IMPLEMENTING MOTION SENSORS FOR AUTOMATED WINDOW BLINDS WAND DEVICE

COMPARATIVE ANALYSIS OF LIGHT EXPOSURE ON WORKING INDOORS VERSUS WORKING OUTDOORS

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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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From 2009 to 2019, the world's energy consumption has increased by more than 100 exajoules, which is one quintillion or ten to the power of eighteen joules, according to a statistical review of world energy by British Petroleum (2020) with oil, gas, and coal making up about 84.3% of the energy consumed in 2019 (p. 8). The desire for renewable technology and sustainable methods has become more prevalent in order to reduce the reliance on nonrenewable energy sources which contribute to rising carbon dioxide emissions. One strategy that can be implemented to conserve energy is the automation of window blinds within homes.

Various innovations have been made to improve or replace the window blinds through automation to provide more sunlight and lessen the dependence on artificial light sources to reduce energy consumption. Furthermore, the natural sunlight controlled by the window blinds is revealed to be correlated to better mental health and productivity which could lower overall stress (An, Colarelli, O'Brien, and Boyajian, 2016). Despite these sustainable, healthy options providing a hands-free solution for managing sunlight, they require customers to install their product, an additional labor fee for others to prepare the product, or trivialize the supplementary role of window blinds: maintaining privacy. With the recent pandemic forcing individuals to stay home and rising levels of apprehension, home privacy becomes the forefront feature of the window blinds (Chakraborty et al., 2020; Gerke, Shachar, Chai, and Cohen, 2020). Furthermore, the complications of self-installing an unfamiliar device and further costs are unnecessary additions to stress that nullify the positive mental aspects of natural lighting. Thus, the technical research will demonstrate an energy-conserving product suitable for the contemporary environment that addresses the pitfalls of previous designs. The loosely coupled STS research will analyze the natural light levels and their associated effects on indoor workers compared to that of outdoor workers. The Gantt chart shown in Figure 1 displays the start and completion dates of the work needed for the technical research and STS research.

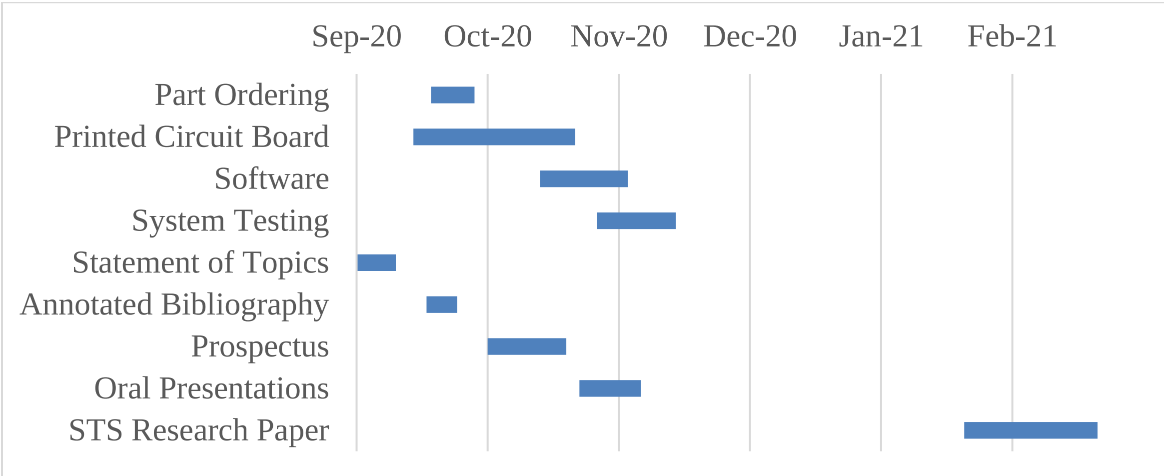

Figure 1: Gantt Chart: The graph displays the duration of the technical deliverables which are the first four tasks. The last five tasks shown are the STS deliverables. (Chan, 2020a).

