HOME MAINTENANCE AND MONITORING SYSTEM FOR HOUSING PROJECTS: DEVELOPERS' PERSPECTIVE IN MALAYSIA

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ABSTRACT

The increasing number of maintenance-related issues and homeowner complaints in housing projects highlights the need for more effective home maintenance and monitoring systems among developers. In Malaysia, persistent defects, inefficient maintenance practices, and limited system integration continue to affect housing quality and long-term asset performance. This study aims to identify current implementation practices, key factors, system criteria, and challenges of home maintenance and monitoring systems from developers' perspectives, and to propose an improved framework. A qualitative approach was adopted using semi-structured interviews with ten housing developers in Peninsular Malaysia. Purposive sampling was applied to select participants with relevant industry experience in housing development and maintenance management. Data were analysed using thematic analysis based on Braun and Clarke's framework. The findings reveal that current implementation practices consist of online platforms, integrated systems, and physical methods, indicating a hybrid and partially digitalised approach. Key factors include centralized communication, defect monitoring, maintenance strategies, safety management, and operational efficiency. Major challenges include lack of standardization, manpower shortages, environmental constraints, recurring defects, and limited homeowner engagement. The study proposes a comprehensive framework to improve maintenance system effectiveness and provides practical insights for developers to enhance stakeholder coordination and maintenance performance in housing projects.

KEYWORDS

Home maintenance, Monitoring systems, Housing developers, Defect management, Thematic analysis, Malaysia, Defect Liability Period (DLP)

1. INTRODUCTION

Housing is closely linked to human well-being, safety, and overall quality of life. In Malaysia, rapid urbanisation, population growth, and economic development have increased the demand for residential properties. Therefore, housing development has been growing quickly in both urban and suburban areas. However, even with this rapid growth, issues related to maintenance and construction defects are still quite common. These problems can affect the quality of housing, reduce residents' satisfaction, and impact the long-term performance of buildings [1-3]. In Malaysia, maintenance-related issues are still commonly reported, especially problems like structural defects, leakage, and poor workmanship in both public and private housing [4,5,50]. This situation is not only happening in Malaysia but also in other countries, where poor maintenance can lead to building damage and higher lifecycle costs [12,17,61]. Home maintenance is the ongoing process of keeping homes in good shape and making sure they are

safe, functional, and long-lasting. It includes regular checks, repairs, and replacements that are meant to keep the building working well throughout its life. Good maintenance is very important for stopping small problems from becoming big ones, which can lead to negative feedback from homeowners.

This study addresses the following research questions:
RQ1: What are the current implementation of home maintenance and monitoring system among developers?
RQ2: What are the needs of improving current home maintenance and monitoring system among developers?
RQ3: What constitutes an effective home maintenance and monitoring system for developers?
This study focuses on developers' perspectives regarding home maintenance and monitoring systems in Peninsular Malaysia. The study specifically examines maintenance and monitoring practices during the post-construction maintenance phase of residential housing projects.

Therefore, this study aims to:
1. Identify the current implementation of home maintenance and monitoring systems among developers
2. Determine the key factors, criteria, and challenges affecting system effectiveness
3. Propose a comprehensive framework for improving home maintenance and monitoring systems.

This study contributes by providing an integrated developer-focused framework within Malaysia housing maintenance management, which remains underexplored in existing housing maintenance literature.

2. LITERATURE REVIEW

2.1. Home Maintenance and Monitoring Systems

A home maintenance and monitoring system can be described as an integrated solution that combines software, hardware, and communication technologies to support the planning and monitoring of maintenance activities in residential buildings. Through this system, homeowners and developers can keep track of building conditions, organise maintenance work, and respond to defects more efficiently [9,49,64]. According to the British Standards Institution (BS 3811), maintenance refers to a combination of technical and administrative actions carried out to retain or restore an asset so that it can perform its intended function. This highlights the need for a more structured approach for maintenance to ensure the long-term performance and reliability of residential properties [2,4,52].

In residential buildings, maintenance can be grouped into several types, including preventive, corrective, predictive, and prescriptive maintenance [22,23,57]. Preventive maintenance is usually scheduled to reduce the risk of failure. Predictive maintenance, on the other hand, uses data and monitoring tools to identify possible issues earlier. Corrective maintenance is done after a failure has already occurred, while prescriptive maintenance uses more advanced analysis to suggest suitable actions. With the use of intelligent monitoring systems, maintenance activities can be improved through real-time data collection and analysis. This supports better decision-making based on actual conditions [7,8,64]. Overall, these systems help improve maintenance planning, reduce downtime, and enhance building performance [12,19,48]. Although different maintenance approaches provide distinct operational advantages, the effectiveness of these

systems largely depends on proper system integration, real-time monitoring capability, and coordination between stakeholders involved in maintenance activities.

Recent developments in smart home technologies and Industry 4.0 have increased the use of digital monitoring systems in residential buildings. These systems rely on sensors, Internet of Things (IoT), and data analytics to improve building performance and extend its lifespan [7,23,47]. Integrated digital platforms also make it easier to manage data in one place and improve communication between stakeholders, which can support maintenance operations [13-14,38]. However, the use of these systems is still not consistent across housing projects. This is mainly due to several challenges, including technical, organisational, and user-related factors. Issues such as poor system integration, high implementation cost, limited technical knowledge, and resistance to new technologies continue to affect wider adoption [9,38,45].

