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Optimizing Workplace Productivity and Health Through Improved Lighting: A Case Study

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Abstract

This study investigates the influence of lighting conditions on employee performance and well-being in the timber industry. Through a review of existing literature and empirical analysis, the research explores whether enhanced lighting can improve productivity, reduce fatigue, and promote overall health. The findings indicate that optimal lighting, particularly daylight-like illumination, significantly enhances worker efficiency and comfort while also mitigating issues related to mold and mildew. Additionally, exposure to natural light provides psychological benefits that contribute to increased safety and well-being. To implement these improvements, the study recommends installing additional lighting or skylights in key work areas. These enhancements are expected to foster a healthier and more productive work environment. The research underscores the essential role of proper lighting in supporting employee performance and workplace satisfaction.

Keywords
Workplace Lighting, Employee Productivity, Occupational Health, Timber Industry, Natural Illumination.

1. Introduction
This study focuses on the role of environmental factors, particularly lighting conditions, in shaping employee performance and well-being within the timber industry. The industry has long been recognized for its commitment to sustainable practices, innovation, and operational excellence. As companies continue to prioritize environmental stewardship, it becomes increasingly important to understand how various factors, such as lighting, influence work

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efficiency. Research has shown that the physical work environment can significantly impact employee performance, engagement, and overall job satisfaction. For instance, optimal lighting levels not only improve comfort and reduce fatigue but also enhance focus and stimulate creativity. This study investigates how specific environmental factors, particularly lighting, affect employee efficiency. The insights gained will help guide management in optimizing the work environment, ultimately contributing to the success of operations.

1.1 Objectives

The primary objective of this study is to assess the impact of environmental factors—specifically humidity levels, lighting conditions, and sound levels—on work efficiency within the timber industry. The specific aims are as follows:

- To determine the optimal lighting intensity for maximizing work efficiency.
- To analyze the effects of different types of lighting (natural versus artificial) on employee focus, mood, and productivity.
- To provide recommendations for optimizing the work environment to enhance employee performance and overall operational effectiveness.

2. Literature Review

2.1 Environmental Factors, Humidity, and Employee Performance

Research has established that environmental factors, such as temperature and humidity, significantly influence employee performance and workplace comfort. Studies indicate that maintaining optimal humidity levels enhances worker comfort and minimizes fatigue. Optimal performance has been found to occur when workplace temperature ranges between 72 and 75 degrees Fahrenheit, while humidity should be maintained between 40% and 60%.

Wolkoff *et al.* (2021) examined the relationship between indoor temperature, air humidity, ventilation, and employee performance, highlighting that improper environmental conditions could compromise health and productivity. Their findings underscore that physiological responses are strongly linked to maintaining suitable indoor environmental factors for workers' well-being. Before them, Tsutsumi *et al.* (2007) corroborated these findings by demonstrating how changes in humidity from warm and humid environments impact human comfort and productivity. Their study highlights the physiological effects of temperature and humidity shifts, emphasizing the importance of maintaining steady environmental ranges to reduce strain and enhance performance outcomes.

2.2 The Role of Lighting on Worker Performance

Lighting in workspaces is another critical environmental factor influencing employee productivity and mental health. The quality, type, and adjustment of lighting levels can impact workers' performance through psychological mechanisms, such as mood and alertness. The studies reviewed identify that both artificial and natural lighting affect mood, attention, and overall productivity.

Juslén and Tenner (2005) explore the mechanisms by which changing lighting in industrial settings impacts employee performance. Their findings highlight that workers' psychological responses are shaped by variations in lighting, emphasizing the interrelation between lighting adjustments and cognitive functioning. Similarly, Konstantzos *et al.* (2020) provide a comprehensive review that establishes the connection between lighting environments and task performance, showing that light can either support focus or hinder mental clarity depending on its intensity, color, and quality. Natural lighting also plays a vital role. Studies suggest that exposure to natural light can enhance mood, reduce stress, and promote mental alertness while lowering the risk of physical illness. Shishegar and Boubekri (2016) analyzed the effects of daylight exposure on mood and productivity, finding that natural light minimizes depression and stress while enhancing workers' general health.

Aryani *et al.* (2020) emphasize that the intensity, type, and color of artificial lighting also impact employee mood. They report that workers exposed to brighter artificial lighting for brief periods, such as 21 minutes, exhibit mood boosts and improved alertness. This supports the idea that proper lighting can act as an intervention to combat fatigue and promote engagement during long working periods. Furthermore, lighting safety is crucial. Łakomy (2023) highlights risks associated with both insufficient and excessive lighting in industrial workplaces. Dim lighting can lead to vision strain and hazards by obscuring potential risks, while overly bright lighting can lead to fatigue and reduced attentiveness. Both extremes increase the probability of accidents, making proper regulation of lighting essential for worker safety.

