AN APPROACH TO CAPTURE FACILITY MAINTENANCE AND REPAIR INFORMATION TO STORE CHANGE HISTORY

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ABSTRACT

During operations, changes happen to facilities frequently due to maintenance and repair (M&R) work, upgrades and renovations. Consequently, corresponding facility information needs to be updated so as to provide reliable information to facility operators and managers. Moreover, the record of facility changes is necessary to understand the patterns of failures and to support proactive maintenance decisions. Therefore, there is a need to enable storing of the information about such changes at the time that they occur. In current practice, facility documents are not frequently updated and a complete history of changes is not available for supporting facility management decisions. The authors' objective is to streamline the capturing of M&R information when these activities are performed, so as to have a history of facility changes that can be used to understand how a building is deteriorating and to support facility information updates. By observing M&R work records, we identified the need for capturing different types of facility and change information for different types of M&R work. Moreover, we observed the need for a spatial database to support pattern analysis by identifying clusters that may not be found by using traditional databases. We developed a taxonomy of M&R work that classifies various types of work on different types of facility components and lists associated information modules that represent data required to be collected in the field. This approach enables a formal approach for capturing change information as a result of M&R work by providing customized templates for each type of work. The focus of this paper is to present the need for customization of information capture templates. The paper also gives a description of the approach of formally generating customized templates based on a taxonomy of M&R work and linking the captured history information with a facility information model. Enabling such a linkage will be the first step towards reasoning about the M&R history in order to analyze how a building deteriorates, identify problems in the building, and inform the users of facility information update needs.

Keywords: Facility maintenance, maintenance changes, change history, maintenance planning.

1. INTRODUCTION

Decisions about facility operations and maintenance require integration of various types of information created by architects, engineers and constructors stored in dispersed facility documents (such as building system maintenance records, work orders, and building systems data maintained on CAD systems (Tracy 2001)) some of which are in different formats and structures than facility operators need (Clayton et al. 1999). Facility management personnel need to organize and maintain such information in order to support building operations and maintenance and repair (M&R) activities. The challenge is not only to integrate this dispersed information, but also to keep them up-to-date so that they will reflect the as-is conditions of the facility. During operations, changes happen to facilities frequently due to maintenance and repair work, upgrades and renovations. Consequently, corresponding facility information needs to be updated so as to provide reliable information to facility

operators and managers. In current practice, such updates are not done as frequently as they need to be, resulting in significant costs due to ineffective decisions and re-collection of as-is data when needed (Gallaher et al. 2004). Moreover, the record of facility changes is necessary to understand the patterns of failures and to support proactive maintenance decisions. Therefore, there is a need to enable storing of the information about such changes at the time that they occur. When the change information is captured in the field, it should be possible to update facility documents and store a history of changes for further analysis of how the building changes and deteriorates. In current practice, facility documents are not frequently updated and a complete history of changes is not available for supporting facility management decisions.

The authors' objective is to streamline the capturing of maintenance and repair information when these activities are performed, so as to have a history of facility changes that can be used to understand how a building is deteriorating and to support facility information updates. In order to develop an approach to support this objective, we performed case studies to observe current M&R work records in an educational facility and a medical facility. During these case studies, we identified the need for capturing different types of facility and change information for different types of M&R work. Moreover, we observed the need for a spatial database to support pattern analysis by identifying clusters that may not be found by using traditional databases (Akcamete et al. 2010). Since information at different levels of detail is required for capturing different changes to a facility, we developed a taxonomy of M&R work. This taxonomy classifies various types of work on different types of facility components and lists associated information modules that represent data required to be collected in the field. This approach enables a formal way of capturing change information as a result of M&R work by providing customized templates for each type of work. These templates are generated based on the type of the M&R work and the component that will be worked on. Information modules are generated considering not only the need to capture change information, but also the need to represent and analyze the history in a Building Information Model (BIM).

In this paper, the authors discuss the need for customization of information capture templates. The paper also gives a brief description of the approach of formally generating customized templates based on a taxonomy of M&R work and linking the captured history information with a BIM model. Enabling such a linkage will be the first step towards reasoning about the M&R history in order to analyze how a building deteriorates, identify problems in the building, and inform the users of facility information update needs.