IMPLEMENTING MOTION SENSORS FOR AUTOMATED WINDOW BLINDS WAND DEVICE

Due to the coronavirus, many individuals are experiencing high levels of anxiety (Chakraborty et al., 2020). Students and employees are forced to remain indoors to conduct their daily activities online which could increase the stress they already had from their school or occupation as well as raise privacy concerns for confidential work. However, An et al. (2016) from Central Michigan University and Hong Kong Baptist University note that "Exposure to natural elements (e.g., green spaces) can reduce the impact of stress . . . increase psychological well-being . . . and support recovery from illness" (p. 2). Thus, the technical project aims to reduce stress and preserve home privacy through self-regulating window blinds to provide optimal natural light exposure along with automated privacy.

Numerous papers and patents detail varying methods of either removing or improving window blinds. One joint study conducted by the California Polytechnic State University and

University of Brawijaya created a hardware prototype of window blinds that adjusted the wand based on photoresistors measuring the light intensity (Taufik & Hasanah, 2018, p. 2). Another study conducted by Karmakar and Chattopadhyay (2017) at the Federation University Australia recommended adding extensions such as exterior blinds, an exterior awning, and an interior curtain to better adapt for saving energy each season by reducing heat gain and cooling loss (p. 1). Alghamdi and Almawgani (2019) at Najran University suggested the approach of replacing the glass of windows for Polymer Dispersed Liquid Crystal (PDLC) glass which has the ability to change between transparent and opaque based on sunlight levels (p. 1). On the commercial side, the company Tilt patented their product known as MySmartBlinds which is a solar-powered window blinds hardware that is connected to Bluetooth and has a temperature sensor (U.S. Patent No. 10,458,179, 2019). Another patent describes a solar-powered window shade system that lowers and raises the window shade based on temperature and sunlight levels (U.S. Patent No. 7,389,806, 2008). Prior studies and products have not demonstrated an energy-conserving product that offers automated privacy as well as a straightforward design suitable for the contemporary environment.

The objective of the technical project is to present a system that simplifies the installation process for automated window blinds technology and maintains homeowner confidentiality while conserving energy. The proposed system is made up of a microcontroller unit that is connected to four subsystems: sensing, actuation, communication, and power. The sensing subsystem consists of ambient light and motion sensing. The user will be able to select their desired levels of illuminance from the sun and the light sensor will determine if the current light intensity accommodates the user's preferences and adjust accordingly if not. The motion sensor will detect suspicious trespassers outside of the house and send a signal to the actuation subsystem. The actuation subsystem contains the motor driver, stepper motor, and encoder. The motor driver will be a Darlington transistor array that controls the stepper motor by rotating the motor clockwise or counterclockwise to regulate the blinds by connecting to the tilting mechanism, while the encoder avoids mechanical failure of the blinds by tracking the current tilt. The communication subsystem is separated into the physical device and the mobile application. To configure the system, physical buttons will be available for the user while the mobile application will enable remote control and calibration of the system through wireless connection. The power subsystem comprises a wall adapter, barrel jack, and regulators which will supply the necessary power for the other subsystems. The aforementioned subsystems and microcontroller unit are displayed in Figure 2.

