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A framework for monitoring-based commissioning: Identifying variables that act as barriers and enablers to the process

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ABSTRACT

The practice of monitoring-based commissioning (MBCx) using energy management and information systems (EMIS) has been shown to enable and help sustain up to 20% energy savings in buildings. Despite research that has quantified the costs, benefits, and energy savings of MBCx, the process remains underutilized. To understand why MBCx is not more frequently adopted and how to encourage its use, this research synthesizes qualitative data from over 40 organizations, currently engaging in MBCx. The outcome of this research is a framework containing variables that emerged from the qualitative data, marked as barriers or enablers, organized by phases of the MBCx process. The framework is comprised of 51 emergent variables that fall within 13 different categories. The variables that most frequently act as barriers are *data configuration, measurement & verification (M&V), developing specifications for EMIS*, and *data architecture*. Although some variables that act as barriers for one organization were identified as enablers for another. For example, *payback/ROI* was considered a barrier 7 times and an enabler 3 times. One organization had difficulty making the business case for the initial investment for MBCx due to lack of cost information, while another was able to justify large investments with documented savings of previously implemented measures identified through MBCx. The framework formally validates barriers found in previous research, and can be used by practitioners to better understand common experiences with MBCx. This research highlights the need for a similar collective data set to validate common enablers to MBCx and also the need for empirical research to determine relationships between variables.

1. Introduction

The process of monitoring-based commissioning (MBCx) can help sustain optimal energy performance in buildings, while maintaining occupant comfort [1–3]. In the building efficiency literature, MBCx entails ongoing commissioning with the goal of continuous building performance improvement by way of data monitoring and analysis [4,5]. MBCx can enable the identification of otherwise untapped energy conservation measures and also verify the energy savings from the re-commissioning of existing equipment [5].

Alongside the evolution of MBCx there is the evolution of system monitoring technologies to support the process. Specifically, energy management and information systems (EMIS) enable and help sustain up to 20% site energy savings [6]. Many technologies fall under the umbrella term EMIS (e.g. building automation systems, information monitoring and diagnostic systems, energy information systems). All of these technologies aim to efficiently manage building energy use. EMIS can report and analyze whole-building energy use (e.g. water or electricity), system-level energy use (e.g. just HVAC), or offer a combination of the two.

Despite the demonstration of benefits from MBCx in the 1990s and the beginning of a paradigm shift from retro-commissioning to MBCx in the early 2000s [7], the process remains under-utilized [6]. This could be because there are still variables acting as barriers to MBCx and supporting technologies like EMIS [8], confusion about the process, and skepticism towards its benefits [9].

This research aims to make MBCx more transparent by creating a framework of enablers and barriers to its use, based on the synthesis of experiences from organizations implementing EMIS and MBCx. Frameworks can serve as a guide for a specific outcome by organizing interlinked concepts. The framework contains variables that emerge from qualitative data, organized by phases of the MBCx process, and will point out those that are commonly experienced as barriers or enablers to the process. The framework can act as a guide to organizations implementing MBCx by making

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variables that impact the process more evident; it also suggests further empirical research to determine the relationship between these variables and energy saving outcomes.

The overarching goal of this research is to facilitate otherwise untapped potential for site energy savings by creating a tool for building owners practicing MBCx. This research is intended to benefit commercial building stakeholders such as building owners, facility managers, building engineers, and energy managers involved in the MBCx process, as well as researchers interested in targeting understudied areas of MBCx.

2. Background

Background information relevant to this work includes the relationship between MBCx and information systems, definition of the MBCx process, and examples of variables, or factors impacting the successful implementation of MBCx.

