MAINTENANCE MANAGEMENT PROCESS MODEL FOR SCHOOL BUILDINGS: AN APPLICATION OF IDEF\textsubscript{0} MODELLING METHODOLOGY

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ABSTRACT: The lack of a clear understanding of the maintenance management process is one of the major sources of difficulties in the maintenance of school buildings. A clearer understanding of the maintenance management process can be achieved by constructing a process model of the existing practices using a suitable process modelling technique. The purpose of this study was to develop a process model for the management of maintenance of school buildings using the IDEF\textsubscript{0} structured modelling technique. The modelling process is divided into three phases, (i) the information gathering phase, (ii) the model development phase and (iii) the experts’ evaluation and validation phase. In the first phase, information on existing maintenance practices was obtained through questionnaires and document analysis of policies, standing orders and maintenance reports. In the second phase, a process model was drafted through an iterative process using the IDEF\textsubscript{0} process modelling technique. In the third phase, the draft process model was submitted to three experts on maintenance management from the Ministry of Education Malaysia for evaluation and validation. A ready to implement process model for the maintenance management of school buildings was constructed upon validation by the experts.

Keywords: Process model, Maintenance management of school buildings, structured modelling technique definition, Project Management

1. INTRODUCTION
Maintaining school buildings in good condition through preventive measures make sense for academic, health as well as economic reasons (Lair, 2003; Sufean Hussin, 2003, Wei Wu, 2003 dan Muhammad Hamid, 1997). However, there appears to be a lack of preventive maintenance culture in general (Nazaruddin et-al, 1989, USM and UTM, 1991, New Straits Times, September and December 2005).

One of the root causes of the problem is the lack of an understanding of the maintenance management process among school administrators as such it hinder the schools from designing a good maintenance programme for their schools (Hamisah Hafni, 2003). Process mapping has been identified as one of the techniques that can facilitate one’s understandings of a process through a rigorous analysis of and an appropriate representation of the existing process using suitable mapping or modelling tool. Examples of process mapping tools include flow charts, Petri nets, Unified Modelling Language, the Integration Definition for Function Modelling (IDEF\textsubscript{0}). This article will discuss the development of a process model for the management of school buildings using the IDEF\textsubscript{0} modelling system.

2. IDEF\textsubscript{0} MODELLING system
The IDEF\textsubscript{0} modelling system is a structured design and analysis technique based on graphics syntaxes and semantics (Wilson et al., 1998). This system enables a designer to produce a process model that is descriptive as well as comprehensive. Developed in the 1970s, it was initially used by the United States air force for integrated computer aided manufacturing. In the early 1980s the U.S National Institute of Standards Technology (NIST) published the system in the Federal Information Processing Standard as a manual under the topic of Integration Definition for Function Modelling (IDEF\textsubscript{0}) (FIPS PUB 183 (1984)). Through continuous improvements of the manual, the Institute of Electrical and Electronics Engineers (IEEE) established the IDEF\textsubscript{0} standards (IEEE Std 1320.1-1998). Since then IDEF\textsubscript{0} has been often used not only for process modelling but also for evaluation of current process models.

3. The IDEF\textsubscript{0} technique
IDEF\textsubscript{0} uses two basic elements as its modelling language, i.e., boxes that represent activity and arrows that represent the interfaces. These interfaces are input, output, control and mechanism. The input element can be anything that will be processed by the activity to produce the output. The output element is whatever that is produced by the activity and the control can be condition, situation or information that control the activity, i.e., the answer to how or why. Lastly the mechanism is the human resource (group or individual) or tool that is required by the activity to change an input to an output. Figure 1 is a basic IDEF\textsubscript{0} model, including syntax descriptions.

The basis of the IDEF\textsubscript{0} modeling system is the classification of information using four questions, i.e., (i) What are the activities?, (ii) what is input that needs to be transformed into outputs? (iii) What are the elements that influence / control / regulate / constraint those activities? and (iv) Who/what will implement those activities? These questions are called the ICOM questions for Input, Control, Mechanism and Output. The information mapped is then presented in the form of graphics and texts and arranged in a hierarchical form.
**Controls**
What are the elements that control maintenance activities?

**Mechanisms**
What are the elements that run the system?

**Inputs**
What are the elements to be transformed to output?

**Outputs**
What is produced after maintenance activities are carried out?

*Figure 1 Basic IDEF₀ model with ICOM elements (A-0 level)*

4. **IDEF₀ Procedures**
Three main stages of process modeling in the IDEF₀ system, (i) constructing a context model, (A-0 model) (ii) identifying the main activity from the A-0 activity (first decomposition to obtain A0 model), (iii) identifying sub-activity of the main activities in the A0 model (second decomposition). The IDEF₀ system limits the number of decomposed activity to a minimum of three and a maximum of six. Each decomposed activity is labeled with a number according to the label of the parent activity. An IDEF₀ diagram does not contain information on timing. Figure 2 illustrates how a parent activity is decomposed into its sub-activity.

*Figure 2 Decomposition of a parent activity to its sub-activities*

The IDEF₀ technique which uses simple modeling language of graphics and texts makes it easily interpreted by users. The emphasis on the hierarchical decomposition increases the effectiveness of communication between all involved in the process modeling, i.e., the analyst, the designer and the user.

