ISSN 1392-3730/eISSN 1822-3605

JOURNAL of CIVIL ENGINEERING and MANAGEMENT

2025
Volume 31
Issue 5
Pages 482–501
https://doi.org/10.3846/jcem.2025.23764

INTEGRATING LINE BOT AND BUILDING INFORMATION MODEL TO DEVELOP CONSTRUCTION INFORMATION MANAGEMENT SYSTEM

Yu-Jen CHENG[1], Minh-Tu CAO[1], Shih-Hsu WANG[2], Ngoc-Mai NGUYEN[3], Shih-Sin CHEN[1], Wei-Chih WANG[1]✉

[1]*Department of Civil Engineering, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[2]*Department of Civil Engineering, ROC Military Academy, Kaohsiung, Taiwan*
[3]*Department of Civil Engineering and Environmental Informatics, Minghsin University of Science and Technology, Hsinchu, Taiwan*

Article History:
- received 5 January 2024
- accepted 16 January 2025

Abstract. In the lifecycle of construction projects, the participation of various specialized members often leads to challenges in recording or retrieving information in real time. This can result in missing data or inaccurate project control decisions, due to the inability to access essential information swiftly and accurately. Recognizing the ubiquitous use of instant messaging platforms on mobile phones and the widespread adoption of Building Information Modeling (BIM) for information storage and management, this research proposes an innovative integration of chatbots with BIM to establish a robust construction information management system. Utilizing "LINE", a popular communication software, as the foundation, this study develops four specialized chatbots (LINE BOTs) tailored for different phases of construction projects, namely design, construction, and maintenance. These chatbots employ a rule-based and conversational approach to aid construction personnel in real-time recording and retrieval of project information. During the maintenance phase, users can also access relevant equipment objects through the BIM model using mobile smart devices, further improving maintenance efficiency. Moreover, the chatbots are equipped with a string-matching mechanism to enhance the precision of data recording and retrieval processes. The effectiveness of this system is demonstrated through a case study on a public construction project.

Keywords: chatbot, LINE BOT, building information modeling (BIM), construction projects, mobile information management.

✉Corresponding author. E-mail: *weichih@nycu.edu.tw*

1. Introduction

The success of construction projects across their planning, design, construction, and maintenance/operation stages hinges on the effective collaboration of diverse professional teams. This collaboration yields a plethora of varied information and data, necessitating constant updates, modifications, and queries. For instance, during the planning/design phase, vital information includes timelines, regulations, and meeting minutes. The construction phase demands tracking of daily completed quantities for each cost item, progress updates, site photographs, and access to shop drawings and specifications. In the maintenance/operation phase, the focus shifts to data pertaining to mechanical/electrical/plumbing (MEP) equipment and their maintenance/repair records. Inadequate real-time recording or retrieving of this information can lead to significant omissions, adversely impacting the quality, schedule, and cost decisions of construction projects (Yang et al., 2021; Senthilkumar et al., 2010; Deng et al., 2022; Lin et al., 2022).

Currently, many platforms have been developed in the industry to support the storage, exchange, management, and collaboration of engineering project management information, such as the Project Management Information System (PMIS) (Shin et al., 2016), Aconex (Oracle Aconex, 2022), Autodesk BIM 360 Field (Autodesk, 2023), and FinalCAD (Finalcad Collaboration, 2023). However, since different project owners adopt various project management platforms, other project participants (such as architects and contractors) are required to install and learn multiple software systems that have similar functions but different interfaces and information needs. This leads to "app fatigue" – users become tired and frustrated due to the abundance of available software (Seo et al., 2004). Additionally, the general usability of these platforms is often low, as users must access the platforms or utilize all their features only through computers with specific software installed. This not only prevents users from recording and querying important project information in real-time but also affects the quality of data recording (Cho et al., 2023).

In recent years, the surge in instant messaging software use and the growing adoption of mobile communication applications have propelled chatbots to the forefront. Song (2018) indicated that project participants frequently use instant messaging software to exchange project information because of three major factors, including (1) mobile devices (e.g., smartphones or tablets) typically having instant messaging software already installed, (2) users being familiar with the software interface, and (3) the software being free. Therefore, developing chatbots within instant messaging software can not only ensure the timeliness of data (users can input and query information in real-time) but also help avoid app fatigue and reduce system development costs (Cho et al., 2023). Currently, in academia, there have been developments of web-based or instant messaging software-integrated chatbots for construction projects. However, previous research has focused on addressing specific tasks during the construction phase, such as construction site equipment management (Tsai et al., 2022), construction progress management (Adel et al., 2022), and construction daily work reports (Cho et al., 2023). These studies have paid less attention to the information needs during other phases of the project lifecycle and have seldom discussed supportive mechanisms that could improve problem-solving efficiency in practice (e.g., visualization and proactive reminders).

Building Information Modeling (BIM) extends beyond its primary role in 3D visualization and spatial representation. BIM's associated information proves invaluable in managing tasks across all construction project stages (Wang et al., 2016). For instance, in early stages, BIM supports designers with conceptual development and regulation feasibility reviews. During construction, it offers insights for quantity take-offs and constructability, and later, it facilitates maintenance/operation management. BIM's utility has expanded from building projects to the civil engineering domain, where it integrates with other software tools and hardware facilities, making it a cornerstone for comprehensive project information management (Bryde et al., 2013; Tsay et al., 2022; El-Diraby et al., 2017).

Therefore, this study proposes employing the mobile communication software "LINE" to utilize chatbots across various phases of a construction project's lifecycle. With BIM's support, this research introduces a chatbot-based system designed to assist project stakeholders in instantly recording, accessing, and visually presenting construction information via mobile smart devices.

2. Literature review

This study's literature review concentrates on three key areas: the evolving role of chatbots, the prevailing trends and challenges in construction information management within the industry, and the application of BIM in enhancing construction information management practices.

2.1. Chatbots

Chatbots, designed to simulate human interaction through natural language, predominantly operate on platforms such as mobile smart devices and PCs (Wang et al., 2021). The inception of chatbots traces back to 1966 with ELIZA, initially developed for clinical therapy. ELIZA mimicked the conversational style of psychotherapists using fixed scripts, keyword-matching rules, and pre-written responses, marking the first instance of a chatbot capable of engaging in user interaction that resembled human conversation (Dsouza et al., 2019).

Chatbots analyze human language to provide appropriate responses or guide users through scripted dialogues to achieve specific objectives. Based on their design and logic, chatbots are classified into two categories: retrieval-based and generation-based (Dsouza et al., 2019). Retrieval-based chatbots function on rule-based conversational models and respond based on predefined rules and database queries. In contrast, generation-based chatbots require extensive training with large datasets to comprehend user intent.

With advancements in mobile technology reshaping communication methods, chatbots have become increasingly integral in user interactions and are being rapidly developed for various platforms (Muniasamy & Alasiry, 2020). Saka et al. (2023) highlight that conversational artificial intelligence has substantial potential benefits in the architecture, engineering, and construction industry, but this area remains relatively untapped. For instance, combining a blockchain-based network (BBN) with chatbot technology, Adel et al. (2022) developed a web-based information exchange and management system for construction firms. This system utilizes blockchain technology to establish a serverless chatbot, allowing users to record and query construction progress information through questions posed by the chatbot. This includes details such as task codes, task names, task statuses, remaining work, incurred costs, and dates. Tsai et al. (2022) employed image recognition and multiple object tracking technologies to develop a site equipment management assistant (SEMA) system, which includes a chatbot that can collect and query site equipment entry and exit times, driver names, equipment types and quantities. Cho et al. (2023) developed a chatbot-engaged messenger based on a mobile messenger platform, designed to collect and manage daily reports and communication information from contractors. Out of the 105 data points collected, 70 were imported from the project management information system, while the remaining information was input by users through conversations with the chatbot. In general, current mobile device chatbot implementations are primarily within messaging apps such as Facebook Messenger, LINE, WeChat, Telegram, Slack, or embedded in websites, apps, or physical robots through a Conversational User Interface (CUI) (Satu et al., 2015; Wang et al., 2021).

In Taiwan, "LINE" and Facebook's "Messenger" dominate the instant messaging platform market, with LINE being particularly prevalent (Shen, 2019; Ryota, 2023). Capitalizing on LINE's widespread use, the Taiwan Water Resources Agency developed a chatbot named Diana for disaster prevention. Diana enables users and decision-makers to access information swiftly and efficiently through intelligent dialogue search features, comparing user inputs with an existing database (Taiwan Water Resources Agency, 2019). Diana's capabilities include active warning information, environmental information push, static picture information response and query, intelligent smart search, and other functionalities. When users input incorrect words or vague questions, Diana's conversational intelligence search function compares these inputs with the system's database and suggests several related keywords for the user to choose from.

Considering LINE's extensive use in Taiwanese industries for project communication, this study proposes integrating a chatbot within the LINE platform (LINE BOT). This integration aims to enhance information retrieval and management efficiency across all stages of a construction project's lifecycle.

2.2. Current industry trends and challenges in construction information management

As various industries increasingly embrace digitalization to boost management efficiency, the building and civil engineering sectors are also moving towards electronic, informational, and network-based operational models, transforming traditional work patterns (Pan & Zhang, 2021). Construction projects, known for their extensive workloads and prolonged durations, face the challenge of managing complex and dynamic information, often hindering seamless data sharing among project participants. Previous studies highlight a prevalent issue in construction projects: the inconsistency in information available to different team members, leading to inefficient communication (Deng et al., 2022; Dawood et al., 2002).

The success of construction projects is heavily reliant on the accurate and consistent exchange of information among team members. Advances in Information and Communication Technology (ICT) have significantly contributed to addressing daily information management needs in construction engineering, thereby improving communication efficiency (Deng et al., 2022; Lin et al., 2022). However, the challenges posed by the vast amount of daily information, complex processing flows, frequent ad-hoc scenarios, and limited information management capabilities still impede engineering personnel from accessing crucial data in real time (El-Diraby et al., 2017; Tupenaite et al., 2008). Thus, leveraging ICT in construction information management should ideally meet these demands, providing a more encompassing solution for engineering personnel.

Previous research and practical implementations of information management systems in construction engineering confirm that ICT can enhance traditional management methods, improving real-time data logging and querying by stakeholders (Deng et al., 2022; Lin et al., 2022; El-Diraby et al., 2017). For example, Senthilkumar et al. (2010) developed an interface management system and database for the design phase, enabling the identification and resolution of design interface issues via web forms. The generated reports from this system alert designers to specific interface issues in their weekly meetings, thereby increasing management efficiency. In a similar vein, Siao and Lin (2012) introduced a network-based information system for the construction phase, effectively linking interface management records and project relationships. This system aids participants in addressing job-related issues during construction through shared information.

Despite these advancements, knowledge management development in construction engineering is still insufficient, primarily due to varying expertise levels among professionals, divergent interpretations of knowledge management, and limitations in handling diverse information management models (Carrillo & Chinowsky, 2006). Considering the complex professional knowledge in construction engineering, ICT can significantly aid in knowledge management to meet the practical needs of project participants. Integrating existing, widely-used software platforms can substantially reduce adaptation barriers, facilitating a more streamlined approach to knowledge management in the field.

