

Extending the UTAUT2 Model with Environmental and Social Factors: The Case of Indonesia's Environmental Pollution and Damage Control Information System

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ABSTRACT

This study examines business owners' acceptance of Indonesia's Environmental Pollution and Damage Control Information System using an extended UTAUT2 model that incorporates environmental awareness and social responsibility as moderators. A quantitative survey of 368 business owners across six regions was analyzed with Structural Equation Modeling (SmartPLS 3.0) to assess measurement validity, structural relationships, and moderating effects. Results indicate that performance expectancy and social influence significantly impact behavioral intention, while habit and facilitating conditions strongly influence actual system use. Effort expectancy, hedonic motivation, and price value showed minimal effects. Environmental awareness did not significantly moderate adoption, whereas social responsibility enhanced the link between habit and behavior. These findings emphasize the importance of practical benefits and ethical considerations over enjoyment or cost in adopting environmental technology. The study contributes academically by integrating sustainability-focused factors into UTAUT2 and offers practical guidance for policymakers seeking to boost adoption in environmental governance.

Keywords—environmental pollution; environmental damage control information system; technology acceptance; extended UTAUT2 model

I. INTRODUCTION

Environmental pollution and ecological degradation are critical global issues that threaten public health, biodiversity, and long-term sustainability [1-3]. Rapid industrialization, urban growth, and heavy resource extraction have led to the pollution of air, water, and soil, as well as deforestation. The Polluter Pays Principle (PPP) stresses that companies responsible for pollution should be held financially accountable for mitigation and environmental restoration [4, 5]. Without adequate control measures, environmental degradation can lead to respiratory diseases, loss of farmable land, freshwater shortages, and weakened ecosystems [6]. International organizations such as the WHO and the UNEP underscore the severity of these issues, particularly in developing countries where untreated industrial wastewater and air pollution are typical.

In Indonesia, these environmental issues are worsened by uneven law enforcement, limited monitoring capacity, and diverse industrial activities [7, 8]. To address this, the Ministry of Environment and Forestry (MoEF) created the Environmental Pollution and Damage Control Information System. This digital platform monitors air and water quality, industrial emissions, peatlands, coastal waters, and electronic reporting. Despite being adopted by thousands of companies, adoption rates differ, with modules like SIMPEL having only 58% active participation. This uneven participation hinders real-time monitoring, compliance, and effective environmental governance. Improving system use is therefore vital to enhancing environmental management results.

User adoption is essential for the success of technological initiatives like the Environmental Pollution and Damage Control Information System [9, 10]. Business owners, responsible for reporting on environmental performance, assess whether the system accomplishes its objectives. Low or inconsistent adoption weakens environmental governance efforts and limits the system's effectiveness. Understanding the behavioral, social, and contextual factors that influence technology acceptance is crucial for designing effective policies, training programs, and compliance strategies. These factors ultimately decide whether technology can support environmental protection objectives.

This study utilizes the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) to investigate factors influencing system adoption, such as performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit [11-13]. To include sustainability factors, the model expands UTAUT2 with environmental awareness and social responsibility as moderating variables [14, 15]. This approach connects traditional technology acceptance theory with sustainable development principles, capturing both functional and ethical motivators of user behavior. Figure 1 illustrates these relationships, showing the direct effects of technological constructs on usage behavior, moderated by environmental awareness and social responsibility. This offers a theoretically

based perspective on incorporating sustainable development considerations into technology adoption research.

The study examines business owners' behavioral intentions and actual usage of the Environmental Pollution and Damage Control Information System in Indonesia, emphasizing the direct effects of UTAUT2 constructs and the moderating roles of environmental awareness and social responsibility [3, 13, 16-22]. Environmental awareness reflects users' knowledge and values regarding ecological preservation, while social responsibility includes ethical and community obligations aligned with CSR frameworks [21, 22]. By integrating these dimensions into UTAUT2, the study provides a comprehensive understanding of technology acceptance, linking sustainability principles with adoption behavior. This framework guides both theoretical insights and practical advice for policymakers to enhance compliance, adoption, and the effectiveness of environmental management systems.