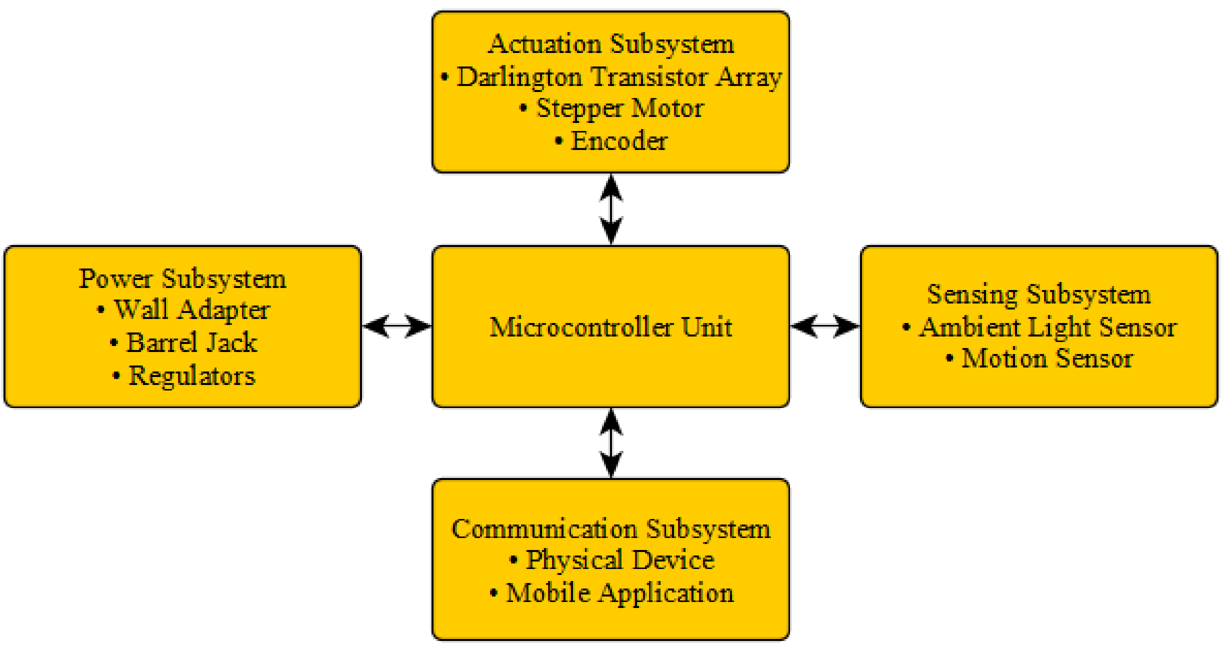

Figure 2: Block Diagram: The diagram presents the four subsystems listed with their specific parts connected to the microcontroller unit. (Chan, 2020b).

The technical project will be constructed and tested with Computer Engineers Edward Agyeman, Kwadwo Tenkorang, and Mesgana Dinare using a $500 budget in the Electrical and

Computer Engineering Capstone Design course instructed by Harry Powell of the Electrical and Computer Engineering Department. The project will consist of producing a printed circuit board (PCB) for the microcontroller and integrating the sensor and motor components to the overall system. For the motion sensor component, a pyroelectric infrared sensor will be used as these types of sensors “are perfectly matched for motion detection applications due to their small size, low cost, and low power consumption” and “are mostly used as occupancy detectors” (Gami, 2017, p.1). Testing for the correct operation of the board will be conducted with a National Instruments VirtualBench in the National Instruments Engineering Discovery Laboratory. The technical project along with the technical report should be completed by the end of the Fall 2020 semester since the course lasts for only one semester.

When the technical project is completed, the expected result is to accentuate the significance of maintaining physical privacy as the technical project is just one adaptive method for the current environment. A scholarly article will be written and will contain the research, function, and design of the technical project. The processes necessary to construct the technical project have been taught in previous courses in order to guarantee its successful completion.

COMPARATIVE ANALYSIS OF LIGHT EXPOSURE ON WORKING INDOORS VERSUS WORKING OUTDOORS

A prodigious number of employees must remain at home due to the recent pandemic. This shift in daily activities from going outside to staying indoors all day closely resembles a house arrest which could prove to be extremely stressful. A potential factor that contributes to this rising pressure could be a lack of nature, specifically sunlight as Dumont and Beaulieu (2007) from the University of Montreal asserted that “Light exposure has . . . shown to be a factor in the maintenance of optimal mental health" (p. 559). Dumont and Beaulieu (2007) also noted an analysis regarding the natural light exposure for day workers:

> For people working at least 8 h a day, about half of the time awake is spent at work. Light exposure is, therefore, largely determined by light levels in the work environment . . . Many indoor workers having little access to natural light complain of . . . sleep disorders, fatigue, lack of concentration and depressed mood. (p. 560).

This topic is further explored as another study done by Tefft (2012) from the Department of Economics at Bates College examines how the index of darkness, which is the daily hours of no sunlight, is correlated to seasonal affective disorder (SAD) and health-related quality of life (HRQOL) as "adverse mental health outcomes . . . [are] associated with (a) more hours of darkness and (b) worsening employment status" (p. 253). Furthermore, the New York Times details how the sleep patterns of children have changed due to "less outdoor activities, less face-to-face interpersonal communications and even less sunlight" which negatively affects mood and could also be applied to adults (Klass, 2020). In 2016, An et al. analyzed the effects of sunlight on employees and found that "Exposure to natural elements is associated with decreased levels of diastolic blood pressure, depression, and anxiety . . . and increased attentional capacity" (p. 2). Thus, the amount of natural light exposure holds a significant role in the productivity and mental health of employees.