2.3. Application of BIM in construction information management

In recent years, Building Information Modeling (BIM) has emerged as a critical technology in construction projects, playing an essential role at every stage. Throughout the construction process, information is progressively added to or modified within the BIM model to fulfill a range of objectives (Tsay et al., 2022; Liu & Issa, 2013; Olawumi & Chan, 2019; Costa & Sicilia, 2020; Wang et al., 2022). For instance, El-Diraby et al. (2017) introduced the Green 2.0 platform in the design phase. This platform enables participants to log in via computers or mobile devices to engage in online discussions on green building topics. It enhances green construction decision-making by sharing BIM files and integrating them with energy simulation software, thereby presenting building design alternatives in a 3D visual format. However, this platform has limitations regarding user permissions, restricting users to viewing the BIM model, participating in discussions, and accessing monitoring data and other publicly shared information.

During the construction phase, researchers such as Fazeli et al. (2021) have specifically focused on the application of BIM in quantity take-offs for estimations.

They have developed various BIM-based cost estimation methods, which leverage BIM to automatically aggregate quantities of cost items, aiding in cost estimation. This approach addresses the limitations of traditional conceptual cost estimation methods and provides more cost-efficient solutions.

In the later stages of a project, the BIM model transitions to a tool for operation management. Tsay et al. (2022) suggested incorporating maintenance and repair information of MEP equipment into the BIM model during the construction phase. This integration creates a database for future equipment maintenance management. However, the ongoing requirement for maintenance management personnel to update information about equipment and facilities remains a significant challenge for effective facility maintenance management.

2.4. Research gaps

Data exchange throughout the construction project lifecycle is a continuous and iterative process, involving the request, input, review, modification, and approval of data, information, and documents between owners, architects, and contractors. Previous studies have employed ICT technologies to develop various tools for real-time recording and querying of important project information. However, the abundance of available tools has led to app fatigue (Seo et al., 2004). A pragmatic approach is not to develop standalone information exchange systems, but rather to create data exchange mediums within commonly used instant messaging software (Song, 2018; Cho et al., 2023). Although previous studies have developed construction chatbots integrated with instant messaging software (e.g., Tsai et al., 2022; Cho et al., 2023), these studies focus on managing only specific tasks during the construction phase. The present study extends to consider the chatbot potential application across various stages of the project lifecycle and investigate additional supportive mechanisms that could enhance practical problem-solving efficiency (e.g., proactive reminders and BIM visualization) for construction projects.

3. Establishing construction information management system

This study develops the LINE BOT and BIM-based Information Management System (LBBIM system), as depicted in Figure 1. The core concept of this system involves utilizing a unified database (namely, Module 2) to facilitate access to information. This approach is designed to ensure the accuracy and consistency of project data throughout the various stages of construction projects, including planning/design, construction, and operation/maintenance.

The LBBIM system comprises three main modules: Module 1 focuses on the collection of project information, Module 2 is dedicated to establishing a comprehensive construction information database, and Module 3 involves the development of LINE BOTs tailored for construction information management. Each module plays a critical role in ensuring the system's overall functionality and effectiveness. Notably, the arrows in Figure 1 depict the flow of data, illustrating the mechanism of information transmission between modules. Additionally, the software packages and programming languages used for implementing each module are listed in Figure 1 and are further explained in Section 3.4 (Computer Implementation).

3.1. Collecting project information (Module 1)

The project information collection in our study is achieved through three distinct methods, each corresponding to a specific module. Module 1.1 involves the development of BIM model information using Autodesk Revit. It includes the creation of a 3D model of the project and the collection of relevant model information. This encompasses basic data such as equipment object families and floor levels, quantity information like rebar, formwork, and concrete for each building component, as well as maintenance information including equipment details and space numbering. The gathered BIM model details are then imported into a database in spreadsheet format for efficient management.

Module 1.2 is dedicated to uploading project-related documents. It utilizes Google Drive as the storage platform for documents such as construction regulations, quantity take-off sheets, and drawings/specifications. These documents provide a foundational resource for subsequent information and data retrieval.

In Module 1.3, the process begins with the design of a daily construction log template. This template features fields for weather conditions, report date, a summary of construction execution (detailing activities performed and their completed quantities), a summary of materials used on site, and an account of labor and equipment deployed. Additionally, this module involves importing the contractual cost items of the construction project into the daily log template. These cost items, along with the daily log template, are then stored in the database (Module 2).

3.2. Establishing construction information database (Module 2)

This system employs the Microsoft Azure SQL (Structured Query Language) platform to establish a database that integrates construction information/data with LINE BOT. This database is uniquely configured to directly accept data from text files and Excel files provided by Module 1.

In detail, the BIM model data from Module 1.1, which include geometric data (such as length, width, and height) and attribute data (such as associated cost items, quantities of these items, and space numbering) for each BIM object (columns, beams, slabs, walls, and equipment), are exported from Revit into spreadsheets and then imported into the database. A noteworthy feature of the Module 2 database is its ability to automatically calculate the quantities of specific cost items (for example, rebar, wood form, or concrete) in response to user queries. For instance, when a user employs the LINE BOT from Module 3 to inquire about the total wood form quantity required

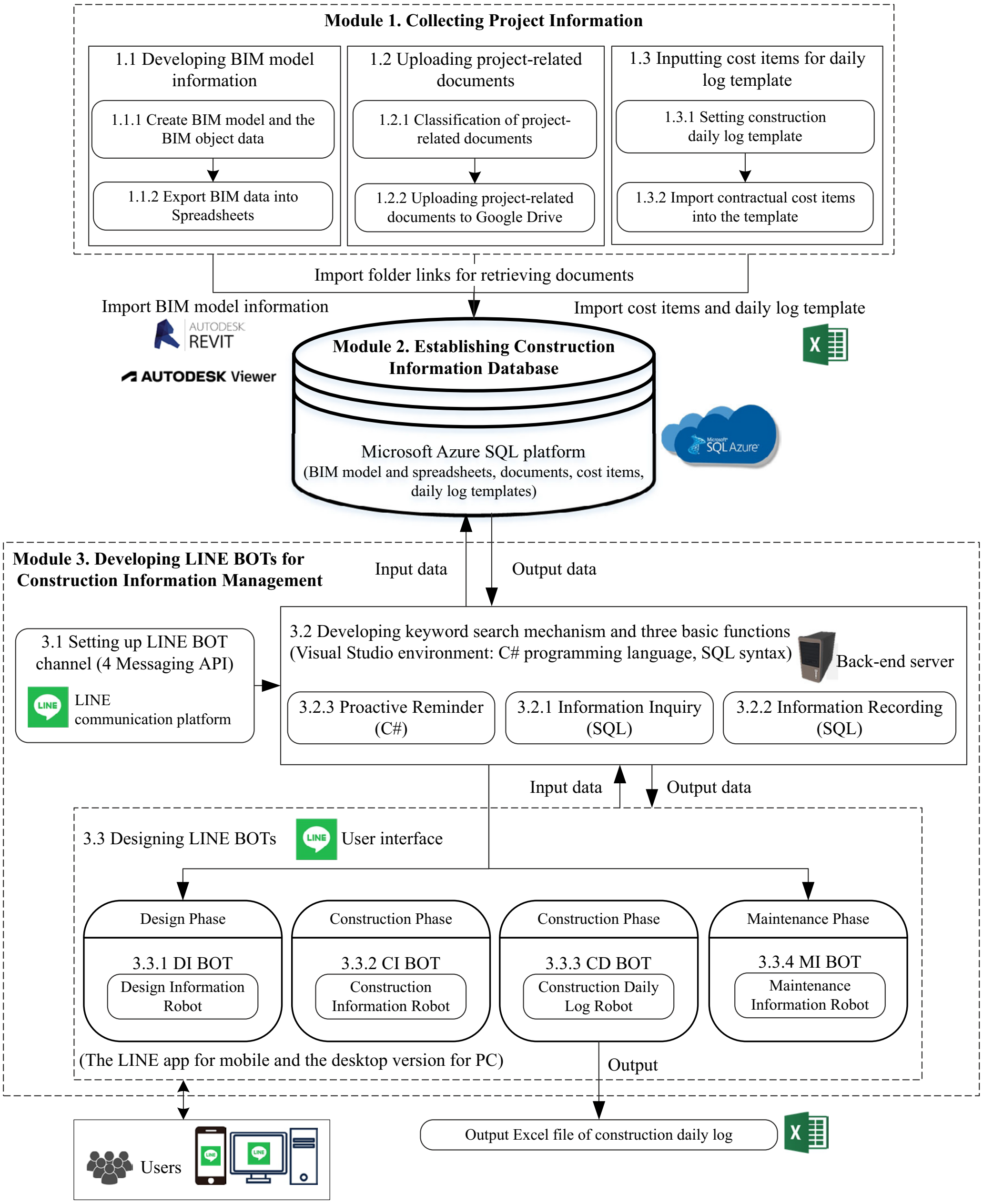


Figure 1. Proposed LBBIM information management system

for the first floor of a project, the system retrieves form quantities associated with each structural element on that floor from the database, computes the total, and relays this sum to the user.

Furthermore, specific data/file folders are established in Module 2 to store project stage-specific data, such as construction drawings, photos, regulations, or plans (for design, construction, or maintenance phases). After uploading the project-related documents (Module 1.2) to Google Drive, the paths for data retrieval (or folder links) of these documents are preserved for future reference and queries. Lastly, the construction daily log template from Module 1.3 is also stored in the database. This enables system users to utilize LINE BOT (Module 3) for inputting and retrieving data related to construction daily logs.

Overall, this structured approach ensures an efficient and integrated management of construction project information, leveraging the capabilities of the Microsoft Azure SQL platform and LINE BOT for seamless data handling and retrieval.

3.3. Developing LINE BOTs for construction information management (Module 3)

In this study, we have developed LINE BOTs using a rules-based chatbot approach to support construction information management. Unlike generation-based chatbots, which dynamically generate responses based on a wide range of inputs and learning algorithms, our LINE BOTs operate on predefined rules. They are programmed to search the database for specific queries, thus efficiently providing system users with the required information.

3.3.1. Setting up LINE BOT channel (Module 3.1)

In Module 3, the development of the LINE BOT begins with the creation of a Provider on the LINE Developers website, tailored for managing construction projects. This step lays the groundwork for the entire module. Subsequently, four distinct Channels, each equipped with a LINE messaging API, are developed. These Channels correspond to four different chatbots, detailed in Module 3.3, setting the stage for the module's functionality.

