The Development of an Environmental Monitoring Dashboard for Hourigan for the Contemplative Commons Jobsite

(Technical project)

Understanding Construction Employee Responses to Wearable Technologies to Facilitate their Integration in the Construction Industry

(STS project)

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Construction is not known for being a sustainable industry, either in regards to its impact on the environment or its impact on the workforce that makes building possible. According to the Global Alliance for Buildings and Construction in its *2019 Global Report for Buildings and Construction*, the construction industry was responsible for 6% of global energy consumption (Figure 2). According to The Center for Construction Research and Training in *The Construction Chart Book* (2018), the construction industry was responsible for the largest number of worker deaths in 2015 among all industries in the United States (Figure 38a.) and workers within the construction industry were more likely to die of respiratory illnesses than their counterparts in other industries between 1992 and 2011 (Figure 51d.). Given statistics like these, it is clear that the weight of the industry's lack of engagement with and focus on sustainability is being felt by both the environment and its workforce. Combined with the industry's tendency to begin utilizing new technologies and systems slowly (Ribeirinho et al., 2020, p. 17), the question of how to improve industry practices becomes more pressing.

Part of what makes these questions related to sustainability both exciting and challenging is the consideration that environmental sustainability and taking care of the industry's workforce are not issues that can be addressed independently. Due to the interconnected nature of construction sites and activities, any action taken to address one concern will impact others. If actions are taken carefully and deliberately, there is an opportunity to create multiple benefits. For instance, if a comprehensive plan to monitor and address air quality concerns is put in place, it has the opportunity to benefit the environment surrounding the jobsite, as well as improve employee health for those working on the site every day. In contrast, an action like improper

disposal of hazardous waste, even though it could, in theory, reduce employee exposure to such waste, could have significant negative environmental impacts.

Considering the multi-facetted nature of sustainability within the construction industry, my technical project and STS project both address and attempt to create tools to increase sustainability. My technical project involves the creation of an environmental monitoring dashboard for a construction site, designed to allow a general contractor to better understand how construction activities and conditions affect air quality and sound levels in and around the site. My STS project explores resistance to the introduction of wearable technologies like smartwatches among the construction workforce, despite the potential safety and well-being benefits these devices could provide. While these projects are being conducted largely separately and address very different aspects of the construction industry, for the reasons I shared above, the solutions I develop for one could contribute to improvements in the other. For instance, Awolusi, Marks, and Hallowell identify examples of wearable technologies capable of measuring sound levels (2018, p. 100), an environmental factor. Ultimately, the goal of both projects is to contribute to the development of a more sustainable future for the construction industry, both in the human and environmental contexts.

Technical Topic

My technical project involves the creation of an environmental monitoring dashboard for Hourigan. Hourigan is a general contractor with a history of "strategically partnering with higher education institutions due to the institutions' ability to recognize industry leading technology and processes that add value and drive overall success for projects" ("Market: Education", 2022) and is in the process of constructing the Contemplative Commons on the Grounds of the University

of Virginia (UVa). The goal of our project is to help Hourigan better understand their environmental impacts, both immediately on site and in the surrounding areas. This understanding is particularly relevant for Hourigan in this context because, according to the Project Executive Ryan Byrd in a conversation we had during our initial site visit, Hourigan's focus on erosion and sediment control and limiting environmental impacts contributed significantly to their success in winning the job due to the proximity of the site to the Dell pond (R. Byrd, personal communication, September 27, 2022) (see Figure 1.).

Figure 1. The Dell pond and the Contemplative Commons Construction Site. From "University of Virginia Breaks Ground on Contemplative Commons", by A. E. Bromley, 2021, *UVAToday*.

According the UVa department of Environmental Resources, "[a] restored stream… flows into the Dell pond where natural physical, biological, [and] chemical processes improve the quality of the water" ("The Dell", 2022), meaning protecting the Dell pond is of high importance to UVa.

My team will develop a dashboard by installing sensors designed to measure PM10 levels and noise levels (see Figure 2. for example) around the site and in areas adjacent to the site

including in a nearby parking garage adjacent to a nearby building. Figures 3. and 4. show the locations of on-site sensors on annotated plan sheets.

