BIM-BASED KNOWLEDGE MANAGEMENT FOR BUILDING MAINTENANCE

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ABSTRACT

Decisions in Building Maintenance (BM) are mostly based on professionals' accumulated knowledge and available information about building elements and technologies. This research aims to develop an integrated system to capture, retrieve and manage information and knowledge for BM. The proposed system has three modules; case browsing module, case retrieving module, and case retaining module. This paper discusses the development of the case retaining module using the BIM technology. The module is used to identify the information/knowledge relevant to maintenance cases and pursue the related affected building elements by these cases. The system development was based on analysis of number of interviews and case studies conducted with professionals working in public BM departments. The paper concludes that implementing a BIM-based knowledge management system can help improve the performance of BM operations.

Keywords: BIM, Building Maintenance, Knowledge Management

1. INTRODUCTION

BS 8210:1986 defines Building Maintenance (BM) as "*work, other than daily and routine cleaning, necessary to maintain the performance of the building fabric and its services*"(BSI, 1986). Furthermore, significance of BM can be well acknowledged as its core business is maintaining the "*nation's most valuable asset*" (CIOB, 1990). However, BM is yet recognised as part of the Facilities Management (FM) sector (Barrett & Baldry, 2003) and simultaneously part of the construction sector (Ali et al., 2006; Doran et al., 2009). This probably aided the recognition of BM as a non-core business in organisations (Waheed & Fernie, 2009) which consequently has limited the attention towards "*free thinking*" and improvements for delivery of services (RICS, 2009). Nevertheless, skills and knowledge in refurbishment management are more significant than those in general construction management (Egbu, 1999). This highlights the importance of FM and BM activities with involved expertise and the constant need for improvements.

During the whole lifecycle of a building, different stakeholders independently handle each stage. As a result, only limited information is exchanged between teams of each stage which is generally limited to spread sheets, word documents, 2D drawings (Vanlande et al., 2008). Therefore, history, decisions made, and realised insights may be fully or partially lost during the life span of a building. Until recently, the construction industry has been generally revolved around 2D software with limited uses of 3D models for visualisation and design development (Singh et al., 2011). Indeed, the use of intelligent software is becoming a necessity to cope with the rising complexity in constructing and maintaining buildings. While 2D software mainly serves as a digital drafting tool, virtual structures are created in Building Information Modelling (BIM) based software through collaboration between stakeholders. The principal aim of BIM is the management of stakeholder input throughout the entire lifecycle of a project (Dzambazova et al., 2009). Therefore, BIM abilities can be utilised as an efficient mean in reducing and mitigating difficulties when managing activities during the complete building lifecycle. Furthermore, as operational stages of buildings can last for decades, activities of BM have to evolve with time to maintain the delivery of satisfactory service when products and technologies become absolute. Therefore, having accessible sufficient information is a key challenge before commencing maintenance operations. BIM-based software has the ability to extend its use to facilities and maintenance management. A system that utilises the features of BIM technology can considerably improve the delivery of BM services.

In practice, FM organisations already implement BIM in their processes; application areas include components locating, facilitating access of real-time data, maintainability checking, and automatic creation of digital assets (Becerik-Gerber et al., 2012). There are several BIM-focused studies aimed at improving FM and BM practices. Examples include: BIM based package for the FM Exemplar project of Sydney Opera House which is developed to manage digital data generated by procurement and benchmark sections of the project (Akhurst & Gillespie, 2006), AROMA-FF which is developed to utilise data including BIM databases to obtain information and geometric representation of facilities and equipment (Lee & Akin, 2011), and the web-based Facilities Maintenance Management (FMM) prototype decision support system proposed by Hao et al. (2010). FMM is based on basic processes for Asset Management, Corrective Maintenance, Preventive Maintenance, and Condition-based Maintenance. Whereas BIM related studies mainly focus on utilising technical information, associating Knowledge Management (KM) principles can help in achieving new levels of efficiency in BM performance.