2.2. Maintenance Practices and Issues in Housing

Effective maintenance management is important to keep buildings safe and usable. It also helps maintain the condition of the building over time. If maintenance is not done properly, it can lead to higher cost, lower asset value, and dissatisfaction among occupants [6,48,58]. In Malaysia, issues such as cracks, leakage, and poor workmanship are still common. This is more obvious during the Defect Liability Period (DLP) [3,4,63]. Similar situations also happen in other building sectors. Poor planning and delays in fixing defects can cause buildings to deteriorate faster and increase lifecycle cost [11,12,61].

Previous studies mention several problems in maintenance systems. These include lack of standardization, weak data handling, poor communication, and issues in decision-making [12-14,38]. Poor coordination between stakeholders may also contribute to delays and inconsistent maintenance outcomes [15,16,40].

Work order management is also a key issue. Without clear procedures, it is hard to prioritise tasks. This may cause delays in fixing defects and affect building performance and user satisfaction [19,20,48]. Poor scheduling and weak tracking systems also affect maintenance work. This is more serious in large housing projects [19,21,64]. In some cases, recurring defects show deeper problems in design, construction, or maintenance practices. Therefore, a more integrated and proactive approach is needed [17,18,62]. These repeated problems show that better feedback systems are needed. Continuous monitoring is also important. This can help improve maintenance performance and reduce repeated defects [23,56].

2.3. Role of Developers in Housing Maintenance

Developers play an important role in maintenance and monitoring systems, especially after construction and during the Defect Liability Period (DLP). They are responsible for implementing the system, checking quality, fixing defects, and coordinating with different parties [24,49,59]. In practice, developers act as the link between contractors, consultants, and homeowners. As a result, communication is important. Good coordination is also needed so that issues can be handled on time and services can run smoothly [16,11,40].

During the DLP, developers need to fix defects identified after project completion within a certain time. If this is not done properly, it can lead to higher costs, delays, and dissatisfaction among homeowners [25,26,53]. Defects usually happen due to design issues, poor workmanship, lack of supervision, and weak communication between stakeholders [27,62]. If defects are not managed properly, the same issues may happen again. This will increase maintenance workload and affect building performance [17,18].

Developers also need to make sure maintenance work follows regulations, contract requirements, and quality standards. In Malaysia, housing developers are required to comply with the Housing Development (Control and Licensing) Act 1966, which regulates housing development activities and protects homebuyers' interests. During the Defect Liability Period (DLP), which commonly ranges from 12 to 24 months after project completion depending on contractual agreements, developers are responsible for rectifying defects reported by homeowners within the stipulated period. In addition, the Certificate of Completion and Compliance (CCC) process requires developers to ensure that residential buildings comply with safety, quality, and regulatory requirements before occupancy. Failure to effectively manage maintenance and defect rectification during this stage may affect homeowner satisfaction, operational performance, and the developer's reputation. This includes housing rules, safety requirements, and expected performance levels [2,3,48]. If these are not followed, it can cause legal problems. It may also affect the developer's reputation, especially in a competitive housing market.

In addition, developers need to handle different responsibilities. This includes meeting regulations, managing cost, and handling customer expectations. Housing projects are becoming more complex, especially with digital systems being used. Because of this, developers need more structured and efficient maintenance strategies [28,61]. Digital systems can help improve maintenance, but they also bring challenges. Issues like system integration, high cost, and lack of technical skills are still common. Developers may need to invest more in technology and improve workforce capability [10,9,38].

2.4. Challenges in Home Maintenance and Monitoring Systems

Even with new technology, developers still face many challenges when implementing maintenance and monitoring systems. One major issue is the lack of standard operating procedures (SOPs). In many cases, clear guidelines are not available, resulting in inconsistent maintenance practices and varying service quality [12,48]. Without standardized workflows, coordination between stakeholders becomes more difficult and may reduce the effectiveness of maintenance operations.

Another challenge is the shortage of skilled workers, particularly in areas such as electrical, plumbing, and HVAC systems. This may affect maintenance efficiency and contribute to delays and higher operational costs [29,61]. Due to these limitations, developers often depend on external contractors, which may result in inconsistent service quality and reduced control over maintenance activities [2,19,49].

Environmental and site conditions also affect maintenance and monitoring systems. Weather conditions and site limitations may interrupt maintenance activities and affect system performance and reliability. Recurring defects remain another challenge, indicating weaknesses in defect management and monitoring systems [17,60,62]. Therefore, maintenance systems need to be more flexible and adaptive to different operational conditions.

User-related issues also affect the implementation of digital maintenance systems. Some homeowners are not familiar with digital platforms and may lack the knowledge or awareness required to effectively use the system [9,15,55]. Resistance to new technologies and low user participation may further reduce the effectiveness of digital maintenance systems, particularly when transitioning from traditional maintenance approaches [10,11,40].

2.5. Research Gap

Although extensive studies have been conducted on building maintenance and defect management, limited research has focused on integrated home maintenance and monitoring systems from the developers' perspective, particularly in the Malaysian context. Most existing studies primarily emphasize technical maintenance systems, homeowner perspectives, or general facility management practices, with less attention given to the operational and strategic challenges faced by developers [9,11,49].

There is also a lack of comprehensive frameworks that integrate system implementation, operational factors, user needs, and maintenance challenges within a unified structure. In many cases, these elements are studied separately rather than collectively, resulting in limited understanding of the actual complexity of real-world maintenance implementation [13,38,44]. Consequently, existing frameworks are often insufficient in addressing the coordination, communication, and operational integration required among developers, contractors, maintenance personnel, and homeowners.

Therefore, this study addresses the identified gap by examining home maintenance and monitoring systems from the developers' perspective and proposing a comprehensive framework that integrates implementation practices, influencing factors, system requirements, and operational challenges within a unified structure.

3. METHODOLOGY

This section describes the research methodology adopted in this study, including the research design, participant selection, data collection procedure, and thematic analysis process used to analyse the interview data collected from housing developers in Malaysia.

3.1. Research Design

This study adopted a qualitative research design to investigate the current implementation, factors, criteria, and challenges related to home maintenance and monitoring systems among housing developers in Malaysia. A qualitative approach was selected because it enables an in-depth understanding of developers' experiences, perspectives, and operational practices regarding maintenance and monitoring systems in housing projects.

Semi-structured interviews were employed as the primary data collection method to obtain detailed insights from participants while allowing flexibility during the interview sessions. This approach enabled respondents to elaborate on their experiences and provide contextual information relevant to the study objectives. The study focused on housing developers operating in Peninsular Malaysia who were directly involved in maintenance coordination, project management, and monitoring activities within residential housing projects.

The qualitative approach was considered appropriate because it supports the exploration of complex operational and organizational issues that may be difficult to capture using quantitative methods. In addition, thematic analysis was applied to systematically identify recurring themes, patterns, and relationships from the collected interview data based on the framework developed by Braun and Clarke.

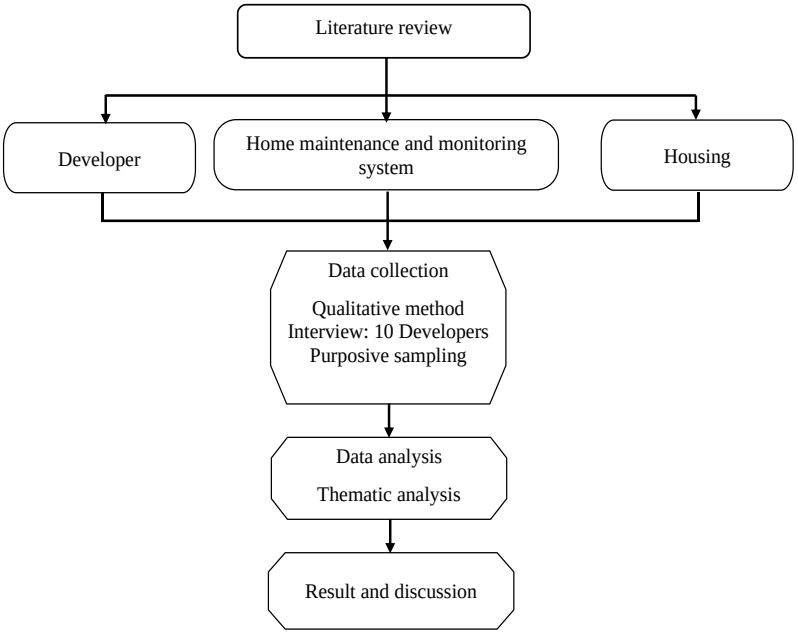

Figure 1. Research methodology framework

Figure 1 illustrates the overall research methodology adopted in this study, beginning with qualitative data collection through semi-structured interviews until thematic analysis and framework development.

3.2. Participant Selection and Sampling

This study employed purposive sampling to select participants with relevant knowledge, expertise, and experience related to home maintenance and monitoring systems in housing projects in Peninsular Malaysia. Purposive sampling is commonly used in qualitative research to identify and select information-rich participants that are relevant to the research objectives [32]. The use of purposive sampling allows researchers to obtain detailed and meaningful insights from respondents who are directly involved in the studied phenomenon [43].

A total of ten housing developers participated in this study. The participants consisted of project managers, engineers, maintenance personnel, project coordinators, and technical staff who were directly involved in maintenance coordination, monitoring activities, and operational management in residential housing projects. The selection of participants was based on their professional involvement and practical experience related to housing maintenance and monitoring systems.

Although two respondents had less than five years of professional experience, they were actively involved in operational maintenance activities and monitoring coordination within their organizations. Therefore, their perspectives were considered relevant to the objectives of the study.

The sample size was considered appropriate for thematic analysis as previous studies suggested that thematic saturation can generally be achieved within a relatively small number of interviews depending on the homogeneity of participants and the scope of the study [33,39]. According to

[33], thematic saturation across qualitative studies was commonly achieved between 10 and 15 interviews.

To maintain confidentiality and anonymity, all respondents were represented using coding labels such as R1, R2, and R3 during data analysis and reporting. Prior to the interview sessions, respondents were informed regarding the objectives of the study and verbal consent was obtained before participation.

3.3. Data Collection Procedure

Data collection for this study was conducted through semi-structured interviews with ten housing developers in Peninsular Malaysia. Semi-structured interviews were selected because they provide flexibility for participants to elaborate on their experiences while still allowing the researcher to focus on the objectives of the study [35,36]. This approach enabled the collection of detailed and contextual information related to home maintenance and monitoring systems among developers [35-37].

The interview sessions were conducted using both face-to-face and online meeting approaches depending on participants' availability and location. Face-to-face interviews allowed direct interaction between the researcher and respondents, enabling better observation of participants' responses and communication during the interview sessions [35]. Online interviews were also utilized as an alternative approach to facilitate participation from respondents located in different geographical areas and to provide greater flexibility during the data collection process [36, 42].