This study applies the chatbot design process outlined by Das and Khan (2018) to establish a comprehensive, rule-based dialogue flow for the LINE BOT, as illustrated in Figure 2. The process begins with the user inputting a query (via text) or selecting a command in the dialogue window to perform a function, such as retrieving or inputting/recording information. Then, utilizing Webhook Events, the LINE Messaging API is configured to instantly notify and respond when specific events are triggered. Webhook functions as an HTTP callback mechanism (Handoyom et al., 2018), meaning when a designated event occurs, the LINE Messaging API dispatches an HTTP POST request to the pre-configured channel's Webhook endpoint. This enables the system to notify about relevant events and provide responses to the user. Upon receiving a message, the LINE BOT parses the text and applies pre-set rules to interpret the user's intention or commands. Upon receiving a message, the LINE BOT parses the text and applies pre-set rules to interpret the user's intention or commands. Notably, the major pseudocode and C# syntax for parsing texts and applying pre-set rules are also provided in Figure 2.

Based on the above interpretation, the LINE BOT executes one of three functions: information inquiry, recording, or proactive reminder. It guides the user through the process, either by prompting keyword input or command selection, to fulfill the user's needs. If the dialogue is incomplete or the response unsatisfactory, the LINE BOT proceeds to the next round of dialogue.

3.3.2. Developing keyword search mechanism and three basic functions (Module 3.2)

In the rules-based framework of Module 3.2, the system accurately identifies the specific information corresponding to a user's inquiry based on the keywords within the inquiry. This search process progresses from a "general subject" to "specific data". In scenarios where a user inputs a keyword that lacks sufficient specificity, the system activates a specially designed keyword search mechanism. This mechanism utilizes fuzzy matching techniques to offer all relevant data from the database to the user.

Unlike traditional keyword mapping methods (Tsai et al., 2022; Cho et al., 2023), this study devises a new

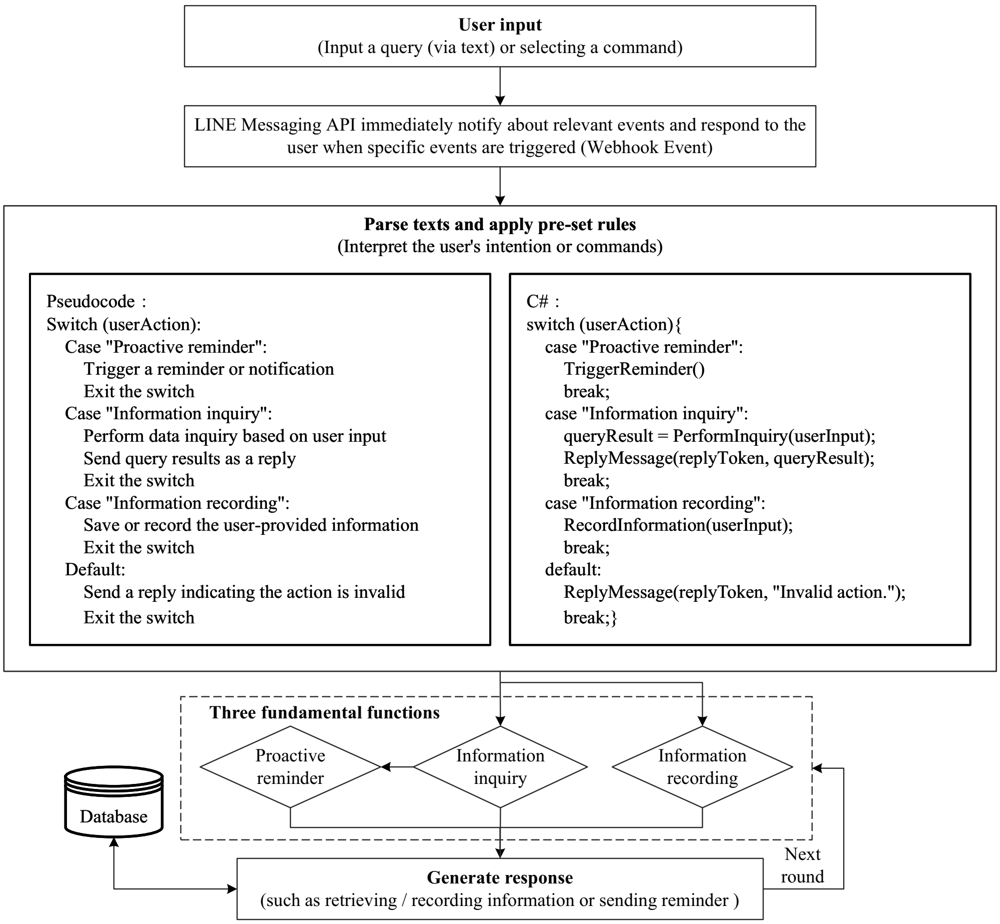


Figure 2. Overall rule-based dialog flow in LINE BOT

keyword search mechanism to enhance the robustness of chatbot responses. Conventional methods compare the similarity between user-inputted keywords (complete strings) and a built-in keyword mapping (matching) table to determine the triggered response (some studies employ a decision tree). In contrast, this study uses character segmentation and word matching similar to the method of matching document file names to find the most appropriate response from the database. The proposed keyword search mechanism in this study is shown in Figure 3.

In Figure 3, the process initiates with the system "splitting the string of inquiry keywords" once a user submits an inquiry. This involves two steps: firstly, the conversion of Arabic numeral keywords into Chinese characters (Step 1.1), and secondly, the segmentation of Chinese keywords into individual characters (Step 1.2). These individual or combined Chinese characters then serve as the targets for the search. The system subsequently scans the database to identify files with filenames matching any of the search targets. Ultimately, the system presents all matching files to the user, allowing them to select the file that best addresses their inquiry. Notably, the major pseudocode and C# syntax of each step for this proposed keyword search mechanism are also provided in Figure 3.

To ensure compatibility between the database (Module 2) and the LINE BOTs, Module 3.2 leverages Microsoft's Azure SQL for database development and employs Microsoft-based Visual Studio software for programming the LINE BOTs. This strategic use of Microsoft technologies eliminates potential incompatibilities between the database and the chatbots. Within the Visual Studio environment, the C# programming language is utilized to develop the chatbot's three fundamental functions: information inquiry, information recording, and proactive reminder.

(1) Information inquiry function (Module 3.2.1): The workflow of the rules-based information inquiry function is illustrated in Figure 4. This process begins when a user initiates a new inquiry for information retrieval. The module first verifies the validity of the inquiry and then assesses its specificity. If the inquiry is found to be ambiguous, the system provides additional options

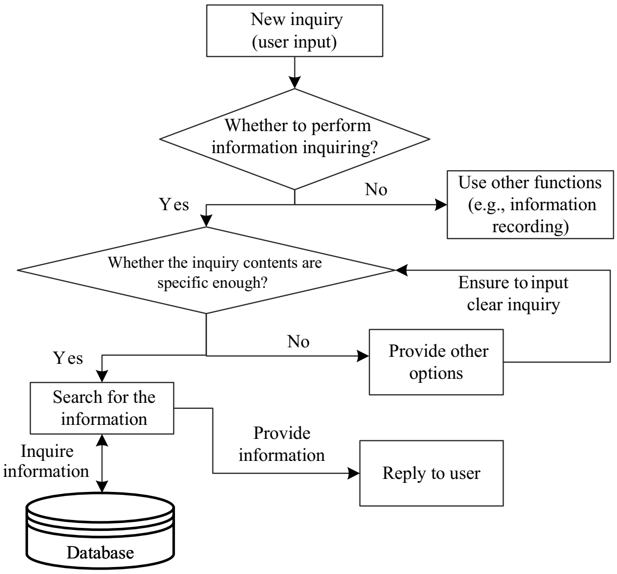


Figure 4. Workflow of information inquiry function (Module 3.2.1)

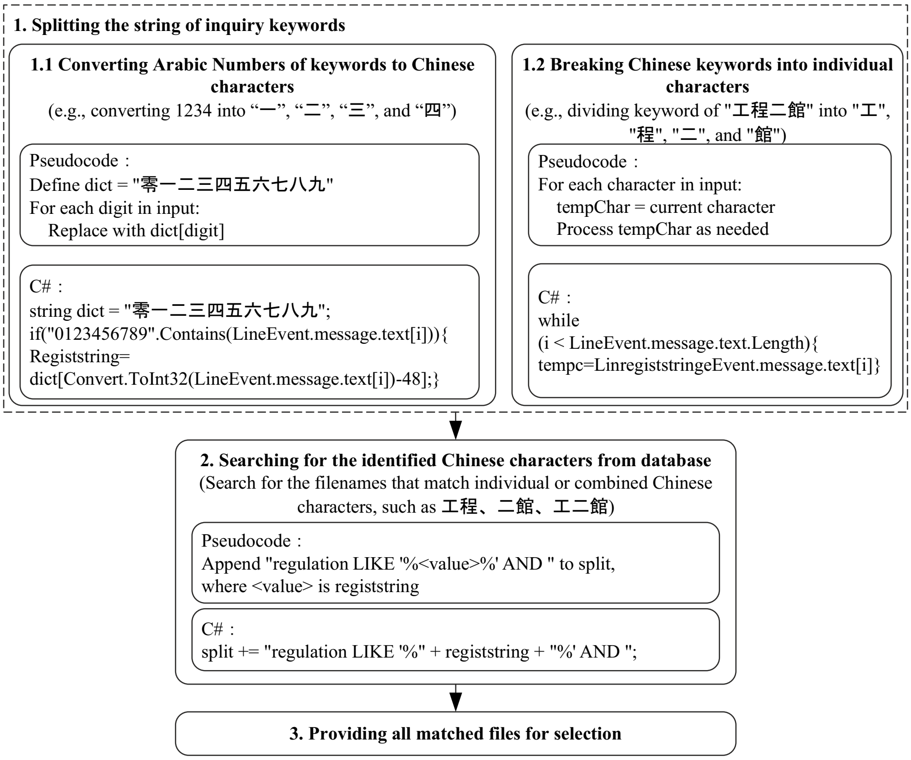


Figure 3. Proposed keyword search mechanism

```
else
{
    OleDbConnection con = new OleDbConnection();
    con.ConnectionString = ConfigurationManager.ConnectionStrings["Connection"].ToString();
    con.Open();

    string sqlCmd = "SELECT * FROM Inquire events WHERE date LIKE '%" + LineEvent.message.text + "%'";
    OleDbCommand cmd = new OleDbCommand(sqlCmd, con);
    OleDbDataReader dr = cmd.ExecuteReader();
```

Figure 5. Example of using SQL syntax for information inquiry function

to assist the user in formulating a more precise request. Upon confirmation of the user's inquiry, the module retrieves the pertinent information from the database and responds to the user with the relevant data.

Figure 5 illustrates an example of "inquire events" to demonstrate the implementation of Module 3.2.1. Specifically, this study uses SQL syntax to write a SELECT FROM statement to retrieve "events" data from the specified fields of the database's "detail table". The LIKE statement is then applied to query the recorded values in these fields, such as the minutes, recorded time, and date of a particular event.

(2) Information recording function (Module 3.2.2): The workflow of the rules-based information recording function is depicted in Figure 6. This process initiates when a user submits a request to record information. Initially, the module verifies the legitimacy of the information recording request. Once confirmed, it presents a series of questions to the user. These questions are designed to guide the user through the details input/recording process. This question-and-answer guidance sequence is maintained until the user has responded to all the questions. Subsequently, all the gathered data is recorded into the database. Importantly, this guided process is implemented to ensure that the user provides all necessary records or data (such as maintenance data) for a specific recording subject (like maintenance records or minutes). This approach is aimed at preventing the submission of incomplete or inconsistent information.

