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Enhancing Environmental Impact Assessment Enforcement Capabilities on Soil Erosion and Sedimentation Using Mobile Application

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ABSTRACT

Environmental Impact Assessment (EIA) enforcement is a critical mechanism for ensuring that development projects in Malaysia comply with regulatory requirements, particularly in relation to soil erosion and sedimentation control. Despite its importance, post-approval EIA enforcement remains constrained by manpower limitations, fragmented project information, manual reporting practices, and limited integration of digital tools. This study aims to evaluate existing EIA enforcement practices, assess enforcement readiness, and determine the need for a mobile-based enforcement solution to strengthen regulatory implementation. Guided by the ADDIE instructional development model, this research employed a quantitative needs analysis involving 45 enforcement and processing officers from the Department of Environment (DOE). The findings indicate that while officers demonstrate strong professionalism and technical competence in both field-based and desktop enforcement, operational effectiveness is affected by information gaps and administrative inefficiencies. Survey results further reveal high technological readiness among officers, with 98% using mobile devices during enforcement activities, 96% having more than five years of mobile device experience, and 93% supporting the development of a dedicated mobile EIA enforcement application. All respondents agreed that mobile-based reporting is more effective than existing manual methods. Reliability analysis from the pilot study confirmed high internal consistency, with Cronbach's Alpha values ranging from 0.70 to 0.83 and a KR-20 value of 0.836. Key application features prioritised by officers include access to EIA approval conditions (mean = 4.78), LD-P2M2 inspection modules (mean = 4.71), structured checklists, and real-time field reporting tools (mean ≥ 4.76). Overall, the study demonstrates that a purpose-built mobile enforcement application is not only technically feasible but represents a strategic intervention to enhance enforcement efficiency, support evidence-based decision-making, and strengthen digital environmental governance in Malaysia.

Keywords: Environmental Impact Assessment (EIA); enforcement; soil erosion; sediment control; mobile application; ADDIE Model

INTRODUCTION

Soil erosion and sedimentation are critical environmental issues that pose significant threats to ecosystems, agriculture, and water quality. As the global population continues to grow and urbanization expands, the need for effective monitoring and soil erosion and sedimentation control measures become increasingly urgent. Environmental Impact Assessments (EIA) are crucial in evaluating the potential impacts of construction projects in urban areas. However, traditional methods of the soil issues monitoring often fall short in terms of real-time data collection and time consuming. The advent of mobile applications presents a promising solution to enhance soil erosion and sedimentation monitoring that improves EIA compliance. This paper explores the specific features of mobile app models that can improve real-time data collection and effectiveness in soil erosion and sedimentation monitoring systems.

In Malaysia, the Environmental Impact Assessment (EIA) became a mandatory legislative requirement in April 1988 under the Environmental Impact Assessment Order of 1987 (DOE 1987), which outlines specific prescribed activities. This legislative approach was influenced by the United States' National Environmental Policy Act (NEPA) of 1969 (Briffet, Obbard, & Mackee, 2012). As per the EIA Prescribed Activities 2015, there are currently 38 activities that require the implementation of an Environmental Impact Assessment. According to Section 34A(2C) of the Environmental Quality Act (EQA) 1974, project proponents planning to carry out any of these prescribed activities must appoint a qualified professional to conduct the EIA. The completed assessment report must then be submitted to the Director-General of the Department of Environment (DOE) for approval before the project can proceed (DOE 2017). The EIA process in Malaysia comprises three main stages: the research phase, the evaluation phase, and the post-evaluation phase. This paper specifically focuses on the Post Submission phase, where the DOE's enforcement measures come into effect.

EIA ENFORCEMENT

Enforcement is a critical component of any effective compliance program, working in tandem with education, surveillance, inspections, and incentive mechanisms to act as a strong deterrent (EPA 2024). Effective enforcement sends a clear message to potential violators, encouraging adherence to regulations by showcasing the consequences of non-compliance. On the other hand, weak enforcement can undermine environmental management efforts (UNEP 2019). The effectiveness of enforcement strategies continues to be a topic of debate globally, with each country facing unique challenges and constraints in implementing environmental laws.

DIGITAL ENVIRONMENTAL GOVERNANCE AND SMART ENFORCEMENT

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Recent studies on environmental governance indicate that regulatory systems are increasingly shaped by digital technologies, moving away from conventional compliance approaches toward more systematic, data-oriented enforcement models. The integration of digital governance mechanisms has been associated with improved regulatory performance and has been identified as a contributing factor in supporting wider sustainability objectives (Zhao, Zhang & Lu 2024). At the same time, advances in big data analytics and Internet of Things (IoT) technologies have enabled the development of monitoring platforms that facilitate near real-time environmental data acquisition, analysis, and informed policy formulation across different regulatory contexts, as indicated by rising research activity especially in China, the United States, and South Korea (Lubis et al. 2025).

Recent research further suggests that digital compliance monitoring frameworks increasingly incorporate artificial intelligence, cloud computing, and sensor-based technologies to strengthen enforcement functions. These technologies allow regulators to move beyond episodic inspections by supporting continuous oversight of environmental performance and improving the early identification of potential non-compliance (Atamewan 2024). Examples from Silva et al. (2016) & Muhammad Dwian et al. (2024) demonstrate the application of such digital tools in various national settings, reflecting a broader transition toward smart environmental enforcement, where mobile technologies, interoperable information systems, and analytical tools are used to enhance regulatory effectiveness and compliance outcomes.

DIGITAL EIA ENFORCEMENT IN MALAYSIA

In Malaysia, research by Abdul Rahman, Khairul Nizam, and Zaini (2019) identified several key barriers impacting the DOE ability to enforce regulations effectively. These included insufficient manpower, lack of skilled personnel, limited funding, unclear legal mandates, weak inter-agency cooperation, and the absence of enforcement guidelines. These issues were most pronounced in rapidly developing regions, where fast-paced activities stretched enforcement capabilities thin. At that time, the legal framework did not specifically require the DOE to validate compliance beyond documentation, allowing project proponents to rely solely on paper evidence to meet the Conditions of Approval (COA). Although legal reforms have addressed some of these gaps, enforcement challenges persist due to limited resources and expertise.

