Energy, Information, and the New Work of Building Operations in the Digital Age

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Motivation for Research:

The construction industry is experiencing a data revolution paired with a drive for sustainable operations. Innovation, information, communication access, and integration provide an opportunity to utilize this abundance of data to reach sustainability goals and benchmarks. Issues relating to climate change and sustainability are amongst the most pressing challenges of our modern generation. Within the United States, buildings are some of the leading consumers of energy as they account for more than 40% of the energy consumption nationwide (energy.gov), impacting both humans and the environment in which we live. Real time data integration technologies, such as Internet of Things (IoT) systems are coming to the forefront as a potential opportunity to reduce building energy consumption while enhancing control and access to critical building information. An Internet of Things (IoT) system is defined as a network of physical objects with sensing and communication capabilities that enable data synthesis and processing through seamless access to domain-specific software and services (Louis, Dunston, 2018). However, systematic information management technologies such as IoT systems are difficult to implement and involve a higher level of commitment to systems operation and maintenance than the traditional Building Automation Systems (BAS) which are prevalent today (Blum et al., 2023). Thus, what is emerging in the adoption of IoT technologies to replace or complement current BAS for improved energy management is a shift in work in the facility maintenance (FM) sphere. This shift in work involves changes in responsibilities, introduced/improved data management operations, a reorganization of traditional FM practices, and a new reliance on digital information systems rather than their prevalent analog/pneumatic alternatives. In essence, in order for advanced technologies to produce the desired energy reduction goals of an organization, we must first understand how to best integrate these novel technologies into our existing FM organizations and understand how operations must change to accommodate their maintenance and management requirements.

The objective of this research was to understand how FM organizations and their operations must adapt in order to leverage IoT technologies/strategies to achieve lower energy consumption and better-performing built environments. The focus of this research is around how work changes for facility managers/operators with the introduction and use of IoT systems for the management of buildings/building campuses. This research looked at "work" holistically, including both the organizational impact on work that utilizing these technologies will require and the technical requirements of implementing, managing, and maintaining these systems. Once we understand the evolution of work with the transition from analog and pneumatic based BAS systems to advanced digital systems (defined below), our buildings may begin to reap the benefits of enhanced energy conservation and efficiency through improved practice.

Research Questions:
Our research questions for this study are below:

1. How will the existing work change for facility managers/operators when transitioning from an (analog-digital hybrid) BAS to an IoT system and strategy?

2. What new work will emerge when transitioning from a building operated by an (analog-digital hybrid) BAS to an IoT system and strategy?

Defining Concepts:
Internet of Things (IoT) - a network of physical devices, vehicles, appliances and other physical objects that are embedded with sensors, software and network connectivity that allows them to collect and share data (IBM). IoT devices can range from simple smart thermostats to complex energy and pressure sensors/monitoring devices.

Mechanical System Typologies:

Analog Control System - A mechanical system which is not digital or computerized (Merriam-Webster). A system that still requires manual alteration in order to function properly.

Pneumatic Control System - A mechanical system containing or operated by air or gas under pressure in order to function properly (oxford).

Digital System - A technological system that uses hardware and software components to transform data into virtual representations of information. A series of digital systems working together forms what is known as a network (Australian Government Department of Education). Digital systems allow for the manipulation of mechanical and electrical systems without the need of analog methods, but rather with the use of their digital alternatives.

***Hybrid System* (digital-analog)**: A system composed of both analog and digital control components. A transitory state between an analog and digital based system.

<u>Research Method:</u>

The field of "smart" building facility management is complex, dynamic, and rooted in human-centric social interaction. Studies that looked at the introduction of new technologies in building organizations show that non-technical problems such as interorganizational issues, effective collaboration, sharing and storing information, and organizational structure are some of the biggest barriers to adoption and forward technological progress in the industry (Won et al., 2013). Studies such as these highlight the importance of non-technical factors in understanding why things occur the way that they do and provide evidence that human-centric research is important and relevant to an active organization-based investigation. Consequently, we used qualitative methods in this research to allow for the exploration of

IoT systems within their naturally occurring context (Yin, 1993), in order to capture the important nuances of a dynamic and ever-changing environment like an active FM organization.