An interview guide consisting of open-ended questions was prepared based on the research objectives and literature review, following systematic data collection approaches commonly applied in research methodology studies [54]. The interview questions focused on the current implementation of home maintenance and monitoring systems, factors influencing system implementation, required system criteria, and challenges encountered during maintenance operations. During the interviews, respondents were encouraged to share their practical experiences, operational issues, and suggestions related to maintenance and monitoring practices in housing projects.

Prior to the interview sessions, respondents were informed regarding the objectives of the study and verbal consent was obtained before participation. All interview responses were recorded through note-taking and transcription processes for data analysis purposes. To maintain confidentiality and anonymity, respondents were represented using coding labels such as R1, R2, and R3 during reporting and analysis. The study was conducted in accordance with standard research ethics principles to ensure confidentiality, voluntary participation, and protection of respondent information.

3.4. Data Analysis

The collected interview data were analysed using thematic analysis based on the framework developed by [30]. Thematic analysis is a qualitative analytical method used to identify, analyse, and interpret recurring patterns and themes within qualitative data. This approach was selected because it provides a systematic process for organizing and interpreting textual interview data related to home maintenance and monitoring systems among developers.

The analysis process consisted of six phases. The first phase involved familiarization with the data through repeated reading of interview transcripts and notes to obtain a comprehensive

understanding of participants' responses. The second phase involved generating initial codes by identifying significant statements, repeated ideas, and relevant issues from the interview data. In the third phase, related codes were grouped together to generate broader themes and sub-themes associated with the research objectives.

The fourth phase involved reviewing and refining the identified themes to ensure consistency and relevance with the collected data. During the fifth phase, the themes were further defined and labelled according to their conceptual meaning and relationship to the study objectives. Finally, the sixth phase involved interpreting and reporting the findings by presenting the developed themes together with supporting explanations and respondent perspectives [30]. Thematic analysis enabled the researcher to systematically identify themes related to the current implementation of home maintenance and monitoring systems, influencing factors, system criteria, and implementation challenges among housing developers.

To enhance the trustworthiness and reliability of the findings, several strategies were applied throughout the analysis process. Consistent coding procedures and repeated review of interview data were conducted to improve data interpretation and reduce inconsistencies. An audit trail was maintained during coding and thematic development to ensure transparency in the analytical process. In addition, the findings were continuously compared with previous literature to strengthen the credibility and consistency of the identified themes. Member-checking was also conducted through clarification of several interview responses during the data interpretation process to improve the credibility of the findings. In addition, triangulation with previous literature was applied to strengthen the consistency and reliability of the identified themes.

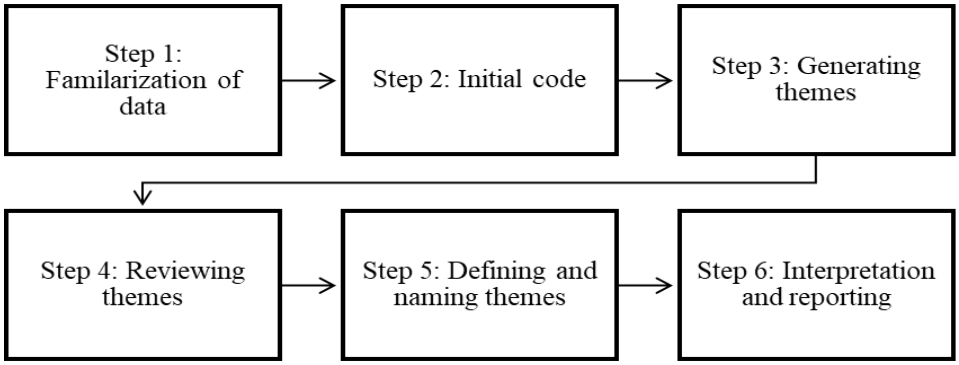

Figure 2. Process of thematic analysis

Figure 2 illustrates the six-phase thematic analysis process adapted from Braun and Clarke [30], which was applied to systematically analyse the interview data collected from housing developers.

4. RESULTS

4.1. Overview of Thematic Findings

The data collected from ten housing developers were analysed using thematic analysis, resulting in four major themes:

(i) current implementation of home maintenance and monitoring systems,
(ii) driver factors for system implementation,

(iii) system criteria requirements
(iv) Challenges encountered in implementation. Each theme consists of multiple sub-themes reflecting the practical experiences and perspectives of developers in managing housing maintenance systems. The use of thematic analysis enabled the systematic identification, organisation, and interpretation of patterns within the qualitative data, ensuring that the findings accurately represent participants' responses [31,34,41,51].

Table 1. Profile of participating developers.

Respondent	Role/Position	Experience	Organization Type
R1	Project Manager	>10	Housing Developer
R2	Site Engineer	5–10	Housing Developer
R3	Maintenance Manager	>10	Housing Developer
R4	Project Executive	5–10	Housing Developer
R5	Technical Engineer	5–10	Housing Developer
R6	Assistant Manager	>10	Housing Developer
R7	Site Supervisor	<5	Housing Developer
R8	Project Coordinator	5–10	Housing Developer
R9	Engineer	5–10	Housing Developer
R10	Maintenance Officer	<5	Housing Developer

Table 1 presents the developers that involved in this study. Although all respondents were categorized under housing developers, they represented different professional roles, project responsibilities, and operational experiences related to maintenance and monitoring practices within residential housing projects in Peninsular Malaysia.

4.2. Current Implementation of Home Maintenance and Monitoring Systems

The findings show that the current implementation of home maintenance and monitoring systems among developers is still a mix of digital and conventional methods. One respondent explained that "most maintenance updates are still handled through WhatsApp, emails, and manual records because the systems are not fully integrated yet" (R3). From the thematic analysis, three main approaches can be identified, which are online platforms, integrated systems, and physical platforms.