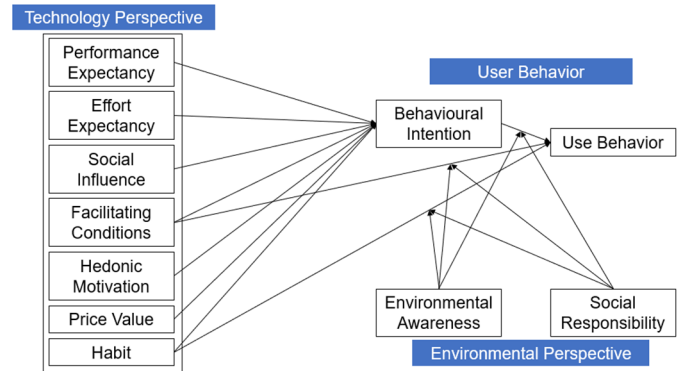


Fig. 1. Conceptual framework.

II. METHODOLOGY

A. Research Design

This study used a quantitative approach to analyze technology acceptance and usage among business actors adopting the Environmental Pollution and Damage Control Information System, employing both descriptive and causal analyses. Independent variables consisted of "Performance Expectancy", "Effort Expectancy", "Social Influence", "Facilitating Conditions", "Hedonic Motivation", "Price Value", and "Habit". The dependent variables were "Behavioural Intention" and "Use Behaviour", with "Environmental Awareness" and "Social Responsibility" acting as moderators. Questionnaire items were adapted from validated UTAUT2 instruments and pilot-tested with 30 respondents to ensure clarity, reliability, and content validity. To minimize common method bias, anonymity was guaranteed, question order was counterbalanced, and Harman's single-factor test was applied. Data were collected over four months (May–August 2024) from users across six major regions in Indonesia—Sumatra, Java, Maluku & Nusa Tenggara, Kalimantan, Sulawesi, and Papua. SmartPLS was chosen for structural equation modelling due to its suitability for small to

medium sample sizes, its ability to handle complex models with moderating effects, and its minimal assumptions about data distribution, all of which improve methodological rigor and replicability.

B. Population and Sample

The study included 4,520 companies utilizing the Environmental Pollution and Damage Control Information System across six major regions of Indonesia (Table I). To ensure a representative sample, the Slovin formula was used with a 95% confidence level and a 5% margin of error, resulting in a sample size of 368 companies. Proportional random sampling was then used to assign respondents based on each region's share of the total population (Table II), with 162 companies in Java and 3 in Papua, thus ensuring statistical validity and reducing sampling bias. This approach ensured fair representation from both densely and sparsely populated regions, improving the generalizability of the results and accurately reflecting national patterns of system acceptance and use.

TABLE I. POPULATION OF COMPANIES USING THE KLHK APPLICATION

No.	Island/Region	Population
1	Sumatra	1,263
2	Java	1,990
3	Maluku & Nusa Tenggara	111
4	Kalimantan	782
5	Sulawesi	339
6	Papua	35

TABLE II. POPULATION AND PROPORTIONAL SAMPLE OF COMPANIES USING THE KLHK APPLICATION

No.	Island/Region	Population	Formula	Sample
1	Sumatra	1,263	$(1,263 / 4,520) \times 368$	103
2	Java	1,990	$(1,990 / 4,520) \times 368$	162
3	Maluku & Nusa Tenggara	111	$(111 / 4,520) \times 368$	9
4	Kalimantan	782	$(782 / 4,520) \times 368$	64
5	Sulawesi	339	$(339 / 4,520) \times 368$	28
6	Papua	35	$(35 / 4,520) \times 368$	3

C. Data Analysis Techniques

Data for this study were gathered through a structured online questionnaire that used a 5-point Likert scale to assess business users' perceptions of the Environmental Pollution and Damage Control Information System. Questionnaire items were adapted from validated UTAUT2 instruments and modified to include constructs of environmental awareness and social responsibility, with translation and back-translation to ensure accuracy. A pilot test with 30 respondents assessed clarity and initial validity, and items were adjusted based on feedback. Procedural remedies, such as assuring anonymity, randomizing question order, and separating predictor and outcome items, were used to decrease common method bias. Practical insights from respondents, including reporting issues,

regulatory difficulties, and CSR motivations, were also included. Data were analyzed with SmartPLS 3.0 across three SEM stages: the outer model for validity and reliability, the inner model for R² and Q² evaluation, and bootstrapping for hypothesis testing ($T > 1.96$, 5% significance). This approach guarantees methodological rigor, replicability, and robustness while incorporating a practical, human aspect into the findings, supporting a thorough understanding of factors that influence technology adoption among business users.