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2.3 Natural Light and Mental Health

Natural light has been proven to have profound effects on employee mental health. Studies indicate that access to natural light improves mood, reduces symptoms of depression, and enhances mental alertness among workers. Van Bommel (2006) explored the non-visual biological effects of lighting, emphasizing the connection between light exposure and workers' mental well-being. Van Bommel’s research highlights how exposure to natural daylight supports workers' psychological needs, reduces stress levels, and enhances their ability to focus. This study reinforces the importance of designing workplaces with access to natural light as part of a comprehensive approach to worker wellness and productivity.

3. Methods

This study focuses on assessing the environmental conditions at workstations, specifically lighting and temperature, to evaluate their impact on employee performance. To gather the necessary data, we measured the illumination levels and temperature at various workstations using an MT-912 light meter (see Figure 1). The measurements were recorded in foot-candles (lumens per square foot) for light intensity and in Celsius for temperature. The data collected were subsequently entered into an Excel file for analysis, where graphs were created to visually represent the variations in lighting and temperature across the workstations. These findings are presented in the Chart and Data section of this report.

Figure 1. MT-912 light meter collecting data

The measurements were taken during a guided tour of the facility by a trained employee. At each workstation, we placed the MT-912 light meter at the location where employees' eyes would typically focus while operating machinery or performing manual tasks. This approach provided a reliable baseline for measuring the lighting at each workstation. Along with light measurements, we also recorded the temperature at each workstation. Most workstations were lit by artificial lighting, which allowed for consistent control of lighting variables. However, a few areas received natural light, which was factored into the analysis as well.Temperature variations in the plant were considered, as the facility is open, and outdoor temperatures influence the indoor climate. For instance, readings taken earlier in the morning reflected cooler conditions, while later measurements showed an increase in temperature due to the rising outdoor temperatures. These temperature fluctuations were cross-referenced with the external weather conditions to ensure accurate data interpretation.

The results were visually represented on a map, highlighting areas with lower lighting levels. This map serves as a tool for identifying "dark spots" within the facility. Using this map we can determine where additional light sources, either natural or artificial, should be installed to improve lighting conditions. Furthermore, we calculated the total cost of installing artificial lighting and skylights to meet the optimal lighting range of 30-50 foot-candles for maximum work efficiency. The details of these calculations are provided in the next section.

4. Data Collection

The average illumination level at the workstations is measured at 28 foot-candles. While this is not an unacceptable value, it leaves room for improvement. It is important to note that the average is not always the most reliable indicator in this type of research, as individual workstation readings can vary significantly, ranging from 2 to 80 foot-candles. Such variability is expected in this environment, as perfect consistency is difficult to achieve. For this study, we have established an optimal lighting range of 30 to 50 foot-candles as our standard. Given this, there is clearly an opportunity to improve the consistency of artificial lighting across the plant. It is also important to note that these measurements are specific to the workstations and do not account for lighting conditions in other areas of the plant, which may be brighter or darker due to different lighting arrangements or the absence of adequate lighting. Figure 2 shows an illustration of the illuminance at different locations on the production line.

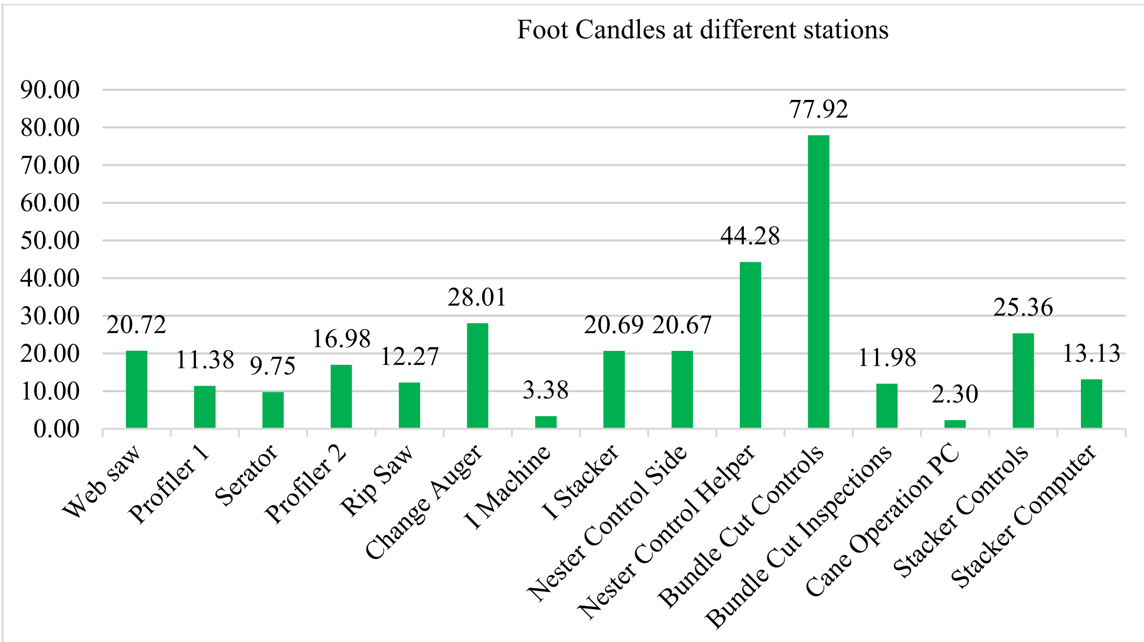

Figure 2. An illustration of the illuminance at different locations on the production line

