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Critical Factors Affecting the Promotion of Emerging Information Technology in Prefabricated Building Projects: A Hybrid Evaluation Model

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Abstract: Emerging information technology (EIT), characterized by intelligence, digitization, and automation, can facilitate activities such as stakeholder cooperation, information management, and construction management to enhance the overall performance in prefabricated building projects (PBPs). A variety of EITs are currently being used in PBPs, but their development is relatively sluggish and still in the infancy stage. Previous studies have explored the challenges and barriers of EIT in PBPs; however, the correlations between these factors have not been thoroughly examined. Therefore, the goal of this study is to pinpoint the characteristics and connections between EIT-affecting elements. Based on the technology–organization–environment (TOE) framework, this study firstly summarizes 20 influencing factors of EIT adoption and promotion in PBPs mentioned in the previous literature through a literature review. Then, EIT experts were invited to conduct semi-structured interviews to evaluate the relationship and the degree of influence among 20 influencing factors. Finally, the DEMATEL-ISM approach was used to assess the characteristics of each factor and the hierarchy between them. The results demonstrated that the influencing degree of the environmental dimension was more significant and had a greater influence on the whole network of influencing factors. The factors of the organizational dimension have a higher influenced degree and are easily influenced by other factors. Due to the current lack of awareness of EIT, the majority of the technology-related influencing factors have a less significant effect on adopting and promoting EIT. In summary, this study assists in analyzing the characteristics and correlations of the factors that influence EIT adoption and promotion in PBPs and identifies critical influencing factors. It also aids the government and stakeholders in developing a deeper understanding and knowledge of EIT, thereby promoting the development of EIT in PBPs.

Keywords: prefabricated building projects; emerging information technologies; influencing factors; DEMATEL-ISM

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1. Introduction

The prefabricated construction (PC) method solves the problems of low production efficiency, serious environmental pollution, lengthy construction times, and material waste caused by traditional construction methods and is considered to be a major innovation in construction technology in the construction industry [1–4]. Although it has been recognized and supported by the global construction industry, PC has amplified the fragmented characteristics of the construction industry, which has brought many new problems [5]. These problems stem from various factors, including fragmented workspace, interrupted workflow, numerous stakeholders, and an enormous quantity of information [6–8], which may hinder the performance of prefabricated building projects (PBPs) and the sustainable development of the construction industry. On the other hand, as PBPs become larger and more complicated, revisions, rework, or quality problems are more likely to arise during the design and construction phases [9,10]. The main problem is that the stakeholders involved in PBPs who are in charge of different tasks have sporadic relationships, poor coordination and communication, and little control over the entire project [11,12]. To this end, scholars are actively looking for innovative means and methods to overcome the above problems.

Compared with traditional on-site construction, the prefabricated construction method moves the production work to the factory, which improves the standardization and mechanization of the production process, and also promotes the automation and mass production of components [13,14]. This feature makes it easier for PBPs to apply the emerging information technology (EIT) in the concept of Industry 4.0, that is, to use digital and intelligent means to solve the problems mentioned in the above paragraph [12]. At present, EITs used in PBPs include but are not limited to building information modelling (BIM), Radio Frequency Identification (RFID), Internet of Things (IoT), etc. These EITs can improve design and construction quality, enhance communication efficiency between stakeholders, and promote information sharing in PBPs [15–17]. For example, BIM is often used in building system design, collaborative design, 3D visualization, and conflict visualization, which can effectively reduce changes and rework problems, and also provide a collaborative platform for different stakeholders [18,19]. RFID can collect, store, share, and trace the information of prefabricated components in real time, which is beneficial for stakeholders to grasp dynamic information in a timely manner and alleviate information asymmetry [20,21]. The IoT can enhance the world connection by enabling the integration of things in both the physical world and cyber space [22], for example, real-time monitoring of greenhouse gas emissions [23], providing on-site assembly services for prefabricated construction [24], etc. It can be found that the use of EIT in PBPs can greatly improve the performance of PBPs, and has been generally recognized by the government, scholars, and industry participants.

However, in the construction industry, the promotion of EIT is extremely passive and slow. At present, some scholars have studied the influencing factors of EIT adoption and promotion in the construction industry. Taking BIM as an example, BIM consists of a series of software that assists practitioners with tasks such as model construction, conflict detection, and visualization. However, the poor compatibility of these software with data have led to unsatisfactory effects of BIM application [18,25]. Due to the lack of professional knowledge and professionals related to EIT, the problems that EIT solved in prefabricated buildings are limited and the benefits are insufficient [26]. At the same time, the cost of adopting and training in EIT also hinders its promotion in PBPs [27]. In addition, Qin et al. used the DEMATEL method to identify the critical influencing factors affecting the adoption of EIT in the construction industry in terms of technological, economic, organizational, and environmental dimensions [9]. Chen et al. developed a research model based on the TOE framework to identify the adoption of EIT in the Chinese construction industry, and analyzed and discussed the significance of each influencing factor [11]. Although the current studies have systematically explored the influencing factors affecting the adoption and promotion of EIT in PBPs, it still lacks an in-depth analysis of the linkages between the influencing factors [9,11]. In fact, the factors affecting EIT adoption and promotion do not play a role in isolation, and exploring the relationships among factors can provide a deeper understanding of EIT adoption and promotion paths. Therefore, the purpose of this paper is to identify the influencing factors of EIT adoption and promotion in PBPs and to explore the association between these factors to understand the path of EIT adoption and promotion. This is the first time of conducting correlation analysis and path analysis on the influencing factors of EIT adoption and promotion in PBPs, which will help researchers understand the interaction between influencing factors to better promote the development of EIT. The article is structured as follows. In Section 2, the EIT used in PBPs, the technology–organization–environment (TOE) framework, and influencing factors are reviewed. In Section 3, the research framework and methodology of this study are elaborated. In Sections 4 and 5, influencing factors and their interrelationships are analyzed and discussed. Finally, Section 6 concludes the paper and gives an outlook on future work.

2. Literature Review

2.1. EIT in PBPs

Emerging information technology refers to digitization, automation, and intelligence to help stakeholders manage and implement activities [28]. The primary functions of EIT are to help stakeholders collect, acquire, integrate, analyze, exchange, and share information and data in PBPs [29]. To date, various EITs have been adopted in PBPs to improve overall performance, including building information modeling (BIM), radio frequency identification (RFID), Internet of Things (IoT), Big Data, cloud computing, blockchain, digital twin, sensors, virtual reality (VR), augmented reality (AR), and mixed reality (MR) [29–31]. These EITs can cover multiple applications of PBPs in the pre-design and planning, production, transportation, on-site assembly, and operation and maintenance stages, bringing great changes to the implementation of PBPs. For example, BIM, VR, AR, and MR are mainly used in design and visualization [12,32,33]. RFID, Big Data, cloud computing, blockchain, and sensors can be applied to the management of large amounts of information in PBPs [29,30]. The IoT can be used as an integrated platform to achieve interconnection [34,35]. Digital twins can realize the mapping between physical and virtual entities, and can simulate, analyze, predict, and optimize PBPs [36]. In addition, a trend in EIT development is the integration of multiple EITs to better solve problems in PBPs. In order to solve the problems of incomplete and untimely data exchange and lack of traceability existing in BIM, Li et al. designed an Internet of Things-enabled BIM platform, which integrated BIM, IoT, RFID, and VR to better serve the on-site assembly of prefabricated buildings [24].