The concept of KM has been implemented by organisations to gain better market share and competitive advantage (Nonaka & Takeuchi, 1995). While it has been acknowledged that individuals possess their tacit knowledge, genuine potential benefits reside in transforming individual knowledge into institutional knowledge (Egbu, 2000). Several studies have been revolving around utilising and managing of knowledge in BM. Ali et al. (2002 and 2004) introduced the prototype MoPMIT to improve the management of Reactive Maintenance projects. Other examples include: “Building Maintenance Community of Practice” by Fong & Wong (2009), and the web-based system “Consulting Knowledge System” by Lepkova & Bigelis (2007). The chief objective of such applications is the improvement of knowledge sharing and communication between stakeholders in BM. However, an application that utilises the intelligent objects of BIM to manage information and knowledge would provide better service delivery of BM. This paper proposes a BIM-based knowledge management system that not only facilitates the capturing and retrieval of information and knowledge but also the ability to trace and associate maintenance cases of a building.

2. SYSTEM ARCHITECTURE

The proposed system “Knowledge Management of Building Maintenance” (KMoBM) comprises three modules: case browsing module, case retrieving module, and case retaining module. These modules are accessible through a web-based user-friendly interface. Software applications can be developed in different platforms including those of web-based and desktop. Based on the findings of Almarshad et al. (2011), a web-based platform was considered to be the most appropriate in development of the system. Main benefits for a web-based system include no installation, can be accessed from any location and data is remotely stored and maintained.

The case browsing module allows users to navigate and browse maintenance cases. The case retrieving module utilises the process of case-based reasoning in retrieval of similar maintenance cases. The case retaining module uses IFC protocol to integrate building BIM models with the KMoBM system. The adopted taxonomy of knowledge cases of maintenance operations in KMoBM is based on the findings of the interviews and case studies conducted with professionals working in public BM departments (Almarshad et al., 2010). This paper is part of a larger research and will only introduce and discuss the case retaining module of the system. This module is illustrated in the following sections.

3. PROJECT AND CASE PARAMETERS

A challenge was faced during the development of the proposed KMoBM system with regards to the process of knowledge and information retaining from a BIM model. The issue was in the form of retrieving case-based details from element-based structure model. Virtual projects developed in BIM-based software comprise of elements such as wall, door, footing, etc. while the proposed system is based on knowledge cases utilised by professionals. Therefore, in order to deal with this discrepancy, additional parameters in Rivet were utilised for the elements in the BIM model.

Revit associates elements with two forms of parameters: instance and type parameters. The software facilitates users to add, remove, edit, and organise properties of each parameter which includes format and data. In our case, custom instance parameters were added to manage the discrepancy between the KMoBM system and the software. Figure 1 illustrates the process of preparing and managing the parameters in Revit. The steps include the creation of parameters and then specifying their properties. Defining the properties involves selecting the type, data format, and categorisation.