AN UNCLEAR DECISION BETWEEN INDOOR WORK AND OUTDOOR WORK

The complication of the problem arises when determining whether employees should work outside or inside. Measurements on the amount of light exposure indoor and outdoor employees received were conducted by Aarhus University Hospital, Aalborg University, Bispebjerg Hospital, and University of Copenhagen which revealed,

> indoor workers were exposed to light intensities during daylight hours that may reduce general well-being and mood, especially during winter. Outdoor workers were during summer daylight hours exposed to light levels comparable to those used for the treatment of depression. (Daugaard et al., 2019, p. 663)

Despite the results implying that working outdoors would be the superior solution for the well-being of employees, Hahn et al. (2011) from the University of Copenhagen and various hospitals discovered that outdoor work "has a gainful effect on mood but not on depression" (p. 448). However, there are two important considerations on these two studies that must be noted. First, Daugaard et al. and Hahn et al. have a few similar origins, specifically in authors, Aarhus University Hospital, University of Copenhagen, and Denmark which suggests a conflict in data. Second, the research by Daugaard et al. was published eight years later than the research by Hahn et al. which could indicate new data has proven the ability of natural light exposure from outdoor work to assist in curing depression and addresses the conflict mentioned previously.

There have also been studies that recommend improvements to indoor conditions. One popular example is the implementation of high-performance green buildings (HPGBs) which have "environmental design features such as . . . natural ventilation, access to sunlight, and use of non-toxic materials" (Dreyer, Coulombe, Whitney, Riemer, and Labbé, 2018, p. 2). Dreyer et al. (2018) concluded in their research that the "benefits of nature-based experiences can extend to real-life indoor environmental features of green buildings" and "employees' satisfaction with their indoor environmental features is a crucial factor that may impact their wellbeing" (p. 13). Therefore, while outdoor work has more sunlight exposure, indoor work within HPGBs has the potential to replicate the outside environment, yet not enough comparative research has been made to determine a clear victor.

ENGINEERS AND MANAGERS AS THE DECISION MAKERS

Engineers build the foundation toward their preferred stakeholders. These relevant social groups involved as well as their interactions can be analyzed through a social construction framework from the *STS Frameworks* handout as displayed in Figure 3 (Carlson, 2009, p. 4).