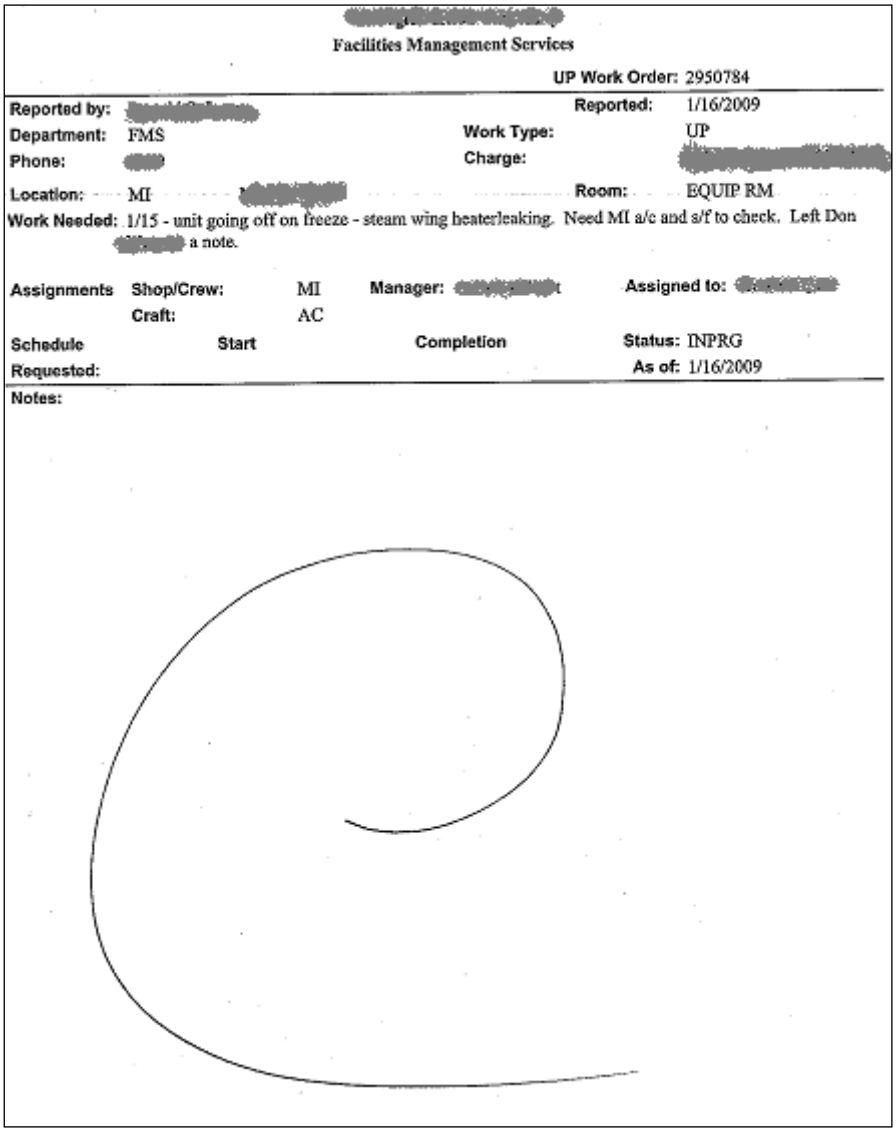
2. MOTIVATING CASE STUDY

2.1 Problems in the current industry practice

During the operations and maintenance phase, work orders (WOs) are used to communicate maintenance and repair (M&R) information and to store changes happening to facility conditions as a result of M&R work. According to Teicholz (2001), it is possible that a large organization processes over 500,000 work orders a year, each with 100 items of related data requiring the organization to track and store 50 million data fields. This figure shows that facility operators need to manage a significant amount of data, even when only considering the work orders generated. Therefore, there is a need to formally manage this information in order to keep facility data up-to-date and easily accessible when needed.

