CSF FULL PROPOSAL

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

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Executive Summary:

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 AI enabled technology. Using new technology in the old operational ways will not change energy consumption. This 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 propose to develop a framework detailing how the existing work of facility strategists and operators 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 We can not achieve sustainability goals if building operations use new building maintenance systems in old and outdated ways.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. In order to address this grand challenge and reduce our building's energy consumption, Digital Twin (DT) and intelligent building technologies are emerging as a potential solution through more sustainable building and infrastructure operations including energy management. Currently most UW facilities are managed with Building Automation Systems (BAS). 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).

While software vendors and facility owners have begun to explore the implementation of digital twin technology for energy optimization (Sin YT, Michal Touš, 2021), there are questions about how these tools will change facility operations practices. We propose to develop a framework detailing how

the existing work of facility operators will change with the implementation of a digital twin system, (e.g., fewer manual tasks, higher need for the management of automated systems, higher reliance on collaboration), and what new work will be introduced for the facility management team in terms of energy management practices (e.g. higher reliance on data analytics, introduction of tech. specialists). Our research questions 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?

To complete this research we propose a series of case studies of University of Washington campus buildings in various stages of technological integration. 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. UW facilities maintenance will provide us direct lines of communication to other UW divisions such as the Campus Sustainability and Energy, Utility, and Operations units who have also expressed interest and support in this project. This partnership will allow 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 IoT 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.

The research process will include the following steps:

1. Literature review to identify the current state of technology and practice in facility management (currently in progression, finished by summer quarter 2023)
2. Case study analysis of 3 (or more) facilities, all utilizing some form of digital twin based strategy for energy management. Our team has already identified three potential buildings/technologies which we would like to focus on as case studies 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 campus wide energy meter monitoring program, the automation window actuators for Founders Hall which are part of the smart building infrastructure, the lighting control occupancy sensors in Founders Hall and the automatic window tinting technology implemented at the 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 propose 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.

The 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.
5. Written report of research outcomes including a framework mapping the new "work" necessary in the transformation of facility management to utilizing digital twins

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. We will publish this technical report on our Center's website (cerc.be.uw.edu). We will also disseminate these findings in industry and academic journal articles and present at conferences to build awareness of the research results.

Budget and Funding information

The total adjusted amount requested for this research project based on the comments of the CSF committee and discussion in preliminary meetings with the CSF is $19,832.60. We believe this amount will be sufficient to get this project started in the summer quarter as a feasibility study. Below is a itemized budget breakdown for this research:

Research Proposal Budget	Summer Quarter		Total:
Direct Costs			
01 Salary Details			
Role: PhD, Summer Hourly 2023	**6543**	24 hours per week	
Role: MS, Summer Hourly 2023	**5664.6**	24 hours per week	
Role: PhD, TBD Fall & Winter 2023			
Salary Total:			**12207.6**
02 Benefits			
Role: PhD, Summer Hourly 2023	**1407**		
Role: MS, Summer Hourly 2023	**1218**		
Role: PhD, TBD Winter & Spring 2023			
Role: MS Student Winter & Spring 2023			
Benefits total:			**2625**
Personnel Total:			**14832.6**
03 Other Contractual Services (ex. interview transcription, publication support etc.)			**2000**
04 Travel (ex. conferences) - NIBS Building Innovation conference			**3000**
05 Student Aid			
Total Other Direct Costs			**5000**
Total Direct Costs			**19832.6**

Within the proposal budget, the salary details for both the Ph.D and Masters student researchers would be used to support full time integration into the facility management team for 24 hours/week by both researchers. We have reduced this researcher participant observation and in-person time from a full 40 hour/week to 24 hours/week in order to comply with the CSF committees' comments and request to reduce the budget to be in the $20,000 range. *03 Other Contractual Services* refers to interview transcription and data coding softwares such as Atlas.ti which will be critical to our data analysis as well as any publication fees for journal submissions etc. *04 travel* would cover potential conference presentation fees, for example the NIBS Building Innovation Conference which our team has already applied to present for in September with a focus on the results of this research study. We will also be presenting our research framework for comment and review by knowledge experts in June at the Engineering Project Organization and Management Conference (EPOC) in Berlin, Germany.

Potential other funding sources for this project outside of the CSF could come from a variety of fellowship opportunities which we have applied for and are awaiting results from.These fellowships include The Bullitt Foundation Environmental Fellowship, The Charles Koch Foundation, and the Link Foundation Modeling, Simulation, and Training Fellowship. We are awaiting response between April and June for these opportunities and are hopeful that additional funding will come from one of these resources.