III. RESULTS AND DISCUSSION

A. Outer Model Results

The outer model evaluation checks the validity and reliability of the measurement model to ensure that each construct and its indicators are appropriate for further analysis. As shown in Table III and Figure 2, all reflective indicators have outer loadings above the recommended threshold of 0.70, demonstrating strong indicator validity and confirming that each indicator is closely linked to its latent variable. Additionally, the Average Variance Extracted (AVE) values for all constructs surpass 0.50, indicating that more than half of the variance in the indicators is accounted for by their respective latent variables. Composite Reliability (CR) values are above 0.60, and Cronbach's Alpha values exceed 0.70, confirming strong internal consistency and reliability. The moderation effects exhibit ideal values (AVE, CR, and Alpha = 1.000), demonstrating the strength of their measurements. Overall, these findings show that the measurement model satisfies the necessary validity and reliability standards, providing a solid basis for the inner model analysis.

This research identified and compiled all measurement items for the core UTAUT2 constructs (Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, Hedonic Motivation, Price Value, Habit, Behavioral Intention, and Use Behavior), adapting them from the original UTAUT2 scale to fit the context of Indonesia's Environmental Pollution and Damage Control Information System [18]. The adaptation process included a thorough back-translation procedure and content validity checks conducted by three academic experts to ensure contextual relevance and conceptual accuracy. When expanding the model, the Environmental Awareness (M1) construct was built based on environmental awareness literature, emphasizing perceived environmental risks, understanding pollution impacts, and awareness of environmental policies [19, 20]. Similarly, the Social Responsibility (M2) construct was adapted from literature on individual and organizational social responsibility to reflect concerns for community well-being, involvement in environmental and social activities, and perceived contributions to sustainability [13, 21]. Moderating effects were included to examine whether environmental and social factors influence the relationships between the core UTAUT2 variables and Use Behavior.

Details of all constructs, measurement items, and their sources used in this study are provided in Table IV. All core variables were adapted from the UTAUT2 model (Venkatesh et al., 2012), with modifications to fit environmental pollution control systems. Two new constructs, Environmental

Awareness and Social Responsibility, were introduced to represent pro-environmental and pro-social behaviors, respectively [13, 19-23]. Table IV thoroughly lists each construct used in our extended UTAUT2 model, including its measurement items and sources of adaptation. The table shows the original UTAUT2 variables—Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, Hedonic Motivation, Price Value, Habit, Behavioral Intention, and Use Behavior—along with two new constructs introduced to address environmental and social factors: Environmental Awareness and Social Responsibility.

For each UTAUT2-based construct, we modified the wording of the original items to suit our research on environmental pollution control systems. For example, the original Performance Expectancy item "Using the system improves my performance" was changed to "Using the system improves my performance in controlling environmental pollution" to better reflect the environmental context. Similarly, items for Effort Expectancy, Social Influence, Facilitating Conditions, Hedonic Motivation, Price Value, and Habit were rephrased to align with the scope of environmental monitoring and pollution control. This approach ensures content validity while maintaining the theoretical foundation of UTAUT2 [18].

M1 and M2 were added constructs to expand UTAUT2 and include environmental and social aspects of user behaviour. Measurement items for Environmental Awareness were adapted from earlier research, focusing on respondents' understanding of environmental issues and how the system helps reduce pollution [13, 19-23]. Social Responsibility items were also adapted from previous research, emphasizing a duty to reduce pollution and viewing the system as a reflection of social responsibility [24]. These constructs enhance the original UTAUT2 model by incorporating pro-environmental and pro-social behavioural dimensions. Additionally, interaction terms between facilitating conditions, habit, and behavioural intention with environmental awareness and social responsibility were included as moderating effects (X4M1, X4M2, X7M1, X7M2, ZM1, ZM2). This enables us to test whether environmental and social factors amplify or diminish the relationships among UTAUT2 constructs and use behaviour. By including the specific measurement items and their sources in Table IV, we have enhanced transparency and traceability in the item development process. This addition directly addresses the reviewer's concern about the lack of item listing and adaptation details.