However, in current practice, information about changes is not captured at the required levels of detail when existing work order templates/methods are used. Figure 1 shows an example of a work order that records the work done in response to a heating pipe leak. As can be seen from the figure, the only information captured about this repair is the building in which the problem occurred, the date and the description of the problem, and the shop and the person responsible from the repair. The exact repair performed in response to this leak and the resulting changes are not recorded, the work done is summarized with a letter "C" meaning work order is complete. Lack of change information includes the location of the change, exact component being changed, how it is changed and the reasons for and impacts of the change. As this example illustrates, the content of the information captured is based on a generic template provided to tradespeople for all types of work and the willingness of tradespeople to provide more information about the work performed. This is the only feedback from the field that

will be used to update the facility information and limited information about the changes in WO documents makes it very difficult to update FM databases with the resulting changes from M&R activities. Since current methods are generally labor intensive and error-prone, there is no guarantee of comprehensiveness, accuracy and consistency of the facility information.



Facilities Management Services

UP Work Order: 2950784

Reported by: [redacted] Reported: 1/16/2009

Department: FMS Work Type: UP

Phone: [redacted] Charge: [redacted]

Location: MI [redacted] Room: EQUIP RM

Work Needed: 1/15 - unit going off on freeze - steam wing heaterleaking. Need MI a/c and s/f to check. Left Don [redacted] a note.

Assignments Shop/Crew: MI Manager: [redacted] Assigned to: [redacted]

Craft: AC

Schedule Start Completion Status: INPRG

Requested: As of: 1/16/2009

Notes:

Figure 1: An example of work order recording the work done in response to a leak (some information is erased for anonymity).

As previously discussed, the information captured in WOs is often the only feedback from the field about the changes at the end of a maintenance or repair work. Since the change information is not captured at the required levels of details, WOs cannot fully support updating related facility data. As a result, facility documents and databases remain outdated. The authors observed several examples of outdated facility records due to lack of change documentation or reluctance to update related facility documents. Figure 2 illustrates an example floor plan from a facility that we investigated the work order records. The plan on the left shows the current as-is representation and plan on the right shows the existing plan in the facility records depicting the “current” conditions. The room highlighted with a red rectangle was renovated and some of the interior walls were demolished to connect spaces. This renovation and demolishing of the walls have not been captured in the facility drawings stored in the

facility management (FM) database. This out-dated information will cause erroneous analysis of the space and its usage, and will also be misleading for facility maintenance and repair work.

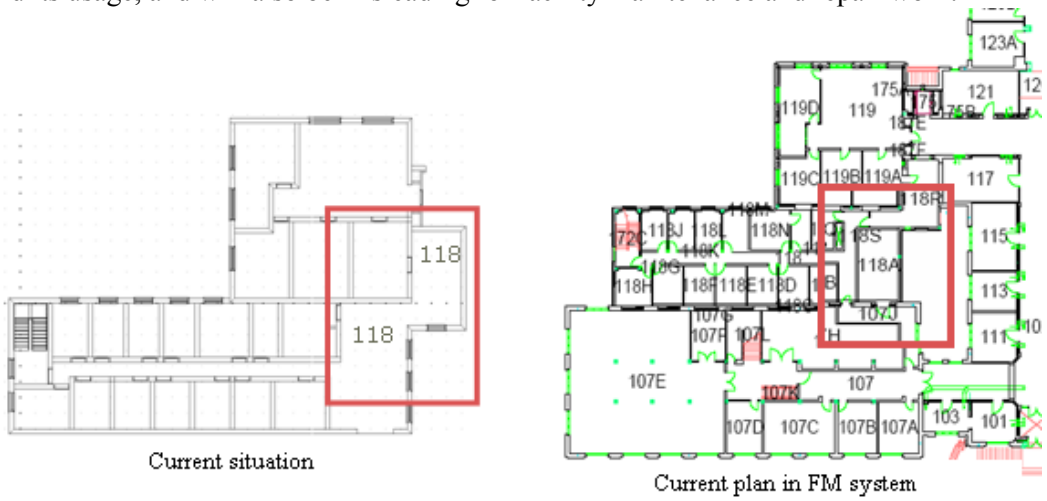


Figure 2: Example floor plans after lounge renovation.

2.2 Need for customized maintenance and repair work information capture

In order to investigate the current information management practice of maintenance and repair work in depth, the authors performed a case study by collecting work orders (WOs) from commercially available computerized maintenance management system (CMMS) databases that are used by facility management services departments of an educational facility and a medical facility. Two illustrative examples of work orders are presented in Figures 3 and 4, which are screenshots of the WOs in the CMMS system, in order to describe the identified problems. Example work order 1 in Figure 3 is a reactive maintenance task for repairing a leaking pipe and work order 2 in Figure 4 is a corrective maintenance task for replacing a light fixture in a room.

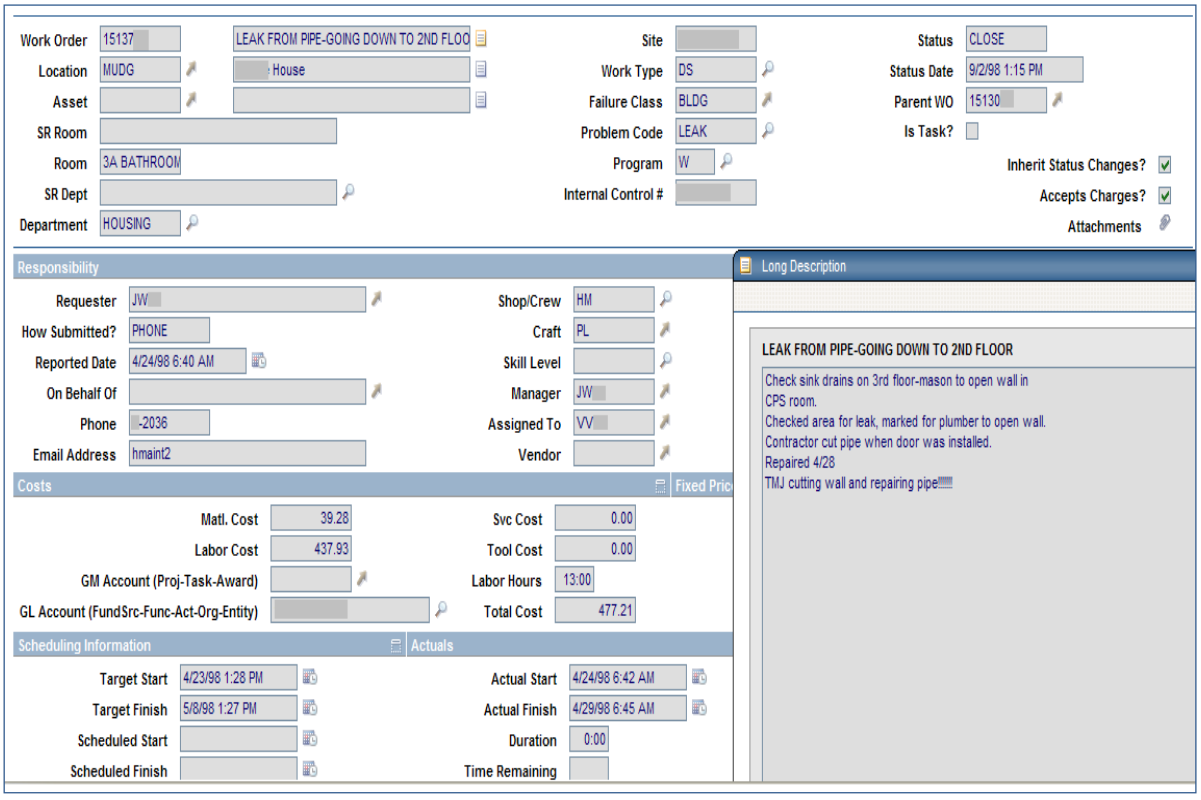


Figure 3: Example of a work order filled out in relation to a reactive maintenance task: Leak in the pipe and repairing of pipe and cutting and repairing of wall (Work order 1).

As shown in the figures, the information in relation to both maintenance work and associated changes is captured using the same WO template. However, this practice causes several problems with respect to change information capture as will be explained in the following paragraphs.