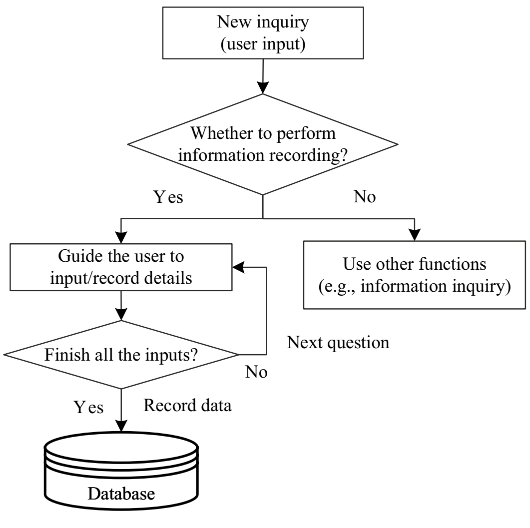


Figure 6. Workflow of information recording (writing) function (Module 3.2.2)

Figure 7 presents an example of "the minutes of major events" to display the implementation of Module 3.2.2. That is, this study uses SQL syntax to write an INSERT INTO statement to store the meeting minutes into the specified fields of the database's "detail table." The VALUES statement is then used to save the recorded values in these fields, such as the minutes, recorded time, and date for a specific event.

(3) Proactive reminder function (Module 3.2.3): The workflow for the rules-based proactive reminder function, which builds upon the workflow of Module 3.2.2 (Information Recording Function), is shown in Figure 8. Once the user completes information recording, this module evaluates the necessity of activating the proactive reminder function. If activation is deemed necessary, the module proceeds to guide the user through inputting reminder information. This process, involving a question-and-answer guidance sequence, continues until all reminder-related inputs are completed by the user. The entered data are then stored in the database.

The proactive reminder function encompasses two types of reminders: an instant reminder and a pre-set-reminding-time reminder. For instance, the instant reminder is triggered when the system identifies new data/information being written or uploaded into the database, prompting it to send immediate reminders to the relevant project members. In the case of the pre-set-reminding-time reminder, consider a meeting reminder scenario. Users enter the reminder time and relevant information into the database. The system is then programmed to automatically send reminders to all meeting participants at specified intervals, such as every five minutes (or any other pre-set interval) before the scheduled meeting time.

```
OleDbConnection con = new OleDbConnection();
con.ConnectionString = ConfigurationManager.ConnectionStrings["Connection"].ToString();
con.Open();
string date = DateTime.Now.ToString("yyyy/MM/dd");
string time = DateTime.Now.ToString("hh:mm:ss");
string sqlCmd = "INSERT INTO record minutes of major events VALUES ("
+ sArray[2] + "," + sArray[4] + "," + sArray[6] + "," + sArray[8] + ",#" + time + "#,#" + date + "#); ";
OleDbCommand cmd = new OleDbCommand(sqlCmd, con);
```

Figure 7. Example of using SQL syntax for information recording function

Figure 9 also presents an example of "the minutes of major events" to show the implementation of Module 3.2.3. When new information is entered into the system, the implemented C# syntax (PushMessage) is used to control the designated chatbot, enabling it to proactively send reminder messages to specified users.

3.3.3. Designing LINE BOTs (Module 3.3)

This study leverages the three fundamental functions – information inquiry, information recording, and proactive reminder – to design four distinct chatbots. These chatbots support information management during the design, construction, and operation/maintenance phases of a construction project.

To accommodate the vast array of information arising in the construction phase, two robots, Construction Information Robot (CI BOT) and Construction Daily Log Robot (CD BOT), are specially devised for managing specific/major data and daily log data, respectively, to streamline information management. Furthermore, based on the basic functions outlined in Module 3.2, Module 3.3 expands to include 15 application functions across the four LINE BOTs. Figure 10 graphically summarizes the established functional commands, triggering events (using Webhook events), and data types for each application function associated with each LINE BOT.

(1) Design Information Robot (DI BOT) (Module 3.3.1): In the design phase, DI BOT is tasked with four application functions, including recording and inquiring about the minutes of major events, inquiring about governmental/architectural design regulations, and reminding project members of upcoming design meetings. Take the first application function shown in Figure 10 for example. The "record minutes of major events" function allows system users to input (or record) and retrieve key event details (such as preliminary and final design decisions, design contract start dates, etc.) into the database. This assists in tracking whether design deliveries align with contractual deadlines. The triggering event for inputting or retrieving this information is categorized as "event type".

(2) Construction Information Robot (CI BOT) (Module 3.3.2): CI BOT is developed for recording, updating, and retrieving construction information/data. It encompasses six application functions, such as inquiring about quantities of cost items for specific BIM building objects, uploading/inquiring site photos, albums, and updating/inquiring drawings or specifications.

(3) Construction Daily Log Robot (CD BOT) (Module 3.3.3): CD BOT aids in inputting construction data into the daily log, such as the number or quantity of labor, equipment, and materials used, and tracking construction progress. Figure 11 presents CD BOT's workflow, including inputting and inquiring data from the daily log and exporting the filled daily log in Excel format. CD BOT also enables tracking progress data from the daily log to monitor the current schedule status.

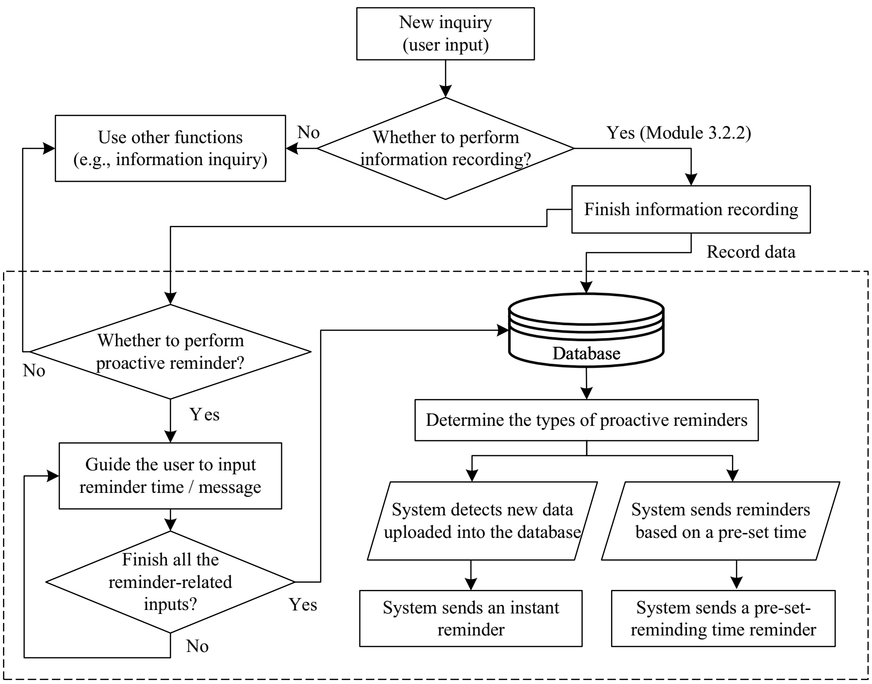


Figure 8. Workflow of proactive reminder function (Module 3.2.3)

```
:    cmd.ExecuteNonQuery();
:    isRock.LineBot.Utility.PushMessage(AdminUserId, "new major events!\n" + responseMsg, ChannelAccessToken);
}
```

Figure 9. Example of using C# syntax to proactively send reminders or notifications

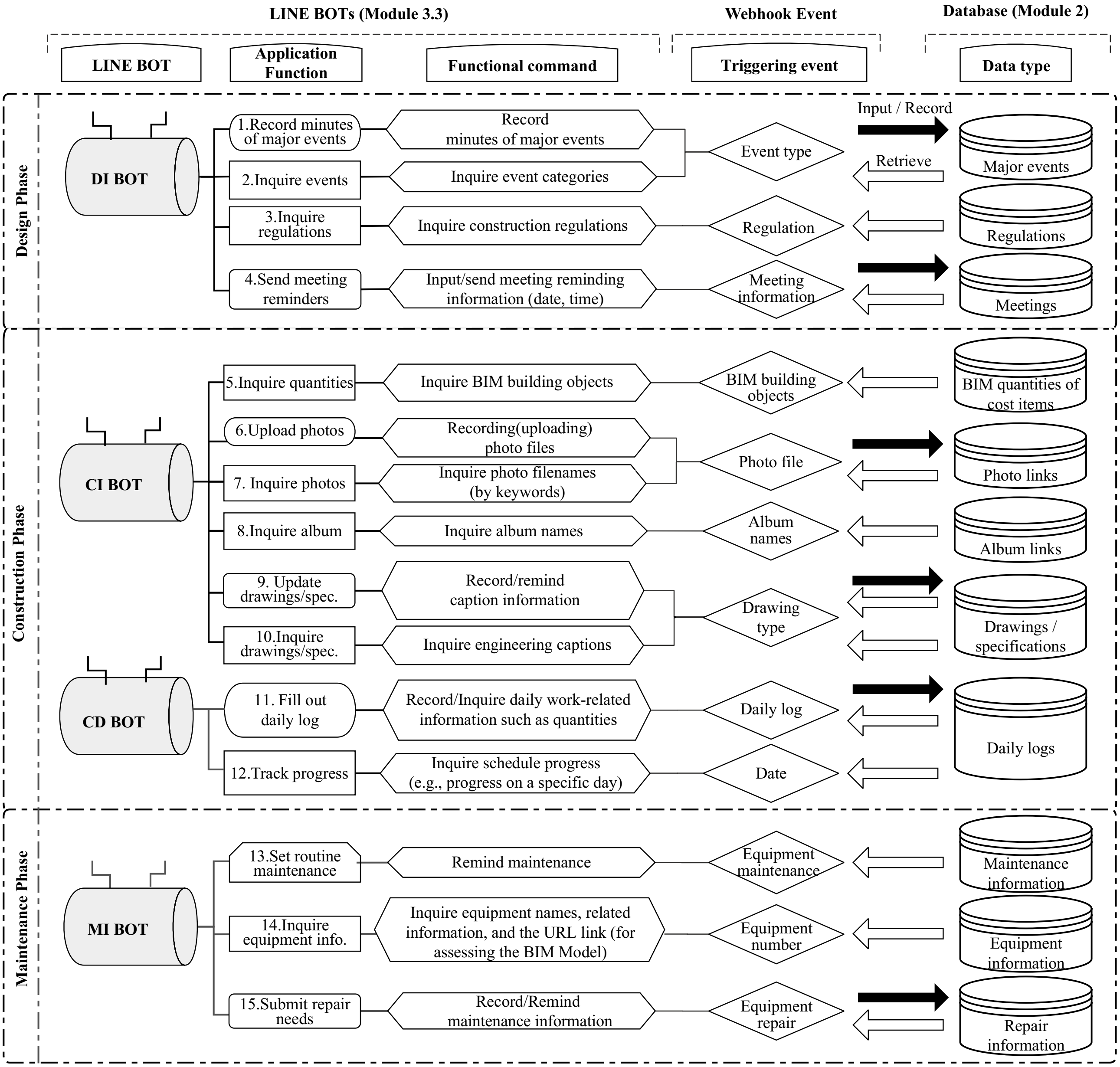


Figure 10. Summary of functional commands, triggering events, and data types for each application function in LINE BOTs