5. **DEVELOPMENT OF BUILDING MAINTENANCE MANAGEMENT PROCESS MODEL**
The School Building Maintenance Management Process Model (SBMM Process Model) was developed in three main stages.
• Stage I - gathering of information
• Stage II - developing a draft process model
• Stage III – verifying the process model

Stage I: gathering of information
Stage I involves gathering of information on existing practices from three levels of sources, country (central), states and districts. Three information gathering techniques used were document analysis, questionnaires and interviews. Documents analyzed include government circulars and maintenance reports. Fifty eight school heads and five education administrators were included in the questionnaire and interview samples respectively.

Stage II – Developing the draft model
The draft model was developed through and interactive mapping operations of existing maintenance process. Information is mapped based on the answers to the four ICOM questions. Through the interactive process, the context model (A-0) was first produced, followed by the main function model (A0 model) and followed by the sub-function models A1, A2 and so on.

Context model
The context model was constructed based on the answers to the four ICOM questions. Based on the first ICOM question two input elements were identified,
(i) Type of building
(ii) Equipment/materials

Based on the second ICOM question, eight control elements were identified,
(i) Building plans,
(ii) Inventory records/log book,
(iii) Equipment specifications/standards,
(iv) Vendors,
(v) Types and costs of materials,
(vi) Technical knowledge and skills,
(vii) Budget allocations
(viii) Associated forms

The identified control elements are the necessary recipe that will ensure the maintenance management process run smoothly. A single missing element can introduce a flaw in the process which can contribute towards an increased in deferred maintenance.

Based on the third ICOM question, a single expected output is identified which is “an effective maintenance management process”. Finally, based on the fourth ICOM question, three personnel at the school level have been identified as the necessary mechanism for ensuring the implementation and monitoring of the system, namely school heads, senior assistants and building maintenance management committee. Figure 3 illustrates the context model showing the relationship between input, control, mechanism and output.
Main function model
The second level in the hierarchy of the SBMM Process Model (level A0) is the main function model. The main function model is the results of the decomposition of the context model. Similar to the previous process, the identification of the main functions and its descriptions were achieved by asking the four ICOM questions. The main functions were identified from existing practices and the A0 model was developed by integrating information on existing practices (based on the results of document analyses, responses to questionnaires and interviews) and best practices. The six activities identified for the main function model are:

(i) Identify building status (A1)
(ii) Assess and evaluate defects (A2)
(iii) Estimate maintenance costs (A3)
(iv) Plan maintenance activities (A4)
(v) Implement maintenance activities (A5)
(vi) Evaluate and report maintenance (A6)

The representation of the relationships and descriptions of the six activities is called model A0 and is illustrated in Figure 4.

Figure 4 shows the relationships between all elements in the process which helps to clarify the roles and responsibilities of personnel, identify resource needs, highlights the sequence of activities etc, in the maintenance management process.

Decomposition of main function
Decomposition of the main function was the next step in the model development process. Each of the main function is then decomposed into their sub-activities and the ICOM elements are identified by asking the four ICOM questions. The summary of sub activities identified is given in Table 1.

Table 1 Main activities and the number of corresponding sub-activities

<table>
<thead>
<tr>
<th>Main activity</th>
<th>No of sub-activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1-Determine building status</td>
<td>4</td>
</tr>
<tr>
<td>Main activity</td>
<td>No of sub-activities</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>A2-Evaluate and estimate defects</td>
<td>4</td>
</tr>
<tr>
<td>A3-Estimate maintenance</td>
<td>3</td>
</tr>
<tr>
<td>A4-Plan maintenance activities</td>
<td>4</td>
</tr>
<tr>
<td>A5-Implement maintenance</td>
<td>5</td>
</tr>
<tr>
<td>A6-Evaluate and report maintenance</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
</tr>
</tbody>
</table>

At this stage in the work process, the model is known as the working model. When all the activities have been decomposed, the combined model represents the process of maintenance and management of school buildings. The node tree (in Malay) for the overall process is shown in Figure 5. In its complete form the model integrates information on policies, circulars, responsibilities of personnel in the management of school buildings. The completed model, ready for experts evaluation is known as the draft model.

**Stage III: Experts verifications**

The draft model was evaluated by three technical experts who were serving the Ministry of Education as assistant director (architect), project architect and project engineer. These experts have had more than 10 years experience in the field. The evaluation and verification process is an iterative one (Presley et-al, 1993) starting with submission of the draft model to the experts. The experts looked at all information presented in the model and marked with a tick (√) to show their agreements and with a cross (X) in red ink to show their disagreements with any presented information. The experts also give suggestions for improvements. The returned model is called recommended model is then refined by the author accordingly and the experts’ opinion was sought for confirmation where necessary. Three types of feedback were obtained from the experts; questions on syntaxes, questions on textual information and recommendations.

The experts agreed that the activities, their sequence and descriptions were accurately represented. The experts also gave some suggestions on additional control elements which were incorporated into the model. The model was not submitted again as the changes were minor and verifications were obtained through phone discussion. The model is now recognized as a publication model; ready to be used school heads as guidance for the maintenance management of school buildings.

6. **CONCLUSION**

This article describes the development of a process model for maintenance of school buildings using the IDEF0 methodology. The development of the model involves a three stage process namely data gathering, development of a draft model and verification of the draft model. The systematic process has resulted in a process model for maintenance management. The resulted model is an integrated and comprehensive model that is able to clarify the process of building maintenance. The strength of the model lies in the fact that it can provide a detailed concrete evidence of the relationships between four management parameters namely maintenance activities, maintenance objects, human resource, and materials.

Therefore, the applications of this model are expected to improve understanding of the maintenance process. Even though the model has been developed based on data of school building maintenance, the model is potentially adaptable for maintenance of other types of buildings by modifying the four parameters, input, control, mechanism and output.
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