We also collected the illuminance of natural sunlight to justify the utilization of skylight as an alternative to artificial lighting. Figure 3 illustrates that natural sunlight provides sufficient illumination for most major portions of a workday, particularly between mid-morning and mid-afternoon. Outside this window, especially in the early morning and late afternoon, sunlight alone does not meet the minimum required lighting level of 5,000 foot-candles. While some days, like March 6 and March 13, offer strong, sustained light, variability due to date and weather conditions highlights the need for supplemental artificial lighting to ensure consistent and safe visibility across the entire workday.

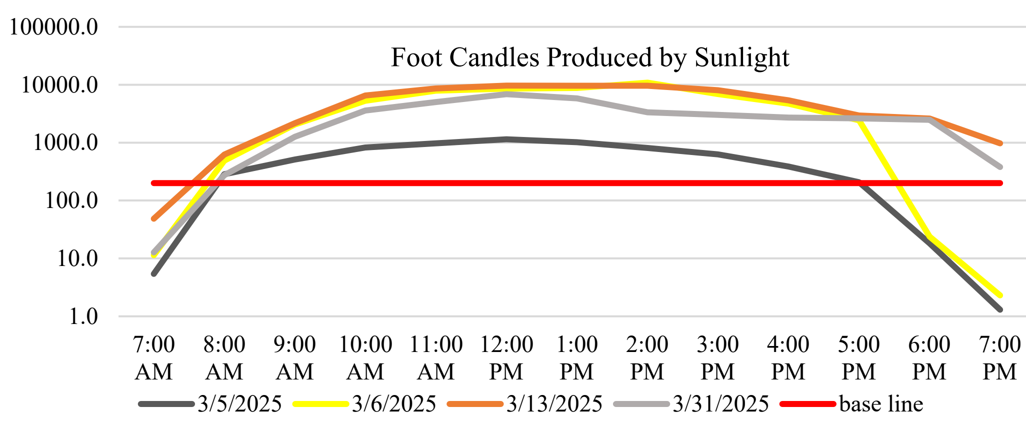

Figure 3. Illuminance produced by the sun on different dates

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5. Results and Discussion

The lighting assessment [shown in Figure 2] reveals considerable variation in illumination levels across workstations, with the majority falling below the recommended range of 30–50 foot-candles. Several key areas exhibit insufficient lighting, which can negatively impact visibility, precision, and overall safety. Only two stations meet the optimal lighting standard. These results underscore the need for a more uniform lighting approach throughout the facility. Addressing the deficiencies—particularly in the dimmest areas—will help improve working conditions, reduce eye strain and fatigue, and support greater efficiency. Potential solutions include installing additional artificial lighting or integrating natural light through skylights to ensure consistent and adequate illumination.In this section, we compare the costs and benefits of installing artificial lighting versus skylights to achieve the optimal illumination range of 30–50 foot-candles, which supports maximum worker efficiency at the production line.

5.1 Artificial Lighting Cost Analysis

For the artificial lighting installation, we focused on 12 operator stations, each approximately 10 feet by 10 feet with an 8-foot height. To achieve 50 foot-candles of illumination at each station, 5,000 lumens are needed. The selected fixture is a 4ft LED strip light with a capacity of 5,853 lumens per fixture.

- Cost per fixture: $65
- Cost of installation per fixture: $150
- Total cost for 12 stations:
    - Fixtures: 12 × $65 = $780
    - Installation: 12 × $150 = $1,800
    - Grand Total: $780 + $1,800 = $2,580

Thus, the total cost for installing artificial lighting at 12 operator stations is $2,580. This includes all fixtures and installation costs necessary to bring the lighting within the optimal range of 30–50 foot-candles.

5.2 Skylight Cost Analysis

To compare the skylight installation costs, we determined the number of skylights required to cover the 22,048 square feet of the production line, with a 31-foot ceiling height. Each skylight is a 4 ft × 8 ft Velux Dynamic Dome [Figure 4] with a 60° light spread.

Figure 4. The Velux Dynamic Dome

- Skylight size: 4 ft × 8 ft
- Ceiling height: 31 feet
- Light spread angle: 60° total (±30° from vertical)
- