WORK ORDER PROCESSING TIMES – DOES BIM MAKE A DIFFERENCE…?

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ABSTRACT

Owners are adopting Building Information Modeling (BIM) for facility management (FM) of buildings based on its perceived benefits, rather than actual research data to support its use. Initial studies indicate that having quick and easy access to information related to building systems and equipment can result in saving maintenance work order processing time. This paper investigates the differences in work order processing times when using BIM for FM in Texas A&M Health Science Center (TAMHSC) facilities, by conducting a statistical analysis of actual work order processing times for multiple campuses of TAMHSC, located in the state of Texas, U.S.A.

INTRODUCTION

The US Department of Commerce Technology Administration, the National Institute of Standards and Technology (NIST) (2004) defines interoperability as “the ability to manage and communicate electronic product and project data between collaborating firms’ and within individual companies’ design, construction, maintenance, and business process systems”. Inadequate interoperability is a major cause of inefficiency in the capital facilities industry because of the industry’s fragmented nature and the presence of many small companies that are slow to adopt advanced technologies. Inefficiencies such as manual re-entry of data, doubling of business functions, and continued reliance on paper-based information systems are a direct result of inadequate interoperability. A study conducted by the U.S Department of Commerce Technology Administration, NIST (2004) estimates the financial cost of inadequate interoperability at $15.8 billion per year. The report further estimates that owners and operators incur two-thirds of this cost during operations and maintenance of a facility.

Kasprzak and Dubler (2012) state that in order to improve the operations of any facility, it is most important to integrate different sources of information throughout the project life cycle from the beginning of a project. To maximize interoperability, owners must identify and integrate these information requirements in the contract documents during the early stages of a project life cycle. A collaborative Building Information Modeling (BIM) to facility management (FM) data exchange solution integrated at the beginning of a project would help to reduce life cycle costs with a more efficient facility operations and maintenance (O&M) process, and would help develop efficient operational workflows.

The operations and maintenance phase is the longest phase in the life cycle of any facility. Efficient operations and maintenance is crucial for healthcare buildings due to the presence of complex mechanical, electrical and plumbing (MEP) systems, and the sensitive nature of the buildings’ occupants. Thus, adequate interoperability assumes prime importance for the safe and efficient function of healthcare buildings.

Texas A&M Health Science Center (TAMHSC), an academic unit of the Texas A&M University System. provides comprehensive healthcare solutions through education, research and service in dentistry, medicine, nursing, pharmacy, public health, and medical sciences. TAMHSC operates eight campus locations in the State of Texas. TAMHSC adopted a BIM and Construction-Operations Building Information Exchange (COBie)-based approach for facility management in two of its newly built campus buildings in the cities of Bryan and Round Rock. The other campus buildings in the cities of College Station, Corpus Christi, Houston, Kingsville, Dallas, McAllen and Temple still follow the traditional drawing-based approach for storing and accessing information for facility management. Broaddus and Associates (Broaddus) is a privately held facility program management firm that assisted TAMHSC with formulating and implementing BIM and COBie databases for the management of its newer facilities. Broaddus helped integrate COBie data into the Computerized Maintenance Management System (CMMS) used by Texas A&M University for facility management, with the help of “AiM” software developed and sold by AssetWorks.

Broaddus and AssetWorks conducted a pre-analysis study (Beatty et al., 2013) to estimate the reduction in time required to process a work order by using a BIM and COBie-based process. The findings of the pre-analysis study state that by following a BIM and COBie-based approach, there could be an 8.7%

reduction in time spent processing maintenance work orders. This reduction in processing time may be attributed to having quick access to accurate and complete digital information and documents (Beatty et al., 2013). Since the projects have been operational for more than three years, there is abundant data to assess the accuracy of the predicted benefit. This paper analyzes the change in time spent processing preventive and corrective maintenance work orders by using BIM and COBie data for FM of TAMHSC campus buildings. This paper compares work order processing times from the data collected in the CMMS of TAMHSC to determine the differences in time spent processing work orders.

LITERATURE REVIEW

Cost of inadequate interoperability in the capital facilities industry within the U.S.

