Automation in Construction 18 (2009) 536–546

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Shadowing tradespeople: Inefficiency in maintenance fieldwork

Sanghoon Lee *, Ömer Akin

5000 Forbes Ave., School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15213, USA

ARTICLE INFO

Article history:
Accepted 18 November 2008

Keywords:
Facilities maintenance
Maintenance activity
Efficiency evaluation
Informational support

ABSTRACT

This research investigates current practices in Operations and Maintenance (O&M), from the initial phase of assigning maintenance requests through the completion of the requests, in order to identify types of inefficiency and their causes. Fifty-eight real maintenance cases have been shadowed; and maintenance activities performed by the tradespeople have been recorded with time data corresponding to each activity. O&M inefficiencies categorized into two groups, Structural and Individual, are demonstrated through specific cases. A statistical analysis is used to show how O&M tasks, activities, and categories impact overall O&M performance. The results show that tradespeople vastly underutilize maintenance data in the field due to problems with data accessibility and reliability. Based on the shadowing activity results, we observed 12+% potential for improvement in maintenance time efficiency by providing proper information support.

1. Introduction

There is significant potential for improvement in the performance of building equipment and facilities maintenance fieldwork. Operations and Maintenance (O&M) occurs throughout the lifecycle of a building. Not surprisingly, the majority of expenses are incurred during O&M. Many strategies have been developed to enhance the O&M environment. However, it is well-known that the maintenance industry adopts new technologies more slowly than other industries. Although the industry's tools and maintenance support systems have been enhanced considerably, for decades, its overall style of maintenance fieldwork has remained essentially unchanged. Furthermore, tradespeople vastly underutilize maintenance data in the field due to problems with data accessibility and reliability. This research investigates current practices from the initial phase of assigning maintenance requests through the completion of the requests in order to identify inefficiency in maintenance fieldwork and to develop strategies to improve the O&M environment with information support.

1.1. What is O&M?

The Federal Energy Management Program (FEMP) [1] defines O&M as "the activities related to the performance of routine, preventive, predictive, scheduled, and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety." Mann [2] defines facility maintenance as "the activities required to keep a facility in as-built condition, continuing to have its original productive capacity." Chanter and Swallow [3] see it as "work which enables the building to continue to efficiently perform the functions for which it was designed," and Cotts and Lee [4] define it as "the work necessary to maintain the original anticipated useful life of a fixed asset; the upkeep of property and equipment."

Therefore, O&M encompasses the activities that Facilities Management Services (FMS) personnel perform to ensure that facilities continue to fulfill their intended functions. More specifically, the term "Operations" include activities performed to provide comfortable working and living environments, whereas "Maintenance" provides equipment upkeep to prevent functional failure. The definitions above, however, do not take into account one critical factor: the limited resources in terms of materials and human labor that FMS personnel use during O&M.

1.2. Importance of O&M

The O&M phase is the longest period in the lifecycle of a building. Consequently, the majority of expenses are accrued during the O&M phase [5]. According to Teicholz [6], more than 85% of total costs spent over the life cycle of a building are on O&M. Furthermore, good O&M improves the efficiency, reliability, and safety of a building.

For example, Pacific Northwest National Laboratory (PNNL) has developed an O&M decision support system called "Decision Support for Operations and Maintenance (DSOM)," which is "an expert O&M system that integrates plant operations, fuel management, and maintenance process [7]." With DSOM in one application, they were able to eliminate a potentially dangerous water hammer condition as well as increase output efficiency by about 13% [8]. In addition, Portland Energy Conservation, Inc. (PECI) [9] has stated in their report to the U.S. Department of Energy for FEMP that good operation strategy can save 5–20% on energy costs without a significant investment.

* Corresponding author. Tel.: +1 412 268 2008; fax: +1 412 268 7507.
E-mail address: shl1@andrew.cmu.edu (S. Lee).

0926-5805/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.autcon.2008.11.002

1.3. Types of O&M

O&M activities are categorized in different ways. Thomas [10] sees three areas:

- "Demand work: where the client calls in for service, where breakdowns in equipment require repairs and emergency events that affect the facilities department."
- "Preventive maintenance work: where a scheduled program of work maintains the investment in the physical assets for a corporation. These assets may be equipment assets or facility assets."
- "Project work: where changes to the business focus require a reorientation of space and people or the changes in regulations require upgrades to maintain compliance, such as ADA, EPA, or OSHA." ADA, EPA, and OSHA stand for Americans with Disabilities Act, Environmental Protection Agency, and Occupational Safety and Health Administration.