B. Internal Model Results (Hypothesis Testing)

The evaluation of the internal (inner) model in this study focused on hypothesis testing to examine the relationships between latent variables, as shown in Figure 3. Using the bootstrapping technique in SmartPLS 3.0, each path coefficient was assessed based on its Original Sample (O) value, T-statistics, and p-value. The results in Table IV offer an overview of the model's predictive relationships, highlighting key factors that influence behavioural intention and actual use behaviour in adopting the Environmental Pollution and Damage Control Information System. Performance expectancy (H1) and social influence (H3) had strong, positive, and significant effects on behavioural intention, while facilitating

conditions (H4b) and habit (H7b) significantly impacted actual use behaviour. Behavioural intention (H8) also strongly predicted usage behaviour. Among the moderating effects, only social responsibility (H10b) significantly strengthened the relationship between habit and usage behaviour, highlighting the importance of socially responsible attitudes in reinforcing habitual engagement.

Several hypotheses were not supported, including effort expectancy (H2), hedonic motivation (H5), price value (H6), and the moderation effects of environmental awareness (H9a–H9c) (Table V). The lack of significance in effort expectancy suggests that users in Indonesia prioritize functional performance and compliance over ease of use when adopting a complex environmental management system. Similarly, hedonic motivation and price value were secondary to operational utility and social legitimacy. At the same time, environmental awareness alone did not significantly influence behavioural outcomes without structural, institutional, or incentive-based support. These findings offer necessary refinements to the UTAUT2 model in sustainability studies, highlighting the importance of considering both technological and socio-regulatory factors when analysing technology adoption in environmental governance.

C. Discussion

The findings show that Performance Expectancy significantly influences the Behavioural Intention to adopt the Environmental Pollution and Damage Control Information System. Business actors are more likely to use the system when they perceive tangible improvements in operational performance, consistent with previous studies [9, 23]. Demonstrating these benefits is essential for encouraging user interest and commitment, and it supports SDG 12 (Responsible Consumption and Production) by promoting environmentally responsible business practices. Effort Expectancy, while positive, did not significantly influence Behavioural Intention, indicating that ease of use is less critical in adoption decisions for complex environmental platforms. Indonesian users focus more on system effectiveness, regulatory compliance, and adherence to industry standards than on simplicity [21]. Improving usability is still useful, but strategies should highlight functional and compliance benefits to drive adoption and further support SDG 12.

Social influence emerged as a key driver, exerting a strong positive effect on behavioural intention. Peer recommendations, industry norms, and collective expectations shape adoption decisions, especially in coordinated environmental management contexts [9, 10, 15]. Using peer networks and sector leaders can promote the adoption of SDG 12 and SDG 13 (Climate Action) by encouraging wider environmentally responsible practices. Facilitating Conditions had a significant impact on Actual User Behaviour but not on Behavioural Intention. The availability of infrastructure, resources, and technical support is essential for sustained system use [9, 13]. Ensuring robust infrastructure and ongoing support helps businesses consistently implement responsible environmental management practices, contributing to SDG 12. Hedonic motivation had a negative, insignificant impact on behavioural intention, suggesting that enjoyment is less critical

in professional, compliance-focused settings [9, 10, 19, 21, 22]. Operational efficiency outweighs pleasure when using the system, indirectly supporting SDG 12 by highlighting effective resource management and sustainable operational practices. Price value also had a negative, insignificant effect on behavioural intention, suggesting that perceived costs are secondary to compliance and functional benefits [14]. The system is viewed as an essential tool, where long-term advantages outweigh cost concerns, reinforcing responsible environmental practices and SDG 12 objectives. Habit did not significantly impact Behavioural Intention but markedly influenced Actual User Behaviour, supporting the idea that routines maintain long-term engagement [14]. Reinforcing habitual use promotes consistent application of environmental management practices, advancing SDG 12 and SDG 13 by integrating responsible consumption and environmental protection into everyday business operations. The moderation analysis showed mixed results. Environmental Awareness did not significantly moderate the relationships between Facilitating Conditions, Habit, or Behavioural Intention and Actual Use, suggesting that awareness alone may be

insufficient without incentives or institutional support [9, 18]. Social Responsibility significantly strengthened the relationship between Habit and Actual Use, indicating that ethical considerations boost habitual engagement [19, 21]. Integrating CSR into adoption strategies encourages sustainable and climate-conscious business practices, supporting SDG 12 and SDG 13.