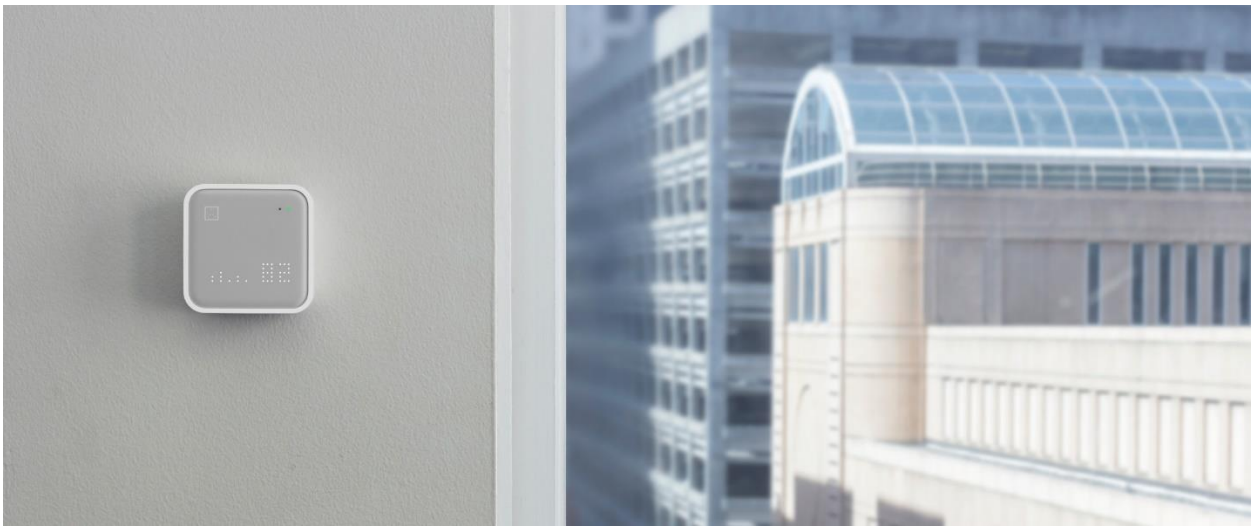

Figure 2. An image of the sensors available to my team through our advisor. From *Awair Omni*, 2022, Awair.

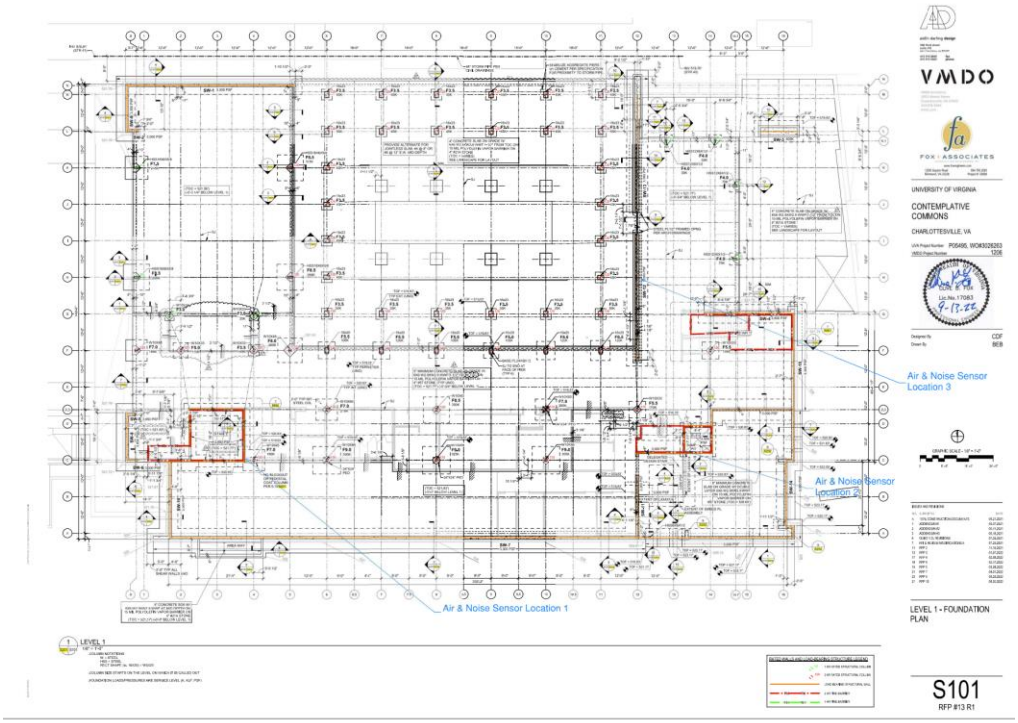

Figure 3. Sensor locations on level 1 of site (Repak, A. & Naddoni, R., 2022)