Developers in their maintenance processes commonly use online platforms. These include software systems, email, and messaging tools that are used for reporting issues, monitoring systems, and sharing information between stakeholders [38-39,46]. Developers use these platforms to handle maintenance requests, communicate with homeowners, and check system performance. However, the way these platforms are used is not the same across all organisations. Some have better systems, while others use them in a more basic way. In certain cases, these platforms work independently and are not fully integrated, indicating that digital adoption remains inconsistent across housing projects [9,38].

Besides that, some developers also use integrated systems, especially systems developed internally within the organisation. These systems combine different functions such as data management, monitoring, and internal communication. This helps developers to keep information in one place and improve coordination within the team. Even so, fully integrated systems are still

not widely used. In many situations, the system is not well connected with external parties like homeowners and contractors. As a result, the system is often limited to internal use and does not cover the whole maintenance process [13,38].

In addition, physical platforms are still being used in practice. Developers continue to rely on manual methods such as paper forms and face-to-face discussions to record and manage maintenance work. These methods are often used together with digital tools. Nevertheless, depending on manual processes can cause several issues, such as repeated data, slower information flow, and limited access to information. As a result, using both digital and manual systems together can lead to fragmented workflows and inconsistent data handling in maintenance operations [14,40].

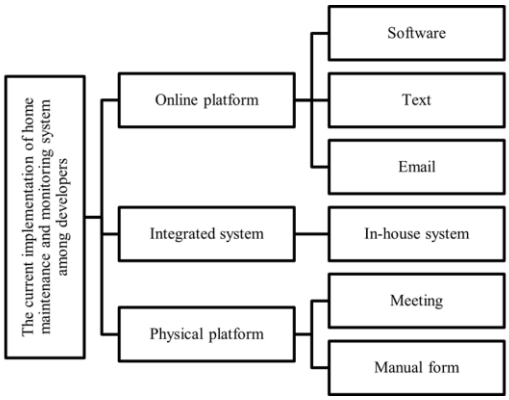

Figure 3. Current implementation of home maintenance and monitoring systems.

As illustrated in Figure 3, the current implementation of home maintenance and monitoring systems consists of three main approaches, namely online platforms, integrated systems, and physical platforms, reflecting a hybrid implementation across developers.

The findings indicate that the implementation of home maintenance and monitoring systems among housing developers remains partially digitalised rather than fully integrated. Although online platforms and integrated systems are increasingly used, manual documentation and conventional communication methods are still widely practiced. Another respondent stated that "the system used internally helps monitor defects and maintenance progress, but communication with homeowners is still managed separately" (R6). This reflects the transitional stage of digital transformation within housing maintenance management among Malaysian developers, where technological adoption continues to coexist with traditional maintenance approaches.

4.3. Driver Factor for System Implementation

The analysis identified several key factors that influence the implementation of home maintenance and monitoring systems among developers. These factors are mainly based on the actual needs and priorities of developers when managing maintenance work.

Centralized communication was identified as one of the most important factors influencing home maintenance and monitoring systems. One respondent stated that "a centralized platform helps reduce communication delays and makes defect tracking easier between developers and contractors" (R4). Most respondents emphasized that centralized communication improves coordination, information sharing, and maintenance monitoring among stakeholders. Developers highlighted the importance of having one platform where all stakeholders can communicate easily. With a centralized system, information can be shared more clearly, tasks can be

coordinated better, and maintenance activities can be monitored more effectively. In practice, this also allows real-time updates and improves visibility across different maintenance processes [16,40].

Defect monitoring was also considered an important factor. Developers mentioned that tracking defects in a systematic way is necessary to maintain building quality and ensure issues are resolved on time. This includes identifying defects during construction, after completion, and tracking recurring problems. Proper tracking helps improve documentation and makes it easier to follow up on issues at different stages [17,63].

Maintenance strategies were another key factor. Developers apply different approaches such as preventive, proactive, and predictive maintenance to keep the system reliable and efficient. These approaches help in managing maintenance work more effectively and reduce the chances of system failure. A more structured approach also makes planning and execution of maintenance tasks more organised [7,48]. Another respondent explained that "maintenance planning becomes more systematic when all maintenance information is centralized in one system" (R7).

Safety and risk factors also influence how systems are implemented. Developers are aware of the need to ensure occupant safety and reduce risks related to system failures. Because of this, maintenance and monitoring systems are often designed to support risk identification and control, especially in terms of system reliability and operational safety [12,64].

Operational effectiveness in maintenance was also highlighted as an important factor. Developers focus on resolving issues quickly, improving efficiency, and making better use of available resources. These aspects help improve the overall performance of maintenance systems and support continuous improvement in maintenance work [19,49].

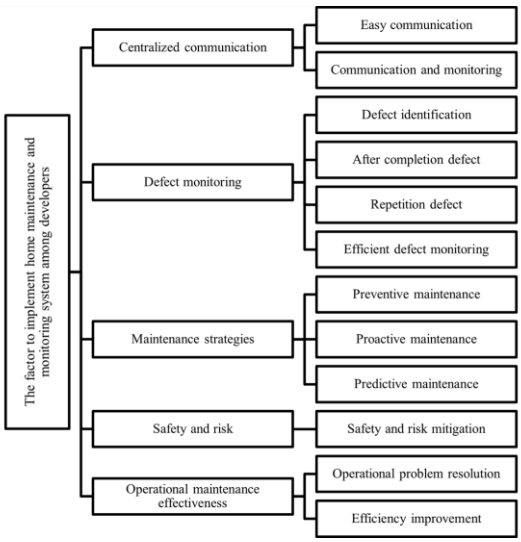

Figure 4. Driver factors influencing system implementation.