Policy implications highlight the demonstration of operational and compliance benefits through training, pilot projects, and benchmarking. Social influence can be utilized via peer networks and industry champions, while facilitating conditions require sufficient infrastructure, technical support, and capacity-building programs. Given the limited impact of Effort Expectancy, Hedonic Motivation, and Price Value, adoption campaigns should focus on functional utility and regulatory alignment. Incorporating CSR frameworks into routine engagement strategies further boosts sustained system use, collectively improving the effectiveness, sustainability, and equity of environmental governance initiatives, with clear contributions to SDG 12 and SDG 13.

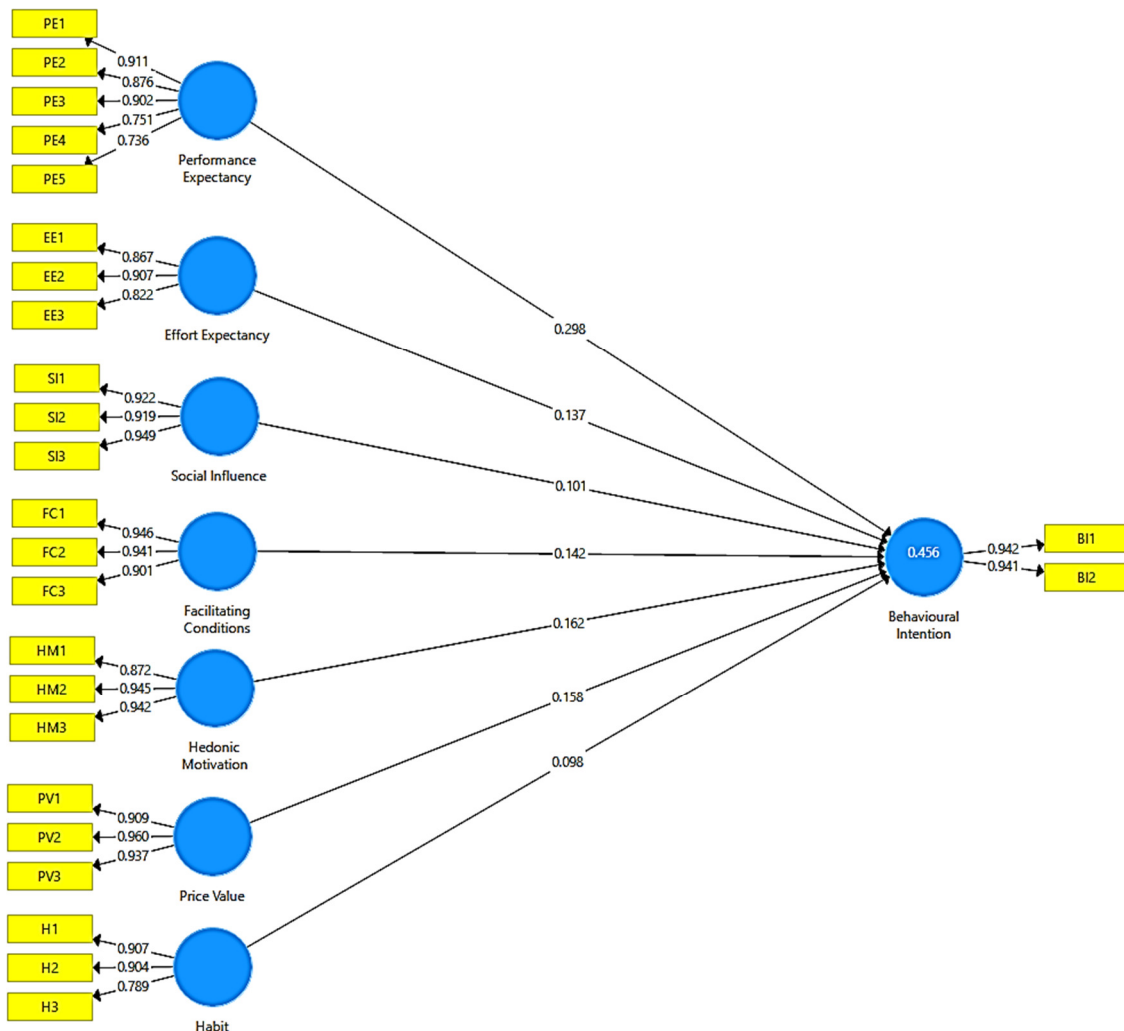


Fig. 2. Outer models.

