws may include standards, energy consumption regulations, environmental protection laws and policies related to renewable energy and data transmission.

Personal and human factors: This criterion is related to the role of individuals in managing energy consumption and energy-efficient performance on the Internet. Factors such as individual awareness and education, user behaviour and consumption habits, energy-related behaviours and cultural attitudes towards energy consumption are identified in this section. Financing: This criterion refers to the financial resources required to invest in technological infrastructure to optimize energy consumption related to the Internet. Financing includes initial investment, investment over the life of the infrastructure, financing of research and development projects, as well as financial support mechanisms. Technological infrastructure: This criterion includes the technologies and infrastructure used in the Internet of Energy. Among the infrastructures used to optimize energy consumption, high-performance servers, smart communication networks, cooling systems, and energy-efficient hardware equipment can be mentioned. Cultural and social factors: This criterion refers to the culture and values of society that affect energy consumption and its optimization measures. Factors such as social attitudes towards environmental sustainability, organizational cooperation, and community communication in this area are identified in this criterion.

Security factors: This criterion is related to security issues in the Internet of Energy infrastructure. This includes data protection, protection of critical infrastructure, protection of IT equipment, and countering security threats on the Internet. Technological resources: This criterion addresses technological resources for optimizing energy consumption related to the Internet. These resources include technologies, methods and innovations that facilitate improved energy efficiency, careful energy management and optimal use of energy resources. Knowledge resources: This criterion refers to the knowledge and information required to develop and implement the Internet of Energy model. This includes scientific research, continuous education and training, databases and information systems, access to geographic information and satellite images, and other resources that provide knowledge and awareness in this area.

Here are several practical suggestions for improving energy efficiency and optimizing its consumption in the context of the Fourth Industrial Revolution:

1. Suggestion of using sensors and smart devices: The use of sensors and smart devices in various industries can help improve energy efficiency. Using smart sensors, energy consumption can be reduced at specified times and based on real needs. These sensors can collect real-time information and apply settings that provide the most optimal use of energy.

2. Connection and collaboration between devices: By connecting and collaborating between different devices through the Internet of Things, energy consumption optimization can be promoted. For example, connecting manufacturing devices to a smart system can help fine-tune energy consumption and reduce energy waste. Also, by connecting different devices, more information can be collected and analysed to identify optimization patterns.

3. Use of data analysis and artificial intelligence: The use of data analysis and artificial intelligence can help optimize energy consumption in the context of the Fourth Industrial Revolution. By analysing production data and device performance, intelligent algorithms can be implemented that apply the most optimal settings for energy consumption. These algorithms can operate more advanced than traditional systems and minimize energy consumption. Improving energy efficiency and optimizing its consumption through the Internet of Energy in the context of the Fourth Industrial Revolution can help reduce costs, conserve natural resources, and protect the environment. It also helps increase the productivity and performance of connected industries and organizations to achieve sustainable and intelligent development.

Declaration of Competing Interest

The author declares that he has no competing financial interests or known personal relationships that would influence the report presented in this article.

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