2.2. Technology–Organization–Environment Framework

The technology–organization–environment (TOE) framework has been widely used in research related to the adoption of new technologies [37]. The theory argues that the adoption and promotion process of new technologies is influenced by three dimensions: technology, organization, and environment [38]. Among them, technological factors are reflected in the characteristics and functions of EIT itself and the advantages of adopting and promoting EIT in PBPs [39,40]. Organizational factors are reflected in the degree of enterprise support for EIT adoption in PBPs and the impact of organizational characteristics and resources [38,41]. Environmental factors mainly refer to the impact of the industry environment on the adoption and promotion of new technologies [38]. Previous studies have applied the TOE framework to study the influencing factors of the adoption of Big Data in small and medium-sized enterprises (SMEs) [40], the adoption of BIM in the construction industry [11,39], and the adoption of social media in the construction industry [42]. Therefore, it is used as a theoretical basis for analyzing the influencing factors of EIT adoption and promotion in PBPs.

2.3. Critical Challenges of EIT Promotion in PBPs

Based on the TOE framework, we identified the influencing factors of EIT adoption and promotion in PBPs from three dimensions: technology, organization, and environment. First, in the technological dimension, the relative advantages and complexity of EITs [11,43], the lack of standards and perfect processes [44], the interoperability between EITs, and the security of information in EIT are considered as influencing factors for the adoption and promotion of EIT in PBPs [12,34]. Second, in the organizational dimension, much of the literature agrees that the attitude of top managers has a very significant impact on the adoption and promotion of EIT [9,11,44,45]. In addition, organizational structures and workflows, traditional mindsets, the number of EIT experts and technicians, and EIT adoption, operational, and training costs can also influence EIT adoption and promotion [44,46,47] . Similarly, in the environmental dimension, the factors that affect the adoption and promotion of EIT in PBPs include the requirements of national policies and regulations, the needs of EIT in the industry, and competition from similar companies [9,43].

According to the above analysis, we identified 20 influencing factors in this study, as shown in Table 1.

Table 1. Factors for the adoption and promotion of EIT based on TOE framework in PBPs.

Dimension	Code	Factors	Reference
	TE1	Integrating the workflows in PBPs	[11,48]
	TE2	Matching the workflows in PBPs	[11,46,49]
	TE3	Complexity of EIT Implementation	[44,50–52]
Technological	TE4	Maturity of EIT	[9,19,39,43,53]
	TE5	Standardization level of EIT	[9,19,45,54]
	TE6	Interoperability between EITs	[12,34,55,56]
	TE7	Continual updating of EIT	[10,12]
	TE8	Ensure the security of information	[10,34,57]
	OR1	Attitudes of top management towards EIT	[11,19,44,58]
	OR2	Organizational structure to support EIT	[19,47,49]
	OR3	EIT training programs	[45,59,60]
Organizational	OR4	Acquire professional knowledge and talents related to EIT	[12,46,61]
	OR5	Change-resistant attitudes in PBPs	[53,62]
	OR6	The cost of applying, training, updating and development EIT	[9,10,19,39,44,53]
	OR7	The benefit of adopting EIT	[9,19,53]
	EN1	Pressure on competitors to adopt EIT in PBPs	[11,39,43,53]
	EN2	Customer demand for EIT in PBPs	[11,43,44]
Environmental	EN3	Pressure on partners to adopt EIT in PBPs	[9,11,43]
	EN4	EIT-related national policy requirements	[12,19,43,53]
	EN5	The need for EIT in PBPs	[11,39,43]

3. Methodology

The purpose of this study was to explore the correlation relationship between factors in order to gain a deeper understanding of EIT adoption and promotion paths in PBPs. To achieve the above goals, the following methods were used in this study: (1) literature review; (2) semi-structured interviews; (3) DEMATEL-ISM. The detailed process is shown in Figure 1. First, the factors influencing the adoption and promotion of EIT under the TOE framework were identified through a literature review, which is described in detail in Section 2.3, as shown in Table 1. Secondly, on the basis of identifying the influencing factors, a questionnaire was designed to conduct semi-structured interviews with experts in this field, and the correlation between the influencing factors was obtained. Next, the collected data were analyzed using the DEMATEL-ISM method to obtain the attributes of the influencing factors and the influence paths. The specific application method will be introduced in the following subsections.

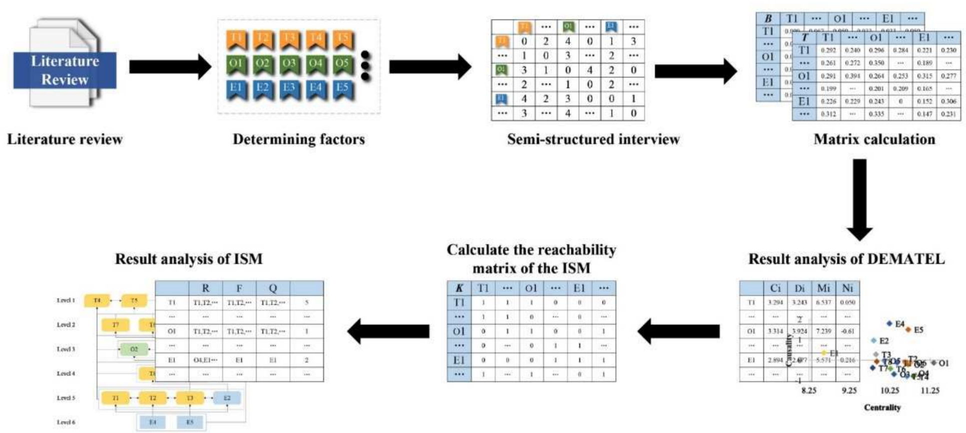

Figure 1. Research Framework.

3.1. Data Collection

Since determining the association between the influencing factors of EIT adoption and promotion requires experts with extensive empirical knowledge and a solid professional foundation, we selected semi-structured interviews to collect the association between influencing factors in this study. Semi-structured interviews are conducted with individuals who have broad expertise and experience and can better fill knowledge gaps in complex research questions [63]. On the other hand, interviews are flexible and allow for in-depth analysis and discussions between researchers and respondents to provide new information [64]. Boach et al. collected stakeholders' views on the added value of BIM in the operational phase through semi-structured interviews [65]. Pan et al. conducted semi-structured interviews with the management and engineers of the target precast concrete manufacturers and with sales managers of the technology suppliers to collect the reasons for adopting or not adopting robots [43]. It can be found that the semi-structured interview is an effective way to collect data for studying the adoption of new technologies.

Furthermore, the application of EIT in PBPs is still in its infancy, and researchers have limited understanding of EIT. Therefore, based on the 20 influencing factors identified under the TOE framework and the form of the data needed in DEMATE-ISM, six experts with extensive experience in the field were invited to conduct interviews in this study. Before the interview, we designed a questionnaire to assist in obtaining expert information and evaluation. The questionnaire consists of two parts. The first part was used to collect basic information such as professional type, educational background, and work experience of experts. The second part was used to collect experts' evaluations on the relationship and influence strength of the 20 influencing factors. The data serve as the basis for the subsequent analysis. Therefore, in the second part, these experts were asked to assess whether there was an association between the 20 influencing factors and to score the degree of influence between pairs of factors with an association using a 5-point Likert scale from 0 to 4. The range spanned from 0 (no impact) to 1 (minimal impact), 2 (moderate impact), 3 (high impact), and 4 (very high impact). Finally, we collected six evaluations on the relationship between the influencing factors and the degree of influence. The specific information of these six experts is shown in Table 2, including stakeholders from designers, manufacturers, contractors, and research units. In addition, all six experts have three or more years of experience in using EIT, and have a relatively in-depth understanding of the adoption and promotion of EIT in PBPs. Therefore, the data of this study are valid and representative.

Table 2. Profiles of respondents.

Categories	Respondent Types	Number of Respondents	Percentage (%)
Occupation type	Designers	2	33.3%
	Manufacturers	1	16.7%
	Contractors	1	16.7%
	Research units	2	33.3%
Educational background	Ph.D.	2	33.3%
	Master's degree	1	16.7%
	Undergraduate or below	3	50%
Years of experience in EIT	6–10	1	16.7%
	3–5	3	50%
	<3	2	33.3%

3.2. Process Based on DEMATEL-ISM Method

The Decision Experimentation and Evaluation Laboratory (DEMATEL) uses a matrix structure to model the pairwise relationships between the influencing factors of complex problems [66,67]. It mainly uses the experience and knowledge of experts to make judgments on complex problems [68]. This method effectively discovers direct and indirect relationships between influencing factors and their interdependencies [69]. That is to say, DEMATEL divides the factors into cause and effect groups by calculating the influencing degree and the influenced degree of the factors to distinguish the attributes of the factors [66]. To further analyze the hierarchical relationship of each factor and clarify its internal relationship, this paper includes the interpretation structural model (ISM) method. The combination of both is helpful to identify the impact degree of emerging technology adoption and to construct a hierarchical structure of factors, which can effectively analyze the correlation between factors [70]. Thus, in summary, the use of DEMATEL-ISM can improve the understanding of clusters of specific and intertwined problems and help identify practical solutions through hierarchical structures [71,72]. Researchers often use this method to perform factor analysis based on this feature. For example, Reza Hoseini et al. used the DEMATEL-ISM method to explore the obstacles and challenges of BIM implementation in the construction industry and provide effective recommendations for adopting of BIM in the construction industry [73]. Li et al. used the DEMATEL-ISM method to analyze the influence degree and hierarchical structure of miners' insecurity emotion formation factors [74].

Summarizing previous studies, the steps for implementing the DEMATEL-ISM method in this study were formed [70,74,75]:

1. Determine the influencing factors of EIT adoption and promotion in PBPs. X represents the set of factors, and the factors are labeled as $x_1, x_2, \ldots, x_n$;
2. Determine the direct influence matrix A. The semi-structured interview method was used to compare the influence of x_i on x_j and its degree of influence (0–4). The comparison of the factor with itself is considered to have no effect; that is, the value of the diagonal in the direct influence matrix is 0. Therefore, the matrix A is shown in Equation (1):

$$A = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix} \quad (1)$$

where x_{ij} represents the degree of influence of x_i on x_j, and n is the number of EIT influencing factors;

3. Calculate the normalized direct relation matrix B through the method of the largest sum of rows. In other words, summing each row of matrix A, and normalizing the values in matrix A according to the rows' maximum value to obtain normative influence matrix B, whose expression is shown in Equation (2):

$$B = \frac{x_{ij}}{\max\left(\sum_{j=1}^{n} x_{ij}\right)} \quad (2)$$

4. Calculate the comprehensive influence matrix T. Matrix T represents the comprehensive effect of the direct and indirect influences between the influencing factors. When the matrix B conducts successive self-multiplication, all the values of the matrix will approach 0, that is, $\lim B_k = 0$. Its expression is shown in Equation (3):

$$T = \lim_{K\to\infty}\left(B + B^2 + \cdots + B^K\right) = \lim_{K\to\infty} B\left(I - B^K\right)(I-B)^{-1} = B(I-B)^{-1} \quad (3)$$

   where I is the identity matrix of the same order as B;
5. Calculate the influencing degree, influenced degree, centrality, and causality of the factors. The influencing degree refers to the sum of the values of each row in the comprehensive influence matrix, which represents the comprehensive influence value of factor x_i on all other factors, denoted as C_i. The influenced degree refers to the sum of the values of each column in matrix T, which means that x_i receives the comprehensive influence of all other factors, which is denoted as D_i. The centrality

of x_i (M_i) is the sum of its influencing and influenced degree, while the cause degree of x_i (N_i) is the difference between its influencing and influenced degree. If N_i is greater than 0, then x_i is the cause factor; otherwise, x_i is the effect factor. The above calculation equation is shown in (4)–(7):

$$C_i = \sum_{j=1}^{n} x_{ij},\ (i = 1, 2, \cdots, n) \tag{4}$$

$$D_i = \sum_{j=1}^{n} x_{ji},\ (i = 1, 2, \cdots, n) \tag{5}$$

$$M_i = C_i + D_i,\ \ (i = 1, 2, \cdots, n) \tag{6}$$

$$N_i = C_i - D_i, (i = 1, 2, \cdots, n) \tag{7}$$

6. Determine the overall influence matrix *E*. The matrix *E* is composed of the matrix *T* plus the identity matrix *I*. Its expression is shown in Equation (8):

$$E = T + I \tag{8}$$

7. Determine the reachability matrix *K*. When calculating the reachability matrix, a threshold λ needs to be introduced to eliminate the relationship between factors with less influence and facilitate the division of the structural hierarchy.

Since the value of λ directly affects the hierarchical division of the reachability matrix, how to determine the threshold λ is critical to establishing the reachability matrix. This study adopts the averaging method; that is, the threshold λ is determined by calculating the average value of the factors in the comprehensive influence matrix *T*. In matrix *K*, k_{ij} is calculated as shown in Equations (9) and (10):

$$If\ t_{ij} > \lambda(i, j = 1, 2, \cdots, n), k_{ij} = 1 \tag{9}$$

$$If\ t_{ij} < \lambda(i, j = 1, 2, \cdots, n), k_{ij} = 0 \tag{10}$$

where t_{ij} is the factor in the comprehensive influence matrix T. k_{ij} = 1 means that there is a strong influence relationship between factors x_i and x_j; on the contrary, there is no or weak influence relationship between x_i and x_j;

8. Construct a multi-level ISM model. The hierarchical division needs to determine the antecedent set ($F(x_i)$), reachable set ($R(x_i)$), and common set ($Q(x_i)$), which can be divided by Equations (11)–(13). If $Q(x_i) = R(x_i)$, then factor xi belongs to the first level; and repeating Equations (11)–(13) can perform the hierarchical division for all factors:

$$F(x_i) = \{x_j | x_j \in X, k_{ji} = 1\}, (i = 1, 2, \cdots, n) \tag{11}$$

$$R(x_i) = \{x_j | x_j \in X, k_{ij} = 1\}, (i = 1, 2, \cdots, n) \tag{12}$$

$$Q(x_i) = F(x_i) \cap R(x_i), (i = 1, 2, \cdots, n) \tag{13}$$

4. Results and Analysis

4.1. Result Analysis of DEMATEL

We calculated the influence degree of each factor on the EIT adoption and promotion in PBPs via DEMATEL. First, six direct influence matrices were obtained based on the scores of six experts for each pair of factors. The average values of the six direct influence matrices were calculated as the final direct influence matrix A in this study, as shown in Table 3. Then, according to Equations (2) and (3), this study used MATLAB to calculate the normalized direct relation matrix B as well as the comprehensive influence matrix T, as shown in Tables 4 and 5, respectively. Next, indicators such as the influencing degree, influenced degree, centrality, and causality of each factor can be calculated by Equations (4)–(7), and the figure of cause–effect of influencing factors of EIT adoption and promotion in PBPs is generated. The details are presented in Table 6 and Figure 2.

Table 3. Direct Influence Matrix A.

	T1	T2	T3	T4	T5	T6	T7	T8	O1	O2	O3	O4	O5	O6	O7	E1	E2	E3	E4	E5
T1	0	4	2	3	4	3	2	2	3	3	2	2	3	3	3	2	2	2	2	3
T2	4	0	2	3	3	3	2	2	3	3	3	3	3	3	3	1	2	2	3	3
T3	3	3	0	4	3	4	3	2	2	2	3	3	3	3	3	2	2	2	1	2
T4	3	3	2	0	3	3	3	3	3	3	2	3	2	3	2	2	3	2	2	2
T5	3	3	3	3	0	3	3	2	3	3	3	3	2	2	3	1	2	2	2	2
T6	3	3	2	3	3	0	3	3	3	2	3	3	2	2	3	2	2	2	2	2
T7	2	2	3	3	3	3	0	3	3	2	2	3	2	3	2	2	2	2	2	2
T8	2	2	3	3	3	2	3	0	3	3	3	3	2	2	2	2	3	2	2	3
O1	3	3	2	3	3	3	3	3	0	4	3	3	3	3	4	2	3	3	2	2
O2	3	3	2	3	4	2	2	2	4	0	3	3	3	3	4	2	2	2	2	2
O3	3	3	3	3	3	2	2	2	2	3	0	3	2	3	3	2	2	2	2	2
O4	3	3	2	3	3	3	2	2	3	3	3	0	2	3	3	3	2	2	2	2
O5	2	2	3	3	3	3	2	2	3	3	3	3	0	3	3	2	2	2	3	2
O6	3	3	2	3	3	3	3	3	3	3	3	3	2	0	4	3	2	2	2	2
O7	3	3	3	3	2	3	3	3	4	3	4	4	3	4	0	3	3	2	2	3
E1	2	2	2	2	2	2	3	3	2	2	3	3	3	2	2	0	2	3	2	2
E2	2	2	3	3	3	2	3	4	3	3	3	3	3	3	3	2	0	3	2	3
E3	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	1	1	0	2	2
E4	2	3	3	4	3	3	3	3	4	3	3	3	3	3	3	3	3	3	0	4
E5	3	3	3	3	3	3	3	3	3	3	3	4	4	3	3	3	3	3	4	0

Table 4. Normalized Direct Relation Matrix B.

	T1	T2	T3	T4	T5	T6	T7	T8	O1	O2	O3	O4	O5	O6	O7	E1	E2	E3	E4	E5
T1	0.000	0.067	0.033	0.050	0.067	0.050	0.033	0.033	0.050	0.050	0.033	0.033	0.050	0.050	0.050	0.033	0.033	0.033	0.033	0.050
T2	0.067	0.000	0.033	0.050	0.050	0.050	0.033	0.033	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.017	0.033	0.033	0.050	0.050
T3	0.050	0.050	0.000	0.067	0.050	0.067	0.050	0.033	0.033	0.033	0.050	0.050	0.050	0.050	0.050	0.033	0.033	0.033	0.017	0.033
T4	0.050	0.050	0.033	0.000	0.050	0.050	0.050	0.050	0.050	0.050	0.033	0.050	0.033	0.050	0.033	0.033	0.050	0.033	0.033	0.033
T5	0.050	0.050	0.050	0.050	0.000	0.050	0.050	0.033	0.050	0.050	0.050	0.050	0.033	0.033	0.050	0.017	0.033	0.033	0.033	0.033
T6	0.050	0.050	0.033	0.050	0.050	0.000	0.050	0.050	0.050	0.033	0.050	0.050	0.033	0.033	0.050	0.033	0.033	0.033	0.033	0.033
T7	0.033	0.033	0.050	0.050	0.050	0.050	0.000	0.050	0.050	0.033	0.033	0.050	0.033	0.050	0.033	0.033	0.033	0.033	0.033	0.033
T8	0.033	0.033	0.050	0.050	0.050	0.033	0.050	0.000	0.050	0.050	0.050	0.050	0.033	0.033	0.033	0.033	0.050	0.033	0.033	0.050
O1	0.050	0.050	0.033	0.050	0.050	0.050	0.050	0.050	0.000	0.067	0.050	0.050	0.050	0.050	0.067	0.033	0.050	0.050	0.033	0.033
O2	0.050	0.050	0.033	0.050	0.067	0.033	0.033	0.033	0.067	0.000	0.050	0.050	0.050	0.050	0.067	0.033	0.033	0.033	0.033	0.033
O3	0.050	0.050	0.050	0.050	0.050	0.033	0.033	0.033	0.033	0.050	0.000	0.050	0.033	0.050	0.050	0.033	0.033	0.033	0.033	0.033
O4	0.050	0.050	0.033	0.050	0.050	0.050	0.033	0.033	0.050	0.050	0.050	0.000	0.033	0.050	0.050	0.050	0.033	0.033	0.033	0.033
O5	0.033	0.033	0.050	0.050	0.050	0.050	0.033	0.033	0.050	0.050	0.050	0.050	0.000	0.050	0.050	0.033	0.033	0.033	0.050	0.033
O6	0.050	0.050	0.033	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.033	0.000	0.067	0.050	0.033	0.033	0.033	0.033
O7	0.050	0.050	0.050	0.050	0.033	0.050	0.050	0.050	0.067	0.050	0.067	0.067	0.050	0.067	0.000	0.050	0.050	0.033	0.033	0.050
E1	0.033	0.033	0.033	0.033	0.033	0.033	0.050	0.050	0.033	0.033	0.050	0.050	0.050	0.033	0.033	0.000	0.033	0.050	0.033	0.033
E2	0.033	0.033	0.050	0.050	0.050	0.033	0.050	0.067	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.033	0.000	0.050	0.033	0.050
E3	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.050	0.033	0.033	0.017	0.017	0.000	0.033	0.033
E4	0.033	0.050	0.050	0.067	0.050	0.050	0.050	0.050	0.067	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.000	0.067
E5	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.067	0.067	0.050	0.050	0.050	0.050	0.050	0.067	0.000

Table 5. Comprehensive Influence Matrix T.