We selected case study research to investigate the nuanced and complex changes to work that IoT systems introduce into the operations of buildings. The benefit of qualitative case study design in this research is that it does not rigidly define and limit the potential data which could lead to valuable conclusions but rather promotes the in-depth exploration of an active FM organization while allowing the important factors which are unique to each FM team to naturally frame its context. This research included a two part case study in partnership with the University of Washington's Facilities Division around IoT implementation and use within their active facility organization. Part A of the case study focused on the organizational changes to work that utilizing advanced IoT systems brings, and part B focused on the technological processes and new work that must accompany this transition. This research was funded by the University of Washington Campus Sustainability Fund (CSF) in partnership with UW Facilities. Within the realm of qualitative case study, we utilized participant interviews, document collection, and naturalistic observation as the dominant research methods to guide our investigation.

Key Findings:

This research is still in the data collection/analysis phase however some preliminary key findings are below. By the time of the conference in June, this section will be expanded and further developed. Uniquely, preliminary findings show that the introduction of technologies such as IoT devices which allow for the automation of processes and the ability for remote work at the University of Washington are actually increasing the responsibilities of facility managers, operators, and technicians even though the physical human effort required to manage buildings in a traditional way is no longer present. This is because the utilization of these systems allows for increased data tracking, the ability to customize spaces to user preferences/requirements, increased opportunities for application, and increased responsibilities around making this influx of data useful for both building operators and users alike.

In the tables below are the results of our preliminary data analysis effort which utilized inductive and deductive qualitative coding strategies to analyze our collected interview, document, and observational data.

Table One: Organizational Impact on Work

Organizational Changes to Work:	Implications:
Technical skill-set requirements/ Introduction of IT support roles in operational technology	- Technician/operator understanding of network communication - Ability for device configuration/ troubleshooting - Introduction of liaison role between IT and FM
Communication	- Necessity for enhanced communications between FM and IT - Organizational understanding of technical terminology - Growing interdisciplinary communication requirements
Establishing Standards	- Standards for device selection - Standards for device configuration - Standard procedures around device maintenance and issue response - Development of tested/trusted data workflow
Interorganizational Collaboration	- Distribution of growing management responsibilities in siloed environment - Interorganizational relationship building/trust development - Managing competing interests from disciplinary groups - Establishment of leadership roles in trade specific groups - Establishment of standard data flow through organizational divisions
Decision Making	- Involvement of facility management division in early decision-making - Development of standards around device selection - Establishment of management responsibilities prior to system integration - Leveraging vendor specific knowledge in decision-making
Managing Resistance to Change/Transition turbulence	- Training/ improved education around digital tools - Introduction of hands-on technicians/operators in decision making - Focus on direct benefit of technology on day-to-day operations - Establishment of mechanisms to ensure continual digital usage

Through this research, it is becoming clear that FM processes and operations must adapt to best utilize advanced IoT systems. Broadly, the skill set requirements for operators and technicians are becoming more technical rather than mechanical, requiring knowledge of IoT system architecture, network connectivity, and vendor specific programming. With the transition to integrated IoT technologies, the communication barrier between technicians/operators and IT professionals must come down as it becomes increasingly important that these groups are able to regularly communicate and collaborate in order to solve IoT related problems. This transition requires changes in communication patterns and the necessity for technicians/operators, facility managers, and IT professionals alike to be able to communicate effectively and understand technical terminology that was largely not critical when managing analog or mechanical systems. In addition, the management of integrated IoT systems requires a holistic approach to building management, leading to the necessity to break down disciplinary silos and increase team wide communications amongst diverse disciplines to effectively manage systems which span across disciplinary boundaries.

The findings of this study additionally emphasize the importance of creating standards for IoT device selection, configuration, maintenance, and issue resolution. With the applicability of IoT systems to diverse building spaces continually growing, the necessity for standard implementation and management procedures becomes critical to managing this onslaught of new integration opportunities.