Accountability & Feasibility:

Below is an itemized timeline of our research project tailored to the 2023 summer quarter feasibility study which was discussed with the CSF committee in preliminary meetings. We have spoken with UW Facility Management and have been given full approval to begin research at this stage, ensuring that our research and fieldwork will begin at the beginning of the summer quarter.

UW Academic Quarter	Activity	Time
Summer Quarter (Jun. 2023 - Sept. 2023) Project formation / prelimary case study selection	Project Formation / Kickoff	Jun. 2023
	Begin meetings with Facility Managers and University Sustainability Managers for qualitative data collection	Jun. 2023
	Focus group interviews (FGI) - - Within each case with facility managers, O&M staff, operators, technicians, and sustainability strategists	Jun. - Jul. 2023
	Participant Observation - Meetings, day-to-day operations, interactions around tech. etc.	Jun. - Jul. 2023
	Expert Interviews: Building Digital Innovation Specialists - Digital Twin Consortium - National Institute of Building Sciences	Jul. - Aug. 2023
	Data Analysis	Jul. - Aug. 2023
	Final report writing	Aug. - Sept 2023
	Conclusions and editing	Aug. - Sept 2023
	Report findings and publish	Sept. 2023

Our project team consists of the following members:

Principal Investigator: Dr. Carrie Dossick, Prof.

Principal Investigator: Daniel Dimitrov, PhD Student

Research Assistant: MS Student TBD

This research project is "shovel-ready" and we anticipate beginning research with UW Facility Management at the start of the summer quarter. We have made the connections with UW facilities teams and ensured an adequate research site through the relationship and agreement to do this research with UW Facilities and particularly Systems Engineer Cesar Escobar from the Department of Business Innovation and Technology. We are currently concluding an in depth literature review and preparing our research methodology and plan. We hope to begin observations and interviews as soon as possible on this project.

Sustainable Impact:

Buildings are some of the leading consumers of energy as they account for over 40% of the energy consumption nationwide (energy.gov). A campus as large, active and technologically developed as the University of Washington is no exception, requiring significant energy consumption to maintain its day to day operations. The UW is actively taking steps to reduce their energy consumption through the integration of advanced building energy monitoring and control technologies and has committed to taking steps towards decarbonizing the Seattle campus entirely. However, this is a monumental goal which will require major efforts campus wide, including the advancement of building technologies and operational strategies. While capital projects invest in new systems, the facilities management teams are challenged by learning to maintain and operate these systems. The UW facility and energy management teams have seen an uptick in technological adoption and integration in campus buildings and are actively trying to learn and adapt to these novel and advanced tools, recently forming a new team to manage these systems. However, we have already identified tension and hesitation from facility maintenance teams to adopt these new technologies, learn how to operate novel systems, and change the ways they have been working for decades, which leads to complications in the push for campus sustainable development. Innovation is a complex process of iteration, capacity building, and shifts in professional practices which is at the core of what our team would like to investigate.This research seeks to understand the complexities, tension points, and organizational processes which must accompany the drive toward advanced sustainability on campus buildings. The results of this research will support campus operations innovation through the identification of how facilities organizations must change to most optimally use new digital twin/IoT technologies for optimal sustainable operations.

We believe that technology alone is not enough to achieve maximum sustainability, but rather the people using and operating technologies play a pivotal role. This is why we intend to tackle the issue of technological adoption through a qualitative lens in order to get a full and realistic view into the UW facility management teams to understand what practice changes (e.g. roles, responsibilities, skills, knowledge) are necessary to support digital twin/IoT based technologies. The results of this study can then inform UW facility Management practices and accelerate the effort to increase campus wide sustainability. Our project's impact will be measured through the evaluation and feedback of the UW Facilities Management teams with whom we work and do this research. The goal is for the developed framework at the conclusion of this research to support both sustainable and organizational improvements in terms of technological integration that leads to energy savings. We additionally intend to leverage our professional network of digital innovation specialists from both the technological and organizational side

to conduct interviews and share our research findings in order to measure our impact and outcome transferability to other settings.