Figure 4 presents the key driver factors influencing system implementation, including centralized communication, defect monitoring, maintenance strategies, safety considerations, and operational effectiveness.

4.4. Criteria for Effective System Implementation

The findings show that a few criteria are needed for the system to work properly. These are based on what developers need when managing maintenance work.

Appointment management was identified as an important system criterion by several respondents due to frequent coordination issues between maintenance teams, contractors, and homeowners during defect rectification activities. One respondent explained that "scheduling maintenance appointments manually often causes delays and overlapping work activities, especially in large housing projects" (R5). It helps developers arrange maintenance schedules and coordinate activities with homeowners and contractors. Clear scheduling can reduce delays and improve response time, particularly when multiple stakeholders are involved in a housing project [19,48].

Labour and resource optimization emerged as an important criterion due to manpower limitations and coordination challenges experienced during maintenance operations. Developers need systems that can help manage manpower more effectively. In some cases, outsourcing is required, so the system should also allow monitoring of contractor performance. This helps ensure maintenance work is completed within the required timeframe while improving productivity and reducing operational inefficiencies [2,61].

User support is another important criterion. Some users may not be familiar with the system. Therefore, features such as guidance, training, and notification functions are necessary to help users understand system operations and reduce errors during maintenance activities [15,55].

On-site efficiency is also required. Developers prefer systems that can be accessed through mobile devices to support maintenance activities on site. Real-time updates are important for monitoring work progress. At the same time, offline functionality is also necessary, especially in locations with unstable internet connections. These features help maintenance personnel perform tasks more efficiently during site operations [23,64].

Data management was also identified as a key system requirement. The system should be capable of detecting defects, tracking maintenance issues, and allowing information access across different devices. Proper data management supports better decision-making, reduces data duplication, and improves coordination throughout maintenance operations [14,38].

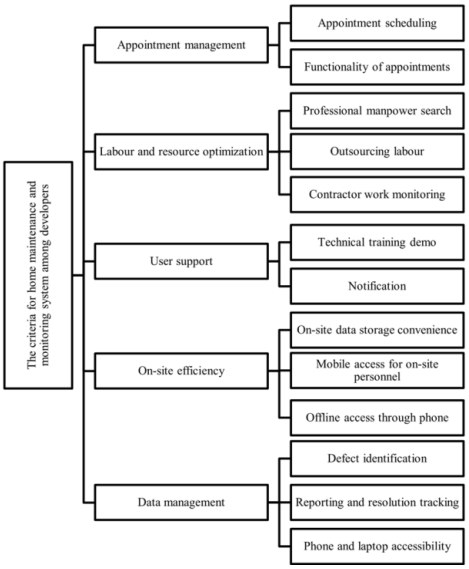

Figure 5. Criteria for effective system implementation.

Figure 5 illustrates the key system criteria identified from developers' perspectives. The findings indicate that operational coordination, scheduling efficiency, resource management, and user accessibility are among the most emphasized criteria for improving maintenance and monitoring effectiveness. These criteria reflect the practical operational challenges experienced by developers during maintenance implementation and defect management activities.

4.5. Challenges in System Implementation

Even though home maintenance and monitoring systems are already being used, there are still many challenges. These challenges show the limitations faced by developers when handling maintenance work.

Most respondents highlighted that the absence of standardized maintenance procedures creates inconsistencies in defect rectification practices across different housing projects, particularly when multiple contractors and maintenance teams are involved. One respondent explained that "maintenance coordination becomes difficult when different contractors follow different work procedures and reporting methods" (R8). Service quality may also vary between projects and maintenance cases. At the same time, many developers still depend on manual processes, which affect coordination and documentation efficiency and reduce the overall effectiveness of maintenance operations [12,38].

Manpower was also identified as a major challenge. Another respondent stated that "finding skilled workers for electrical and plumbing maintenance is still challenging, especially during urgent defect rectification work" (R5). Skilled workers are still insufficient, particularly for electrical, plumbing, and HVAC maintenance work. Due to these limitations, maintenance activities and defect rectification processes may experience delays [29,61].

Weather and site conditions also affect maintenance operations. Bad weather and site limitations may interrupt maintenance activities and reduce the effectiveness of planned maintenance work. These operational constraints are difficult to control, particularly in large housing projects [23,61].

Defect management was another issue highlighted by developers. One respondent mentioned that "tracking recurring defects using spreadsheets becomes difficult when the project involves a large number of housing units" (R6). Developers explained that tools such as spreadsheets are still commonly used, although these tools have limitations in tracking, monitoring, and analysing recurring defects. This situation may contribute to delays in resolving maintenance issues and reduce the effectiveness of defect monitoring activities [17,62].

Homeowner involvement was also reported to be limited in some cases. Some users are unfamiliar with digital systems and are less active in using maintenance platforms. Another respondent explained that "some homeowners still prefer manual communication methods instead of using digital maintenance platforms" (R2). Limited user participation affects communication and coordination processes, which may delay maintenance reporting and defect rectification activities [9,15,55]. The findings suggest that maintenance challenges among Malaysian housing developers are not solely caused by technological limitations, but are also strongly influenced by operational coordination, contractor dependency, and varying homeowner responsiveness during the maintenance process.