Interoperability is the ability to communicate electronic data between design, construction, maintenance, and business process systems which exist within and between multiple organizations (US Department of Commerce Technology Administration, NIST, 2004). The study identifies some of the causes for inadequate interoperability as the highly fragmented nature of construction industry, lack of standardization and inconsistent technology adoption among stakeholders. Based on interviews and surveys, annual loss of $15.8 billion was quantified for the facilities industry. A majority of this cost is borne by owners and facility managers during operation and maintenance phase of a facility. According to the report, this figure is a conservative estimate of the actual cost as the report does not include the cost for significant inefficiency and lost opportunity associated with interoperability problems.

Importance of interoperability in healthcare buildings

Facility managers in the healthcare industry face unique challenges as they must maintain complex MEP systems while ensuring patient safety (Lucas et al., 2012). Coordinating information from earlier phases of the life cycle, which is often incomplete and housed in multiple systems, may result in delays and monetary loss (Lucas et al., 2013). Response to emergency situations in the facility can affect a patient's exposure to health risks. To improve the management and increase efficiency of information transfer, a BIM based facility management system is proposed by the researchers (Lucas et al., 2012).

Scope for application of BIM for FM

Research indicates that there is scope for wide scale application of BIM in FM. Using BIM, O&M efficiency can be increased in areas such as locating building components, facilitating real time data access, visualization, marketing, and checking maintainability, creating and updating digital assets, space management, controlling and monitoring energy, and emergency management (Becerik-Gerber et al., 2011). To improve the operations of any facility, integrating different sources of information throughout the project life cycle is most important. In order to maximize the interoperability of information, owners should identify these information requirements before beginning a project, and develop a collaborative BIM to FM data exchange solution during the early stages of a project's life cycle. Such information solutions will help reduce life cycle costs with a more efficient facility O&M process and help in developing more efficient operational workflows (Kasprzak and Dubler, 2012).

BIM use is the first step towards a more efficient future where information about the whole building would be integrated and accessible on mobile devices like tablets and phones. Irizarry et al. (2014) conducted a study about the use of mobile augmented reality and the use of aerial drones for facility management in a healthcare environment. Their findings indicate that efficiency can be improved with the use of technology. Further studies indicate that using a web based BIM system can be more efficient than the traditional FM approach (Lin and Su, 2013).

The role of facility owners in the adoption of BIM for FM

In recent years, BIM has become increasingly popular within the design and construction industries, with most large companies using it to some degree. In contrast, the use of BIM by owners for facility management still lags behind the construction industry. Brooks and Lucas (2014) identified the key to successful post-construction BIM utilization. They found that owners' have only a basic understanding of BIM and have very little knowledge with which to utilize this tool to its full potential. They created a framework to identify specific needs of owners, guide the contractor in creating a model to meet those needs , and streamline the turn-over process.

Although facility owners play a vital role in the adoption of BIM for FM, many still lack the technical proficiency and knowledge required to manage and fully utilize BIM processes downstream during operations and maintenance. Research suggests that having a defined plan of action for BIM execution and the skills, staffing, and technology are better indicators of an organization's/owner's competency than are traditional construction administration factors (Giel and Issa, 2014).

Jawadekar S.P. (2012) and Lavy and Jawadekar (2014) reported three case studies on projects of the TAMHSC campus buildings, where COBie data was integrated with the CMMS. They found that there were no laid down rules or procedures for turning over of COBie data for the Bryan and Round Rock campuses of TAMHSC. Further, the data received from the contractor upon completion of the project was not in an interoperable format like COBie, Microsoft Excel spreadsheets, or Industry Foundation Classes (IFC). Hence, the data had to be recreated by a consultant (Broaddus & Associates) for use with the CMMS. However, the owner did streamline the process of data handover in the Round Rock campus, after applying the lessons learned from data integration for the Bryan campus.

Need to quantify potential benefits from using BIM for FM

The GSA BIM for FM Guide (2011) states that there should be a reduction in the time to process work orders since accurate field conditions can be known without a time-intensive search of paper drawings and documents. The guide estimates that O&M contracting costs could be reduced by 3% to 6% by identifying and tracking facility equipment and facility square footage. It may also help reduce the cost for re-documenting. Broaddus & Associates (Beatty et al., 2013) conducted an initial study to estimate the time that could be saved during processing a work order by using a COBie-based process. They predicted the savings by conducting surveys and interviews with facility management staff of the existing Health Science Center campus buildings in Texas. In their study, the work order process was divided into individual steps to determine the time spent during each step.