IAIA (2023) argues that modern environmental management is almost impossible without digital system support, to manage administrative work, compliance and enforcement, with link-up with multiple institutions. Malaysia's EIA scholarship has largely concentrated on procedural effectiveness (Abdul Rahman 2022), governance constraints (Peter Ho, Nor-Hisham & Heng 2020) and compliance challenges (Hazlyn & Leong, 2025), comparatively fewer peer-reviewed studies examine digital tool design/evaluation for enforcement fieldwork. Existing Malaysian/ Malaysia-linked digital monitoring prototypes are typically narrow in scope; - e.g. construction surveillance, dumping detection (Nurul Kamilah et al.

2021), river quality monitoring (Nur Aqilah et al. 2025), - and rarely evaluate DOE enforcement officer workflows, EIA approval conditions follow-up, or user-driven enforcement app development — hence the gap.

To overcome these obstacles, a mobile application could serve as one of the tools to enhance enforcement capabilities. A mobile enforcement application could facilitate real-time compliance monitoring, streamline reporting, and improve communication between agencies and stakeholders. It could also provide features such as digital submission of compliance evidence, automated alerts for corrective actions, and location-based tracking of project sites. Additionally, incorporating training resources within the app could strengthen the expertise of consultants and DOE officers while improving access to EIA data for informed decision-making. By leveraging mobile technology, enforcement efforts could become more efficient, comprehensive, and aligned with modern environmental management needs.

To ensure the development of a mobile enforcement application that effectively addresses these needs, a structured and systematic design approach is essential. The ADDIE model—comprising the phases of Analysis, Design, Development, Implementation, and Evaluation—offers a proven framework that can guide the entire process of application development. By applying ADDIE, the application can be tailored to the specific requirements of EIA enforcement, ensuring that each feature is grounded in actual field challenges, user competencies, and regulatory demands.

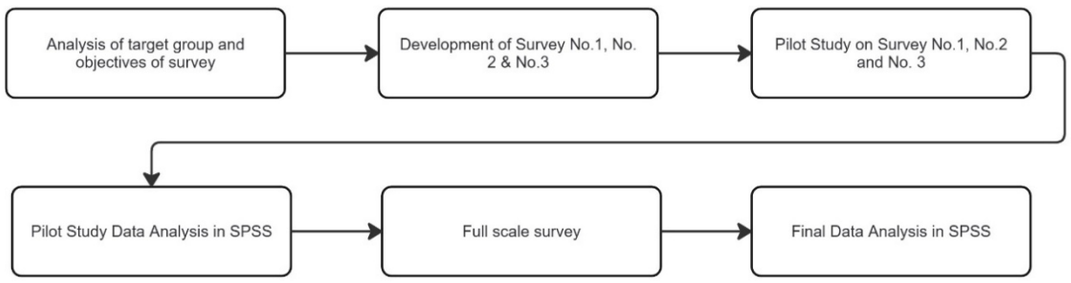

FIGURE 1. Study Design

WHAT IS ADDIE?

ADDIE is an acronym derived from Analysis, Design, Development, Implementation and Evaluation. Although Molenda (2003) suggested that the origin of this model within Instructional Design (ID) field is murky, it is widely understood that the underlying principles are virtually synonymous with instructional systems development. ADDIE is primarily used in instructional design field for educational purpose; however, the structured approach can work in other settings including corporations, military, government agencies (Molenda, Reigeluth, & Nelson, 1996) and software development (Welty 2007). In fact, the ADDIE model is applicable to any situation where instructional solutions are needed, offering flexibility for both educational and non-educational contexts (Branch 2009).

In terms of flexibility to adapt changes, it allows for feedback loops between phases, making it compatible with agile or iterative development models used in mobile app creation (Molenda 2003). Enforcement applications often evolve with regulations or user input making an iterative concept like ADDIE best-suited for the application. As an added advantage, embedding instructional design principles helps in designing applications that not only assist in enforcement but enhance officers' procedural knowledge (Martin & Ertzberger 2013).

METHODOLOGY

RESEARCH OBJECTIVE AND QUESTIONS

It is important to delineate the research objective and research questions. The main objective of this research is to evaluate the effectiveness and readiness of EIA enforcement for soil erosion and sedimentation control in Malaysia, and to identify the need for a digital mobile application to support DOE officers' enforcement activities. In order to achieve the objective above, the following research questions are essential to be answered:

1. To what extent are the resources, project-related information, and institutional support adequate to enable effective EIA enforcement by DOE officers in Malaysia?
2. What are the existing EIA enforcement methods applied by DOE officers for soil erosion and

sedimentation control, and how are these methods perceived in terms of effectiveness?

3. What is the level of technological readiness and perceived need for developing a mobile EIA enforcement application to support soil erosion and sedimentation control enforcement among DOE officers?

STUDY DESIGN

Figure 1 shows the study design used in this paper, which corresponds to the Analysis phase in the ADDIE model. The analysis phase serves to establish the objectives and goals based on the competencies, enforcement environment, as well as the existing knowledge and skills of the officers. As the initial stage in the ADDIE Model, this phase requires the researcher to conduct a comprehensive study that outlines the objectives, target audience, content, application features, and software to be employed during the development phase of the application (Mardzelah, Nurulwahida, Siti Nurmaya, & Mohamad Fadhli, 2018).

DEVELOPMENT OF SURVEY QUESTIONNAIRE

Surveys are commonly used tools in research. As noted by Creswell (2012), there are three main approaches to designing a survey: (a) adjusting an existing survey questionnaire, (b) creating a new survey questionnaire, and (c) incorporating findings from the literature review. For this study, a combination of the first and third approaches was selected. The information gathered during the literature review, along with relevant guidelines on enforcement, soil erosion, and sedimentation, was integrated with a set of previously used surveys that were modified to maintain consistency and validity. The original survey was adapted and adjusted from Abdul Rahman and Zaini (2018). According to the literature, online questionnaires are highly effective for collecting data from participants. In this case, Google Forms was utilized to create and distribute the survey to participants.

