Integration of BIM and Lean Concepts to Improve Maintenance Efficiency: A Case Study

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ABSTRACT

Operations and Maintenance (O&M) is well known for its interdisciplinary knowledge. Currently, maintenance staff usually refers to original blueprints and as-built drawings, and most of which have been rendered useless by decades of upgrades and retrofits. Whilst, low productivity caused by deficient information transmission between the different departments lead to labour wastage and high cost. Building Information Modelling (BIM) as a powerful approach is used as 3D information models for maintenance process visualization and coordination. However, the O&M departments are facing barriers and challenges in BIM adoption as there is no clear guidance or best practice studies from which they can learn and build up their capacity for BIM use in order to increase productivity, efficiency and quality. Lean concepts as new management thinking has suggested a better maintenance process by improving the reliability of flows and waste estimation. This paper aims to apply BIM and lean concepts into practical maintenance to improve efficiency. Firstly, the paper starts by discussing and analysing the limitations of existing O&M activities in this regard. Then, an overview of the proposed approach for integrating BIM, lean and maintenance is presented. Finally, a case study is chosen to verify the integrated approach. The result shows that the approach can effectively improve maintenance efficiency.

INTRODUCTION

Maintenance is a combination of all technical, administrative, and managerial actions during the life cycle of an item intended to keep it in or restore

it to a state in which it can perform the required function(Komonen 2002). Operations and Maintenance (O&M) management continues to be of central importance in Oil & Gas industry. See from the production process perspective, an equipment failure has the potential for serious financial and environmental consequences. Hence an efficient O&M management process is essential for the smooth, uninterrupted running. In addition, O&M management is well known for its interdisciplinary knowledge. Effective O&M requires recalling and integrating knowledge regarding design, construction, operations, and maintenance of each system. However, the Oil & Gas industry is confront with a wide range of challenges. Currently, maintenance staff usually refers to original blueprints and as-built drawings and most of which have been rendered useless by decades of upgrades and retrofits, and maintenance staff lack of knowledge about the technical condition of the components which installed long time ago or applied Cutting-edge technologies can make the maintenance period longer than planned. Whilst, low productivity caused by deficient information transmission between the different departments lead to labour wastage and miscommunication, unnecessary maintenance leads to decreased regularity and increased maintenance costs.

To enhance O&M management efficiency, the building information modelling (BIM) approach is applied. However, the O&M departments are facing barriers and challenges in BIM adoption as there is no clear guidance or best practice studies from which they can learn and build up their capacity for BIM use in order to increase productivity, efficiency and quality. Lean concepts as new management thinking has suggested a better maintenance process by improving the reliability of flows and waste estimation. This paper aims to apply BIM and lean concepts into practical maintenance to improve efficiency.

LITERATURE REVIEW

O&M management encompasses and requires multidisciplinary activities and extensive information. BIM is becoming widely adopted for providing and supporting O&M management practices with its functionalities of visualization, analysis, control, and so on. Facilities management departments can use BIM for renovations, space planning, and maintenance operations(Azhar, et al. 2008). Interactions between BIM and facility management are defined by illustrating application areas and data requirements for BIM-enabled facility management practices(Becerik-Gerber, et al. 2012). To overcome the problems of facility staffs to refer the traditional 2D CAD-based information illustration in the facility maintenance and repeat the record of the information of same facilities, a BIM-based Facility Management (BIMFM) system for facility managers and staffs was developed(Su, et al. 2011). RFID and building information model are used for the facilities components lifecycle management by permanently attaching RFID tags to facility components where the memory of the tags is populated with accumulated lifecycle information of the components taken from a standard BIM database(Motamedi and Hammad 2009). A Akcamete et al. from the point of facility management software systems, discussed opportunities for utilizing BIMs for facilities management, with a specific emphasis on supporting maintenance planning(Akcamete, et al. 2010). The most impressive achievements to date in this area deal mainly with issues on technologies application in facility management like RFID, bar-code and BIM-FM software development. Although

there is agreement about BIM's potential applicability and benefits in the FM stage, it is still unclear how BIM could be used and what the requirements are for successful BIM implementations in FM(Becerik-Gerber, et al. 2012).