	T1	T2	T3	T4	T5	T6	T7	T8	O1	O2	O3	O4	O5	O6	O7	E1	E2	E3	E4	E5
T1	0.224	0.290	0.235	0.293	0.306	0.274	0.248	0.243	0.291	0.279	0.266	0.278	0.262	0.278	0.287	0.206	0.220	0.217	0.211	0.242
T2	0.292	0.233	0.240	0.299	0.296	0.279	0.253	0.248	0.296	0.284	0.286	0.299	0.267	0.283	0.293	0.196	0.225	0.221	0.230	0.247
T3	0.269	0.272	0.201	0.306	0.288	0.287	0.261	0.241	0.272	0.260	0.278	0.291	0.258	0.275	0.284	0.205	0.218	0.215	0.193	0.224
T4	0.266	0.269	0.230	0.239	0.285	0.268	0.258	0.254	0.284	0.273	0.260	0.287	0.241	0.272	0.266	0.202	0.231	0.213	0.206	0.222
T5	0.263	0.266	0.242	0.284	0.233	0.265	0.254	0.234	0.280	0.269	0.271	0.283	0.237	0.253	0.277	0.184	0.212	0.209	0.203	0.218
T6	0.261	0.265	0.227	0.282	0.279	0.216	0.254	0.249	0.279	0.253	0.270	0.282	0.237	0.252	0.276	0.199	0.212	0.209	0.203	0.218
T7	0.237	0.240	0.234	0.273	0.270	0.255	0.198	0.241	0.270	0.244	0.246	0.273	0.228	0.258	0.251	0.192	0.205	0.202	0.195	0.210
T8	0.246	0.249	0.243	0.283	0.280	0.249	0.255	0.202	0.280	0.269	0.271	0.283	0.237	0.253	0.261	0.199	0.228	0.210	0.203	0.233
O1	0.291	0.294	0.253	0.315	0.312	0.293	0.282	0.277	0.264	0.314	0.302	0.315	0.280	0.298	0.323	0.222	0.252	0.249	0.226	0.244
O2	0.276	0.279	0.239	0.298	0.310	0.263	0.252	0.247	0.310	0.236	0.286	0.298	0.266	0.283	0.307	0.210	0.224	0.221	0.214	0.230
O3	0.258	0.261	0.238	0.278	0.275	0.245	0.235	0.230	0.260	0.264	0.219	0.278	0.233	0.264	0.272	0.196	0.208	0.206	0.199	0.215
O4	0.266	0.269	0.230	0.287	0.284	0.268	0.243	0.238	0.284	0.273	0.275	0.240	0.241	0.272	0.281	0.218	0.215	0.213	0.206	0.221
O5	0.251	0.255	0.247	0.289	0.285	0.269	0.244	0.239	0.285	0.274	0.277	0.288	0.209	0.273	0.282	0.204	0.216	0.214	0.222	0.222
O6	0.279	0.282	0.242	0.301	0.298	0.281	0.271	0.266	0.298	0.286	0.289	0.302	0.253	0.238	0.309	0.228	0.226	0.223	0.216	0.233
O7	0.305	0.308	0.281	0.330	0.311	0.307	0.295	0.290	0.341	0.313	0.331	0.345	0.293	0.327	0.275	0.249	0.263	0.245	0.237	0.270
E1	0.226	0.229	0.210	0.246	0.243	0.229	0.235	0.231	0.243	0.233	0.251	0.261	0.234	0.232	0.240	0.152	0.195	0.209	0.188	0.201
E2	0.267	0.270	0.261	0.306	0.302	0.269	0.274	0.285	0.302	0.290	0.293	0.306	0.272	0.289	0.298	0.216	0.197	0.242	0.219	0.251
E3	0.199	0.201	0.184	0.216	0.213	0.201	0.193	0.189	0.213	0.204	0.206	0.215	0.207	0.204	0.210	0.147	0.157	0.138	0.165	0.177
E4	0.293	0.312	0.285	0.350	0.331	0.312	0.300	0.295	0.346	0.317	0.320	0.335	0.298	0.316	0.327	0.252	0.268	0.265	0.209	0.290
E5	0.312	0.316	0.289	0.339	0.335	0.316	0.303	0.298	0.335	0.321	0.324	0.354	0.317	0.320	0.331	0.255	0.270	0.267	0.275	0.231

Table 6. Results of DEMATEL analysis.

Factors	Influencing Degree	Influenced Degree	Centrality	Causality
T1	3.294	3.243	6.537	0.050
T2	3.301	3.237	6.539	0.064
T3	3.383	2.797	6.179	0.586
T4	3.215	3.650	6.865	−0.434
T5	3.016	3.601	6.618	−0.585
T6	3.340	3.464	6.804	−0.125
T7	3.062	3.266	6.329	−0.204
T8	3.128	3.121	6.249	0.006
O1	3.314	3.924	7.239	−0.610
O2	3.334	3.742	7.076	−0.407
O3	2.957	3.729	6.686	−0.772
O4	3.329	3.715	7.045	−0.386
O5	3.233	3.373	6.606	−0.140
O6	3.585	3.681	7.266	−0.097
O7	3.603	3.617	7.220	−0.014
E1	2.894	2.677	5.571	0.216
E2	3.404	2.739	6.143	0.665
E3	2.288	2.589	4.877	−0.301
E4	4.181	2.622	6.804	1.559
E5	3.918	2.991	6.910	0.927

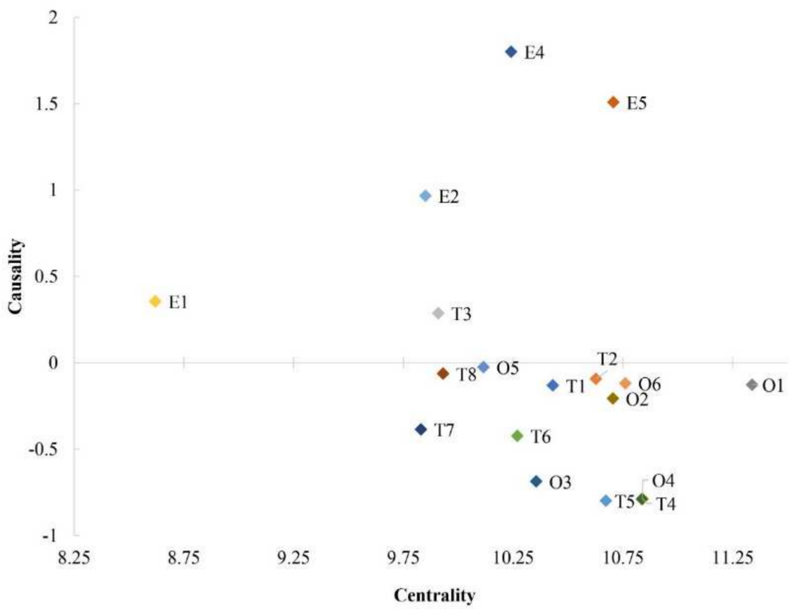

Figure 2. Cause–effect diagram of factors influencing EIT adoption and promotion.

