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

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Introduction and Research Objective:

The built environment industry is in the midst of a data revolution paired with a drive for sustainable campus operations. Innovation, information, communication access, and integration provide an opportunity to utilize this abundance of data to reach sustainable goals and benchmarks. Digital twin and Internet of Things (IoT) enabled devices are emerging ICT (information and communication technology) with the potential to reduce buildings' energy consumption if strategically used, maintained, and operated. However, transitions to use digital twin supported operations will need organizational changes in the ways work is done in order to best utilize this data-rich technology. Using new technology in the old operational ways will not change energy consumption. This ongoing research seeks to understand how the facility and sustainability management groups at the University of Washington will need to change and adapt in order to leverage digital twin technologies to achieve lower energy consumption and better performing built environments in the university campus setting. In this research, we are in the process of developing a framework detailing how the existing work of facility strategists and operators at the UW campus will change with the implementation of a digital twin system, and what new work will be introduced for the facility management team in terms of energy management practices. We intend for this framework to help guide UW facility managers and sustainability strategists in the technology adoption process in order to ease the transition period and most optimally utilize technological systems to their highest potential sustainable output. In order to best leverage new technologies and data systems, research into how the existing roles, responsibilities, teams, and practices will change for facility managers/operators at UW when transitioning to a digital twin system is of utmost importance for the highest potential to achieve sustainability related goals. We can not achieve sustainability goals if building operations use new building maintenance systems in old and outdated ways.

Within the United States, buildings account for over 40% of the energy consumption nationwide (energy.gov), impacting both humans and the environment in which we live. Currently most UW facilities are managed with some form of Building Automation Systems (BAS) or using traditional methods. Shifting to develop and implement more intelligent digital twin based systems will involve changes in the ways people work and interact with the building technology. What is unknown is the types of changes that are needed to fully realize the potential of digital twin technology for energy conservation. We know from digital transformation in the construction sector more generally that these types of changes are both technical as well as organizational (Anderson et.al, 2012). What is emerging in the adoption of digital twins to replace or complement BAS is changes in work (roles, responsibilities, teams, and practices) in the facility management sphere, and it is these changes that are often the most difficult to implement (Borhani et al, 2022, Hui 2016, Bean et al. 2017, AON 2017). Our research questions for this study are outlined below:

1. How will the existing work (roles, responsibilities, teams, practices) change for facility managers/operators on the UW campus when transitioning from a traditional BAS to a modern energy management system to promote energy efficiency on campus?

2. What new work will emerge when transitioning from a building operated by a BAS to a modern energy management system such as a digital twin?

Current State of Research:

Fieldwork and on-site data collection for this research has begun in its initial stages. Our research team intends to heavily focus on the data collection stage of the research process in the summer 2023. As for the current state of research, we have concluded a literature review and have created a draft framework based on the literature. This initial framework is built around the core issues surrounding advanced technology integration and use (e.g. BIM for operations) in facility maintenance from existing case study research. We intend to build upon this framework as the research progresses and are open to any commentary/recommendations.

Research Methodology:

As mentioned above, this paper is part of a larger on-going research project with fieldwork now starting in its initial stages. We report here work in progress and the first step of creating a framework for realized and anticipated changes to facilities management work. The next steps in this research include a series of case studies in order to verify and substantiate the framework and further flesh out our understanding of how facilities management work changes. Using a comparative case study strategy for this research will allow us to see and explore the organizational changes which will accompany the transition to a digital twin system for energy management.

In overview of this project in its entirety, to complete this research we are conducting a series of case studies of University of Washington campus buildings in various stages of DT/IoT integration and use. Our research team has built a partnership with the University of Washington Facility Maintenance division who has agreed to partner with us on this research in UW campus buildings and support us throughout the research process. This partnership allows our research team to conduct in-depth interviews, partake in participant observation, and shadow the facility maintenance team to understand how their work is changing and the new demands on UW maintenance staff. As the UW has begun to invest in DT/IoT based solutions for energy management, using a case study strategy for this research will allow us to see and explore the organizational changes which will accompany the transition to a digital twin system for energy management and focus on particular tension points experienced throughout the different cases in order to yield the most holistic results.

Our research process includes the following steps:

1. Literature review to identify the current state of technology and practice in facility management (completed) and development of a first draft framework.
2. Case study analysis of 4 (or more) campus facilities, all utilizing some form of digital twin based strategy for energy management. Our team has identified these buildings/technologies through discussion and collaboration with the UW facility management division where we have found existing tension points with DT/IoT based technology. These include the following:
    - The campus wide energy meter monitoring program which is part of the university smart grid effort.
    - The automation window actuators, lighting control occupancy sensors and smart building infrastructure in Founders Hall on the UW campus.
    - The smart building infrastructure in Kincaid Hall on the UW campus, which recently went through a complete technological and interior remodeling. This included a complete replacement of the mechanical system and BAS.
    - The smart greenhouse, automatic window tinting technology and smart building infrastructure implemented in the new Health Sciences Education building.