Education and Outreach:

With our research setting being an active university campus, we believe it is important to make the UW community aware of this project and its potential benefits to campus life. At the conclusion of this research, our team plans to widely disseminate our findings in order to share our results and contribute to the body of knowledge. We will publish our technical report on the University's Center for Research In Construction's website (cerc.be.uw.edu, https://cerc.be.uw.edu/ctop-lab/) in order to spread awareness to the UW student and faculty body. We intend to additionally publish our findings on the UW Construction Management department website in order to further spread awareness to our community and target students interested in built environment research. We also intend to publish our research findings in industry and academic journal articles and present at conferences to build awareness of the research results. We will be sharing the status of our research at the Engineering Project Organization Conference in June, 2023 and would like to present the results of this research at the National Institute of Building Sciences (NIBS) Building Innovation Conference in September, 2023. We have submitted an abstract for the conference and are excited to share the results of our research with the industry's leading group of innovators.

In reference to university community involvement and support, the UW community will be involved in this research project in multiple ways. Firstly, the development of this project and interest in studying advanced sustainable building technologies such as digital twins has led to the formation of a student study/interest group led by myself and Dr. Dossick which meets weekly to discuss research, potential opportunities, and new advancements in the field. Through this focus group we have created a community around digital twins at the university and have been able to foster student involvement in the research project itself. Discussion and information sharing through this study group has additionally opened up further opportunities for students to do other work in the field of sustainable building operations. This has led to the direct involvement of a UW Construction Management graduate student in this project as a supporting role in interviews, data collection etc throughout the summer duration of this project. With the support of the CSF, we can continue to find ways to incorporate our excited and enthusiastic undergraduate and graduate students who would like to research sustainable building technologies.

Our education goals for this project are multifaceted. Firstly, we would like to educate facility managers, operators, and technicians on an individual level on how to use the new digital twin/IoT based devices which are being integrated into UW facilities all over campus in order to maximize their potential sustainable output. This in turn may serve to educate the UW Facilities Management Department as a whole on organizational strategies, training, onboarding processes, and data management strategies for future technology adoption and transition periods. We also intend for this research to be published within relevant academic journals and then contribute to the body of knowledge within sustainability, technology, and construction related literature. Finally, through potential conference presentations we intend to spread awareness of our research to as many interested parties as we can.

Student involvement

The direct effect of this research on UW students comes from improved living and learning spaces which can be achieved through effective digital twin/IoT technology adoption and integration processes. This research will aid the facility management teams in advancing their operations and understanding of novel systems in order to use the technology at their disposal to its maximum potential. For example, our investigation into the automation window actuators in Founders Hall, the lighting control occupancy sensors in the same space, and the automatic window tinting technology in the Health Sciences Education Building will aid in improving the indoor living conditions in these heavily trafficked buildings in order to both achieve higher levels of sustainability and occupant comfort. In addition, Facility Management has informed us that misuse and lack of understanding of these technologies has caused disruptions during operating hours, which is a problem we intend to solve in order to improve student learning spaces. Tensions such as these will be addressed by this research in order to improve the everyday experiences of students actively utilizing campus spaces. This will lead to improved living and learning spaces for students, educators, and all building users. Furthermore, this research is directly aligned with University goals of becoming 100% carbon neutral which will only further garner student support and interest in sustainable community development and smart building operations.

This project will directly involve UW students through the participation of a UW graduate student in the department of Construction Management to assist in data collection, interviewing, and observations during the summer quarter of 2023. As mentioned above, the development of this research project and topic interest has led to the formation of a student research group which meets weekly to discuss research, potential opportunities, and new advancements in the field led by Dr. Dossick and Ph.D student Daniel Dimitrov. Through this student research group we have created a community around digital twins at the university and have been able to foster student involvement and interest in the field of sustainable building technologies. Our relationship with the UW Facility Management teams has also opened doors for other students in our research group to engage in studies with the Facility Management team and further support both research in the field of emerging DT/IoT technologies and the UW FM teams sustainable efforts.

Partners and Stakeholders:

Our partner for this research project is the UW Facilities Management/Maintenance Department through collaboration with Mr. Cesar Escobar from the Business Innovation and Technology Unit on campus. This project needs direct approval from Mr. Escobar and his department unit which we have gained through the CSF Project Approval and Support Form which has been signed and provided alongside this research proposal. We will be largely working with the University Facilities Maintenance and Management teams throughout their organization and have been given opportunities and direct lines of communication to other UW departments such as Sustainability and Campus Energy, Utility, and Operations. Important stakeholders for this research study include the UW Facility Management Department including the Business Innovation and Technology Unit, Campus Sustainability Unit, and Campus Energy, Utility, and Operations, as well as our partner organization lead Mr. Cesar Escobar and our research team. In addition to this, we have identified experts in the field who we would like to interview and have agreed to provide their support with this project. These experts will be leveraged to triangulate our data and ensure validity in our conclusions.