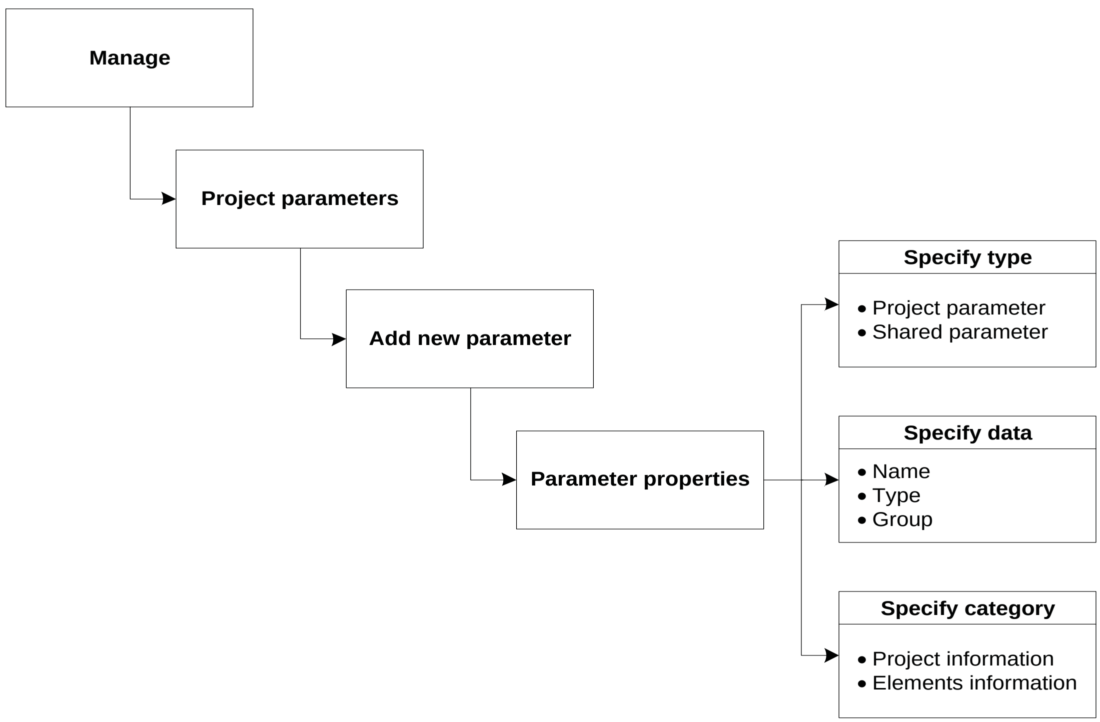

Figure 1: Process of parameter setting in Revit

Two sets of parameters were added for project information and building elements in a way to be consistent with what should be read and retained by the KMoBM system. The first set of parameters contains the generic project information. The proposed parameters of project details to be extracted from a maintenance project are shown in Table 1 below.

Table 1: Parameters of project information in BIM model

Parameter name		Description
1.	Date	Date of the knowledge case.
2.	Client Name	Name of beneficiary unit.
3.	Contractor Name	Name of contractor undertaking maintenance works.
4.	Address	Location of the building.
5.	Governorate	Name of province.
6.	Project name	Name of the maintenance project.
7.	Building type	Usage of the building (school, office building, police station).
8.	Structure type	Concrete, wood, steel, combined, Etc…

The second set of parameters is associated to building elements and comprises of case details and knowledge categorisation. The categorisation used in the system is based on BM contracts currently used in Kuwaiti public sector. This approach to implement the categories of work packages which are well known to the potential users may assist the system to be reached by wider professionals while requiring minimal training. The overall taxonomy adopted for the system consists of three categories: legal, technical and administrative. The legal category includes sections related to contract law, regulations, legal conditions, and health and safety. The Technical category comprises of sections organised based on work packages used in BM contracts. The administrative category contains sections related to BM processes and staff details. The indexing of staff is based on knowledge interest. Having a navigating method based on expertise and knowledge could prompt finding the desired expert when urgently needed. The default taxonomy adopted for the system can be easily modified to suite any particular BM organisation. The proposed knowledge case parameters are shown in Table 2 below.

Table 2: Parameters of knowledge/Information case in BIM model

Parameter name		Description
1.	Category	Legal, Technical, Administrative.
2.	Section	Which section within each category.
3.	Sub-Section	Which sub-section within each section.
4.	Topic	General topic of a captured case.
5.	Issue/Problem	Particular issue/problem of the case.
6.	Reaction/Solution	The reaction/solution to the case.
7.	Keywords	Keywords that identify the case.
8.	Element	The element affected by the case.

4. CAPTURING AND RETAINING OF CASES

Main components of the knowledge retaining module include manual retaining section and uploading through BIM section. The system interface allows users to either directly store cases or by loading the maintenance cases created in the BIM building model. IFC protocol is used in extracting details from BIM models. The details of cases are organised and stored in the database to be later searched for solutions. Figure 2 shows the complete retaining process of knowledge cases.