The attributes of each factor can be obtained by comprehensively analyzing the indicators of influencing degree, influenced degree, centrality, and causality calculated by DEMATEL. Influencing Degree represents the combined influence of factor x_i on other factors, indicating that the factor with a larger value has a stronger influence. E4, E5, O7, O1, and E2 ranked in the top five in terms of influencing degree, which belongs to the environmental and organizational dimensions. It can be shown that factors such as industry needs, EIT-related national policies and regulations, attitudes of top management, and benefits of adopting EIT can not only directly affect, but also indirectly affect the adoption and promotion of EIT by affecting the remaining factors [9,11]. Influenced degree means that factor x_i receives the combined influence of other factors. T4, O4, T5, O1, and O7 have highly influenced degrees, which shows that these factors are susceptible to other factors, and also shows that these factors are more closely related to other factors. Naturally, the improvement of these factors can effectively promote the adoption and promotion of EIT. Centrality demonstrates the importance of factor x_i, among which the centrality of O7, O1, T4, O4, and O6 ranks in the top five. Except for T4, all other factors belong to the organizational dimension, reflecting that the main factor affecting the adoption and promotion of EIT in PBPs are to consider whether the attributes of the organization itself meet the conditions for EIT adoption and promotion [11,44,76]. Finally, the factors were divided into cause and effect factors based on whether the causality was greater than 0, including 6 cause factors (E4, E5, E2, E1, T3, O7) and 14 effect factors (O5, T8, T2, O6, O1, T1, O2, T7, T6, E3, O3, T4, O4, T5). The factors of E4, E5, E2, and E1 appear in the cause group, reflecting that these environmental factors are the more fundamental and driving factors in EIT adoption and promotion. The complexity of EIT is considered to be a major barrier to its adoption and promotion, and the more complex the EIT, the less likely it is to be adopted [45]. The benefits of EIT are the motivation for organizations to adopt EIT [77]. In addition, it is worth noting that O1, O6, and O7 have a high influencing degree, influenced degree, and centrality at the same time, which can be interpreted as the organizations in PBPs being mainly benefit-oriented. When the cost of adopting EIT is acceptable, and EIT is beneficial, the top managers of the organization will support the adoption of EIT.

4.2. Result Analysis of ISM

ISM can be used to build a multi-level model to display the hierarchical relationship between factors. Therefore, the construction of the ISM model was carried out on the basis of the comprehensive influence matrix T obtained from DEMATEL. First, the overall influence matrix E is obtained by adding the comprehensive influence matrix T to the identity matrix I of the same order, which includes the influence of the factors themselves, as shown in Table 7. Then, the threshold λ is calculated, and the reachability matrix K is obtained according to Equations (9) and (10), as shown in Table 8. Here, the value of λ is 0.257. Next, the hierarchies of the factors were divided using Equations (11)–(13), and the results are shown in Table 9 and Figure 3.

Table 7. The Overall Influence Matrix E.

	T1	T2	T3	T4	T5	T6	T7	T8	O1	O2	O3	O4	O5	O6	O7	E1	E2	E3	E4	E5
T1	1.224	0.290	0.235	0.293	0.306	0.274	0.248	0.243	0.291	0.279	0.266	0.278	0.262	0.278	0.287	0.206	0.220	0.217	0.211	0.242
T2	0.292	1.233	0.240	0.299	0.296	0.279	0.253	0.248	0.296	0.284	0.286	0.299	0.267	0.283	0.293	0.196	0.225	0.221	0.230	0.247
T3	0.269	0.272	1.201	0.306	0.288	0.287	0.261	0.241	0.272	0.260	0.278	0.291	0.258	0.275	0.284	0.205	0.218	0.215	0.193	0.224
T4	0.266	0.269	0.230	1.239	0.285	0.268	0.258	0.254	0.284	0.273	0.260	0.287	0.241	0.272	0.266	0.202	0.231	0.213	0.206	0.222
T5	0.263	0.266	0.242	0.284	1.233	0.265	0.254	0.234	0.280	0.269	0.271	0.283	0.237	0.253	0.277	0.184	0.212	0.209	0.203	0.218
T6	0.261	0.265	0.227	0.282	0.279	1.216	0.254	0.249	0.279	0.253	0.270	0.282	0.237	0.252	0.276	0.199	0.212	0.209	0.203	0.218
T7	0.237	0.240	0.234	0.273	0.270	0.255	1.198	0.241	0.270	0.244	0.246	0.273	0.228	0.258	0.251	0.192	0.205	0.202	0.195	0.210
T8	0.246	0.249	0.243	0.283	0.280	0.249	0.255	1.202	0.280	0.269	0.271	0.283	0.237	0.253	0.261	0.199	0.228	0.210	0.203	0.233
O1	0.291	0.294	0.253	0.315	0.312	0.293	0.282	0.277	1.264	0.314	0.302	0.315	0.280	0.298	0.323	0.222	0.252	0.249	0.226	0.244
O2	0.276	0.279	0.239	0.298	0.310	0.263	0.252	0.247	0.310	1.236	0.286	0.298	0.266	0.283	0.307	0.210	0.224	0.221	0.214	0.230
O3	0.258	0.261	0.238	0.278	0.275	0.245	0.235	0.230	0.260	0.264	1.219	0.278	0.233	0.264	0.272	0.196	0.208	0.206	0.199	0.215
O4	0.266	0.269	0.230	0.287	0.284	0.268	0.243	0.238	0.284	0.273	0.275	1.240	0.241	0.272	0.281	0.218	0.215	0.213	0.206	0.221
O5	0.251	0.255	0.247	0.289	0.285	0.269	0.244	0.239	0.285	0.274	0.277	0.288	1.209	0.273	0.282	0.204	0.216	0.214	0.222	0.222
O6	0.279	0.282	0.242	0.301	0.298	0.281	0.271	0.266	0.298	0.286	0.289	0.302	0.253	1.238	0.309	0.228	0.226	0.223	0.216	0.233
O7	0.305	0.308	0.281	0.330	0.311	0.307	0.295	0.290	0.341	0.313	0.331	0.345	0.293	0.327	1.275	0.249	0.263	0.245	0.237	0.270
E1	0.226	0.229	0.210	0.246	0.243	0.229	0.235	0.231	0.243	0.233	0.251	0.261	0.234	0.232	0.240	1.152	0.195	0.209	0.188	0.201
E2	0.267	0.270	0.261	0.306	0.302	0.269	0.274	0.285	0.302	0.290	0.293	0.306	0.272	0.289	0.298	0.216	1.197	0.242	0.219	0.251
E3	0.199	0.201	0.184	0.216	0.213	0.201	0.193	0.189	0.213	0.204	0.206	0.215	0.207	0.204	0.210	0.147	0.157	1.138	0.165	0.177
E4	0.293	0.312	0.285	0.350	0.331	0.312	0.300	0.295	0.346	0.317	0.320	0.335	0.298	0.316	0.327	0.252	0.268	0.265	1.209	0.290
E5	0.312	0.316	0.289	0.339	0.335	0.316	0.303	0.298	0.335	0.321	0.324	0.354	0.317	0.320	0.331	0.255	0.270	0.267	0.275	1.231

Table 8. The Reachability Matrix K.

	T1	T2	T3	T4	T5	T6	T7	T8	O1	O2	O3	O4	O5	O6	O7	E1	E2	E3	E4	E5
T1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0
T2	0	1	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0
T3	0	0	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
T4	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T5	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
T6	0	0	0	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0
T7	0	0	0	1	1	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0
T8	0	0	0	1	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0
O1	0	0	0	1	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0
O2	0	0	0	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
O3	0	0	0	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
O4	0	0	0	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
O5	0	0	0	1	1	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0
O6	0	0	0	1	1	0	1	0	1	0	1	1	0	1	0	0	0	0	0	0
O7	0	0	0	1	1	1	1	0	1	1	1	1	0	0	1	0	0	0	0	0
E1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
E2	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0
E3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
E4	0	0	1	0	0	0	0	0	1	0	1	1	1	1	1	0	1	1	1	1
E5	0	0	1	0	0	0	0	0	1	0	1	1	1	1	1	0	1	1	1	1

Table 9. Hierarchy of factors influencing EIT adoption and promotion.