Survey No. 1 is designed to assess the adequacy of resources for EIA enforcement. It covers respondent demographics, the importance of project-related information such as EIA reports and approval status, and explores challenges faced by DOE officers. Survey No. 2 focuses on identifying existing EIA enforcement methods related to soil erosion and sedimentation control in Malaysia. It includes DOE officers' awareness of current enforcement methods, and their perceptions of these methods. Survey No. 3 gathers feedback on the need to develop a mobile EIA enforcement application for DOE officers. It includes sections on technological readiness, officers' readiness to implement enforcement programs and the importance of key enforcement elements and components.

Four (4) senior DOE officers with extensive working experience in environmental enforcement and EIA processes were identified to conduct a thorough review of all sets of questionnaires. Their expertise was leveraged to assess the clarity, relevance, and comprehensiveness of the questionnaire items. Based on their detailed feedback and recommendations, several improvements were made to enhance the structure, content, and alignment of the questionnaire with the study's objectives, ensuring its validity and practicality for the target respondents.

TARGET DEMOGRAPHY

Based on the organizational structure of the Department of Environment (DOE), each state office designates one (1) officer specifically for EIA review and one (1) officer for EIA enforcement activities. However, in practice, the roles of these officers are often interchangeable, with officers undertaking responsibilities in both reviewing EIA reports and enforcing EIA conditions depending on operational needs and staffing availability. Taking into account the structure across all states and federal territories, the author estimates that there are approximately 50 officers actively involved in EIA enforcement at any given time. This estimated population forms the basis for identifying and targeting respondents relevant to the study, ensuring that the data collected accurately reflects the perspectives of officers directly engaged in EIA enforcement tasks.

PILOT TEST

A pilot study is a preliminary review conducted before progressing to the actual survey. In survey research, a pilot study is mostly conducted to test the suitability of a study instrument before conducting an actual fieldwork phase by using the instrument (Mohamad Adam et al. 2024).

In this study, a pilot test was conducted to assess the reliability of the questionnaire. For sections utilizing the Likert scale, Cronbach's alpha (α) was employed as a statistical tool to measure the internal consistency of the items. This method evaluates the extent to which items designed to measure the same construct—such as a particular trait, perception, or ability—are correlated, thereby determining how effectively they function as a unified measure. For sections using binary (dichotomous) items, the KR-20 formula was applied. Kuder and Richardson's KR-20 is one of the earliest and most widely recognized formulas for evaluating the reliability of tests

with binary response formats (Foster 2021). In the pilot test, fifteen (15) respondents were identified, consisting of DOE officials with experience in either processing EIA reports, implementing EIA enforcement programs, or managing EIA enforcement activities. The sample size is considered reasonable, as Sundram and Nurhanani (2023) recommends that a pilot test sample should typically range between 5 and 30 participants.

RESULTS AND DISCUSSION

RESULT OF PILOT STUDY

The study found that all relevant sections of the questionnaire—whether employing Likert-scale items or dichotomous (binary) questions—met the criteria for internal reliability based on the respective statistical measures: Cronbach's Alpha for Likert-scale items and KR-20 for dichotomous items, as shown in Table 1. The reliability coefficients obtained for each section indicated acceptable to high levels of internal consistency, confirming that the items within each scale consistently measured their intended constructs, as per Joseph and Rosemary (2003) and Vivian, Norhidayah, and Siti Hamidah (2023). The questionnaire is deemed reliable and appropriate for use in the actual survey phase, ensuring the credibility and consistency of the data to be collected.

TABLE 1. Pilot Study Internal Reliability Score

Survey	Items	Internal Reliability Score	Remarks
No. 1	Importance of Project Information	$\alpha = 0.81$	Good
	Challenges in EIA Enforcement	$\alpha = 0.70$	Acceptable
No. 2	Perception on the Existing EIA Enforcement Method	$\alpha = 0.77$	Acceptable
No. 3	Implementation Readiness	KR20 = 0.836	Good
	Perspective on Content for Development and Key Elements for an EIA Enforcement Mobile Application	$\alpha = 0.83$	Good

RESPONDENT DEMOGRAPHY

There were a total of 45 respondents in the survey. 71.0% of respondents (N=32) possess an academic background in various engineering disciplines, including environmental, civil, electrical, chemical, and mechanical engineering. Meanwhile, 11.0% (N=5) of respondents hold qualifications in environmental science, followed by 4.0% (N=2) in environmental management, 4.0% (N=2) in environmental technology, 4.0% (N=2) in physics, 2.0% (N=1) in applied chemistry, and 2.0% (N=1) in industrial chemistry.

In terms of experience, 84.0% (N=38) of the respondents reported having prior involvement in EIA enforcement activities, while the remaining 16.0% (N=7) indicated no such experience. Among those with enforcement experience, 62.0% (N=28) had five years of experience, 18.0% (N=8) had between five and ten years of experience, and 4.0% (N=2) had between eleven and twenty years of experience. Figure 2 illustrates the percentage distribution of respondents based on their EIA enforcement experience.

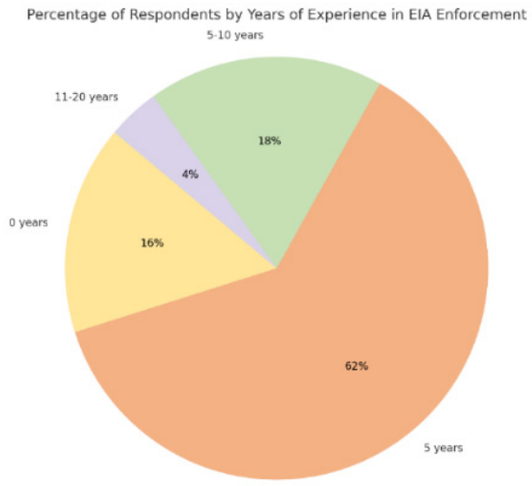

FIGURE 2. Percentage of Respondent by Years of Experience in EIA Enforcement

Although 16.0% of respondents lacked direct experience in EIA enforcement, they possessed substantial expertise in the assessment of EIA reports. Of the total respondents, 73.0% (N=33) had one to five years of experience in EIA report evaluation, 20.0% (N=9) had six to ten years of experience, and the remaining 7.0% (N=3) had between ten and fifteen years of experience. Figure 3 presents the breakdown of respondents' experience in EIA report assessment.