3. Focus group interviews (FGI) within each case with facility managers, O&M staff, operators, technicians, and sustainability strategists to gain perspective and understand operations, goals, strategies, and day-to-day responsibilities.
4. Development of a "new work" framework to capture changes in practices and newly introduced responsibilities in digital twin operations when comparing to/transitioning from a BAS.

To validate the case study findings, we additionally plan to conduct a series of national expert interviews (10-15) of leaders in the field from both the software development and owner operations roles. We will leverage professional networks such as the Digital Twin Consortium and the National Institute of Building Sciences to identify these experts. This effort will help us in triangulation and ensuring the validity of our fieldwork and data.

Key Findings:

In the literature review process of this research we reviewed over 90 studies revolving around the integration and use of Virtual Design and Construction (VDC) technologies (e.g. BIM, IoT, DT) in the construction and facility operations phases. This allowed us to identify commonalities and themes in the integration process and use of these technologies within the AEC realm. This led us to the identification of the most common FM building technology adoption barriers and tension points in the integration of IoT/DT devices into facility management processes based on the literature. Below is a table representing the most common tension points in the adoption and use of new VDC technologies into existing organizations.

VDC Technology Adoption and Use Tension Point Categories:		
Organizational Barriers and Groupings	**Strong and Effective Leadership + Management**	**Knowledge Management (informal knowledge networks)**
Tension Point: Fragmented nature of data – information standardization, storage, sharing procedures etc. within FM organizations are not well established. Unique and siloed data management processes exist within individual teams.	**Tension Point:** Older workforce with low technology skills and established work routines (younger workforce not adequately trained in advanced tech use) → resistance to change and utilization of old methods of operation with new tech.	**Tension Point:** Modeling tools (e.g. BIM) can reduce interpretative flexibility by allowing for much higher design specificity in initial stages → must combat this with combination of digital and physical work and meeting spaces (Messy Talk)
Tension Point: Fragmented / siloed nature of FM teams– organization, communication, work groups, and interorganizational collaboration procedures are unique to teams	**Tension Point:** Low employee and organization wide buy-in/support and positive attitude around transition → decreased effort to change work routines	**Tension Point:** Informal knowledge sharing networks lead to large amounts of FM knowledge being transferred through verbal, unofficial communication routines. Can lead to knowledge loss.
Tension Point: Industry wide issues of legal precedents and defined roles/processes which have been established and maintained in AEC industry (e.g. knowledge loss with handover of traditional DBB projects to operations due to established procedures)	**Tension Point:** Trust issues with technology – FM employees traditionally value and trust information gained from non-official social networks (e.g. experienced employees and their unique knowledge repository rather than tech.)	**Tension Point:** Lack of central data storage environments and data standardization and sharing procedures leads to issues with technology trust and reliability
Tension Point: Formal and traditional communication routines and team hierarchy	**Tension Point:** Inadequate training and readily available support to employees during initial technology integration stages	

With each of these tension points serving as key areas of value for investigation, we will answer our research questions within the context of these identified key issues in IoT/DT device use in UW FM operations. Our interview protocol and research design are additionally targeted to investigate these core issues and pinpoint how work needs to change around these identified tension points.

Further anticipated outcomes of this study include the following:

1. Introduction of new roles and responsibilities in terms of energy management governed by intelligent building technologies and a DT based strategy.
2. Transition from reactive to proactive maintenance of staff due to higher building intelligence leading to newly introduced practices
3. Utilization of the digital twin system as a central point to communication, increasing collaboration and changing traditional management roles
4. Increased understanding, awareness, and convenience for organizations looking to adopt a DT system/strategy in the development of DT oriented standard operating procedures.

The format of the results will be a written technical report describing a framework which maps the new "work" necessary in the transformation of facility management to utilizing digital twins/IoT based systems.

Implications:

Information technology for smart buildings and smart cities is advancing rapidly, allowing organizations to understand building and infrastructure operations in real time. These new advancements have the potential to create major impacts in the realm of sustainability. However, the abundance of data which can be collected through smart technologies such as digital twins create new tension points for organizations: namely how to properly use these technologies in order to achieve their full potential. These organizational tension points make this research critical to the advancement of digital twin implementation and facility management transformation. Prior research found that current industry implementation of digital twin technologies is nascent, undefined, and lacking standard operating procedures. It is essential to understand how work will change around the use of a digital twin system, or in other words it is critical to understand how organizational practices, processes, teams, and responsibilities must adapt to reach the organizations fullest sustainable potential. As research and development into new technologies advances, we must continuously investigate the qualitative elements which allow these technologies to operate as without understanding the people and processes supporting the technology, it cannot be used to its full potential. An understanding of how work can and should change guides both theoretical and practical research and implementation in practice. This will frame future research into how work practices can leverage digitization of operations. This will also guide professional development of building and infrastructure managers in terms of knowledge and skills needed to use digital twin technologies (e.g. data management and governance). Furthermore, this research has the potential to contribute to the larger theories of industry innovation and transformation.

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