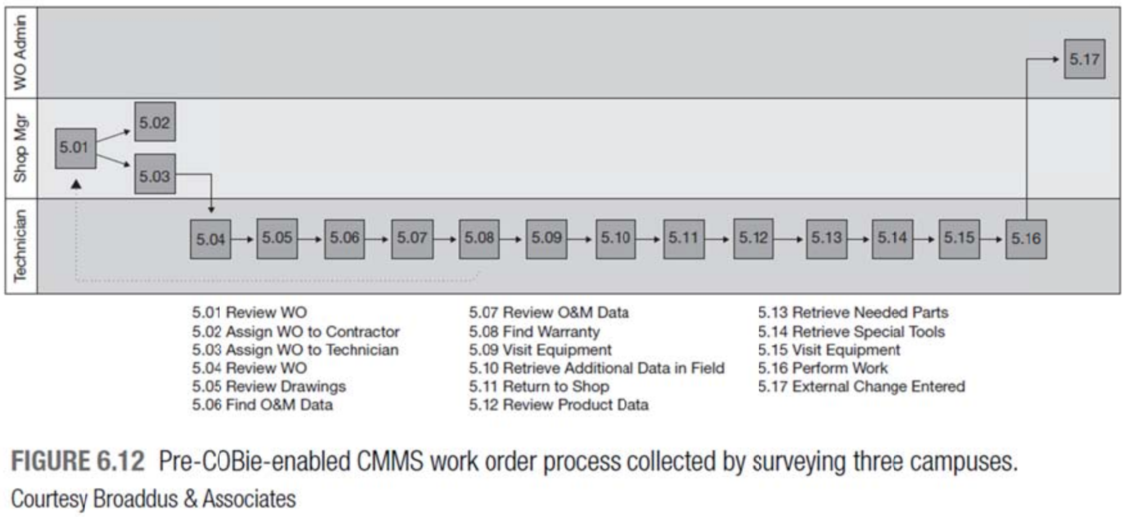

Figure 1: Pre-COBie-enabled CMMS work order process (Beatty et al., 2013)

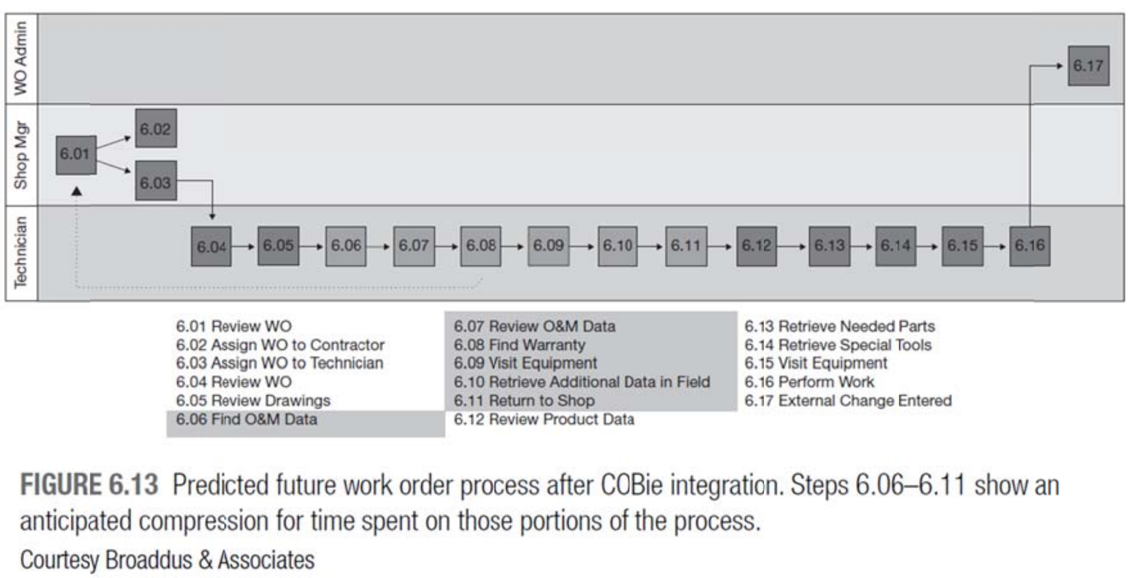

Figure 2: Predicted future work order process, after COBie integration (Beatty et al., 2013)