With this, new work emerges in the distribution of the growing number of new management responsibilities within a previously fragmented/siloed management environment. Assigning management positions and developing trade specific leadership roles becomes critical as systems develop and customers become increasingly aware of the benefits to their work that using IoT systems brings. Changes in decision making structures also become important when implementing IoT systems as leveraging the building and vendor specific knowledge of facility personnel during the device selection process becomes critical to the health and efficiency of the integrated systems over time. As a whole, decision-making processes must shift to integrate a more experience based approach for the best return on investment when implementing new IoT based systems.

Table Two: Technical Impact on Work

Technical Changes to Work:	Implications:
Managing Automated Systems	- Ability for remote work - Holistic understanding of IoT system architecture - New digital skills required for facility operators/technicians - Increased interface/collaboration with IT groups - enhanced communication requirements - More robust quality assessment/control over devices and systems
Advanced Troubleshooting	- More responsive customer service - New work of equipment trending - Creating and interpreting energy visualizations/simulations - Increased alarm management and response - Increased space/lab customization - introduction of new data tracking and management requirements
Advanced Device Configuration	- Organization of device communication (numbering, tagging etc.) - Developing network(s) for unique device communications - Vendor specific software knowledge for unique device configuration - Assigning and managing access control - Updating and maintaining software - Enhanced security requirements
Predictive Maintenance and Trending	- Creating and maintaining trend logs - Advanced storage requirements - Advanced data organization requirements
Data tracking and Management	- Increased reliance on digital tools for data collection and interpretation - New skill set requirements - coding, programming, adaptability to new systems - Introduction of new data centric management roles - Introduction of data interpretation software/tools

From a technical perspective, there are many implications to FM work which must accompany an IoT based organizational transition. Holistically, the management of automated systems requires advanced knowledge of system architecture and the intricacies of establishing and maintaining these systems. This requires that technicians/operators develop new digital skills around device configuration. IoT systems allow for advanced troubleshooting around issue resolution which opens the door to more responsive customer service and therefore an increase in troubleshooting responsibilities. This is due to higher levels of data tracking and alarm response throughout unique spaces on campus, leading to new work for facility operators in creating systems to manage and respond to such alarms and unique customer requests. In addition, the necessity for advanced device configuration leads to an abundance of new work in the organization of devices for communication, like the development of unique device IDs, tagging and setting up network infrastructure for device communication within protocols like BACnet. The application of IoT systems creates new work in assigning and managing device access control and customization, updating and maintaining software as vendors develop their technologies rapidly and communication protocols become obsolete, and ensuring proper security measures around this onslaught of novel continuously communicating technologies.

One of the most powerful implications of implementing data centric technologies is in their ability to open the door to predictive maintenance and trending opportunities around building components. However, this opportunity comes with an abundance of new responsibilities for building managers/operators in developing processes around creating and maintaining trend logs, developing and maintaining common data storage environments, adhering to increased requests for energy trending documentation from governing bodies, and developing the skills around manipulating data to make it useful for future projections, such as creating simulations based on historical/archival data. Adhering to a data centric management approach additionally creates new responsibilities in the critical arena of data tracking and management. This comes in the form of developing user skills in previously unused data collection/interpretation software such as OSI Pi, developing at least a baseline understanding of coding and programming processes to increase adaptability to the ever growing number of new integrated technologies, and the introduction of new data centric management roles set in place to support and be a liaison between FM groups and IT personnel.

Implications:

This research advanced digital adoption in the AEC industry by addressing the issue of technology use from a qualitative standpoint, in an effort to understand the organizational and technical changes that must occur to support the highest sustainable output from implemented IoT systems. The organizational and technological transformation to support advanced and automated processes opens the door to an abundance of new personnel responsibilities in the arena of configuring and maintaining new systems in order for them to produce the desired sustainability goals for which they were implemented. While the general trend in narrative around AI and computing is that it will replace people, studies such as this one show that utilizing advanced technologies will not replace people, but rather change the nature of their work and create **new** work around ensuring the health and productivity of technological systems. With the implementation of real-time data monitoring and tracking technologies, the nature of the built environment is shifting. In order to optimally accommodate such a shift, the nature of the work done to maintain the built environment must also adapt and shift.

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