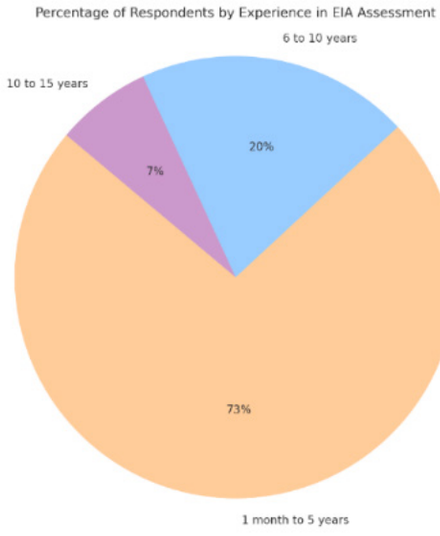

FIGURE 3. Percentage of Respondent by Years of Experience in EIA Report Assessment

Overall, the combination of technical educational backgrounds, hands-on enforcement experience, and EIA report assessment expertise demonstrates that the respondents possess sufficient knowledge and practical exposure to meaningfully evaluate existing enforcement practices, identify operational gaps, and assess the need for digital enforcement tools tools. Accordingly, the respondent group is deemed adequate, relevant, and fit for purpose in addressing the research questions and achieving the objectives of this study

SURVEY 1: CRITICAL IMPORTANCE OF PROJECT INFORMATION PRIOR ENFORCEMENT

Figure 4 presents the mean score analysis of DOE officers' perspectives on the importance of project-related information to be included in the development of an EIA enforcement mobile application for soil erosion and sedimentation control. The results show a consistently high level of agreement, with all items recording mean scores above 4.5, indicating a strong consensus among respondents that complete and accurate project information—such as approved EIA reports, approval status, and existing enforcement records—is essential for effective EIA enforcement.

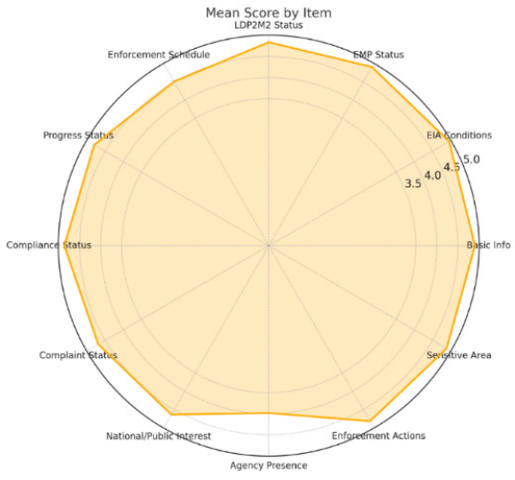

FIGURE 4. Importance of Project Information

This uniformly high mean score suggests that respondents view project information not as a supplementary feature but as a fundamental requirement for enforcement activities. Access to comprehensive project data enables enforcement officers to verify compliance against approved conditions, make informed on-site decisions, and conduct systematic follow-up actions. The findings highlight that strengthening EIA enforcement, particularly for soil erosion and sedimentation control, requires improved accessibility and integration of project information to support consistent, evidence-based, and efficient enforcement practices.

SURVEY 1: CHALLENGES IN EIA ENFORCEMENT

Figure 5 presents enforcement officers' perceptions of challenges in EIA enforcement based on mean score analysis of eleven items measured using a five-point Likert scale. These challenges were grouped into three main themes: project non-compliance and site condition, enforcement workforce and inter-agency limitation, and technological limitation. The findings indicate that enforcement challenges are multifaceted, arising from both project-level non-compliance and institutional constraints that collectively affect the effectiveness of EIA enforcement for soil erosion and sedimentation control.

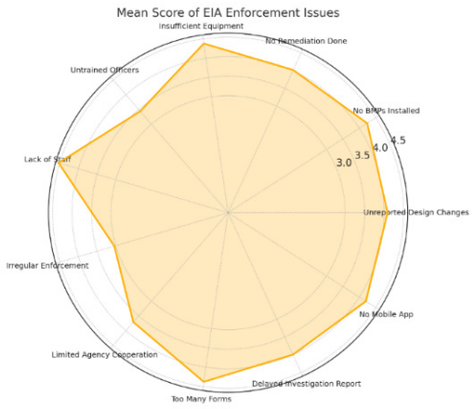

FIGURE 5. Challenges in EIA Enforcement

Issues related to project non-compliance, such as unreported changes to project layout, failure to install Best Management Practices (BMPs), and lack of remediation measures, reflect persistent on-site challenges faced by enforcement officers. At the institutional level, limited manpower, insufficient trained officers, scheduling constraints, and weak inter-agency collaboration further restrict enforcement capacity. In addition, technological limitations were strongly highlighted, particularly the absence of a mobile enforcement application, which recorded a high mean score (4.20) with a moderate standard deviation (0.89). This suggests strong agreement among officers that digital tools could improve the systematic collection, accuracy, and management of enforcement data, thereby supporting more efficient and effective EIA enforcement practices

SURVEY 2: CURRENT EIA ENFORCMENT PRACTICE

Survey No. 2 examines current enforcement practices for soil erosion and sedimentation control under EIA requirements, focusing on field-based and desktop enforcement approaches implemented by the Department of Environment (DOE). Field enforcement is mainly triggered by complaints (91%), prohibition orders (82%), audit reports (64%), and scheduled programs, with inspection frequency varying by project risk. Problematic projects are inspected more frequently (four to six times annually), while lower-risk projects receive one to three visits per year. Enforcement planning is guided by compliance history, project sensitivity, and project scale, with inspections typically conducted by teams of three to four officers and lasting two to three hours. A notable practice is conducting inspections after rainfall events (89%), reflecting an enforcement strategy that prioritizes realistic assessment of erosion and sedimentation control performance under stressed site conditions.

Despite these structured practices, field enforcement remains highly dependent on manual reporting, with 98% of inspection records prepared manually and uploaded later into the DOE system. This increases administrative workload and places additional strain on limited manpower resources, which was identified as a key operational constraint. The findings suggest that enforcement effectiveness is influenced not only by inspection frequency and technical expertise, but also by the efficiency of documentation and data management processes. In this context, the potential use of mobile enforcement applications could enhance real-time reporting, improve data accuracy, and reduce post-inspection administrative burdens.