The pre and post-COBie work order processes are illustrated in Figures 1 and 2, respectively. The anticipated reduction in time takes place in steps 6.06 – 6.11, as shown in Figure 2. The study indicated that there could be a reduction of 8.7% in the time spent on the work order process. This time saving can be attributed to having quick access to accurate and complete digital information and documents (Beatty et al., 2013). The use of advanced technologies is improving efficiency in the buildings industry, but the information flow among various parties involved is far from seamless. Currently, most organizations in the building industry do not quantify the cost reductions attributable to improved processes and technologies. Collecting these metrics is essential for understanding the value of implementing this improved technology (U.S Department of Commerce Technology Administration, NIST, 2007). Systems integration and collaboration in the architecture, engineering and construction (AEC)/FM industry are the keys to enabling technologies that drive the construction industry in improving efficiency. Due to the fragmented nature of the industry, a web based system can serve as a single central repository to store all design information. As evidence of improvements in efficiency, case studies and pilot implementations are needed to validate and showcase these emerging technologies (Shen et al., 2010). BIM is in the early years of application in the facility management industry, and the business value of using BIM has not been measured and/or quantified. Claimed benefits of using BIM are intangible (for example, improved product quality, better decision making capabilities, etc.). Industry participants feel that there must be benefits of using BIM, but there has not been an active effort to quantify or measure these benefits (Becerik-Gerber and Rice, 2010).

OBJECTIVES, HYPOTHESES, AND RESEARCH METHODS

Research Objective

This study analyzes the differences in time spent on processing work orders by using BIM and COBie data versus a traditional drawing-based approach for facility management in Texas A&M University's Health Science Center facilities.

Research Goal

To analyze differences in time spent on processing work orders using BIM and COBIE data versus a traditional drawing-based approach for preventive and corrective maintenance of MEP systems and architectural components in a building.

Research Hypothesis

The null hypothesis for this study is that the mean time spent in processing a maintenance work order is equal for buildings that follow a traditional drawing-based approach for facility management and the buildings following a BIM and COBie-based approach for facility management.

Limitations of the research

1. The information entered by workers about the "actual number of hours" worked on a job is truthful and accurate.
2. Since data collected by the TAMHSC does not provide details about the time spent during each step of the work order process, the researchers assume that the actual number of hours spent on the work order is a sum total of the time spent during each step of the process. This process includes time spent on collecting information about the location of a system within a building, system information such as manufacturer's instructions for maintenance, warranty, details about past maintenance, etc.
3. Different workforces carry out maintenance activities in the various campus buildings. It is assumed that all employees perform at the same level of quality and efficiency.

Delimitations of the research

The proposed study was limited to Texas A&M University Health Science Center Buildings located in the State of Texas, U.S.A.

Research Methods

Data Collection

The data for conducting this research was obtained from TAMHSC with the assistance of Broaddus & Associates. The data was exported in Microsoft Excel format from the CMMS used by the Texas A&M University System. This data provides details about all maintenance work orders performed in TAMHSC facilities since 2011.

Work Order Process

The work orders are issued/requested by building users through the CMMS. Any user of a building (e.g., staff, faculty, maintenance technician, etc.), may place a work order request. Once a work order has been requested by the user, it is added into the queue waiting to be processed. Work orders for all TAMHSC campuses except the Houston and Dallas campuses are examined and sorted by the facility manager of TAMHSC. The work orders for Houston and Dallas campuses are sorted and assigned at the local campus level. The queue of work orders for the all other campuses is then examined by the facility manager of Bryan campus who sorts and assigns the work order to the campus in which the maintenance task is required. Once the work order has been assigned to a particular campus, all maintenance activities related to the work order are carried out at the campus level. The work order may be a single phase or multi-phase work order depending on the complexity of the system and disciplines involved (mechanical, electrical, plumbing, architectural).

Texas A&M University System outsourced FM services for all campus buildings, except the McAllen campus, to a single organization in the beginning of June 2013. For analysis purposes, the researchers selected work orders for a duration of one year, from September 2013 to September 2014. Since FM services for the McAllen campus are not performed by the same organization, work orders from this campus were excluded from the study in order to achieve accuracy and consistency in the findings.