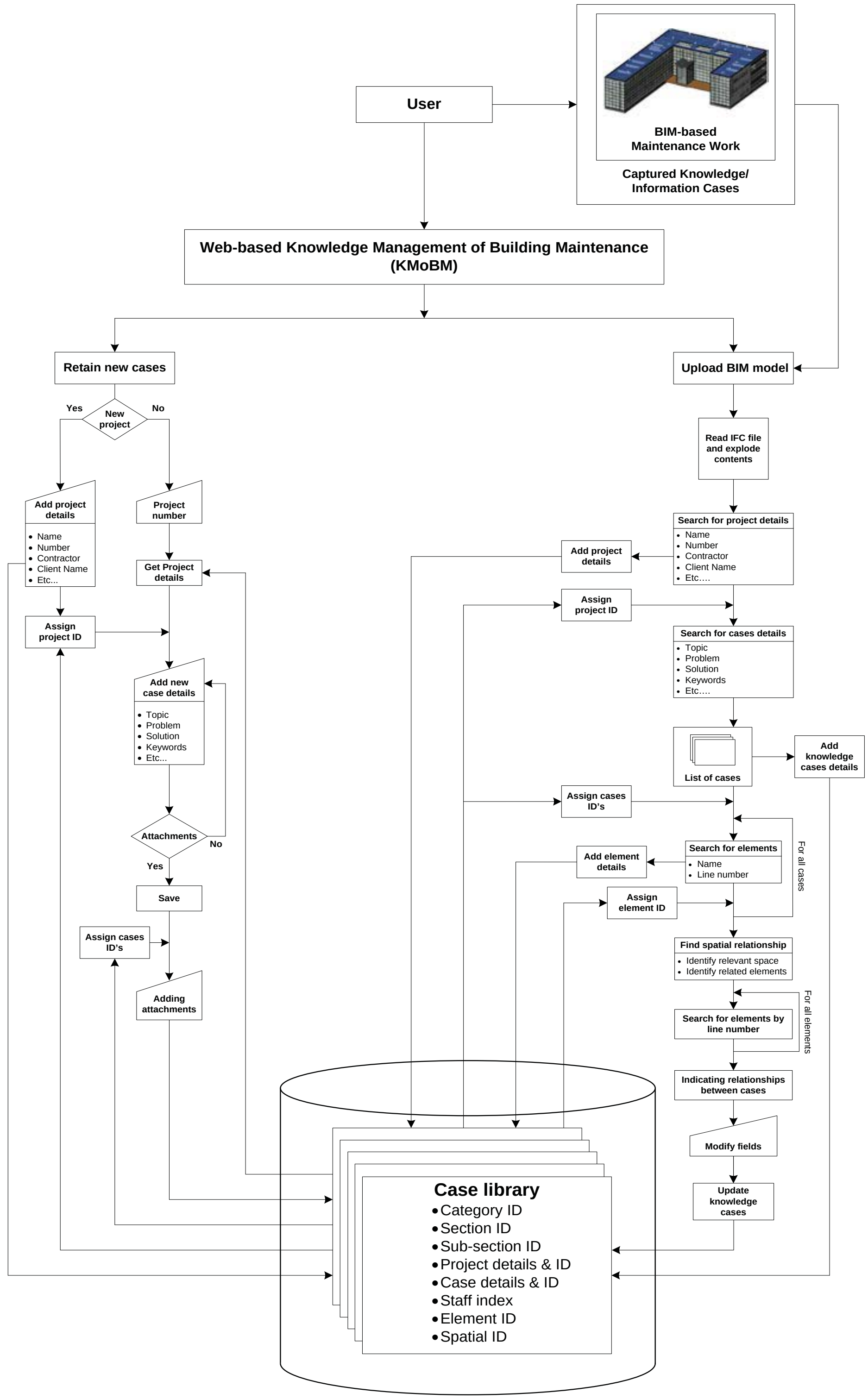

Figure 2: Knowledge case retaining process by KMoBM system

The system interface permit users to create knowledge cases as shown in Figure 3. In this process, users can add maintenance cases to either a stored or newly created maintenance project. The left box of the system allows users to either submit a project number to retrieve the details of a stored project or insert the details of a new project. The fields of project details are illustrated in Table 1. The right box of the system has the fields where new knowledge case details are recorded. The fields of case details are shown in Table 2. Upon storing, unique project and case ID's are assigned to distinguish between projects and to link knowledge cases to a particular project. This method provides two benefits: (1) maintaining the organisation of cases when updates are made and (2) allowing multiple and simultaneous storing of cases to a particular project. This is due to the fact that BM departments can have several maintenance projects concurrently taking place and that single maintenance team can supervise multiple projects at the same time.

Figure 3: Creating case through KMoBM system interface

By loading the BIM building model into the system, the knowledge and information of the maintenance case will be extracted from BIM file then categorised and stored in the system. As shown in Figure 4, the capturing of knowledge/information cases involves users filling the fields of parameters with case details. For example, when an insight has been acknowledged during the works of a maintenance project and believed to be worth capturing as a knowledge case, users can fill in the designated element parameter fields in the BIM-based software, as illustrated in section 3 earlier. The designated attributes include case's topic, problem, solution, keywords and element name. Users then insert category, section and sub-section in which the case to be stored later in the system. This case description will be uploaded to the KMoBM via the IFC file format when uploading the BIM building model. All captured knowledge cases in BIM model can then be identified, stored and organised by the system.