Desktop enforcement complements field inspections and is mainly applied to non-problematic projects (93%) as a cost-effective monitoring approach. Most desktop reviews are conducted one to three times per year, with officers spending one to two hours per review. The same officer typically handles both field and desktop enforcement, supporting continuity in case management and faster follow-up actions. However, desktop enforcement is constrained by incomplete submissions from project proponents, with 91% of officers identifying data gaps as a major challenge. This highlights a systemic limitation in current enforcement practices, where monitoring effectiveness is closely tied to the quality and completeness of project information, reinforcing the need for more integrated and structured enforcement support systems.

SURVEY 2: PERCEPTION ON EXISTING EIA ENFORCEMENT

Survey No. 2 also aims to obtain perceptions on the current methods of EIA enforcement in relation to soil erosion and sedimentation control in Malaysia. This questionnaire consists of two parts: the first part assesses perceptions of

field-based enforcement methods, while the second part assesses perceptions of desktop enforcement methods along with the barriers and constraints encountered during the implementation of both methods. The methods and challenges presented in Table 2 and 3 are based on a literature review of existing enforcement procedures practiced by the DOE. A 5-point Likert scale was used, where a score of 1 represents "strongly disagree" and a score of 5 represents "strongly agree."

TABLE 2. Perception of Existing EIA Enforcement (Field)

No.	Item	Mean Score	Standard Deviation
1.	Field-based EIA enforcement is very important	4.96	0.21
2.	Enforcement visits are carried out until the development of an EIA project is completed	4.84	0.42
3.	Field-based EIA enforcement is carried out after desktop enforcement has been conducted first	3.64	1.09
4.	Conditions of approval for the EIA Report are brought along during EIA enforcement	4.60	0.84
5.	The Compliance Reporting Form for Conditions of Approval of the EIA Report is manually brought to the site during EIA enforcement	4.24	1.00
6.	Before conducting on-site EIA enforcement, the project proponent is informed in advance about the enforcement visit to be carried out by DOE.	3.09	1.36
7.	Project proponents who do not comply with the LD-P2M2 plan are subjected to follow-up action.	4.67	0.64
8.	Observation methods for installed erosion and sedimentation control measures (questions a, b & c below refer to method assessment for one project only)		
	Sampling is conducted by enforcement officers during every enforcement visit.	3.62	1.07
	Sampling is conducted if there is discharge at the final discharge point	4.49	0.84
	Observation of control measures is conducted first before sampling is carried out.	4.38	0.94
	Use of drone technology.	4.78	0.56
9.	EIA enforcement carried out by DOE officers is done with integrity and professionalism.	4.89	0.32
10.	The following elements are obstacles and constraints faced during EIA enforcement:		
	Shortage of enforcement officers	4.62	0.81
	Time constraints in carrying out enforcement	4.31	0.87
	Lack of expertise, knowledge, and experience among officers	4.20	0.84
	Limitations in financial resources	4.16	1.00
	Weaknesses in enforcement guidelines	3.31	1.02
	Weaknesses in legislation	3.00	1.09
	Weak inter-agency cooperation	3.58	1.12
	Lack of professionalism among officers during enforcement	2.44	0.94
	Officers lacking integrity	2.13	1.06
	Lack of commitment among officers	2.22	1.06

TABLE 3. Perception of Existing EIA Enforcement (Desktop)

No.	Item	Mean Score	Standard Deviation
1.	Desktop enforcement is only carried out for projects that are not problematic	3.67	1.40
2.	Desktop enforcement is followed by field enforcement visits if the project is problematic	4.71	0.66
3.	The officer who conducts desktop enforcement and the one who carries out follow-up enforcement is the same person	4.38	0.78
4.	EIA enforcement carried out by DOE officers is done with integrity and professionalism	4.82	0.39
5	The following elements are obstacles and constraints faced during desktop enforcement:		
	Shortage of enforcement officers	4.22	0.82
	Lack of expertise, knowledge, and experience among officers	3.78	0.95
	Limitations in financial resources	3.93	1.18
	Weaknesses in enforcement guidelines	3.04	1.17
	Weaknesses in legislation	2.98	1.20
	Weak inter-agency cooperation	3.36	1.13
	Lack of professionalism among officers during enforcement	2.44	1.12
	Officers lacking integrity	2.09	0.95
	Lack of commitment among officers	2.38	1.13
	Project proponents / consultants are slow in submitting project progress status	3.71	0.97

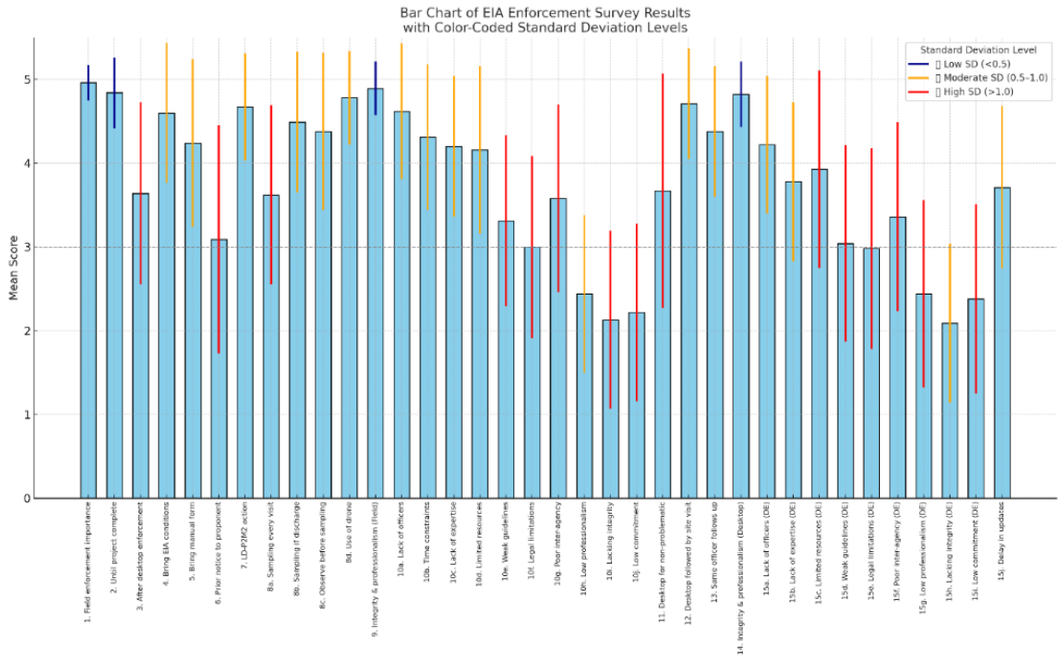

FIGURE 6. Survey Results on Existing EIA Enforcement

Tables 2 and 3 and Figure 6 summarise DOE officers' perceptions of existing EIA enforcement practices for soil erosion and sedimentation control, covering both field-based and desktop enforcement. Overall, the results demonstrate strong confidence in the importance, professionalism, and integrity of current enforcement activities, particularly for field inspections.