Data fields included the campus where the work was performed, description of the type of problem, work order category (i.e preventive, corrective, event, etc.), the actual number of hours taken to process the work order, and the date of work order entry and completion. Work order end date is not usable for research, as it does not reflect the actual date when the work order was completed. The end date of a work order is recorded when the maintenance supervisor marks a work order as “Complete” in the CMMS. This end date may not be accurate for use in this research study as the supervisor updates the status of the work order as per his convenience, and he/she may not update the status of the work order on the actual day it was completed. The facility management data for the campus buildings in Bryan and Round Rock reflect the facilities using COBie data for FM. This data was compared to other campus buildings of the TAMHSC system from the six cities of College Station, Corpus Christi, Dallas, Houston, Kingsville, and Temple, which follow the traditional drawing-based approach.

Upon initial examination of the data, a total of 7,429 work orders were observed for the time period from September 2013 to September 2014. There were 2,111 work orders with “zero” number of actual hours worked. They were not included in the research as they represented inaccurate data entered into the system. In addition, all work orders for the Temple campus had zero actual number of hours worked, leading the researchers to exclude that campus from the study. Another significant observation was that there were no work orders for the Corpus Christi campus in the data, and therefore, this facility was also excluded from this study.

Data Analysis

The researchers excluded work orders with zero number of hours worked from the study and segregated the remaining work orders into five categories: mechanical, electrical, plumbing, architectural, and “not included”. Work orders related to the maintenance of mechanical systems in the building like air handling units, exhaust fans, air compressors, etc., were assigned to the mechanical category. Work orders related to the maintenance of the electrical systems in the building, like lighting, emergency generator, etc., were assigned to the electrical category. The plumbing category consisted of work orders related to maintenance of plumbing systems in the building, like water leaks, drainage of water, plumbing fixtures, etc. The architectural category of work orders was related to the maintenance of building components, like doors, windows, walls, etc. The researchers used the “not included” category to exclude work orders that were not related to Building Information Modeling. These included categories like event setup, i.e., setting up chairs and tables for functions, telecom system complaints (like changing caller identification number), picking up supplies, cleaning dirty areas in the building, moving furniture, etc. After segregating the data, there were 954 work orders in the mechanical category, 1,084 work orders in the electrical category, 636 in the plumbing category, and 732 in the architectural category, for a total of 3,406 work orders.

Separate comparisons for preventive and corrective maintenance categories was not possible, as there was insufficient data in the preventive maintenance category. Work orders for preventive and corrective maintenance were combined to conduct the statistical analysis. Work order times from the Bryan and Round Rock campuses were combined into the BIM user category. These were compared with the work order times for the remaining campuses, which were combined into the Non-BIM user category. A statistical analysis was carried out with a 95% confidence interval on the time spent on processing work orders by using a two-sample t-test.

RESULTS AND DISCUSSION

There are statistically significant differences between the work order processing times of BIM Users and Non-BIM Users in the mechanical and plumbing categories, at the .05 level of significance. Results show that in both cases, BIM users have a higher mean processing time. There is not enough evidence to conclude that there is a statistically significant difference between the work order processing times of BIM Users and Non-BIM Users in the electrical and architectural categories. To check the accuracy and consistency of the results, the t-test was repeated for all categories after excluding the longest 10% and shortest 10% of work order processing times. The results were consistent for all categories except the architectural category, as the mean of Non-BIM users dropped from 61.2 hours to just 1.2 hours. This change was caused by the removal of multiple “combined” work orders in both categories: BIM user and Non-BIM user. One such work order had a total of 1,227.5 hours worked, which combined all renovation activities in four different rooms. This significant drop in the mean work order processing time resulted in a statistically significant difference between BIM users and Non-BIM users at the .05 significance level with a higher mean for BIM users. The results of the t-test are summarized in Table 1 and a graphical comparison of means is illustrated in Figures 3-6. These results are significant as they contradict the perception of owners and facility managers that the use of BIM can help in reducing maintenance work order processing times. However, deriving conclusions based exclusively on the results of the statistical analysis may not be appropriate. After observing the results of the t-test, the researchers shifted focus to the data in order to understand the reason for the results. After observing "work order description" in the data, the researchers found that there were no standard rules for recording the work orders in all facilities: there were many instances where work orders for multiple systems/ components in a building were combined into a single work order in all four categories across all campuses. For example, in the mechanical category, there were instances of maintaining multiple exhaust fans, fan coil units, fume hoods, air handling units, etc. with a single work order in both BIM user and Non-BIM user buildings. These "combined" work orders suggest that there are no standard procedures for recording work orders for all facilities. Such work orders may distort statistical analysis of the work order processing times. Inaccurate recording of information is a hindrance in determining the efficacy of new technological systems. In order to accurately determine the difference in work order processing times, it is crucial for owners and facility managers to establish standard rules for recording work orders across all facilities.