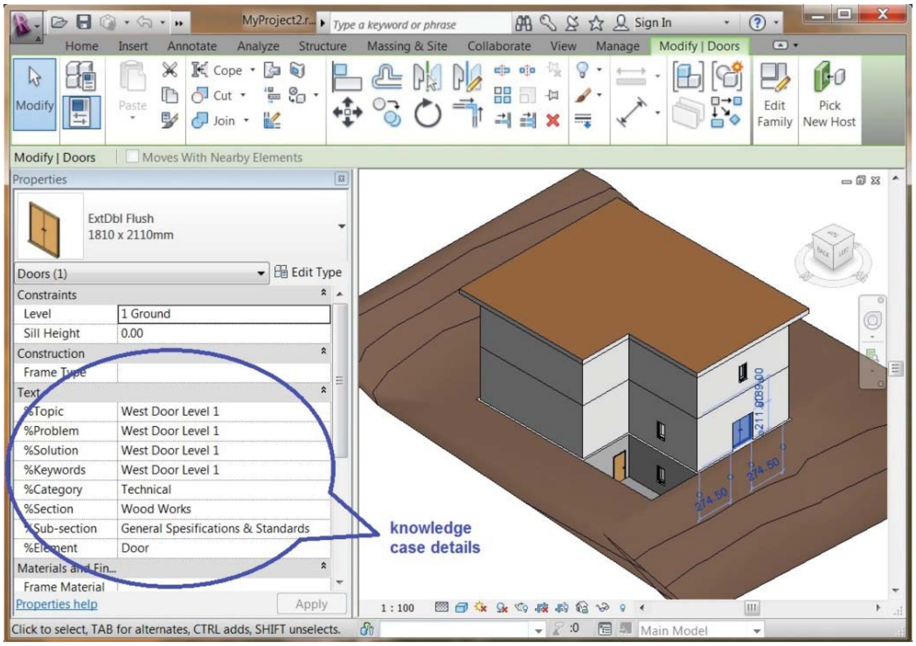

Figure 4: Capturing of maintenance cases in BIM model

The IFC format file includes information related to elements of a project, their hierarchy, relationships, geometry and properties. Figure 5 shows an uploaded project file with captured cases. The project details are shown in the right box of the system and the captured cases are shown in the left box of the system.

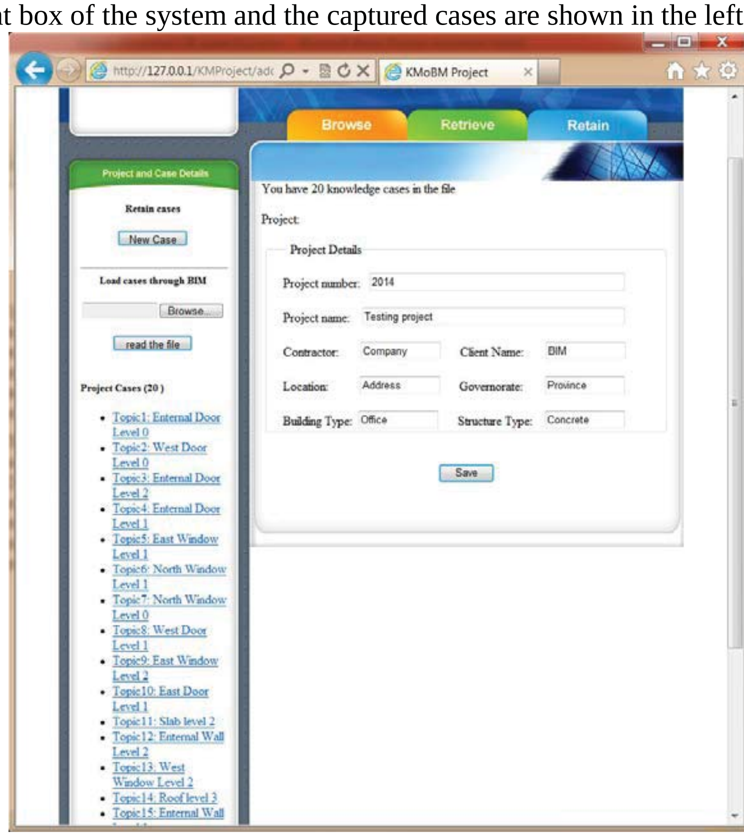

Figure 5: Uploaded maintenance project with captured knowledge cases

The system then stores the identified case details in the allocated fields in database and assigns a unique case ID to each of the stored cases. By using this method in assigning ID's, each project can have multiple cases in which problems and their solutions or recommendations are described. This is due to the fact that professionals may face several problems in a single maintenance project that need to be addressed. As a result, multiple insights could be captured as knowledge cases.