2.1. MBCx relationship to information systems

More than five decades of research in information systems have led to advances in disciplines such as management [10], healthcare [11], and manufacturing [12]. In general, information systems (IS) are defined as networks, software, and hardware that work together to acquire, store, and manage data [13]. The utilization of an EMIS, (see phase two of the MBCx process, in Section 2.2) also requires networks, software, and hardware and could be considered a subset of an IS. Petter et al. [14] defined an IS framework that contains variables that "cause" or at least influence IS success. This framework helped create a better understanding of the IS process and is a starting point for researchers to measure the interactions and outcomes of these variables. Petter et al. [14] defined IS variables based on a synthesis of over 140 studies, then assessed whether these variables, based on literature, have an impact on success outcomes like system use, system quality, user satisfaction, and net benefits. For example, the IS framework identified the variable "user involvement" defined as "the degree to which users participate and are involved in the IS development and implementation process" [14]. User involvement was then found to have conflicting impacts on the use of the IS and the authors suggested further study [14]. A similar framework to Petter, DeLone, and McLean's framework, specific to MBCx and developed in this work, can create a more holistic understanding of MBCx and lay the groundwork for comparable empirical studies.

2.2. MBCx process

Analogous to the traditional existing building commissioning processes, the overall MBCx process includes a planning phase, and an implementation phase [15]. However, to accommodate the use of IS, it also includes a phase for EMIS configuration. Details of the specific steps within each phase are listed in Table 1, as described in Kramer et al. [4].

The outcome of the research presented in this paper is a framework of variables that influence the MBCx process; the framework is aligned with these phases (see Table 1), and can support organizations in implementing the process. However, since, the variables within the framework may be relevant at multiple points in the MBCx process, the specific phase referenced may serve more as a general roadmap than a definitive attribution.

2.3. Examples of variables impacting MBCx

Previous case studies describe some variables [3,6,16–18] that act as barriers, impeding the process, or enablers, supporting the institutionalization of EMIS and/or MBCx, and energy saving goals. These variables can be inherent to the MBCx process, but cause unexpected challenges or barriers. For example, the University of California, Merced (UC Merced), adopted an MBCx process and reported that one of the biggest issues was data quality [3]. Although the performance of data quality checks is a step within the MBCx process, organizations might not know how often this actually impedes the process or that this can lead to issues like false positive alarms that cause cascading alert notifications during the implementation phase.

On the other hand, these variables may not necessarily be defined in the general MBCx process, making it difficult for organizations to anticipate their influence. Using the case of UC Merced again, network and connectivity problems led to false alarms that then required "significant resources" to validate the data [3]. Multiple case studies highlight the use of consulting and advisory services as being valuable to MBCx implementation, but this is not clearly defined within the MBCx process and organizations could benefit from learning about the experience of others. For instance, when using outside consultants to configure EMIS, a lack of documentation and training for staff responsible for continued management of the system can lead to improper ongoing use of EMIS [19,20].

In addition, there are variables described in case studies that can enable energy savings, that are not defined in the MBCx process. For example, one case reports the organization leveraged their EMIS through an energy reduction campaign focused on engaging employees with the building's energy use [21]. The case highlighted the impact of empowering "energy champions" in supporting others to practice energy-saving behaviors [21]. EMIS data has also been used to design programs that create a sense of competition between occupants, retail chains, and even communities leading to energy savings [22].

Although these cases are a rich data source, organizations interested in MBCx could benefit from a framework classifying variables, such as these, that act as either barriers or enablers to the process. A framework provides a more holistic perspective than a case study, with context of other variables and their connections to each phase.

3. Research questions

By using qualitative data from over 40 organizations implementing MBCx and using EMIS for continuous data monitoring and analysis, this research aims to answer the following questions:

(1) What variables emerge from the MBCx process?
(2) At what phase do these variables occur within the MBCx process?
(3) Which of these variables are described as barriers and which are described as enablers?

The qualitative data encompasses a wide range of organizations (in size and type) and multiple EMIS types. The data was coded to determine the emergent variables impacting MBCx and then organized by MBCx process phase to create a MBCx framework. The hypothesis is that variables will emerge as barriers or enablers that are not necessarily defined in the MBCx process. Of those variables, the expectation is to find the majority to be barriers to the process due to the nature of qualitative questions (see Table 2), but we expect that some enablers will emerge as well. It is also expected that some variables will have conflicting results, being barriers to some and enablers to others. These variables are highlighted in the results. Finally, gaps in MBCx knowledge are underscored to encourage further empirical study and outlined in the discussion and conclusion.