Table 1: Results of the t-test analyses for the Mechanical, Plumbing, Electrical, and Architectural categories

Building Type	**N**	**Mean**	**Std. Dev.**	**95% C.I.**	**Difference**	**95% C.I. for Difference**	**P-Value**	**Result**
Mechanical								
BIM Users	247	11.51	42.7	(6.2, 16.9)	7.7	(2.3, 13.1)	0.005	Means differ at the .05 level of significance. Higher mean for BIM Users
Non-BIM Users	707	3.80	10.7	(3.0, 4.6)				
Electrical								
BIM Users	368	3.8	7.3	(3.1, 4.6)	-0.03	(-1.0, 0.99)	0.947	Not enough evidence to conclude that the means differ at the .05 level of significance.
Non-BIM Users	716	3.9	9.5	(3.2, 4.6)				
Plumbing								
BIM Users	151	7.1	12.9	(5.1, 9.2)	4.5	(2.4, 6.6)	0.001	Means differ at the .05 level of significance. Higher mean for BIM Users
Non-BIM Users	485	2.7	4.4	(2.3, 3.1)				
Architectural								
BIM Users	211	5.5	9.0	(4.3, 6.7)	-2.6	(-8.0, 2.8)	0.347	Not enough evidence to conclude that the means differ at the .05 level of significance.
Non-BIM Users	521	8.1	61.5	(2.8, 13.4)				

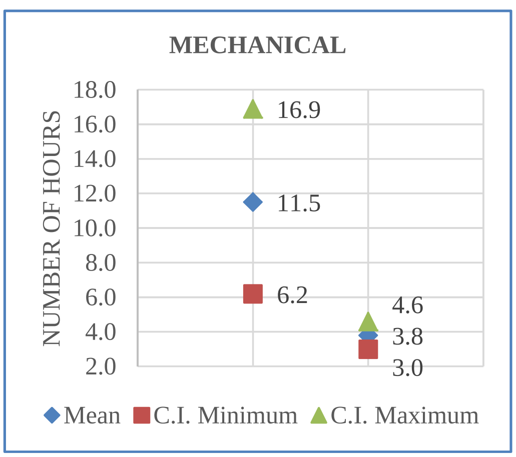

Figure 3: Mean work order processing time and 95% Confidence Interval (C.I.) for the mean of mechanical work orders in BIM user (left) and Non-BIM user (right) facilities.

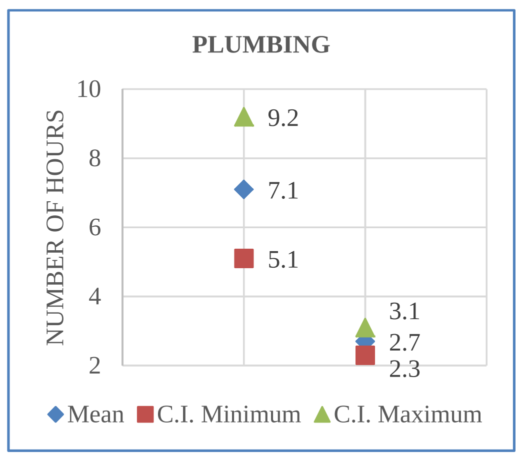

Figure 4: Mean work order processing time and 95% Confidence Interval (C.I.) for the mean of plumbing work orders in BIM user (left) and Non-BIM user (right) facilities.

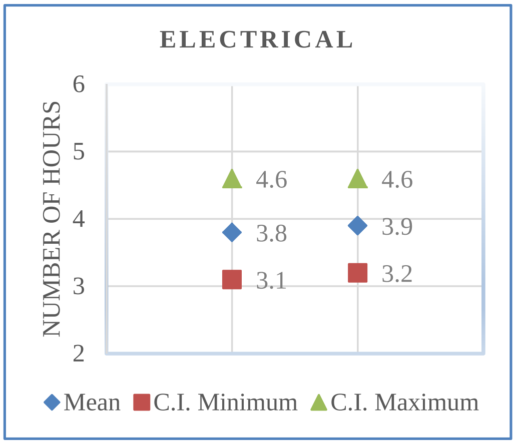

Figure 5: Mean work order processing time and 95% Confidence Interval (C.I.) for the mean of electrical work orders in BIM user (left) and Non-BIM user (right) facilities.