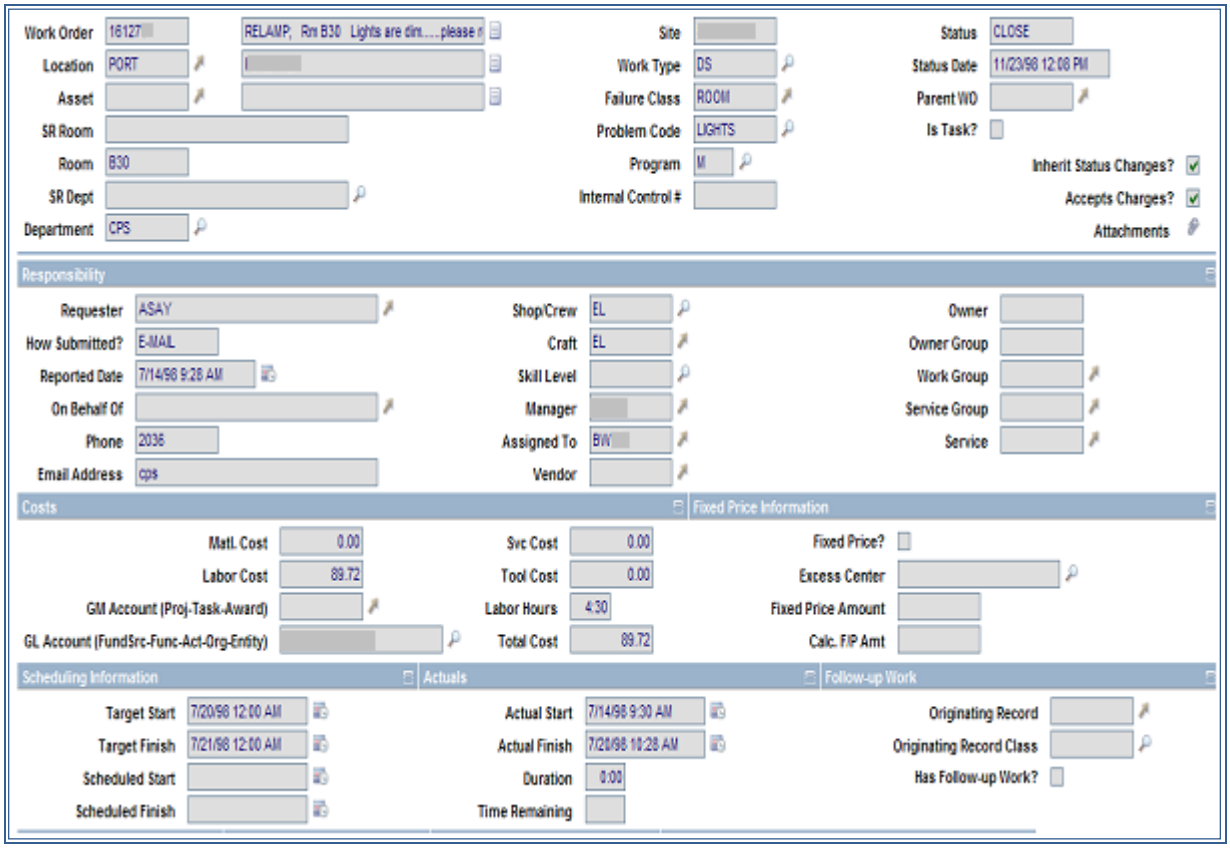


Figure 4: Example of a work order filled out in relation to a corrective maintenance task: Relamp of a room (Work order 2).

Work order 1 includes a change to a part of a piping system; therefore the new pipe has connections to the rest of the system. So, the whole system topology should be updated with this change. Moreover, the leak has impacts on other components of the building (i.e., carpet, dry wall) and during the repair of the pipe a part of the wall needs to be cut and altered as well. Therefore, this repair has several changes and impacts that needed to be captured with the collection of more data in the field. On the other hand, work order 2 is a replacement of a light fixture in a room. This repair is performed on only one component (i.e., a specific light fixture) and therefore collecting data about the replaced light component will be enough to keep the facility data up-to-date.