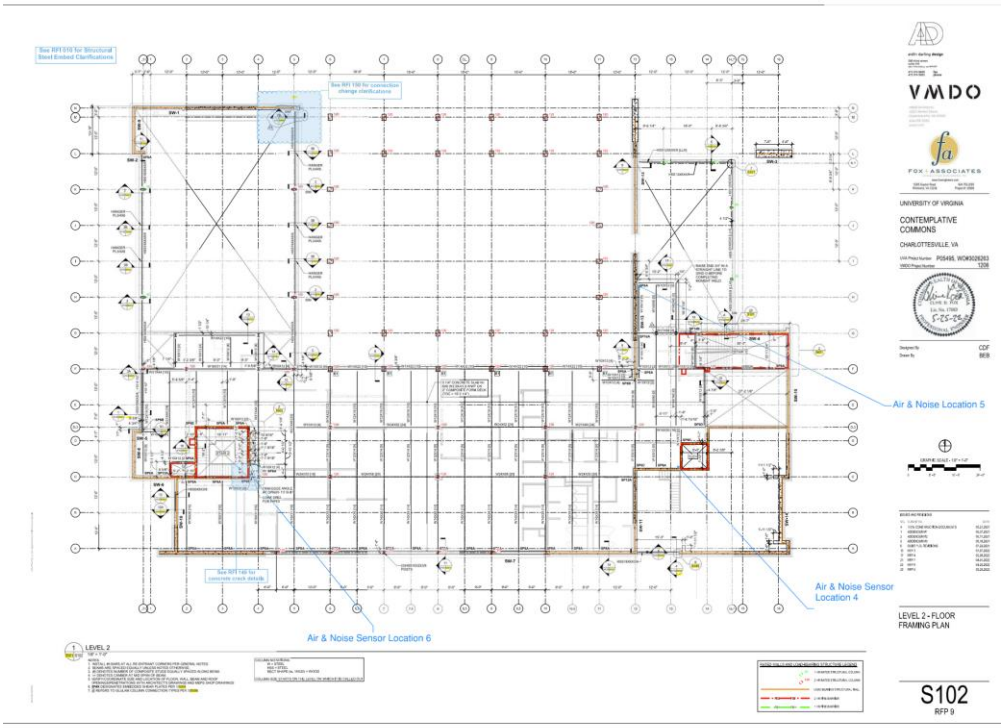

Figure 4. Sensor locations on level 2 of site (Repak, A. & Naddoni, R., 2022)

We will plug the sensors into temporary power stations on site (see Figure 5. for example) and permanent power outlets where available.

Figure 5. Temporary power station is shown in left side of image (Repak, A., Hussain, A. et al., 2022)

Ultimately, the goal would be to link each sensor to an online dashboard that can be accessed by the Hourigan project team. My team will provide a UI design for this dashboard, but will likely not provide a functioning dashboard.

My team also intends to conduct interviews related to worker response to wearable technologies and hopes to compare environmental data collected through the sensors to various activities conducted on site to determine if correlations can be found. We will also conduct a stormwater monitoring study comparing turbidity levels at various locations in the Dell pond system using Decentlab optical turbidity and temperature sensors (see Figure 6. For example).

Figure 6. An image of the sensor my team will use to detect turbidity in the Dell pond system. From *Optical Turbidity and Temperature Sensor for LoRaWAN®*, 2022, Decentlab.

By conducting this comparison, we hope to be able to identify if there are significant sediment discharges from the site during rain events or particular construction activities.

This project relates to my overall work's focus on sustainability because it creates opportunity for Hourigan to identify areas of work in which their construction methods would benefit from more sustainable practices. Though it might not directly create more sustainable practices, the information we provide could lay the groundwork for future sustainable improvements.