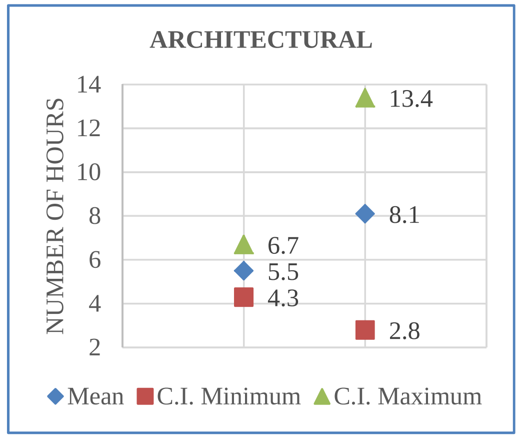

Figure 6: Mean work order processing time and 95% Confidence Interval (C.I.) for the mean of architectural work orders in BIM user (left) and Non-BIM user (right) facilities.

CONCLUSIONS

The shift from 2D drawing-based FM to 3D BIM and COBie databased FM is a relatively new development in the industry. Adoption of new technology is fraught with multiple challenges, especially in an industry that is slow to adopt technology. The focus of this research was to understand the effects of using BIM for FM on work order processing times. To accomplish the research, actual work order data from multiple TAMHSC campus buildings was statistically analyzed.

Existing literature on this topic indicates that using BIM and COBie data for FM processes presents significant benefits. The GSA BIM for FM Guide (2011) states that there should be a reduction in the time to process work orders. To reinforce this, an initial study conducted by Broaddus & Associates (Beatty et al., 2013) indicates that there could be a reduction of 8.7% in work order processing time.

However, the findings of this study contradict the findings of existing literature, as stated above. After conducting a statistical analysis of the actual work order processing times for multiple facilities of TAMHSC, it can be seen that more time was spent on processing maintenance work orders by using the BIM and COBie data for FM in at least two categories, i.e., mechanical and plumbing. There is a lack of evidence to conclude that means differ for the other two categories, i.e., electrical and plumbing. This contradiction in the findings is significant because most of the earlier studies utilized interview and survey methods to determine potential savings, while this study utilized actual work order processing data to derive its conclusions.

Nevertheless, the findings of this study may not necessarily convey the accurate scenario for facilities that use BIM for FM, as there were limitations associated with standardization in recording the work orders throughout the campuses. Hence, we can conclude that in order to validate the effects of using BIM and COBie data for FM, it is important for owners and facility managers to establish standard rules from the very beginning of a project to accurately collect and record work order data.

This paper focuses only on work order processing times to determine the benefits of using BIM and COBie-based data for FM. In order to fully understand the real value addition of using BIM and COBie for FM, future research should consider additional factors, such as user satisfaction, ease of use, time difference in accessing information about a building system/component, frequency of accessing information about a system/component, and the corresponding effects on work order processing times. In an institution that outsources FM services, it would be critical for the owners to determine the effectiveness of outsourcing FM services in order to exercise a greater degree of control on the firms performing these services. For the purposes of this study, and due to the time constraints faced by the researchers, only work orders performed after the outsourcing of FM services were analyzed. Future research could focus on comparing a “before and after” the outsourcing of FM services scenario to determine difference in work order processing times.

INDUSTRY RESPONSE

(Griffith H. personal communication 05/13/2015) These observations will move the industry forward with improved processes, standards, and outcomes. The results of this research do not show positive results. That is not disputed. However, many factors and forced assumptions contribute to these negative results. We must mitigate these factors. We will continue to work toward solutions. Early Adopters are challenged to produce return on investment (ROI) and justifications. This work must show us what adjustments are warranted. This research demonstrates that metrics must be established in advance for outcome quantification. Preventive vs. Corrective: Previously, we concluded and advised that these should be classified separately. In the current study, that could not be done and impacted the results. A more true analysis could be done with normalized work order (WO) classification. FM system use improvement is needed in using the CMMS. It is not enough to specify, capture, organize, validate, and transfer data. Operational use must be aligned to measure the value of the process itself. WO duration is the prime data element in this research. Better process controls at the work order level are needed. Even with mobile technology, this boils down to human factors of time recording.

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