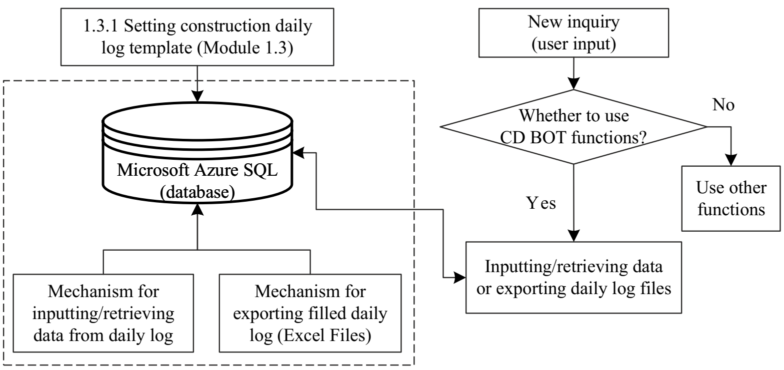


Figure 11. Workflow of construction daily log BOT (Module 3.3.3)

(4) Maintenance Information Robot (MI BOT) (Module 3.3.4): During the maintenance phase, MI BOT facilitates the application functions of routine maintenance scheduling, inquiring about equipment information, and submitting repair needs. When a repair need is submitted, the proactive reminder function activates, and MI BOT sends an immediate repair reminder to all relevant individuals. Additionally, users can visualize the relevant equipment objects within the BIM model by accessing a Uniform Resource Locator (URL) for the BIM file, further enhancing maintenance efficiency (i.e., application function 14 in Figure 10).

3.4. Computer implementation

This section describes the computer complementation software packages and programming languages of the proposed model shown in Figure 1. In the proposed LB-BIM system, Module 1 (collecting project information) is executed by a system user to: (1) export BIM data (Module 1.1, using Autodesk Revit), (2) upload project-related documents (such as drawings and specifications) to Google Drive (Module 1.2), and (3) input cost items into a daily log template (Module 1.3, using Microsoft Excel). The data is then stored in the developed Microsoft Azure SQL database (Module 2), which serves as the data input/output source for Module 3.

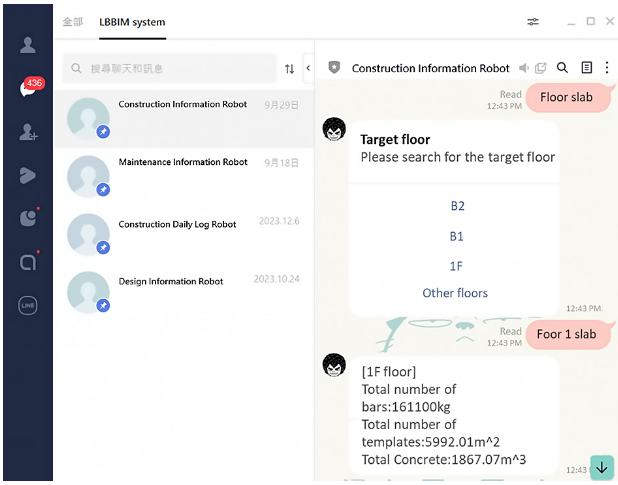


Figure 12. User interface of the proposed system on LINE

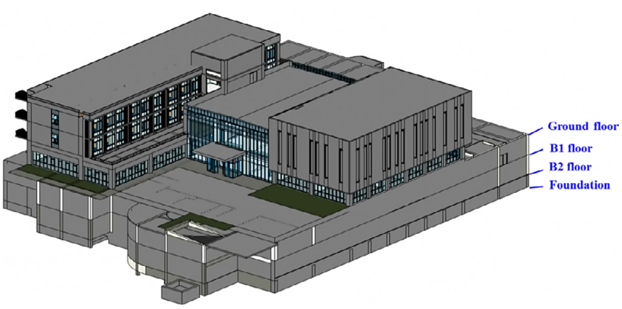


Figure 13. BIM model of the case study

In Module 3.1, this study configures four messaging APIs within the LINE communication platform to correspond to the four previously mentioned LINE BOTs (DI, CI, CD, and MI BOTs). In Module 3.2, the C# programming language and SQL syntax are utilized to develop the proposed rule-based dialog flow (Figure 2), the keyword search mechanism (Figure 3), the workflow for the information inquiry function (Figure 4; Module 3.2.1), the workflow for the information recording function (Figure 6; Module 3.2.2), the workflow for the proactive reminder function (Figure 8; Module 3.2.3), and the workflow for the construction daily log BOT (Figure 11; Module 3.3.3), all within the Visual Studio environment. These programming outputs are stored on a back-end server.

Module 3.3 provides the user interface for the four LINE BOTs, as shown on the left side of Figure 12. As previously presented in Figure 10, the functional commands, triggering events, and data types for each application function associated with the LINE BOTs are programmed using C# and SQL syntax and stored on the back-end server. Moreover, as demonstrated in Section 4.3 (Applications in the Maintenance Phase), an as-built BIM model file for a case project is uploaded to the Autodesk Viewer platform to visualize specific BIM equipment objects along with their associated information.

The proposed system is operational on both the LINE mobile app and the desktop version for PC. In the PC environment, the system runs on Windows operating systems that support 32-bit and 64-bit architectures (e.g., Windows 10 or Windows 11). The system's implementation results are demonstrated in the case study (Figures 14–25).

4. Case study

This study gathers real-world data from a construction project case and conducts virtual testing of the LBBIM system's effectiveness through scenario simulations. The project spans approximately 14 hectares and encompasses a total floor area of about 37,213 square meters. At the outset of this case study, project data from Module 1 are gathered and transferred to Module 2 (the database). As per Module 1.1, a BIM model specific to this project is developed (see Figure 13), and the associated BIM data, such as quantities of cost items for each BIM object, are exported into spreadsheets and subsequently stored in the database. Additionally, a variety of design drawings, design regulations, specifications, and contractual documents are uploaded to the Microsoft Azure SQL database (Module 2), as outlined in Modules 1.2 and 1.3.

The primary aim of this case study is to assess the practicality and effectiveness of the LBBIM System in performing the application functions depicted in Figure 10. This evaluation focuses on the system's ability to efficiently manage and process construction project data, thereby demonstrating its potential utility in real-world construction scenarios.

4.1. Applications in the design phase

In the design phase of construction projects, continuous iterative discussions are crucial to confirm design plans and develop deliverables. This phase often necessitates inquiring about design regulations/specifications, conducting meetings, and recording the minutes of major design decisions/events. The application of DI BOT in this context unfolds as follows:

Firstly, during design meetings, the need for swift retrieval of specific data for immediate review is paramount. Figure 14 illustrates how DI BOT is utilized in real-time to search for concrete regulations that support structural design. Moreover, as shown in Figure 15, DI BOT is employed to record significant events, such as a design discussion meeting, during the design phase. This application significantly enhances the efficiency of accessing and utilizing project design information, thereby improving the quality of decision-making in design discussions.

Secondly, the preparation of meeting materials and ensuring the presence of essential project members are critical for effective design decision-making. For instance, when a system user, such as an engineer representing the owner or design consultant, schedules a design meeting, DI BOT's "send meeting reminders" function is activated. This feature automatically dispatches reminders to the relevant project members ahead of the meeting's commencement.

In summary, the proposed DI BOT offers two primary benefits: the capability to efficiently inquire about and record design information, and the functionality to send timely reminders for upcoming meetings. These advantages highlight DI BOT's role in enhancing the efficiency and effectiveness of the design phase in construction projects.

4.2. Applications in the construction phase

As a project enters the construction phase, the focus of construction management shifts to controlling key aspects such as schedule, budget (cost), quality, and safety. In this context, the ability to inquire about and record a wide array of construction data becomes crucial. The CI BOT, in particular, is utilized in the case study to assess the system's capability in effectively handling various construction-related data and files. This includes uploading and retrieving site photos, construction drawings, specifications, and other relevant documents from the Microsoft Azure SQL database. This function is essential for maintaining an organized and accessible repository of construction data, which is pivotal for effective project management during this critical phase.

(1) As previously mentioned, the quantities of cost items for each BIM building object are stored in the database. Figure 16 shows a snapshot of how CI BOT inquires the database to determine the total amount of formwork required for columns, beams, and walls on the first floor of the case-study project. The snapshot illustrates the BOT retrieving a total sum of 9,159 square meters for formwork. This information is crucial for verifying the accuracy of quantities performed on site, which in turn aids in monitoring construction progress (schedule control) and reviewing intermediate progress payments (cost control). The ability of CI BOT to provide such detailed and accurate data is instrumental in ensuring efficient project management and cost control during the construction phase.

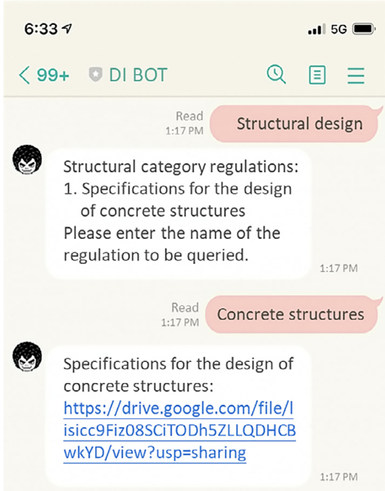


Figure 14. DI BOT uses keywords to inquire concrete regulations for supporting structural design

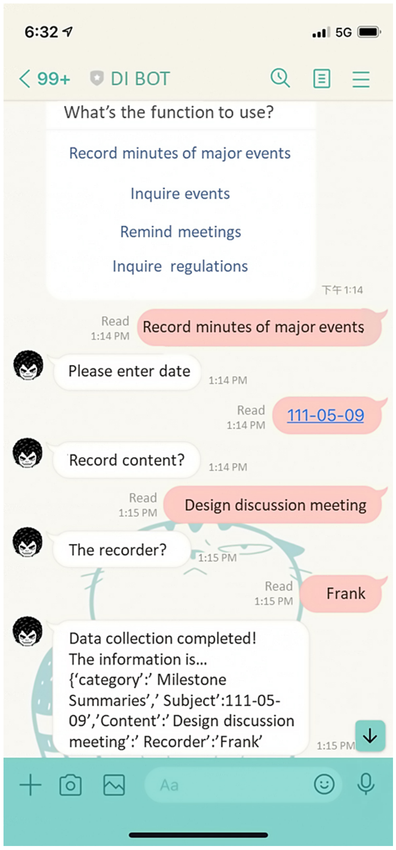


Figure 15. DI BOT records major events during the design phase

(2) Figure 17 demonstrates CI BOT's capability to swiftly locate specific albums (or folders) of construction photos based on various filtering criteria, such as types of album names, photo file names, floors, spaces, or dates when the photos were taken. This function significantly streamlines the process of accessing construction photographs. Instead of manually sifting through cloud drives for individual photos, users can quickly and efficiently retrieve relevant images using targeted search parameters. Additionally, Figure 17 illustrates how a site engineer can upload quality-related photos taken on-site directly into the system. This feature is particularly useful for supporting quality control measures, allowing for immediate documentation and sharing of visual information related to construction quality.