STS Topic

My STS project focuses on another aspect of sustainability relevant to the construction industry: employee safety, health, and well-being. With the development of wearable technologies like smart watches, it is becoming increasingly clear that there is the potential to use such devices to create more sustainable work environments. In a 2017 paper, Lee et al. argue specifically that, "by leveraging wearable sensors and regularly obtaining data at the individual level, we could eventually explain how effectively and positively a worker's physiological reactions can change [their] job demands as well as safety and productivity performances" (p. 351). However, for these technologies to be effective, they must be trusted, accepted, and utilized by employees. Choi et al. studied various factors and how they might impact the likelihood of a worker to utilize a piece of wearable technology and found assumptions related to whether a technology would help the worker complete tasks, potential impacts to an individual's privacy, and how an individual's peers react to a technology all impact how an individual reacts to a piece of technology, but noted "additional studies are needed to investigate external variables… (e.g., organizational support for social influence, training for perceived ease of use, etc.)" (2017, p. 40). My STS project will seek to better understand these "external variables", specifically how existing and historical relationships between workers and the companies that

employ them affect how employees respond to the introduction of data-collecting wearable technologies.

Karen Levy's previous work in the trucking industry provides an STS framework for this project. In the 2015 paper "The Contexts of Control: Information, Power, and Truck-Driving Work", Levy argues that the introduction of monitoring technologies to the trucking industry has removed a level of independence previously enjoyed and utilized by truck drivers over the course of their work and is actively reshaping the work place. Similar trends can likely be found in the construction industries early adoption of wearable technologies. In another 2016 paper, Levy argues that, due to the masculine culture of the trucking industry, there is a particular resistance to the introduction of surveillance technology, because it directly impacts and limits that masculine culture. Considering the construction workforce in 2019 was made up of 90.8% male workers ("Construction Statistics", 2018), similar connections could likely also be made in the construction context.

There is however a significant difference between the tracking technologies used in the trucking industry studied by Levy and the wearable devices slowly being introduced in the construction industry: as shown by Okpala et al. using their success model, wearable devices have the potential to provide benefits to construction workers related to improved safety and health (2021), in a way tracking technologies do not for truckers. These potential benefits mean there is an opportunity to gain support for wearable devices among the construction workforce by sharing their benefits and creating a system for ethical implementation that does not exist in the trucking industry.

Research Question and Methods

I intend to address this topic using the research question: Why are construction workers so suspicious of wearable technologies? Given the potential challenges of introducing wearable technologies into the construction industry, one might question if it is a worthwhile goal. In their 2018 paper, Awolusi et al. describe why the introduction if this technology is important, noting "it is time construction stakeholders and professionals strongly embrace these emerging trends in technological development to drastically enhance safety performance" (Awolusi et al., 2018, p. 104). This STS project could inform how to make this transition possible.

I will analyze this topic through a literature review. First, I will develop a deep understanding of the current state of the implementation of wearable technologies in the construction industry using a combination of research papers and industry texts as available. This preliminary research has begun and was presented in the STS Topic section of this paper. Second, I will research using similar methods how other worker management systems have been implemented in the construction industry and draw parallels between these implementation processes and worker responses to those processes and Levy's work related to the trucking industry. Finally, I will research the history of construction labor, specifically labor movements and conflicts, using a combination of research papers, secondary historical sources, and primary historical sources like speeches if possible. This research will allow me to develop a better understanding of why employees react to certain technologies the way they do.

Conclusion

My technical and STS projects hope to address the issue of sustainability in the construction industry, both from the environmental and human perspectives. Given that, according to a Marsh & GuyCarpenter and Oxford Economics report published in 2021, it is

thought the construction industry will be worth $15.2 trillion by 2030 (p. 5) and according to the U.S. Bureau of Labor Statistics, between 2021 and 2031 a growth of 4% is expected in the construction and extraction industry workforces (“Construction and Extraction Occupations”, 2022), the impact of creating sustainable practices in the industry will only increase in the future. While the results of this work will not necessarily solve either aspect of sustainability the research addresses, it will create a deeper understanding of the issues which could support the creation of specific solutions in the future.

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