Field-based enforcement is regarded as critical (Mean = 4.96) and is conducted throughout the project development phase (Mean = 4.84). Officers consistently bring EIA approval conditions to site (Mean = 4.60), although reporting remains largely manual (Mean = 4.24), indicating limited digital integration. Advance notification of inspections recorded moderate agreement (Mean = 3.09), suggesting a combination of planned and unannounced visits. Strong agreement was also observed for follow-up actions against LD-P2M2 non-compliance (Mean = 4.67). Inspection practices prioritise observation before sampling (Mean = 4.38), with sampling conducted when discharge occurs (Mean = 4.49). The use of drone technology received strong support (Mean = 4.78), reflecting its perceived effectiveness in enhancing inspection efficiency.

Despite high ratings for officer professionalism and integrity (Mean = 4.89), key challenges include manpower shortages (Mean = 4.62) and time constraints (Mean = 4.31). Desktop enforcement is mainly applied to non-problematic projects (Mean = 3.67) and is followed by field inspections when issues arise (Mean = 4.71). Continuity is supported by having the same officer manage both approaches (Mean = 4.38), although monitoring effectiveness is constrained by resource limitations and delayed submissions from project proponents (Mean = 3.71). Overall, the findings highlight the need for improved digital support and coordination to enhance enforcement efficiency and consistency.

SURVEY 3: RESPONDENT TECHNOLOGICAL USAGE AND IMPLEMENTATION READINESS

Survey No. 3 indicates a high level of mobile technology readiness among DOE officers involved in EIA enforcement. A majority of respondents demonstrate strong digital capability, with 64% reporting sufficient proficiency to teach others, 96% having more than five years of mobile device experience, and 98% regularly accessing the internet via 3G/4G networks. Android is the preferred platform (82%), and mobile devices are deeply embedded in daily work routines, with 87% using devices daily and 91% carrying smartphones or tablets during enforcement activities, largely relying on personal devices (78%). Smartphones are the most commonly used device (76%), primarily for internet access, email communication, and report preparation.

Figure 7 further highlights strong acceptance of mobile-based enforcement, with 76% of respondents willing to use a mobile application for monitoring soil erosion and sedimentation, and 93% recognising the need for such an application to improve enforcement effectiveness. Nearly all officers (98%) indicated they would use a mobile enforcement application once available, and all respondents agreed that compliance monitoring would be more effective through mobile platforms. Strong preference for mobile reporting (98%) over manual methods, together with support for online data storage (69%), reflects readiness for digital transition. Overall, these findings demonstrate not only technological readiness but also strong institutional support for developing a dedicated mobile EIA enforcement application to enhance efficiency, data management, and enforcement consistency.

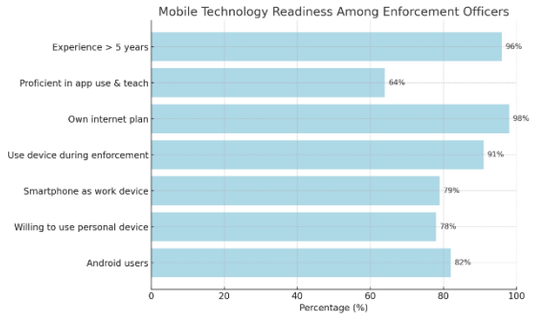

FIGURE 7. Mobile Technology Readiness

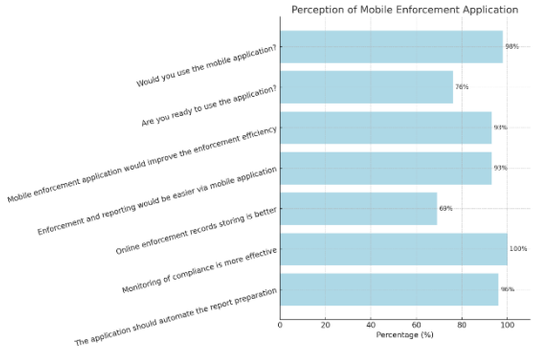

FIGURE 8. Perception on Mobile Enforcement Application

Figure 8 shows a strong positive perception among DOE officers toward the adoption of a mobile enforcement application for EIA implementation. The consistently high agreement across the evaluated items indicates that officers view mobile applications as a necessary operational tool rather than an optional enhancement. This perception reflects practical enforcement needs, particularly the demand for faster access to project information, more

systematic field documentation, and improved reporting efficiency during soil erosion and sedimentation monitoring.

The positive perception also highlights officers' awareness of the limitations associated with existing manual enforcement processes. Respondents believe that a mobile enforcement application would enhance data accuracy, support real-time compliance monitoring, and streamline enforcement workflows. When considered alongside the high levels of technological readiness reported earlier, these findings suggest a strong likelihood of successful adoption and sustained use of a mobile enforcement application, reinforcing its potential role in improving the overall effectiveness and consistency of EIA enforcement.

SURVEY 3: PERSPECTIVE ON CONTENT FOR DEVELOPMENT AND KEY ELEMENTS FOR AN EIA ENFORCEMENT MOBILE APPLICATION

To evaluate the significance of elements and components related to enforcement in the context of soil erosion and sedimentation control, a Likert scale ranging from 1 to 5 was employed, where a score of 1 represents "not important" and a score of 5 represents "very important". Table 4 below tabulates the results of the survey. The same result is also plotted on heat map chart in Figure 9.