Factors	Reachable Set R (x_i)	Antecedent Set F (x_i)	Common Set Q (x_i)	Hierarchy
T1	T1, T2, T3, T4, T5, T6, O1, O2, O3, O4, O5, O6, O7	T1, T2, T3, T4, T5, T6, O1, O2, O3, O4, O6, O7, E2, E4, E5	T1, T2, T3, T4, T5, T6, O1, O2, O3, O4, O6, O7	5
T2	T1, T2, T3, T4, T5, T6, O1, O2, O3, O4, O5, O6, O7	T1,T2, T3, T4, T5,T6, O1, O2, O3, O4, O6,O7, E2, E4, E5	T1, T2, T3, T4, T5, T6, O1, O2, O3, O4, O6, O7	5
T3	T1, T2, T3, T8, O1, O2, O3, O4, O5, O6, O7	T3, O7, E2, E4, E5	T3,O7	5
T4	T1, T2, T4, T5, T6, T7, O2, O3, O4, O6, O7	T1, T2, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T4, T5, T6, T7, O2, O3, O4, O6, O7	1
T5	T1, T2, T4, T5, T6, O1, O2, O3, O4, O7	T1, T2, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T4, T5, T6, O1, O2, O3, O4, O7	1
T6	T1, T2, T4, T5, T6, O1, O3, O4, O7	T1, T2, T4, T5, T6, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T4, T5, T6, O1, O3, O4, O7	2
T7	T4, T5, T7, O1, O4, O6	T4, T7, O1, O6, O7, E2, E4, E5	O1, T4, O6, T7	2
T8	T4, T5, T8, O1, O2, O3, O4, O7	T3, T8, O1, O6, O7, E2, E4, E5	T8, O1, O7	4
O1	T1, T2, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7	T1, T2, T3, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7	1
O2	T1, T2, T4, T5, T6, O1, O2, O3, O4, O5, O6, O7	T1, T2, T3, T4, T5, T8, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T4, T5, O1, O2, O3, O4, O5, O6, O7	3
O3	T1, T2, T4, T5, T6, O1, O2, O3, O4, O6, O7	T1, T2, T3, T4, T5, T8, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T4, T5, O1, O2, O3, O4, O6, O7	2
O4	T1, T2, T4, T5, T6, O1, O2, O3, O4, O6, O7	T1, T2, T3, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E1, E2, E4, E5	T1, T2, T4, T5, T6, O1, O2, O3, O4, O6, O7	1
O5	T4, T5, T6, O1, O2, O3, O4, O5, O6, O7	T1, T2, T3, O1, O2, O5, O7, E2, E4, E5	O1, O2, O5, O7	4
O6	T1, T2, T4, T5, T6, T7, O1, O2, O3, O4, O6, O7	T1, T2, T3, T4, T7, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T4, T7, O1, O2, O3, O4, O6, O7	3
O7	T1, T2, T3, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E2, E5	T1, T2, T3, T4, T5, T6, T8, O1, O2, O3, O4, O5, O6, O7, E2, E4, E5	T1, T2, T3, T4, T5, T6, T8, O1, O2, O3, O4, O5, O6, O7, E2, E5	3
E1	O4, E1	E1	E1	2
E2	T1, T2, T3, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E2	O7, E2, E4, E5	E2, O7	5
E3	E3	E3, E4, E5	E3	1
E4	T1, T2, T3, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E2, E3, E4, E5	E4, E5	E4, E5	6
E5	T1, T2, T3, T4, T5, T6, T7, T8, O1, O2, O3, O4, O5, O6, O7, E2, E3, E4, E5	O7, E4, E5	E4, E5, O7	6

As can be seen from Table 9 and Figure 3, the ISM is used to divide the 20 factors into 5 levels, with the first level being the direct factors, the 2–4 level being the middle factors and the fifth level being the fundamental factors. Generally speaking, the factors located in the lower level play a more critical role in the overall system because it affects other factors in the upper level. For example, E4 and E5 are located at the bottom and belong to the fundamental factors. This is understandable; for one thing, the national policies and regulations of EIT will have a mandatory effect on the adoption and promotion of

EIT [78]. For another, the existence of a need for EIT in PBPs is the premise of EIT adoption. Therefore, both of these factors can fundamentally drive the adoption and promotion of EIT. However, due to the fact that the use of EIT in PBPs is still in the early stage of development, the policies and regulations related to EIT are still incomplete, and the effect on the adoption and promotion of EIT is not significant [79]. T4, T5, O1, O4, and E3 are located at the top level and belong to direct factors. The maturity and standardization level of EIT represent the advanced nature of EIT, and organizations in PBPs are more inclined to choose mature and standardized EIT. In addition, top managers' attitudes toward EIT is the most direct factor in the adoption and promotion of EIT. It is susceptible to the costs and benefits of EIT [77]. It should also be noted that top managers need to consider factors such as the structure of the organization, the expertise and talents in the organization, and change-resistant attitudes when adopting EIT [19]. Finally, the factors in levels 2 to 4 are between the direct influence level and the fundamental influence level, and there are more links between these factors. The fundamental factors can influence the direct factors through these mediating factors. For example, E5 can weaken O5 by influencing T2 to encourage O3 and O4 in the organization, which will increase the acceptance and promotion of EIT in PBPs.

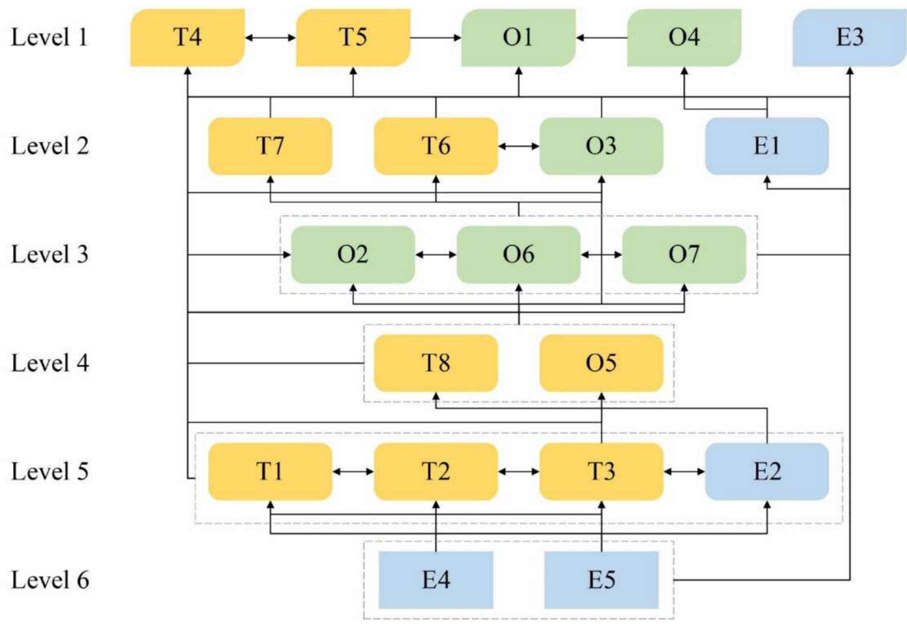

Figure 3. Hierarchical structure model.