Lean concept is a term created to reflect the waste reduction nature of the Toyota production system. It is a term to describe an effective, high-performance method for managing organisations and delivering their core purpose in the most efficient and effective manner while continuing to develop for a sustainable future. A framework for reference has been developed that provides a summary of lean activities possible within a company and maintenance in particular, documented the use of performance measurements and their strategic importance to organisations(Davies and Greenough 2010). Mary et al. assess the merits of lean thinking in highways maintenance(Wolbers, et al. 2005). Farman et al. compared and evaluated the maintenance operations in lean versus non-lean production systems to determine the major factors and parameters of maintenance operations that are most effective in enhancing production to a lean system(Moayed and Shell 2009).

Recent years, there are many researches paid close attention to cooperation between BIM and lean concepts. The utilization of BIM models for process visualization, coordination and future directions is available to all, and brings high benefits for better implementation of lean principles(Galsworth 1997). Sacks et al. propose a framework of BIM functionalities and-associated Lean principles to both guide and stimulate research of such systems beyond construction(Sacks, et al. 2009). And a rigorous analysis of BIM functionalities with prescriptive lean construction principles, identified 4 interactions of which represent constructive interaction (Sacks, et al. 2010).

However, little has been published on lean concepts and BIM in O&M management. The present study builds upon this framework and proposes an approach for the utilization of BIM to enable Lean based O&M management works on Oil & Gas industry.

RESEARCH METHODOLOGY

The goal of the utilization of BIM to enable Lean based O&M management research as a whole is to propose a BIM enabled lean maintenance process. This paper starts at discussing and analysing the limitations of existing O&M activities in this regard. Then, an overview of the proposed approach for integrating BIM, lean and maintenance is presented. Finally, a case study is chosen to verify the integrated approach. The intensive case study was conducted and focused on productivity improvement activities at the Oil & Gas company. This research, focus scenarios simulation and role-playing which guided by a seasoned managers and brainstorms were used to sort out the Oil & Gas industry maintenance process and collect the primary problems that relate to the process. The case study was focused on the process of corrective maintenance. In addition, the discussion was conducted not only reside on the past implementation, but also focus on the future plans and developments via regular seminars.

CASE STUDY

The highly critical nature of the oil and gas activities leads to the high demandingness for smooth, uninterrupted and safe running of Oil & Gas facilities.

Industrial maintenance has two essential objectives which are a high availability of production equipment and low maintenance costs (Komonen 2002). This case study observed was the first stage of a pilot project.

General Description of the Maintenance Process Protocol. As mentioned above, this study starting point was discussing and analysing the limitations of existing O&M activities by scenarios simulation, role-playing and brainstorms. In Oil & Gas company, there are two departments undertake the corrective maintenance work. As shown in Figure 1, operation department is responsible for the facilities operation management, quality assurance (QA) and quality control (QC). Maintenance department is in charge of corrective maintenance and mainly two types of personnel, procurement and maintenance. The workers can be divided to two levels: managers and operators. The maintenance workflow between the two departments in Oil and Gas company can be roughly described into eight phases as following figure 2.

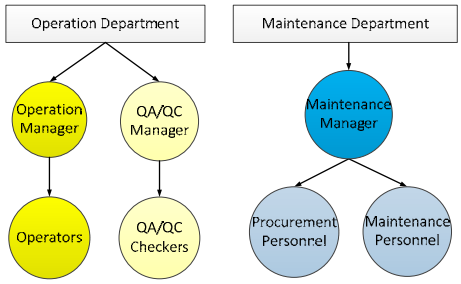

Figure 1. Departmental structure

QA: quality assurance. The first step is the QA/QC checkers collect the facilities problems.

List: a long list of problems was defined and gathered in QA/QC managers; because of the great number of problems to consider, the problems were classified in accordance with the priority (from high to low by the urgency). Then these problems are sort out as work packages (WP) and deliver to the right department/personnel.

WP: generally, these maintenance problems can be divided to 2 levels: repair and facility replacement. This paper decided to focus the maintenance efforts on the facility replacement. In this case, more departments and personnel are involved in and the workflow is more complex. Maintenance managers got the WP and concentrated their attention to the decision-making: who does it, what need to prepare, where is the failure facility, what are the safety issues in facilities installation, what are the potential influence to the facilities overall operation etc.

Procurement: procurement personnel get the facilities information that a change is needed. The efforts in procurement phase include screening and negotiation with contractors.

Delivery: facility contractors deliver the facilities from the place of production or the place where they are sold to the destination.

Permission: facilities replacement needs to get the permission from operation managers because the installation might lead to potential hazard to the uninterrupted flow in operations.