(3) Figure 18 showcases the functionality of CI BOT in uploading construction drawings to the database. It goes further by saving retrieval links associated with these drawings and proactively disseminating these links to relevant project members. This process ensures that the most current construction drawings are readily available, facilitating on-site quality reviews. Consequently, engineers can conveniently access these drawings through the provided links, which can significantly reduce the time needed to retrieve digitally stored documents and data. The CI BOT, therefore, not only aids in efficient information management but also contributes to streamlining on-site operations by making essential documents easily accessible.

Moreover, in the construction phase, it is typical for a construction superintendent to retreat to the on-site office at the end of each workday to fill out the construction daily log, either electronically or on paper. This log typically covers details like the construction tasks performed, materials used, workers and equipment employed, among others. Given the volume and complexity of the data required, this task is prone to omissions or errors.

Figure 19 demonstrates how the proposed CD BOT can streamline this process, enabling superintendents to input daily-log data on-site and in real-time. This approach not only ensures more accurate and timely record-keeping but also allows for the data to be reviewed and modified as needed. Furthermore, the system is capable of automatically generating daily construction logs in an Excel format, significantly reducing the administrative burden and enhancing overall efficiency in documentation.

4.3. Applications in the maintenance phase

Upon the completion of the construction phase, the project transitions into the operation/maintenance stage, managed by the project owner's operation management team. This team is responsible for the building's ongoing operation and maintenance, ensuring its optimal utilization. By utilizing the equipment details and space numbering information sourced from the BIM model, along with the URL link for accessing the BIM model, the MI BOT is specifically designed to assist the operations management team.

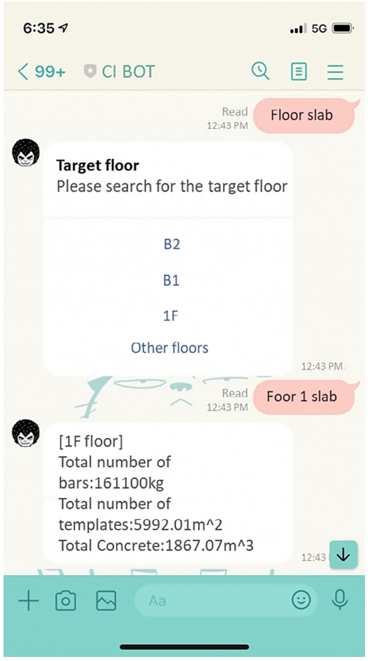


Figure 16. Using CI BOT to inquire the quantities of formwork on the first floor

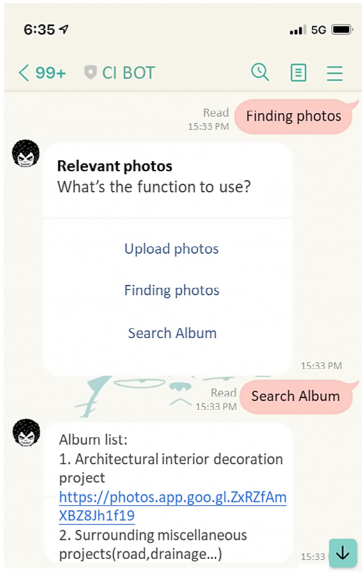


Figure 17. Applying CI BOT to locate specific albums of construction photos

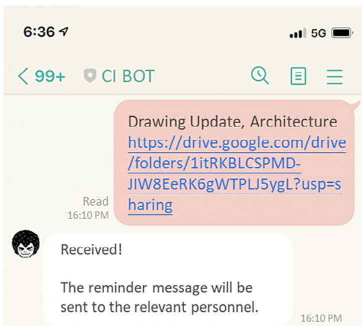
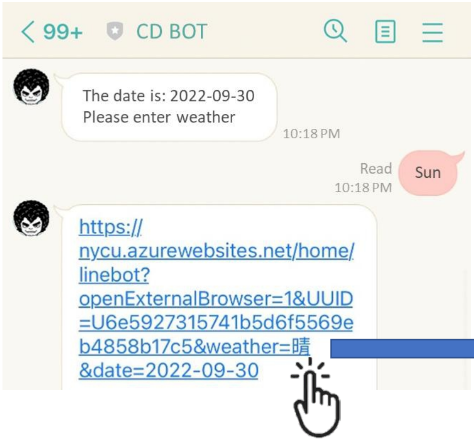
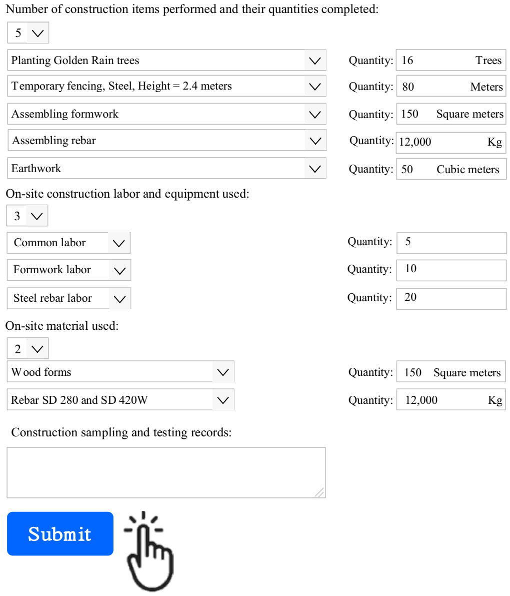


Figure 18. Using CI BOT to update construction drawings and send the links to relevant project members



Step 1. The user inputs the current date and weather through the CD BOT, and the system generates the Azure website URL for the daily construction log, allowing the user to fill in the relevant information.



Step 2. When the user has completed the input, he/she can click the 'Submit' button to generate the construction daily log in an Excel file.

Figure 19. Using CD BOT to input construction daily-log data on site and in real time

Its functionalities include setting routine maintenance schedules, inquiring and recording equipment information, submitting repair needs, sending maintenance reminders, and visualizing BIM equipment objects. The implementation of MI BOT's functionalities offers significant advantages. It streamlines the processes of searching for information, reporting issues, and ensuring maintenance activities are scheduled and executed timely. These features collectively contribute to enhancing the efficiency of the operation and maintenance phase, reducing time and effort required for managing and maintaining the facility.

(1) A key function of MI BOT is its ability to provide quick access to the maintenance data of facility equipment requiring upkeep. This includes crucial information such as the location of the equipment and its historical maintenance records. For instance, Figure 20 illustrates how MI BOT efficiently retrieves the historical maintenance data for a specific air conditioner. By using MI BOT, maintenance personnel can effortlessly access detailed maintenance histories, allowing them to make informed decisions about future maintenance activities and schedules. This functionality not only enhances the efficiency of the maintenance process but also contributes to the effective management and upkeep of the facility's equipment.

(2) As demonstrated in Figure 21, MI BOT can facilitate the submission of repair needs or maintenance reports by guiding the user through a series of questions. Once a repair need or request is submitted, MI BOT promptly sends a repair notice to notify the maintenance personnel, as shown in Figure 22. Furthermore, Figure 23 illustrates that operation personnel can directly access a summary list of the currently submitted repair needs (records) in the database for review and action.

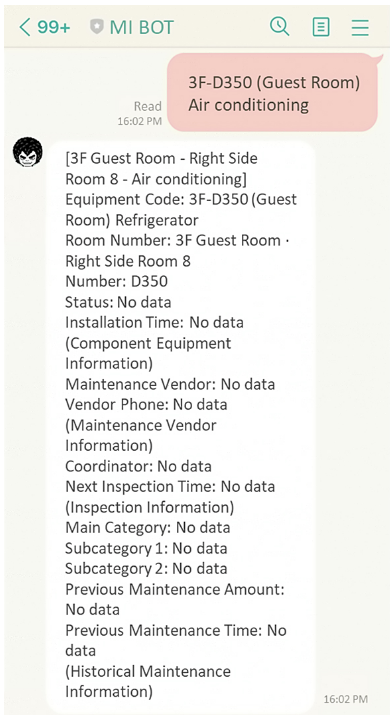


Figure 20. Applying MI BOT to retrieve the historical maintenance data of a specific air conditioner

(3) MI BOT features a proactive notification function. When the maintenance period of a device is nearing its end, MI BOT automatically alerts the administrator based on a pre-set time. This proactive notification is crucial for timely preparation and efficient scheduling of maintenance personnel. It plays a significant role in preventing potential equipment damage that might occur due to human oversight or prolonged neglect.

Such proactive reminders ensure that maintenance is carried out regularly, thus extending the lifespan of the equipment and maintaining optimal operational conditions.

(4) MI BOT allows users to visualize relevant 3D equipment objects within the BIM model, enhancing the system's intuitiveness. During the maintenance phase, an as-built BIM model file for the case project is uploaded to the Autodesk Viewer platform, generating a corresponding URL link that is saved in the construction information database (Module 2). For instance, when a user selects the "View BIM File Link" option in the system, MI BOT sends the URL link to access the BIM model saved on the Autodesk Viewer platform (Figure 24). Figure 25 illustrates how the user can visualize a specific BIM equipment object along with its associated information, facilitating a more intuitive understanding of the equipment's location and status.

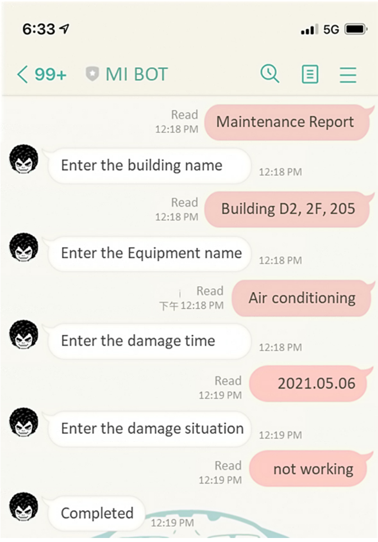


Figure 21. Applying MI BOT to fill out maintenance/repair needs through guided questions

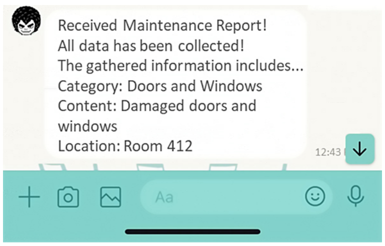


Figure 22. MI BOT sends a repair notice to notify maintenance personnel

5. Evaluations

For an objective evaluation of the proposed system, we invited eight experienced practitioners to provide their insights based on the outcomes of the case study. These practitioners were carefully selected based on their substantial experience in the building industry, each having a minimum of five years of expertise in design, construction, or facility maintenance. Their professional backgrounds are diverse, encompassing roles such as managers, supervisors, or senior engineers. These professionals are affiliated with a variety of organizations, including engineering consultancy firms, architectural firms, and construction companies. Their extensive experience and varied professional positions make them well-suited to offer valuable assessments of the system's effectiveness in practical settings.