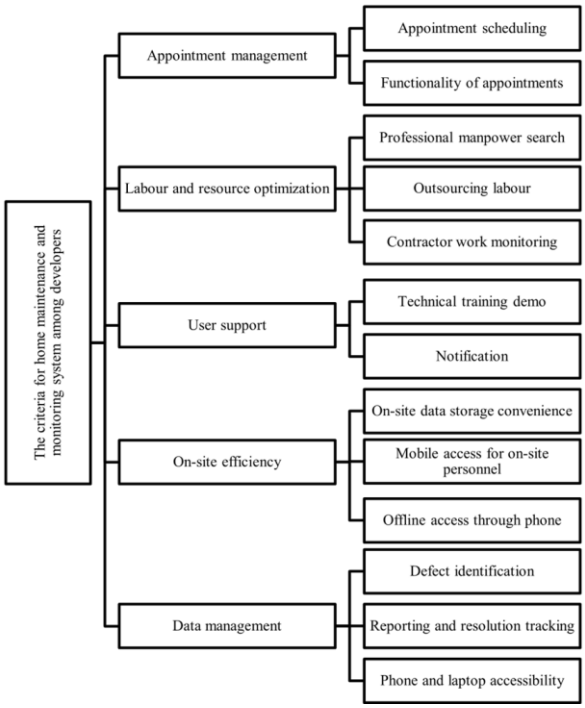

Figure 6. Challenges in system implementation.

Figure 6 summarizes the major challenges identified from developers' perspectives. The findings indicate that operational inconsistency, manpower dependency, environmental conditions, and user-related issues are closely interconnected and collectively affect the effectiveness of home maintenance and monitoring systems. These challenges demonstrate that successful system implementation requires not only technological capability, but also effective coordination, workforce readiness, and stakeholder engagement.

5. DISCUSSION

The findings of this study can be interpreted through a socio-technical systems perspective, where the effectiveness of home maintenance and monitoring systems depends not only on technological capability, but also on organisational coordination, workforce readiness, communication practices, and user engagement. The study demonstrates that technological implementation alone is insufficient without effective interaction between technical systems and human operational processes.

The continued reliance on both digital tools and manual methods suggests that digital transformation within housing maintenance management among Malaysian developers remains at a transitional stage. Although maintenance technologies are increasingly adopted, full system integration has not yet been fully achieved due to operational coordination issues and dependency on conventional communication practices. This partial integration may contribute to inefficiencies in maintenance coordination, defect tracking, and information management. Similar findings were also reported in previous studies, where incomplete digital integration affected maintenance efficiency and overall system performance [13-14,38].

The findings are consistent with previous international studies which reported that maintenance digitalization is often limited by organisational resistance, workforce capability, and integration

challenges within the construction and housing sectors [9,15,38]. However, this study further highlights that contractor dependency and varying homeowner responsiveness remain significant operational concerns within the Malaysian housing maintenance context.

The use of online platforms and integrated systems indicates that digitalization in housing maintenance management is gradually increasing among developers. Nevertheless, manual processes are still widely practiced, suggesting that maintenance systems have not yet achieved full operational optimization. Previous studies also emphasized that the effectiveness of digital maintenance systems depends not only on technological capability, but also on user acceptance, organisational readiness, and operational coordination [9]. In addition, limited integration between developers, contractors, and homeowners may reduce the effectiveness of maintenance coordination and defect management processes [38,64].

Most respondents emphasized that centralized communication improves maintenance coordination and reduces delays during defect rectification processes. Clear communication structures can improve response time, reduce misunderstandings, and support more efficient coordination among stakeholders. This finding is consistent with previous studies which highlighted that communication structure and information flow directly influence organisational efficiency and maintenance performance [16,40].

Defect monitoring is also an important factor in improving maintenance effectiveness and maintaining building quality. The emphasis on continuous defect monitoring indicates that developers increasingly recognize the importance of proactive maintenance management in reducing recurring defects and improving long-term housing performance. This finding suggests that maintenance systems are gradually shifting from reactive defect rectification towards more preventive and data-driven maintenance approaches, particularly during the post-completion stage and Defect Liability Period (DLP). Previous studies reported that design issues, poor workmanship, and inadequate supervision are among the main causes of recurring building defects [17,18,62]. Therefore, effective monitoring and systematic defect tracking are essential to minimize recurring maintenance issues and improve maintenance coordination. The adoption of preventive, proactive, and predictive maintenance approaches also reflects the increasing influence of Industry 4.0 technologies, where data analytics and digital tools are utilized to support maintenance planning and operational efficiency [7,10,23]. However, the effectiveness of these approaches still depends on data availability, system integration, and organisational capability in utilizing digital technologies effectively.

In terms of system criteria, several important elements were identified, including appointment management, resource optimisation, user support, and data management. These elements contribute to improving maintenance efficiency and enhancing system usability. Previous studies also highlighted that maintenance planning and resource allocation are important factors influencing maintenance performance and operational effectiveness [2,19,48]. User support mechanisms were also considered important, particularly for homeowners who may not be familiar with digital maintenance systems [15,55].

Several implementation challenges were also identified in this study. One major issue was the lack of standardized operating procedures (SOPs), which may contribute to inconsistencies in maintenance work and defect rectification practices. Previous studies similarly reported that lack of standardization may reduce operational efficiency and increase maintenance-related risks [12]. Manpower shortage was another major challenge, particularly involving skilled workers in specialised maintenance areas. This limitation may contribute to maintenance delays, increased operational costs, and reduced maintenance quality [29,61].