TABLE 4. Perception on Content on for Development and Key Elements for an EIA Enforcement Application

Elements	Enforcement Components	Mean Score	Standard Deviation
Introduction to Enforcement	Enforcement Procedures	4.67	0.52
	Related guidelines	4.64	0.53
Field Enforcement: Element of Planning and Preparation	Preparation checklist (basic project information, work progress status, project phase, previous compliance status, previous complaint status, etc.)	4.71	0.59
	Preparation checklist for necessary equipment and tools to be brought	4.58	0.66
	Requirement for involvement of agencies other than DOE	4.04	0.98
	Review of compliance with EIA Report approval conditions – based on preliminary information submitted	4.69	0.56
Field Enforcement: Element of preparation of required equipment, documents, and tools to be brought	Environmental Quality Act 1974 Book	4.29	0.92
	Standard Operating Procedure Manual	4.27	0.99
	BMPs Manual	4.38	0.83
	EIA Report Approval Conditions	4.78	0.42
	LD-P2M2 Plan Document	4.71	0.46
	Manual and electronic measuring tools for sampling	4.58	0.58
	GPS	4.58	0.62
	Drone	4.36	0.74
	Camera	4.73	0.50
	PPE	4.56	0.62
	Inclinometer for measuring slope gradient	4.31	0.73
Field Enforcement: Elements of site planning and preparation	Inspection of construction scheduling according to phases	4.56	0.59
	Inspection of preservation of natural areas	4.51	0.63
	Inspection of existing source points	4.47	0.66
Effectiveness of LD-P2M2 Implementation: a) Runoff and Surface Water Control	Earth Bank / Perimeter Dike	4.69	0.56
	Diversion	4.62	0.58
	Lined Waterway (Rock Material)	4.58	0.66
	Catch Drain	4.67	0.60
	Cascading Drain	4.64	0.61
	Riprap	4.69	0.56
	Check Dam (CD)	4.69	0.56
	Temporary Interceptor Dyke	4.51	0.73
	Swale	4.53	0.73

continue...

...cont.

Elements	Enforcement Components	Mean Score	Standard Deviation
	Temporary And Permanent Pipe Slope Drain	4.60	0.69
	Rock Outlet Protection	4.62	0.61
	Sand Bag Barrier	4.62	0.68
	Storm Drain Inlet Protection	4.64	0.61
b) Erosion Control	Mulching	4.58	0.66
	Revegetation	4.69	0.51
	Hydroseeding	4.64	0.61
	Rip-Rap Slope and Channel Protection	4.60	0.62
	Plastic Cover	4.24	1.23
	Erosion Control Blanket / Mat	4.76	0.48
	Surface Roughening	4.53	0.81
c) Sediment Control	Sediment Trap / Basin	4.71	0.51
	Construction Entrance Stabilization	4.62	0.53
	Construction Road Stabilization (Gravelling)	4.69	0.56
	Fiber Rolls, Coir Log	4.60	0.62
	Watting	4.40	0.78
	Silt Fence	4.62	0.65
	Turbidity Curtain / Silt Curtain	4.67	0.64
	Brush Barrier / Matting	4.49	0.73
	Active Treatment System (ATS) (Pump, Chemical Dosing / Polymer, Flocculation & Geo – Tube)	4.51	0.84
	Temporary Access Waterway: Bridge and Culvert	4.51	0.73
Other Field Inspections Elements	Review of feedback or actions taken on previously issued instructions (e.g., instruction notices)	4.80	0.46
	Sampling requirements	4.42	0.87
Desktop Enforcement Inspection	Work progress information	4.76	0.43
	Information on compliance with EIA Report approval conditions	4.73	0.50
	Environmental Monitoring Report (EMR)	4.73	0.50
	Feedback on directed follow-up actions	4.76	0.43
	Environmental Audit Report	4.73	0.50
Follow-up Actions	Field Citation (FC), Instruction Notice, Offer of Compound, Court Action, Field Directive, Prohibition Order	4.76	0.43
Display Dashboard / Reporting	BMPs / LD-P2M2 Plan Compliance Report	4.69	0.56
	Number of enforcement visits	4.58	0.62
	Enforcement follow-up actions (compound / Court / Prohibition Order / Instruction Notice / Field Directive)	4.73	0.45
	Compliance status (compliant / non-compliant)	4.69	0.47
Field Enforcement Reporting (Penguatkuasan di lapangan)	Investigator's information	4.69	0.47
	Investigation information	4.76	0.48
	Project proponent's information	4.76	0.43
	Investigation category (whether complaint or enforcement program)	4.73	0.45
	Project information	4.80	0.40
	Weather conditions	4.71	0.46
	Compliance status with EIA Report approval conditions	4.76	0.48
	Violations of conditions and required improvements	4.76	0.48
	Observation of effectiveness of erosion and sediment control (LD-P2M2)	4.80	0.46

continue...

...cont.

Elements	Enforcement Components	Mean Score	Standard Deviation
	Effectiveness status of erosion and sediment control (LD-P2M2)	4.80	0.40
	Environmental Audit Report	4.80	0.40
	Feedback on actions imposed by DOE	4.80	0.40
	Recommended follow-up actions	4.80	0.40
Desktop Enforcement Reporting	Current compliance status (based on inspection and review of reports and documents)	4.71	0.46
	Recommended follow-up actions (whether site visit is required or not)	4.73	0.45