5. CASE RELATIONSHIP

It is common that several building elements may be affected when maintaining a building. Therefore, the proposed system has been developed to have the ability to seek relationships between maintenance cases of several elements. By tracing history of work and identifying related problems, this feature can provide professionals with comprehensive understanding of issues related to their maintenance works. Since the BIM-based software considers the relationships between building elements, the virtual building model represents the actual constructed building. The notion of process adopted by KMoBM for identifying relationship between cases is based on the concept of intelligent objects of a BIM model.

As shown in Figure 6, after completing the process of storing project information and cases details, the proposed system then identifies the spatial relationships between elements that are provided by the IFC schema. This method is made to reduce the project into smaller manageable subsets. The system then clusters elements along with the associated cases into groups. Each group is then assigned with a unique ID to indicate the relationship between an element and its related spatial group. By the end of this process, related cases in single spatial group are linked to each other. Whenever a case has been searched and demonstrated, related cases of the same spatial group are presented. Figure 6 illustrates an example of the system output for a particular maintenance case and details of related cases.

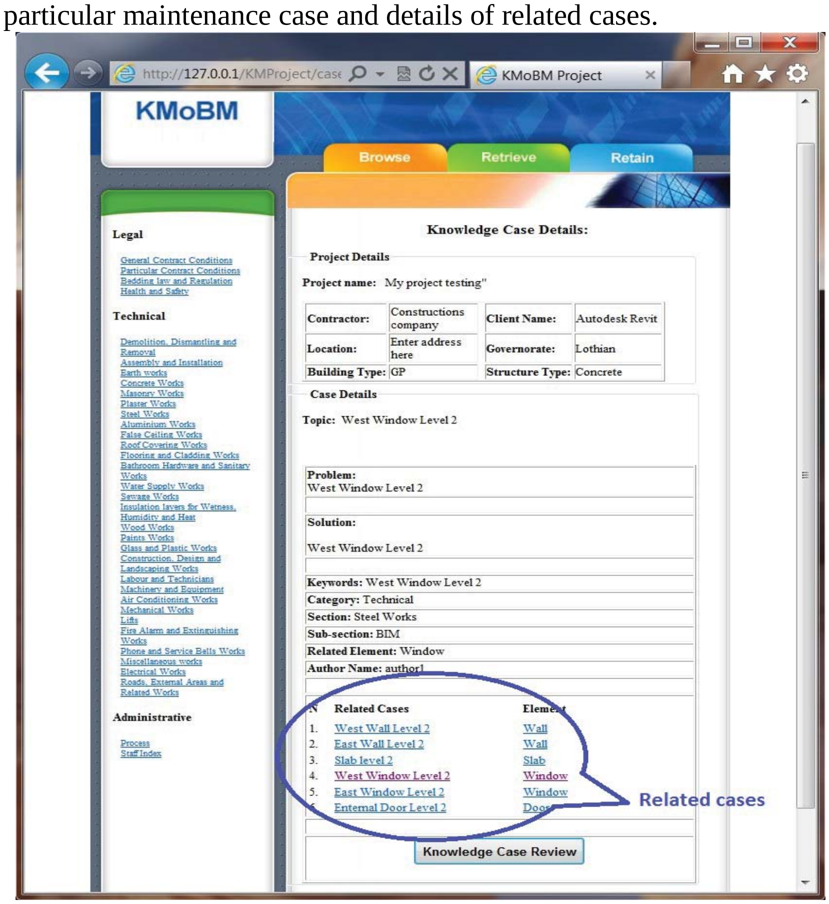

Figure 6: Presentation of knowledge case details in KMoBM with related cases

6. CONCLUSION

Utilising technology to support FM and BM activities can have a positive impact on the delivery of service. Several systems have been developed to facilitate information sharing or knowledge sharing for building maintenance. However, the efficient practice requires a system that can handle both information and knowledge in an integrated way. This paper presented a BIM-based KM system to capture, manage, and retain accumulated information and knowledge of maintenance projects. The case-retaining module, along with other modules in the system, is part of a research aimed at developing a KM system to serve public BM projects. This module makes use of the intelligent objects capability of the BIM model of a building to retain knowledge cases and to identify related cases. Such method can assist in tracing back the history of maintenance cases of a building and providing comprehensive understanding to support the process of decision making. It is concluded that integrated KM and BIM facilities will enhance the practices of sharing information and knowledge.

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