Anadol and Akin [11] have conducted a case study on facilities design and management. In this study, the authors summarize the organization's five types of maintenance as follows:

- "Daily service (DS) is limited service work, scheduled by need priority and availability of trade groups."
- "Unplanned maintenance (UP) is any emergency addressed within 24 hours to insure life safety, to protect university assets or to meet critical user needs."
- "Planned maintenance (PM) is preventive maintenance carried out on a planned schedule to prolong equipment and building life cycle." The organization does not use this term for work order classification in the work order management system. Preventive maintenance (PM) is used, instead.
- "Projects (PR) include installation or modification work which enhances the asset value of a building and its systems."
- "Parts/Contracts (PC) is work pending due to material availability (longer than 1 week) and specialized contracted to supplement service capability." PC is not a term used for the work order management system in the FMS department. They use "In Progress" status for any work orders not completed.

In addition to the maintenance types, there are also repair jobs not yet classified because problems were reported directly through security or coworkers, rather than through the FMS dispatcher who assigns a type of maintenance through the work order system. In this case, work orders are generated on the following day, based on reports made by the tradesperson who carried out the work orders.

Our aim of shadowing FMS tradespeople is to better understand facilities O&M in the field and to collect raw data for these activities and time spent on each activity. Surveys conducted in the 1990s found that useful information in this area was either unsatisfactory or lacking all together [5,12]. Since then, computerized O&M systems have been developed to fill much of the information gap but difficulties in accessing and accuracy of O&M information still remain. This study intends to identify sources of inefficiency in maintenance, which include not only redundant or superfluous activities but also core activities conducted in inefficient ways.

2. Shadowing tradespeople

There have been many studies on the utilization of Facilities Management (FM) systems [13–16] and the roles of FM managers [17,18] to assess current processes and identify opportunities for improvement by performing cost-benefit analyses. However, very little attention has been paid to tradespeople's roles and their performance in the field. Since tradespeople are responsible for responding to and remedying situations, it is essential for them to easily access up-to-date information for effective and efficient operations and maintenance of facilities upkeep.

In this study, we shadowed three electricians and one plumber for four weeks. The operations manager recommended this period of time and the individuals to be shadowed based on the consideration that four weeks would be reasonable period of time to observe a variety of maintenance activities including some cycles of work completion and redundancy with these tradespeople. Each tradesperson has roles and responsibilities. For example, one electrician is responsible for urgent priority and unscheduled daily service, while another electrician takes care of preventive maintenance and projects. They work different shifts to be ready for an emergency at any time of the day. Therefore, in the shadowing experiment we expected to be able to observe how they organize their work orders and develop an accurate record of all that takes place during fieldwork. It was also expected that such a record would reveal how tradespeople complete their tasks, what information they need, and how they get this information.

The observations were recorded on a template developed based on a use-case specification format, which will be described in the next chapter. In addition, a voice recorder was used for time stamping as well as capturing data and tradespeople's behaviors as accurately as possible.

3. Documentation of results

Each record of tasks completed by a tradesperson is parsed into a series of discrete parts called events until each event has only one action. Subjects and objects are actors and components of O&M environments. An actor is a person or a group of persons who carry out the event. They are not restricted to FMS personnel, but include all relevant persons such as building occupants and subcontractors. Then, time data is calculated based on the observation record and the audio clip. The starting time is when the actor starts the action and the ending time is when the actor starts the next action. Time less than a minute is rounded-off. The following is an example to demonstrate our method.

> "An electrician leaves his shop at 10:00AM to replace a light bulb in office A in building X. He arrives at the office at 10:10AM. He replaces the broken light bulb. The completion time is 10:30AM. He returns to the FMS shop at 10:40AM."

In this example, the following are parsed as meaningful words:

- Actions: leaves, arrives, replaces, and returns — main maintenance activities
- Subject(s): electrician — actor of the events
- Objects: FMS shop, office A, building X, light bulb — target objects to each event. If objects are related to information to complete the particular event, the information is listed with a proper code. Information classification with codes is discussed later.
- Time data: 10:00AM, 10:10AM, 10:30AM, and 10:40AM

Table 1 shows the sequence of maintenance events built from the parsed key words.

As the next step, a unique ID is assigned to each activity to reference and identify it at later points in the table and also to use the numbers

Table 1
The sequence of maintenance events built from the example maintenance description.

Actor	Events	Time (min)
The electrician	Transits from the FMS shop to office A in building X	10
The electrician	Replaces a light bulb	20
The electrician	Returns to the FMS shop	10