TABLE III. VALIDITY AND RELIABILITY

Variable	Average Variance Extracted (AVE)	Composite Reliability	Cronbach's Alpha
Behavioral Intention (Z)	0.846	0.917	0.819
Effort Expectancy (X2)	0.872	0.953	0.926
Environmental Awareness (M1)	0.810	0.927	0.882
Facilitating Conditions (X4)	0.758	0.904	0.840
Habit (X7)	0.857	0.947	0.917
Hedonic Motivation (X5)	0.814	0.929	0.883
Moderation Effect X4 M1 Y	1.000	1.000	1.000
Moderation Effect X4 M2 Y	1.000	1.000	1.000
Moderation Effect X7 M1 Y	1.000	1.000	1.000
Moderation Effect X7 M2 Y	1.000	1.000	1.000
Moderation Effect Z M1 Y	1.000	1.000	1.000
Moderation Effect Z M2 Y	1.000	1.000	1.000
Performance Expectancy (X1)	0.726	0.930	0.905
Price Value (X6)	0.804	0.925	0.878
Social Influence (X3)	0.813	0.929	0.885
Social Responsibility (M2)	0.786	0.936	0.909
Use Behavior (Y)	0.781	0.934	0.906

TABLE IV. CONSTRUCTS, MEASUREMENT ITEMS, AND SOURCES (EXTENDED UTAUT2 MODEL WITH ENVIRONMENTAL AND SOCIAL FACTORS)

Variable	Sample Measurement Items	Source/Adaptation
Performance Expectancy (X1)	"Using the system improves my performance in controlling environmental pollution."	Adapted from UTAUT2 [18]
Effort Expectancy (X2)	"Learning to operate the system is easy for me."	Adapted from UTAUT2
Social Influence (X3)	"People who influence my behavior think I should use this system."	
Facilitating Conditions (X4)	"I have the resources necessary to use the system."	
Hedonic Motivation (X5)	"Using the system is enjoyable."	
Price Value (X6)	"The benefits of using the system outweigh the costs."	
Habit (X7)	"The use of the system has become a habit for me."	
Behavioral Intention (Z)	"I intend to use the system regularly in the future."	
Use Behavior (Y)	"I frequently use the system for environmental monitoring."	Adapted from [13, 19]
Environmental Awareness (M1)	"I am aware of environmental problems caused by pollution." / "I understand how the system helps control pollution."	
Social Responsibility (M2)	"I feel responsible to contribute to reducing environmental pollution." / "I believe using this system reflects my social responsibility."	Adapted from [21, 22]
Moderating Effects	Interaction terms between X4M1, X4M2, X7M1, X7M2, ZM1, and ZM2 were created to test moderation.	New for this study

TABLE V. HYPOTHESIS TESTING RESULTS

Hypothesis	Variable	Original sample (O)	T statistics (O/STDEV)	P value
H1	Performance Expectancy (X1) → Behavioral Intention (Z)	0.455	5,986	0.000
H2	Effort Expectancy (X2) → Behavioral Intention (Z)	0.098	1,661	0.097
H3	Social Influence (X3) → Behavioral Intention (Z)	0.461	6,361	0.000
H4a	Facilitating Conditions (X4) → Behavioral Intention (Z)	0.096	1,223	0.222
H4b	Facilitating Conditions (X4) → Use Behavior (Y)	0.247	3,241	0.001
H5	Hedonic Motivation (X5) → Behavioral Intention (Z)	-0.104	1,448	0.148
H6	Price Value (X6) → Behavioral Intention (Z)	-0.036	0,431	0.667
H7a	Habit (X7) → Behavioral Intention (Z)	-0.045	0,636	0.525
H7b	Habit (X7) → Use Behavior (Y)	0.368	7,911	0.000
H8	Behavioral Intention (Z) → Use Behavior (Y)	0.288	8,150	0.000
H9a	Moderating Effect X4 × M1 → Use Behavior (Y)	-0.054	0,653	0.514
H9b	Moderating Effect X7 × M1 → Use Behavior (Y)	0.027	0,285	0.776
H9c	Moderating Effect Z × M1 → Use Behavior (Y)	-0.020	0,248	0.804
H10a	Moderating Effect X4 × M2 → Use Behavior (Y)	-0.145	1,577	0.116
H10b	Moderating Effect X7 × M2 → Use Behavior (Y)	0.251	2,551	0.011
H10c	Moderating Effect Z × M2 → Use Behavior (Y)	-0.020	0,239	0.811