Table 1 summarizes the information that should be collected in relation to work orders 1 and 2. A closer investigation of these two different examples of maintenance work shows the need for customized templates for capturing change information in the field. The reactive maintenance of a plumbing system element that impacts several different components of the facility (such as connecting pipes, dry wall, carpet, the room, and the room below), requires a different number and types of information to be collected as compared to a corrective maintenance of a light fixture element. The resulting changes are different, hence require different parts of facility data to be updated, and this will entail capturing of different information in relation to each change. However, a generic work order template provides limited guidance on what information items to capture. As a result, the same amount and type of data is being recorded in the formal data capture fields for these two tasks, which are very different in nature. Some extra information related to work order 1 is captured as an additional text in

the 'Long Description' field of the work order. These all result in missing information and hence might not fully support updating related facility documents or databases.

Table 1: Summary of information that should be captured in relation to work order examples

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	WO 1 (pipe leak)	**WO 2 (relamp)**
Maintenance type	Reactive	Corrective
Problem at	Water main pipe (ID, type)	Light fixture (ID, type)
Location	Building (ID) Room (ID) Specific location at room	Building (ID) Room (ID) Specific location at room
Impacts on	Connecting pipes (ID, location), Dry wall (ID, type), Carpet (ID, type), Room (ID), Room below (ID), etc.	Light (ID, type), Room (ID
Resulting changes to	Pipe (ID), Wall (ID, type)	Light (ID, type)
Change information	Information about all impacted and changed components (e.g., type, cost, exact location/dimension)	Only info about the replaced light fixture (ID, type, cost)
Need for follow-up	New WO for impacted elements (wall, carpet)	-
Change propagation	Pipe system, and impacted elements	-
Update to component itself	Required (modified)	Required (status change)
Update to impacted components	Required	-
Update to drawings/model	Required	-

As illustrated by the examples described above, different types of facility changes occur as result of different types of M&R work in the field. The differences shown in Table 1 between the resulting changes and corresponding information capture requirements for updating facility data demonstrate the need for customized templates for capturing and storing change information in a formal way. The data fields tailored for maintenance activities are also needed to provide the necessary information for generating a change history and updating facility information databases or models. The change history and up-to-date facility information model will be needed for supporting not only day to day maintenance activities but also maintenance planning and execution.

3. OVERVIEW OF THE APPROACH

There is a need to develop formal methods to capture changes in the field, since current methods of capturing change and work history information are formalized to a limited extent and do not include all the information related to a change at the right level of detail and accuracy. Moreover, since there are different types of changes as a result of different M&R work, change information collection templates need to be customized for each type of change.

The authors' examination of different facility changes and associated information capture requirements showed this need for development of customized change information capture templates. We also performed a case study to analyze the WO history linked with a BIM, to observe how a building has been deteriorating and to identify information update needs. During this study, we observed the need for a spatial database to support pattern analysis by identifying clusters that may not be found by using traditional databases (Akcamete et al. 2010). Spatiotemporal analysis showed trends of repairs over time to specific components or spaces, which could be correlated to building context within BIM, hence enabled to assess relationships between different M&R activities, as well as effect of the usage of a space (e.g., labs) on the need for different M&R work (Akcamete et al. 2010). Therefore, our approach leverages a BIM to reason about a change history as well as to identify the changes to the contextual information that may need to be captured during the M&R work. The authors aim to streamline the capturing of maintenance and repair information by providing templates that list the information items required to be recorded in the field for each M&R work, based on the request and the context. This approach enables formally capturing change information in the field, which will provide the necessary information for generating the change history and updating the facility information. Figure 5 presents the vision for our approach to generate customized templates.