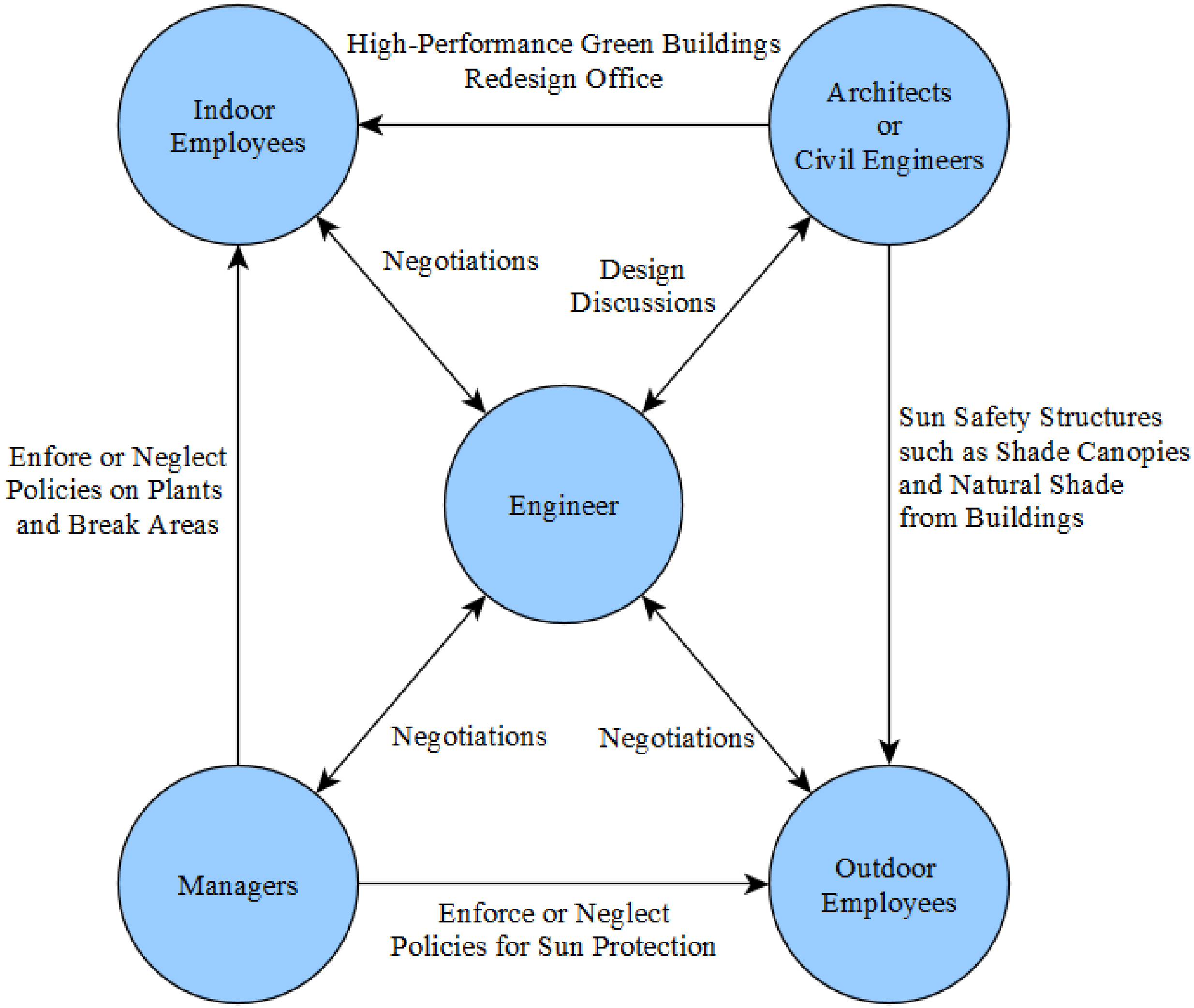

Figure 3: Engineer Social Construction Framework: The centered engineer must communicate with managers, indoor employees, and outdoor employees to come to a final decision with the architect or civil engineer for designing toward indoor workers or outdoor workers. (Adapted by Brandon Chan (2020c) from Bernard Carlson 2009).

The placement of engineers reveals their central role of deciding to cater toward either indoor workers or outdoor workers. After gathering input from managers, indoor workers, and outdoor workers, engineers will discuss potential designs with architects or civil engineers to determine and eventually build structures that favor one of the two concerned groups. HPGBs and office redesigns are advantageous for indoor employees while buildings that offer natural shade and shade canopies are beneficial for outdoor employees. However, the role of managers should not be understated as they hold the ability to either enforce or neglect policies that can use or limit the full potential of the aforementioned structures. In order to understand their authority, the distinction between direct sunlight and indirect sunlight as well as their associated effects must be explained first. Direct sunlight is defined as “sunlight exposure while outside without any interference” which “stimulates vitamin D synthesis” and indirect sunlight is defined as “refracted sunlight, which could be, for example, sunlight exposure through windows” (An et al., 2016, p. 3-4). For indoor employees, the manager can lower the exposure to natural elements by restricting outside access for breaks or reducing the number of plants around the office. For outdoor workers, the manager can provide “personal protection resources such as sunscreen, protective clothing, hats, or eyewear to employees” to prevent skin cancer, but “sun safety is a lower priority than other safety issues” and “training and resources for sun safety at a reasonable cost may not be widely available” according to research funded by the United States National Cancer Institute (Buller et al., 2020, p. 9).

Indoor workers can be further understood by examining their main problem: a lack of sunlight exposure. Specifically, in a survey with more than 1,600 North American employees published by the Harvard Business Review,

> Over a third of employees feel that they don’t get enough natural light in their workspace. 47% of employees admit they feel tired or very tired from the absence of natural light or a window at their office, and 43% report feeling gloomy because of the lack of light (Meister, 2018, para. 3).