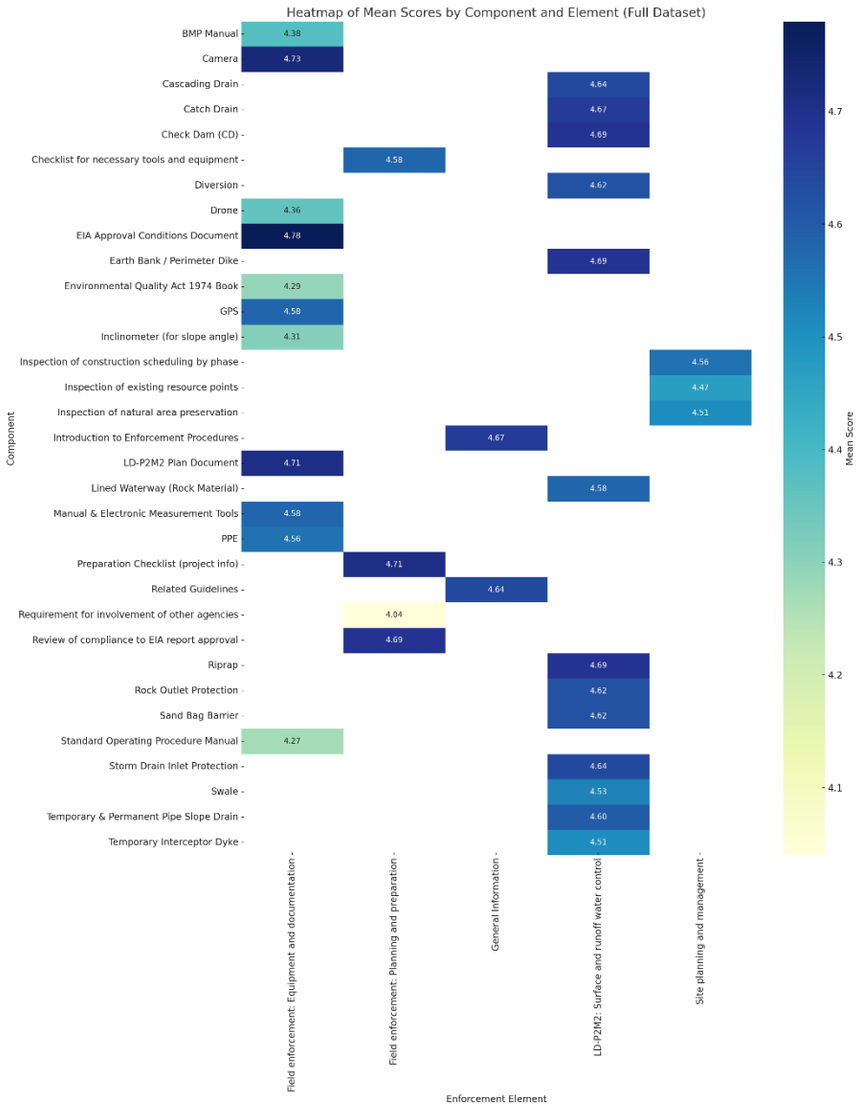

FIGURE 9. Heat Map for the Perspective of Content for Development and Key Elements for an EIA Enforcement Application

The heatmap in Figure 9 reveals consistently high mean scores across all enforcement components, indicating strong agreement among DOE officers on the importance of incorporating comprehensive enforcement content into a mobile EIA enforcement application. Core enforcement references—such as the EIA Approval Conditions Document, LD-P2M2 Plan Document, preparation checklists, and compliance review elements—record the highest mean scores (generally ≥4.7). This pattern highlights officers' reliance on authoritative, project-specific documentation during enforcement activities and underscores the need for these documents to be readily

accessible in digital form. The strong emphasis on planning and preparation elements suggests that officers view effective enforcement as highly dependent on structured pre-inspection readiness, rather than solely on-site observations.

High mean scores for LD-P2M2 surface runoff and water control measures (e.g. check dams, riprap, catch drains, storm drain inlet protection, and slope drains) indicate that practical, site-level erosion and sedimentation controls are central to enforcement decision-making. The strong support for tools such as cameras, GPS, drones, and measurement instruments further reflects the operational need for real-time evidence collection and spatial verification during inspections. In contrast, relatively lower—but still positive—scores for inter-agency involvement suggest that while coordination is important, enforcement effectiveness is perceived to depend more on direct access to technical references and field verification tools. Overall, the heatmap provides clear design guidance: a mobile enforcement application should prioritise integrated documentation, structured checklists, and field data capture tools to align with officers' enforcement workflows and decision-making needs

CONCLUSION

This study demonstrates a clear and pressing need to strengthen the enforcement of Environmental Impact Assessment (EIA) conditions in Malaysia, particularly in relation to soil erosion and sedimentation control. Addressing the first and second research objectives, the findings reveal that while DOE officers possess strong technical competence and demonstrate high professionalism in both field-based and desktop enforcement, existing practices are constrained by incomplete project information, manpower limitations, manual reporting processes, and institutional coordination gaps. These challenges reduce enforcement efficiency and consistency, especially during on-site inspections and follow-up actions, and point to the need for more structured and standardised enforcement support mechanisms.

In response to the third research objective, the study provides empirical evidence of high technological readiness and strong acceptance of digital tools among enforcement officers. The majority of respondents reported extensive experience with mobile devices, regular use during enforcement activities, and a clear preference for mobile-based reporting over existing manual methods. These findings confirm that the operational environment and user capability are conducive to the adoption of a mobile enforcement solution. Guided by the ADDIE model, user needs identified through surveys, expert validation, and document analysis were systematically translated into functional application components, including access to EIA approval conditions, LD-P2M2 assessment tools, structured inspection checklists, evidence capture features, and compliance reporting mechanisms.

Overall, this study establishes that the development of a mobile EIA enforcement application is not merely a technological enhancement but a strategic intervention with important policy implications. The integration of digital enforcement tools provides an opportunity to standardise enforcement procedures, strengthen regulatory oversight, and improve data-driven decision-making within the EIA framework. From a policy perspective, the findings support the incorporation of digital enforcement platforms into existing EIA guidelines and enforcement protocols, thereby enhancing transparency, accountability, and inter-agency coordination. Ultimately, this digital transformation can reinforce environmental governance and ensure that EIA enforcement remains aligned with Malaysia's broader sustainability and environmental policy objectives.

Although the mobile enforcement application was systematically designed using the ADDIE model and validated through expert input, its usability and effectiveness was not evaluated through long-term field deployment or comparative performance analysis against existing enforcement methods. Future research should therefore include pilot implementation across multiple states, incorporate objective performance indicators (e.g. inspection time, data accuracy, enforcement follow-up rates), and engage a wider range of stakeholders to assess interoperability, compliance behaviour, and policy impact, thereby strengthening the generalisability and practical relevance of digital enforcement solutions.

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DECLARATION OF COMPETING INTEREST

None.

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