5. Discussion and Recommendations

5.1. Discussion

The hybrid evaluation model developed in this work combines a literature review for identifying influential variables, a DEMATEL method for analyzing each factor's attributes, and an ISM approach for building a relationship path between the factors. This hybrid evaluation model successfully figures out the problem of sluggish development of EIT in PBPs from a systematic level.

In the first stage, we summarize the factors influencing the adoption and promotion of EIT in PBPs from technological, organizational, and environmental dimensions. The technical dimension mainly focuses on factors such as whether the attributes and functions of the EIT itself can support or replace traditional solutions to improve the efficiency of problem solving, and whether the EIT can be successfully implemented during the adoption process. The organizational dimension emphasizes that when enterprises in PBPs adopt EIT, they need to consider factors such as the structure and resources of the enterprise, as well as whether managers and employees can support the introduction and adoption of EIT. The environmental dimension analyzes the supply and demand relationship of EIT in the construction industry, the behavior of the government, and related enterprises such as customers, competitors, and partners from the perspective of the macro industry environment. In summary, this study establishes a theoretical framework to list the factors that need to be considered in the adoption and promotion of EIT in PBPs in a more comprehensive and systematic structure.

Based on the influencing factors collected in the first stage, DEMATEL provides an effective tool to evaluate the attributes of influencing factors, including influencing degree, influenced degree, centrality, and causality. From the three dimensions of TOE, most of the factors in the technology dimension do not have a significant impact on EIT adoption and promotion. It reflects that organizations in PBPs still lack awareness and understanding of the functions and performance of EIT, resulting in a low demand for EIT [44,80]. The factors of the organization dimension have a high influenced degree, and these factors can directly affect whether PBPs adopt EIT. For example, the organization is the adopter and promoter of EIT, and the supportive attitude of top managers in organizations can directly affect the adoption of EIT. In addition, if the organization has EIT training programs and masters of EIT-related professional knowledge, it will increase the understanding of EIT, thereby enhancing its use and promotion [51,78]. Relatively speaking, the influencing degree of the environmental dimension factor is more significant, which demonstrates that it is necessary to create a positive industrial environment for the adoption and promotion of EIT [81].

Finally, ISM is used to build a multi-level model and analyze the path relationship between critical factors. For instance, O3 is affected by nine factors. Organizations tend to integrate multiple technologies together when using EIT. The interoperability between EIT and the complexity of their implementation drive organizations to train to help workers quickly acquire EIT expertise. The change-resistant attitudes in PBPs and the feasibility of EIT costs negatively influence whether organizations will have training programs for EIT. TI, T2, T3, and O7 can affect most factors. The ability of EIT to integrate and match workflows in PBPs and the complexity of implementation reflect technical feasibility, while EIT benefits reflect economic rationality. These influencing factors can affect all factors of the organizational dimension, which are the main references in the process of stakeholders adopting and promoting EIT.

5.2. Recommendations for Future Research

By analyzing the influencing factors, this study found the deficiencies in the existing work and proposed directions that can be focused on for future research. It is mainly explained from three levels, namely industry, project, and organizational levels.

For the construction industry, the government should play a leading role in the adoption and promotion of EIT. It is necessary to supervise and regulate the adoption and promotion of EIT in the construction industry, especially among SMEs, to expand the scope of EIT promotion. In addition, the government should coordinate stakeholders in the construction industry to develop and improve policies and regulations for EIT adoption and promotion, and promote it at the macro level [11,82].

For prefabricated building projects, the project from planning to operation involves collaboration, information exchange, and sharing among multiple professional stakeholders. The attitudes of multiple professional stakeholders towards cooperation can affect whether EIT can be successfully implemented in PBPs [83,84]. In addition, EIT facilitates information exchange and the degree of information sharing among stakeholders, which can affect the effectiveness of EIT in PBPs. Therefore, improving the cooperative attitudes and the degree of information sharing among stakeholders facilitates the smooth adoption EIT in PBPs.

For organizations in PBPs, it is necessary to respond to the government's encouragement, understand the advantages and performance of EIT applications in PBPs, and actively accept EIT [44,85]. At the same time, to ensure a competitive advantage, organizations should actively participate in the innovation and integration of EIT to adapt to the continuous development of the industry [86].

6. Conclusions

The advantage of EIT lies in the use of intelligent, digital, and automated means to solve problems such as difficulties in information sharing, stakeholder coordination, and construction process management. However, since the development of EIT in PBPs is still in the infancy stage, there are many complex challenges in the adoption and promotion of EIT, and its application in the construction industry is still limited. Therefore, this study aims to analyze the influencing factors and their attributes to understand the influencing paths of EIT adoption and promotion, thereby promoting the development of EIT. First, this study identified 20 influencing factors of EIT adoption and promotion in PBPs through the literature review method, which were divided into three dimensions: technology, organization, and environment. Then, the relationships between the influencing factors and their extent were evaluated through interviews with experts who have extensive experience in EIT application. Finally, the DEMATEL-ISM method is used to analyze the main influencing factors and attributes of EIT adoption and promotion, which is beneficial to increase the awareness of EIT among researchers and industry practitioners and promote the development of EIT. The main findings of this study are as follows:

1. Through the DEMATEL analysis, 20 influencing factors were divided into 6 cause factors and 14 effect factors. The evaluation results show that most of the cause factors belong to the environmental dimension, indicating that environmental factors have a significant influencing degree and can drive the adoption and promotion of EIT in BPBs. Although O1, O6, and O7 belong to the effect factors, they have a high influencing degree, influenced degree, and centrality at the same time, reflecting that the enterprises in PBPs are profit-oriented, and their decision-making power is in the hands of top managers;
2. The ISM was used to develop the multilevel hierarchical model of 20 influencing factors, including direct factors (Level 1), middle factors (Level 2–4), and fundamental factors (Level 5), and to provide influence paths that promote EIT adoption and promotion. With the information provided by the model, researchers and industry practitioners can make targeted solutions to promote EIT in PBPs in actual projects.

Furthermore, this study provides theoretical contributions and practical insights for research related to EIT adoption and promotion in PBPs. The theoretical contribution is to identify 20 influencing factors and in-depth associations of these factors. The main influencing factors and their attributes are also analyzed to provide a theoretical basis for researchers and industry practitioners to promote the adoption and promotion of EIT in PBPs. Meanwhile, this study can enhance cooperative attitudes and the degree of information-sharing among stakeholders in PBPs. It can also improve the government and stakeholders in PBPs to understand and pay attention to EIT, which will help EIT to be implemented more successfully. Therefore, this study can promote the adoption and promotion of EIT in PBPs from both theoretical and practical aspects and narrow the gap between theory and practical application.

However, there are still some limitations in this study, which need to be improved in future research. Due to differences in scale, organizational structure, and resources, large enterprises and SMEs have distinctions in the influencing factors and degrees of EIT adoption and promotion. However, this study does not make a distinction, which can be a direction for subsequent research. Next, since the application of EIT in PBPs is still in the infancy stage, the number of experts with rich EIT expertise is small. Therefore, the sources of data collection are relatively narrow, and the research methods are highly subjective, which means the scope of data sources and the objectivity of data can be expanded in the future.

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