This problem can be visualized using Pinch and Bijker's (1987) Social Construction of Technology (SCOT) model to view current solutions to the problem as shown in Figure 4 (p. 120).

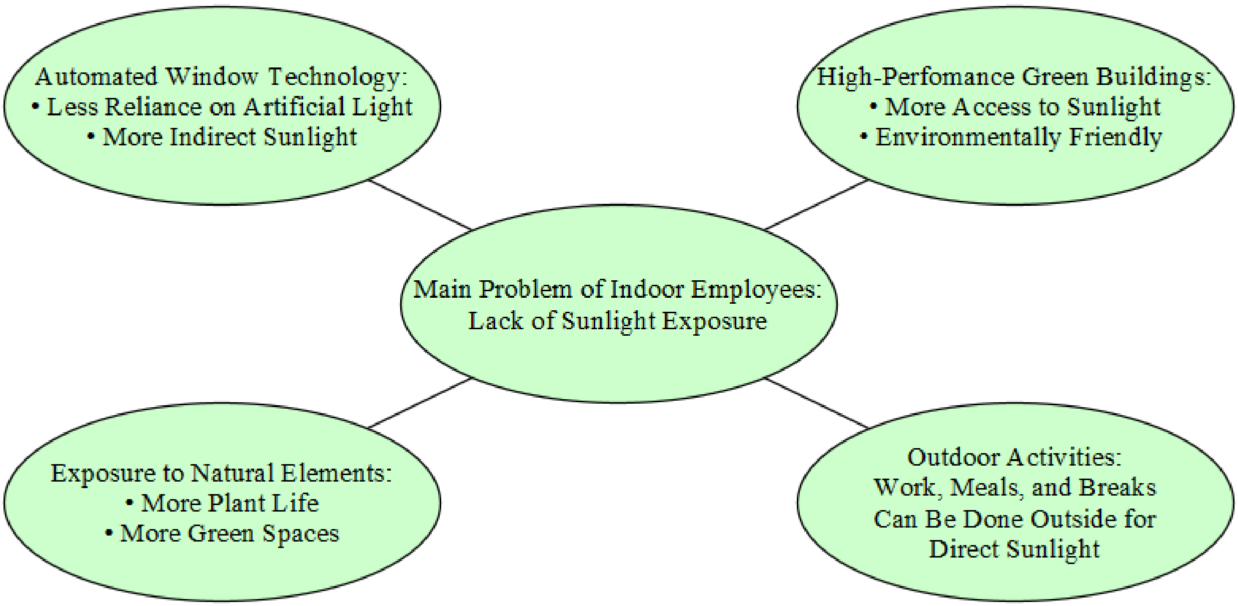

Figure 4: Main Problem of Indoor Employees: A lack of sunlight exposure is what differentiates indoor employees from outdoor employees. Four potential solutions are proposed: automated window technology, high-performance green buildings, exposure to natural elements, and outdoor activities. (Adapted by Brandon Chan (2020d) from Trevor Pinch and Wiebe Bijker 1987).

Four distinct solutions aim to either increase the levels of sunlight or make up for the lack of sunlight. Automated window technology can reduce the reliance of artificial light, and therefore allow for more indirect sunlight which is "negatively associated with depressed mood" (An et al., 2016, p. 12). Another solution is high-performance green buildings which aim to improve the well-being of employees with more access to sunlight (Dreyer et al., 2018, p. 2). Although sunlight has "a more powerful effect than natural elements," it has been found that "greater levels of natural elements exposure were associated with lower depressed mood and higher job satisfaction and organizational commitment" (An et al., 2016, p. 10). Thus, an increase in plants and green spaces through office redesigns could imitate the mental effects of sunlight. Finally, indoor employees, with the permission of managers, can choose to complete work, eat lunch, or enjoy breaks outside for direct sunlight exposure.

The anticipated outcome will be to enable managers and employees to come to an agreement on working either indoors or outdoors by providing awareness on the numerous concerns and improvements of both options. The STS research project will be written as a scholarly article that will determine the superior choice between working indoors and working outdoors through a comparative analysis.

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