The evaluation of the proposed system is organized into three main categories, as detailed in the left half of Table 1: C1 – Usability, divided into three sub-criteria (C1.1 to C1.3), assessing user-friendliness and accessibility; C2 – Functionality, with four sub-criteria (C2.1 to C2.4), focusing on the system's operational capabilities and performance; and C3 – Practical Benefits, encompassing five sub-criteria (C3.1 to C3.5), evaluating the tangible advantages in real-world applications. Each practitioner rates the system

ID	Category	Content	Location	Name	Contact Inform	Time	Date
1	Equipment	Water Dispenser Malfunction	3rd Floor Corridor	Xiao Chen	0912345678	AM 04:25:39	2019/3/7
2	Equipment	Air Conditioning Breakdown	5th Floor 504	Lao Chen	0987654321	AM 04:34:41	2019/3/7
3	Equipment	Air Conditioning Not Cooling	2th Floor 2010	Da Chen	0987123654	PM 04:36:20	2019/3/7

Figure 23. Summary list of submitted repair needs

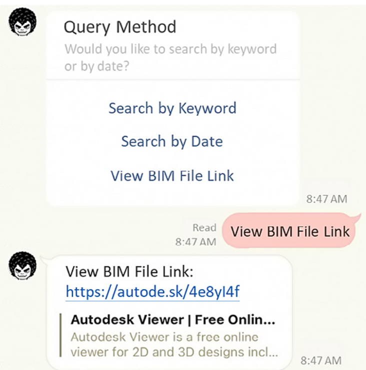


Figure 24. MI BOT sends a URL link for visualizing the BIM model

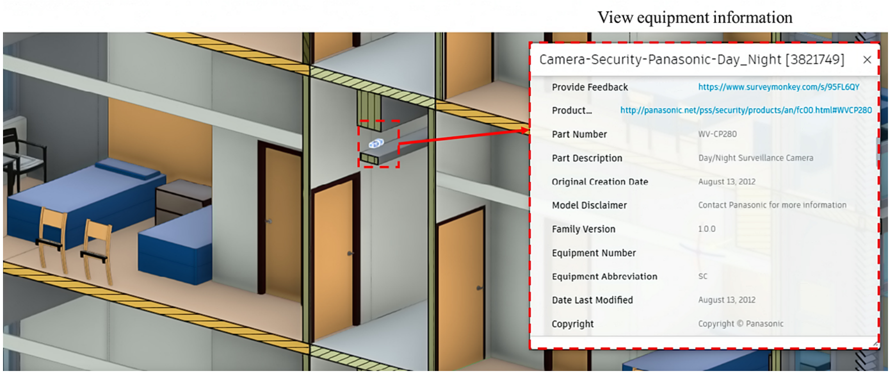


Figure 25. Visualization of specific BIM equipment objects and their associated information

using a Likert scale scoring method, ranging from 1 to 5, where 1 represents “strongly disagree” and 5 signifies “strongly agree” (Lin et al., 2016). This scoring system allows for a nuanced and comprehensive assessment across different dimensions of usability, functionality, and practical benefits.

The evaluation results for the proposed system, as presented in the right half of Table 1, reveal an overall average score of 4.02. This indicates a positive reception in terms of usability (C1: 3.96), functionality (C2: 4.09), and practical benefits (C3: 4.00), affirming the system’s practicality. Notably, practitioners emphasize three main strengths:

(1) Easy to understand the user interface (C1.2: 4.25): The system’s integration with LINE, Taiwan’s widely-used instant messaging software, allows for quick adaptation by project participants. The familiarity with LINE’s interface means users require minimal learning for operations like texting or clicking buttons on their mobile devices.

(2) Convenience to share information among project members (C2.1: 4.25): The system uses LINE as a platform, augmented by chatbots, to manage project information across different phases in a unified database (Module 2). This setup facilitates easy access to diverse information types for project participants. Furthermore, the system’s keyword search mechanism (semantic search) effectively guides users in inquiring or recording information, enhancing the ease of information retrieval or recording.

(3) Easy for practitioners to learn and adapt (C3.5: 4.38): The system’s integration with the widely-used LINE platform significantly eases the learning curve for project participants. There is no need for installing additional software packages or navigating through complex registration and login procedures. Practitioners can effortlessly adapt by simply using their existing LINE accounts to add the specifically designed chatbots, enabling immediate use of the system. This straightforward approach streamlines the adoption process, making it user-friendly and accessible, which is reflected in the high score of 4.38 for this criterion.

Overall, the proposed system is highly regarded for its major advantages, which include an intuitive user interface, convenient information-sharing capabilities, and minimal adaptation time for users. These strengths are underscored by the high scores received in the evaluation categories, reflecting the system’s efficacy in meeting the practical needs of construction project management. However, the evaluation results presented in Table 1 also indicate areas where the system could be further improved or clarified. Addressing these aspects will enhance the system’s overall functionality and user experience, making it even more beneficial for practitioners in the field.

(1) The system can provide sufficient information to users (C1.3: 3.75): The current system does not encompass all types of project information. Essential data like contracts, material test reports, and construction plans were missing during the case study. Additionally, it was noted that some project information types might be more suitable for inquiry rather than modification, such as progress payment documents and design/construction drawings, which are challenging to update due to formal approval processes and mobile screen limitations.

Table 1. Evaluation criteria and results of the proposed system

C1. Usability		Mean score
C1.1	Easy to establish the system	3.88
C1.2	Easy to understand the user interface	4.25
C1.3	Can provide sufficient information to users	3.75
	Average score:	3.96
C2. Functionality		Mean score
C2.1	Conveniency to share information among project members	4.25
C2.2	Ease of uploading and saving project information/data	3.88
C2.3	Capable of recording project information in short time	4.13
C2.4	Reliable and real-time reminder/notification function	4.13
	Average score:	4.09
C3. Practical benefits		Mean score
C3.1	Enhance the accuracy of decision making	3.88
C3.2	Reduce the manpower cost of maintaining project data	3.75
C3.3	Strengthen the management efficiency of project information/data	4.25
C3.4	Sufficiency of available application functions	3.75
C3.5	Easy for practitioners to learn and adapt	4.38
	Average score:	4.00
	Overall average score:	4.02

Notes: An average score is calculated based on the feedback from respondents, using a Likert 5-point scale rating, where 1 represents “strongly disagree” and 5 represents “strongly agree”.

(2) Ease of uploading and saving project information/data (C2.2: 3.88): With various stakeholders like owners, consultants, architects, and contractors using the system, there are concerns regarding the categorization and confidentiality of updated information. To address this, two solutions are proposed: setting different user permissions based on the user's LINE account and using different LINE BOTs for specific project members, thus ensuring appropriate access and confidentiality.

(3) Sufficiency of available application functions (C3.4: 3.75): Experts suggested the addition of more application functions and an automated check function to verify if the summed quantities of cost items exceed contractual limits.

6. Research contributions

The proposed LBBIM system exhibits significant differences in functionality and program architecture compared to existing commercial chatbots, such as the LINE platform's built-in commercial chatbots. Commercial chatbots typically focus on basic scripted dialogue functionalities, such as quickly responding to queries, handling simple inquiries, or guiding users through specific operations. These functions are primarily based on predefined rules or response logic provided by LINE and lack the ability to integrate with industry- or domain-specific databases, limiting their applicability for specialized information management tasks. To address these limitations, this study proposes a program architecture (Figure 1) implemented using the C# programming language and SQL syntax within the Visual Studio environment. This architecture facilitates the development of four LINE BOTs integrated with the Microsoft Azure SQL database, significantly enhancing information management for construction projects.

Table 2 further compares the proposed LBBIM system with related studies, highlighting four major contributions of this research:

(1) Comprehensive lifecycle application

Unlike prior research, which predominantly focuses on chatbot applications during the construction phase, the LBBIM system addresses the information needs of project team members – owners, architects, and contractors – through 15 application functions (see Figure 10). These functions span various stages of the project life-

Table 2. Comparisons between this study and related research

Item	Tsai et al. (2022)	Adel et al. (2022)	Cho et al. (2023)	This study
System name	Site equipment management assistant	Information exchange and management system	Chatbot-engaged system for supporting construction daily work reports	LINE BOT and BIM-based information management system
Lifecycle phase	Construction	Construction	Construction	Design, construction, and maintenance
Management target	Construction site equipment	Construction progress	Construction daily work reports	Design, construction (including daily logs), and maintenance information
System development target	Site engineers	Contractors	Contractors	Owners, architects, and contractors
Instant messaging software	LINE	Web-based; designed on IBM Cloud	KakaoTalk	LINE
Applied technology	Chatbot + image recognition	Chatbot + blockchain	Chatbot	Chatbot + BIM
Data collection	■ Automatic ■ Construction site surveillance images + deep learning	■ Manual ■ Smart contract setup, with users inputting 9 types of progress data	■ Automatic + Manual ■ 70 out of 105 data points sourced from the developed system; remaining data provided through chatbot conversations	■ Automatic + Manual ■ BIM model information (geometric and non-geometric data); remaining data provided through chatbot conversations
Intent analysis	■ Rule-based ■ keyword mapping table + decision tree	■ Generation-based ■ IBM Watson Assistant	■ Rule-based ■ Keyword-matching approach	■ Rule-based ■ Proposed keyword search mechanism (keywords split into individual characters)
Visualization	None	None	None	Visually displays the queried equipment's BIM objects and associated information
Proactive reminders	When equipment enters or leaves the construction site	None	Can remind contractors to fill out data	■ Instant reminder: data update or upload ■ Pre-set time reminder: meeting or important event reminder

cycle, including design, construction, and maintenance. By doing so, the system enhances capabilities in information storage, exchange, collaboration, and management, while also expanding the scope of chatbot applications for construction projects.

(2) Integration with BIM models

The LBBIM system integrates LINE BOTs with BIM models, enabling automatic retrieval of both geometric and non-geometric information. This significantly reduces the need for manual data entry. For instance, the quantity of formwork components in the BIM model (Module 1) is imported into the Azure SQL database (Module 2) for storage and made available for real-time queries via the CI BOT (Module 3.3.2). In the maintenance phase, the MI BOT allows querying of equipment maintenance history and provides BIM model visualization to assist maintenance personnel in quickly locating equipment, thereby improving the efficiency of maintenance tasks.

(3) Enhanced keyword search mechanism

This study introduces an innovative keyword search mechanism that differs from traditional methods, which rely on comparing complete keyword strings. The new mechanism disaggregates and matches individual keyword characters, enabling the system to provide possible matches even when the complete string is mistyped. This approach increases the robustness and reliability of chatbot responses.