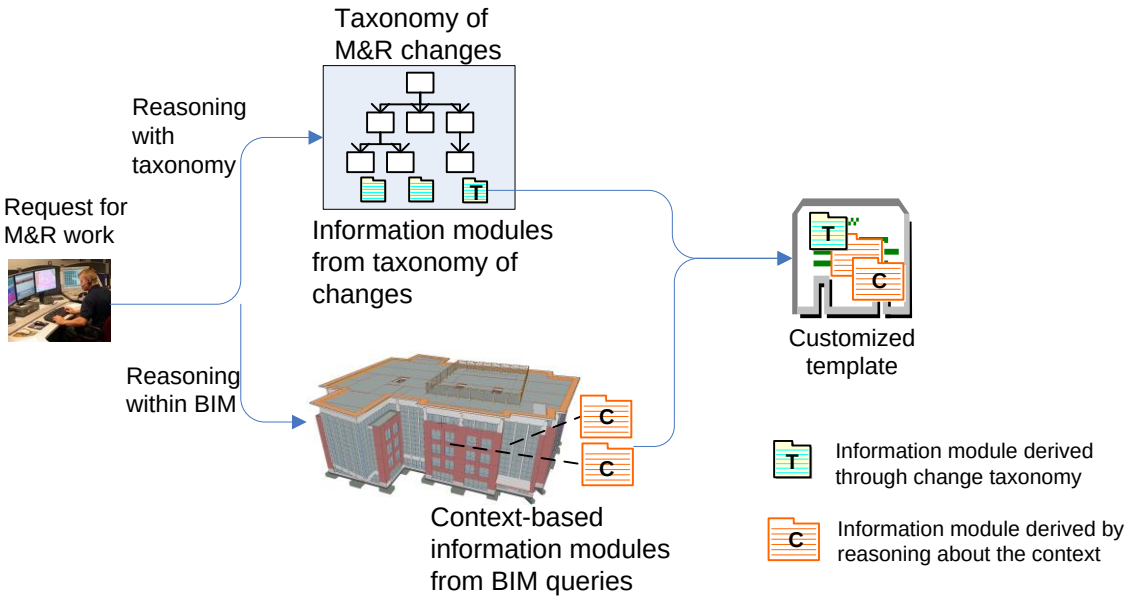

Figure 5: Vision of generating customized templates for M&R work information

The system depicted in Figure 5 generates customized change information capture templates based on the M&R work requests. In this approach, based on a new request for M&R work, a taxonomy of M&R changes is searched for retrieving the associated information module that is listing the information required to be captured in the field. It also queries the BIM for selecting contextual information modules based on the results of the queries. Then, the system combines all the applicable information modules and generates the customized change information capture template for the specific M&R work request. The formalized change capture templates are used to capture information about physical changes made in the field in order to provide computer interpretable information for storing change history and analyzing the history linked with a BIM.

In order to realize this vision and streamline change management and updating with our approach, first it is necessary to understand what types of facility changes occur during operations and what the facility information and model update requirements of those changes would be. With the aim of identifying different types of changes and categorizing them, we performed case studies to examine current M&R work records in an educational facility and a medical facility. As information at different

levels of detail is required for capturing different changes to a facility, we developed a taxonomy of M&R work based on the results of our investigation. This taxonomy classifies various types of work on different types of facility components and lists associated information modules that represent data required to be collected in the field. These information modules are associated with different categories in the change taxonomy, they are created according to the information capture needs of each type of change, and they can be retrieved by M&R work request. The context-based field information modules are composed of information items that capture the needs related to the context of the specific M&R work. These information modules are created based on the conditions of the component on which the M&R work will be performed and information in relation to this specific component is extracted by querying the BIM of the facility. The information modules are generated considering not only the need to capture change information, but also the need to represent and analyze the history in a BIM, hence includes model specific information such as the ID of the components. As a result, the customized templates can be generated based on the type of the M&R work and the component that will be worked on.

4. CONCLUSIONS

In this paper the authors discuss that a formalized approach to streamline capturing facility change information during operations phase is necessary, in order to have a change history for supporting updating decisions as well as analyzing how the facility has been deteriorating. The focus of this paper is to describe the need for customization of M&R work information capture for different types of work and change, that we identified based on our observations and case study results. Current practice of utilizing generic templates is limited in supporting this need and hence results in missing information about the maintenance and repairs and the resulting changes. Therefore, our approach aims to address this problem by classifying different M&R work and changes into a taxonomy and identifying associated information items that needs to be collected in relation to each category. We also leverage a BIM in order to identify contextual information that might need to be collected in the field based on the specific component and its context. We have implemented a proof of concept prototype to enable generation of customized templates and currently we are testing the patterns of M&R work that the approach can support.

After implementing the described approach, the change information captured in these templates needs to be integrated into a facility information repository to enable querying and visualization of change history. The authors believe that reasoning about change history could help in identifying when the facility information needs to be updated. As a result, the facility management personnel can be notified when an update is necessary to generate a new version of the model.

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