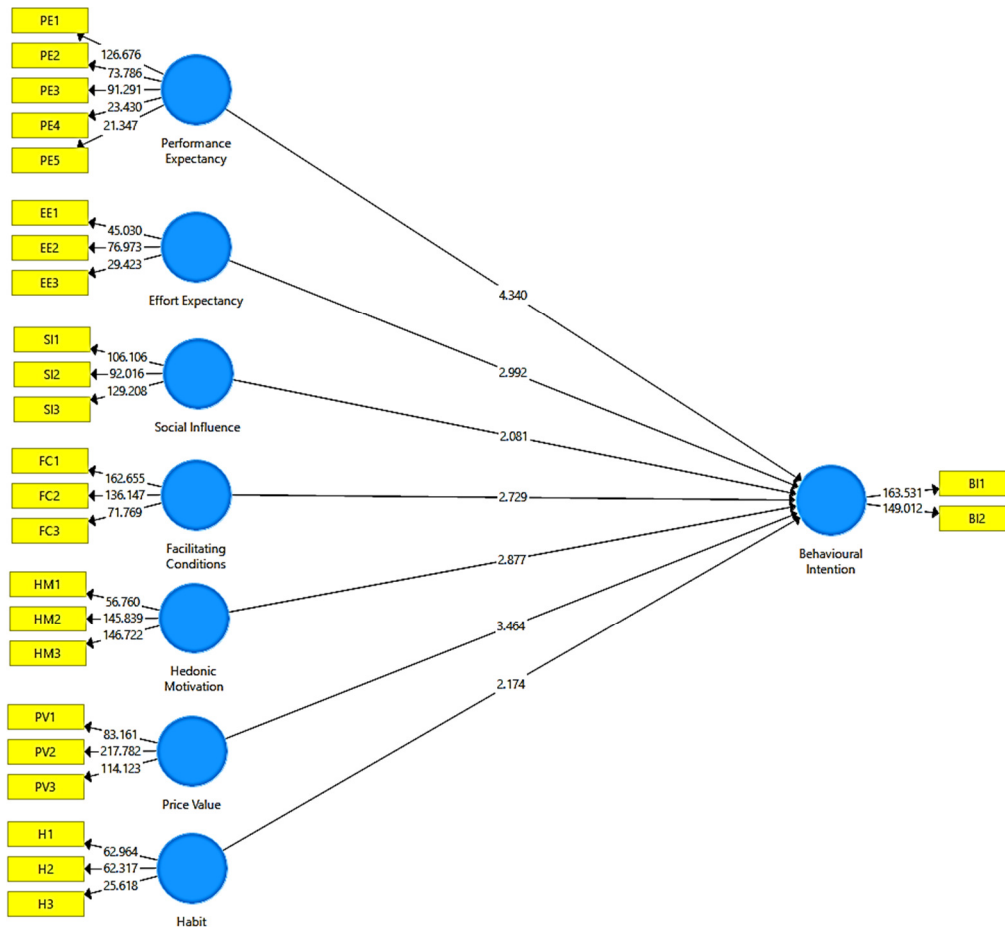


Fig. 3. Inner models.

IV. CONCLUSION

The study shows that Performance Expectancy and Social Influence are the strongest predictors of Behavioral Intention to adopt the Environmental Pollution and Damage Control Information System. Meanwhile, Facilitating Conditions and Habit are crucial for maintaining Actual User Behavior. Behavioral Intention strongly predicts system usage, highlighting the importance of building motivation through clear performance benefits and industry support. The moderating effects of Environmental Awareness and Social Responsibility were mainly insignificant, except for Social Responsibility's positive influence on strengthening the Habit–Behavior link. These results imply that effective adoption strategies should focus on demonstrating real benefits, leveraging social norms, ensuring supportive conditions, and incorporating CSR values to promote ongoing system use.

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