(4) Advanced proactive reminder functionality

While prior studies have offered limited applications for proactive reminders (e.g., notifications about construction equipment arrivals or reminders to fill out daily reports), the proposed system uses C# to establish two types of reminders: instant reminders triggered by data updates and pre-set notifications for meetings or important events. For example, the system can notify relevant personnel of upcoming meeting schedules. Additionally, in the design phase, the DI BOT leverages the information recording function to log key events using event-based filters and stores the data in the database. The proactive reminder function then automatically delivers relevant messages to designated users, ensuring that critical information is communicated in real-time.

These advancements collectively enhance the practicality and efficiency of the LBBIM system, providing a robust tool for managing construction project information across all project phases.

7. Conclusions

The LBBIM system, leveraging the popular instant messaging application LINE, integrates LINE BOT and BIM technologies with a Microsoft Azure SQL database for centralized data storage, offering an innovative solution for construction information management. This system features four specially designed chatbots (DI BOT, CI BOT, CD BOT, and MI BOT), facilitating real-time data entry and retrieval across various project phases. Employing a rules-based, dialog-guided approach, these chatbots support the recording and retrieval of project information. The chatbots are equipped with a keyword search mechanism and three core functions (information inquiry, information recording, and proactive reminder), providing a total of fifteen major application functions. Furthermore, during the maintenance phase, users can also access relevant equipment objects through the BIM model using mobile smart devices.

As per practitioners' evaluations, the system's major strengths include its user-friendly interface, ease of sharing information, and straightforward learning curve for practitioners. However, areas identified for improvement are the need for more comprehensive project information, considerations for data confidentiality, and the addition of application functions.

Future research directions, beyond the discussions in Section 5, might explore enhancing the "keyword search mechanism" with more advanced Artificial Intelligence technologies for efficient semantic searches. Another avenue is integrating LINE BOT with Chat GPT for accessing a wider range of information, such as government procurement regulations and labor safety laws. Moreover, applying the proposed system to other projects for further verification and obtaining feedback is also recommended.

Acknowledgements

We would like to thank the National Science and Technology Council, Taiwan, for funding this research project (Project No. NSC 108-2622-E-009-021-CC3). Special thanks go to the two Master's students Te-Chu Liu and Yi-Tsen Lan from National Yang Ming Chiao Tung University for their assistance in coding the proposed system. Additionally, the authors are appreciated for those practitioners who provided their expertise in testing the case project.

References

Adel, K., Elhakeem, A., & Marzouk, M. (2022). Chatbot for construction firms using scalable block-chain network. *Automation in Construction*, *141*, Article 104390. https://doi.org/10.1016/j.autcon.2022.104390

Autodesk. (2023). *Autodesk BIM 360*. https://www.autodesk.co.uk/products/bim-360-field/overview

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International Journal of Project Management*, *31*(7), 971–980. https://doi.org/10.1016/j.ijproman.2012.12.001

Carrillo, P., & Chinowsky, P. (2006). Exploiting knowledge management: The engineering and construction perspective. *Journal of Management in Engineering*, *22*(1), 2–10. https://doi.org/10.1061/(ASCE)0742-597X(2006)22:1(2)

Cho, J., Lee, G., Song, T., & Jeong, H. D. (2023). Chatbot-engaged construction daily work report using mobile messenger. *Automation in Construction*, *154*, Article 105007. https://doi.org/10.1016/j.autcon.2023.105007

Costa, G., & Sicilia, A. (2020). Alternatives for facilitating automatic transformation of BIM data using semantic query languages. *Automation in Construction*, *120*, Article 103384. https://doi.org/10.1016/j.autcon.2020.103384

Das, A., & Khan, R. (2018). *Build better chatbots. A complete guide to getting started with chatbots*. Apress.

Deng, H., Xu, Y., Deng, Y., & Lin, J. (2022). Transforming knowledge management in the construction industry through information and communications technology: A 15-year review. *Automation in Construction*, *142*, Article 104530. https://doi.org/10.1016/j.autcon.2022.104530

Dawood, N., Akinsola, A., & Hobbs, B. (2002). Development of automated communication of system for managing site information using internet technology. *Automation in Construction*, *11*(5), 557–572. https://doi.org/10.1016/S0926-5805(01)00066-8

Dsouza, R., Sahu, S., Patil, R., & Kalbande, D. R. (2019). Chat with bots intelligently: a critical review & analysis. In *Proceedings of 2019 International Conference on Advances in Computing, Communication and Control* (*ICAC3*), Mumbai, India. IEEE. https://doi.org/10.1109/ICAC347590.2019.9036844

El-Diraby, T., Krijnen, T., & Papagelis, M. (2017). BIM-based collaborative design and socio-technical analytics of green buildings. *Automation in Construction*, *82*, 59–74. https://doi.org/10.1016/j.autcon.2017.06.004

Fazeli, A., Dashti, M.S., Jalaei, F., & Khanzadi, M. (2021). An integrated BIM-based approach for cost estimation in construction projects. *Engineering*, *Construction and Architectural Management*, *28*(9), 2828–2854. https://doi.org/10.1108/ECAM-01-2020-0027

Finalcad Collaboration. (2023). https://www.finalcad.com/solutions/collaboration

Handoyom, E., Arfan, M., Soetrisno, Y. A. A., Somantri, M., Sofwan, A., & Sinuraya, E. W. (2018). Ticketing chatbot service using serverless NLP technology. In *Proceedings of 2018 5th International Conference on Information Technology* (pp. 325–330), Semarang, Indonesia. IEEE. https://doi.org/10.1109/ICITACEE.2018.8576921

Lin, Y. C., Chang, J. X., & Su, Y. C. (2016). Developing construction defect management system using BIM technology in quality inspection. *Journal of Civil Engineering and Management*, *22*(7), 903–914. https://doi.org/10.3846/13923730.2014.928362

Lin, C., Hu, Z.-Z., Yang, C., Deng, Y.-C., Zheng, W., & Lin, J-R. (2022). Maturity assessment of intelligent construction management. *Buildings*, *12*(10), Article 1742. https://doi.org/10.3390/buildings12101742

Liu, R., & Issa, R. R. A. (2013). Issues in BIM for facility management from industry practitioners' perspectives. In *Proceedings of ASCE International Workshop on Computing in Civil Engineering 2013* (pp. 411–418). ASCE. https://doi.org/10.1061/9780784413029.052

Muniasamy, A., & Alasiry, A. (2020). Deep learning: The impact on future eLearning. *International Journal of Emerging Technologies in Learning*, *15*, 188–199. https://doi.org/10.3991/ijet.v15i01.11435

Olawumi, T. O., & Chan, D. W. M. (2019). Building information modeling and project information management framework for construction projects. *Journal of Civil Engineering and Management*, *25*(1), 53–75. https://doi.org/10.3846/jcem.2019.7841

Oracle Aconex. (2023). *Construction project controls software*. https://www.oracle.com/industries/construction-engineering/aconex-project-controls/

Pan, Y., & Zhang, L. (2021). Roles of artificial intelligence in construction engineering and management: A critical review and future trends. *Automation in Construction*, *122*, Article 103517. https://doi.org/10.1016/j.autcon.2020.103517

Ryota, I. (2022). *Reasons why Line's global business continue to expand their market share* (The global business press briefing organized by LINE).

Saka, A. B., Oyedele, L. O., Akanbi, L. A., Ganiyu, S. A., Chan, D. W. M., & Bello, S. A. (2023). Conversational artificial intelligence in the AEC industry: A review of present status, challenges and opportunities. *Advanced Engineering Informatics*, *55*, Article 101869. https://doi.org/10.1016/j.aei.2022.101869

Satu, M. S., Parvez, M. H., & Mamun, S. A. (2015). Review of integrated applications with AIML based chatbot. In *Proceedings of 2015 International Conference on Computer and Information Engineering* (pp. 87–90), Rajshahi, Bangladesh. IEEE. https://doi.org/10.1109/CCIE.2015.7399324

Senthilkumar, V., Varghese, K., & Chandran, A. (2010). A web-based system for design interface management of construction projects. *Automation in Construction*, *19*(2), 197–212. https://doi.org/10.1016/j.autcon.2009.10.007

Seo, H. J., Koo, K. J., & Um, I. J. (2004). Web-based coordination system for daily work report between contractor and subcontractor. In *Proceedings of the Korean Institute of Construction Engineering and Management Conference* (pp. 370–375).

Shen, Y. (2019). The Alliance of Taiwan, Japan, and South Korea: Relying on 21 million active LINE users for connected business banking. *Global Views Monthly* (in Chinese). https://www.gvm.com.tw/article/60292

Shin, Y., Kim, D., Kim, T. Y., & Kim, G. H. (2016). Daily reporting system using digital pen at construction site. *Journal of the Korea Institute of Building Construction*, *16*(2), 177–183. https://doi.org/10.5345/JKIBC.2016.16.2.177

Siao, F. C., & Lin, Y. C. (2012). Enhancing construction interface management using multilevel interface matrix approach. *Journal of Civil Engineering and Management*, *18*(1), 133–144. https://doi.org/10.3846/13923730.2012.657368

Song, T. (2018) *Extracting daily report information from text messages between the field managers* [Master's thesis]. Yonsei University, Seoul, Korea.

Taiwan Water Resources Agency. (2019). *2019 development of intelligence response robot* (Research report). Taipei, Taiwan.

Tsai, M. H., Yang, C. H., & Wang, C. H. (2022). SEMA: A site equipment management assistant for construction management. *KSCE Journal of Civil Engineering*, *26*, 1144–1162. https://doi.org/10.1007/s12205-021-0972-2

Tsay, G. S., Staub-French, S., & Poirier, É. (2022). BIM for facilities management: an investigation into the asset information delivery process and the associated challenges. *Applied Sciences*, *12*(19), Article 9542. https://doi.org/10.3390/app12199542

Tupenaite, L., Kanapeckiene, L., & Naimaviciene, J. (2008). Knowledge management model for construction projects. *Computer Modelling and New Technologies*, *12*(3), 38–46.

Wang, K. C., Wang, W. C., Wang, H. H., Hsu, P. Y., Wu, W. H., & Kung, C. J. (2016). Applying building information modeling to integrate schedule and cost for establishing construction progress curves. *Automation in Construction*, *72*, 397–410. https://doi.org/10.1016/j.autcon.2016.10.005

Wang, J., Hwang, G. H., & Chang, C. Y. (2021). Directions of the 100 most cited chatbot-related human behavior research: A review of academic publications. *Computers and Education*: *Artificial Intelligence*, *2*, Article 100023. https://doi.org/10.1016/j.caeai.2021.100023

Wang, N., Issa, R. R. A., & Anumba, C. J. (2022). NLP-based query-answering system for information extraction from building information models. *Journal of Computing in Civil Engineering*, *36*(3), Article 0001019. https://doi.org/10.1061/(ASCE)CP.1943-5487.0001019

Yang, L. H., Xu, L., Wang, W. C., & Wang, S. H. (2021). Building information model and optimization algorithms for supporting campus facility maintenance management: A case study of maintaining water dispensers. *KSCE Journal of Civil Engineering*, *25*(1), 12–27. https://doi.org/10.1007/s12205-020-0219-7