Environmental and operational factors also influence system implementation. Weather conditions and site limitations may interrupt maintenance activities and reduce the effectiveness of planned maintenance work [23]. Defect management also remains a major concern among developers, particularly involving recurring defects which indicate that some maintenance issues are not fully resolved. Several developers still rely on basic tools such as spreadsheets for defect tracking and monitoring, which limits effective defect analysis and maintenance coordination [17,62].

Homeowner involvement was also identified as an important factor affecting system implementation. Some users are still unfamiliar with digital maintenance systems, resulting in lower system usage and reduced participation in maintenance coordination activities.

Communication issues may also affect maintenance coordination and delay reporting processes [9,15,55]. Overall, improving maintenance systems is not solely dependent on technological advancement, but also requires effective organisational processes, stakeholder coordination, and active user participation. Although digital maintenance systems offer significant operational potential, successful implementation depends on proper integration, communication, and maintenance management practices. This study has several limitations. The findings are based on qualitative interviews involving housing developers in Peninsular Malaysia and may not fully represent practices in other regions or construction sectors. In addition, the relatively small sample size limits the generalizability of the findings.

6. CONCLUSIONS

This study examined the implementation of home maintenance and monitoring systems from developers' perspectives within the Malaysian housing sector. The study identified key implementation practices, influencing factors, system criteria, and operational challenges affecting maintenance effectiveness in residential housing projects.

The findings show that current practices still use a mix of digital tools and conventional methods. These approaches can support maintenance work, but they are not fully integrated. Because of this, the overall system is still not as effective as expected. Several important factors were identified. These include communication, defect monitoring, maintenance strategies, safety, and operational efficiency.

Some key system requirements were also highlighted, such as scheduling, resource management, user support, on-site access, and data handling. These are important to improve system performance.

However, there are still many challenges. These include lack of SOPs, manpower issues, environmental factors, weak defect management, and low homeowner involvement. This indicates that improving the system is not only about technology. It also depends on organisational processes and user participation.

This study contributes by focusing on the developers' perspective, especially in Malaysia. It also proposes a framework that combines implementation, system requirements, and challenges into one structure. For future research, more perspectives can be included, such as homeowners, contractors, and policymakers. This can give a more complete understanding.

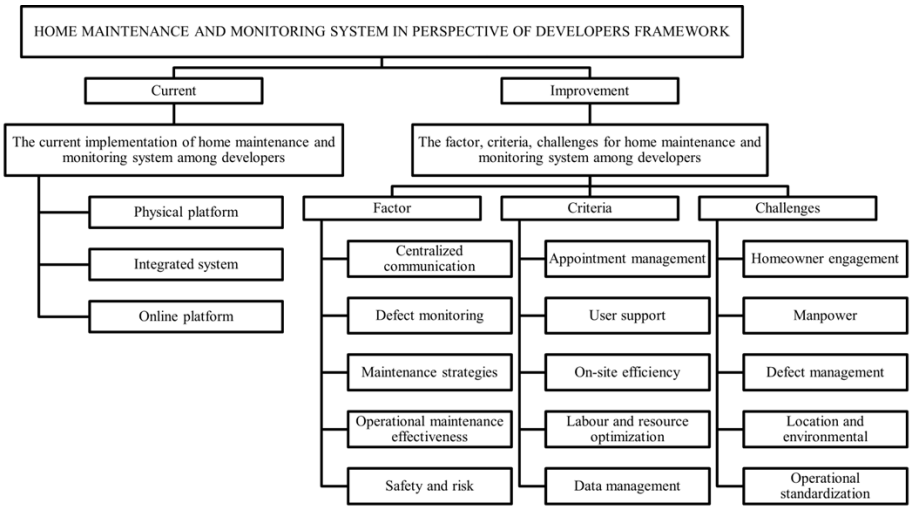

Figure 7. Proposed framework for improving home maintenance and monitoring systems.

Based on the findings, a comprehensive framework is proposed, as illustrated in Figure 7, integrating implementation practices, driver factors, system criteria, and challenges into a unified structure. The proposed framework integrates four main components, namely current implementation practices, influencing factors, system criteria, and operational challenges within home maintenance and monitoring systems. The framework demonstrates the interrelationship between technological implementation, operational coordination, maintenance planning, and stakeholder engagement in supporting more effective maintenance management. Unlike previous studies which primarily focused on isolated technical or operational elements, the proposed framework provides a more integrated structure that combines organisational, technological, and user-related considerations from developers' perspectives within the Malaysian housing context. The framework also highlights the importance of centralized communication, defect monitoring, maintenance coordination, and user participation as interconnected elements influencing maintenance effectiveness. Through this integrated structure, the framework may support developers in improving maintenance planning, reducing recurring defects, and enhancing overall maintenance performance during the post-construction phase. From a practical perspective, developers should strengthen maintenance coordination procedures, improve digital system integration, and enhance communication between contractors, maintenance personnel, and homeowners. Greater emphasis should also be given to standardized maintenance workflows, defect tracking systems, and user-friendly digital platforms to improve maintenance efficiency and long-term housing performance.

6.1. Future Work

Future studies may include broader stakeholder perspectives such as homeowners, contractors, and policymakers to provide a more comprehensive understanding of home maintenance and monitoring systems. In addition, quantitative or mixed-method approaches may be applied to strengthen the generalizability of the findings. Future research may also explore the integration of advanced digital technologies to improve maintenance coordination and long-term housing performance.

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