Installation: in this phase, maintenance personnel review the preparation situation as discussed in WP. If any planned activities for the installation have not

been completed, the maintenance personnel identify the reasons and solve them one by one.

Handover: after the whole process, maintenance managers handover the replaced facilities to operator managers.

TFV views of maintenance. Traditional production process is simply explained as conversion model, which means the production is a conversion of input and output, and production process can be divided into sub processes. What the owner concern is the cost of each operation and the cost of direct labour for that operation(Koskela 1992). Koskela proposed the transformation-flow-value (TFV) theory of the nature of the production in construction(Koskela 2000). Oil & Gas industry mainly composed by a large number of pipelines and the production is highly relying on them. The uninterrupted production process is the key factor for performance and success of Oil & Gas plants. For this feature, TFV theory can be applied in this industry.

Transformation view emphasis on the single process control, there are a series of problems can be pointed out in Oil & Gas plants, such as (a) time consuming or insufficient facilities procurement; (b) large incidence of non-value adding activities in the maintenance process, resulting in long duration and not enough time for generating maintenance solutions;(c) not all maintenance requirements are identified and solved in the transformation among different departments.

Flow view means the maintenance process is regarded as a flow of information, identify the value adding activities and non-value adding activities, in which non-value adding activities like waiting, moving and inspection of information are regarded as waste and should be eliminated.

Value generation in maintenance process is to achieve the best possible value from the client point of view. It is clear that a smooth, uninterrupted running is the requirement for achieving effective value generation in the maintenance process.

TFV theory is the basis of lean thinking, before we recommend the lean concepts to Oil & Gas industry, we need to understand the TFV in this area.

BIM application. The main focuses of the application of the BIM in this process were the following:

- To create the visualisation related to facilities data (e.g. location, maintenance status, product information etc.) and process.
- To guarantee the complete control of information management (information integration and sharing in different departments and workers).
- To allow actions of automatically collect, retrieve and refresh the maintenance information.

To achieve these objectives, a BIM manager was appointed, which played an important role in the maintenance process. The BIM enabled workflow start from system breakdown warnings and part damage warning, these problems will be highlighted in BIM model. The generated checklists exported from BIM model have been sent to QA/QC managers. The BIM model enabled the QA/QC checkers to visualize and anticipate the exact place they would work on, and the exact conditions they would meet. This revised checklists after QA/QC checkers had detailed issues onsite feedback to QA/QC managers again, BIM managers updated issues in BIM model based on the revised checklists.

Maintenance managers, as said before, got the WP and concentrated their attention to the decision-making. Operation managers reviewed and revised recommended maintenance WP from maintenance managers and issued the permission. In this maintenance workflow, including the following procurement, delivery, permission, installation and handover, all the participants shared work related information such as how is the work going on and gave feedback for updating the BIM model, which allowed the other workers to real-time tracking and adjust the work plan in time.

The procurement phase is more complex as the involvement of third party. Procurement personnel had to decide the procurement list and chose the contractors. The period between the procurement and delivery, it was hard to track the freight information which might lead to the delay. These uncertain factors such as information asymmetry: the wrong size, wrong model, had no idea about the matching and installation and bought the wrong items would increase the process variability.

Implementation of lean thinking and BIM in the process of maintenance. The implementation of lean thinking and BIM in the process of maintenance created a virtual environment, allowing for a comprehensive analysis of the entire facility. It allowed for a much more detail management of the work. The exact conditions they would meet because the maintenance reference materials transfer from 2D CAD-based information illustration to 3D or 4D virtual models.

Focus on complete process: As discussed before, BIM enabled complete control of information management mainly about the information integration and sharing in different departments and workers, this type of feature combined with lean thinking achieved the different departments and workers knew exactly which tasks to perform and their progress, which encouraged the adoption of a pull planning system.

Increased process transparency: Since BIM provided an accurate model of the facilities, all the information introduced in the model was real-time tracking and in time adjusting. This allowed for the workers from different positions communication and coordination in the whole process.

Reduced of non-value adding activities: Waste and complexity contribute to time-consuming and costly than needed. We can judge from figure 2 that the traditional maintenance process had so many repeat and waste. Figure 3 shows the concept of eliminating waste and simplifying the maintenance process. Waste is eliminated by defining the maintenance problems in the start of the process accurately and removing unnecessary or non-value-added steps. BIM mainly used for the visualisation in the early stages and lean concepts for the maintenance process reengineering.

CONCLUSION

Motivated by the power of BIM and lean concepts, this paper presented a BIM enabled lean maintenance process for Oil & Gas industry. BIM mainly used for the inspection, assessment, repair and 3D visualization. And lean concepts focus on reduce the variability, reduce non-value adding work and increase the process transparency. For its verification, the theory was implemented on a pilot project. TFV theory is the basis of lean thinking, the results of the case study demonstrated that the integration of BIM and lean concepts had strong application

prospects in Oil & Gas maintenance, and the maintenance process was primarily satisfied with the efficiency improvement.

This is the first stage of the research project, in this phase, the research discussed the applicable technologies and management theories. Future studies are required to fully demonstrate this maintenance process and validated the data that collect from advanced technologies. Augmented reality (AR) is a field of research that combines the real world and computer generated data, integrates BIM with AR so as to enable the physical context of each construction activity or task to be visualized in real-time(Wang Xiangyu, et al. 2013). Use AR for the workers collaboration(Wang and Dunston 2006), human-machine interface in virtual environment-based equipment operation training(Rezazadeh, et al. 2009), assembly task based on the AR system(Hou and Wang 2011), and improve the facility management efficiency from the design stage(Wang Ying, et al. 2013) to collect data about the efficiency improvement. The completion of further studies for the development of a more comprehensive BIM LEAN platform will enable the maintenance process in Oil & Gas industry to adopt this emerging technologies and management thinking for actual field practice. A data comparison study between the current maintenance process and the one using the BIM and lean concepts is also required to analyse the time and cost efficiency.

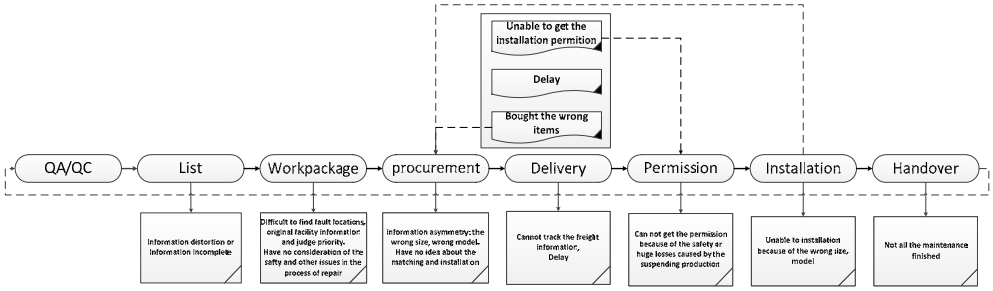

Figure 2. Original maintenance road

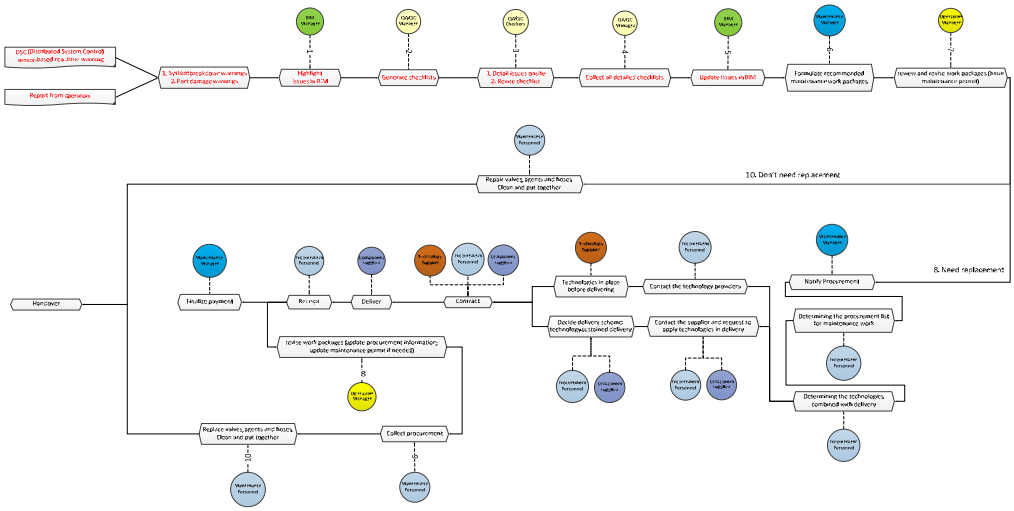

Figure 3. Optimized maintenance road within integration of BIM and Lean Concept

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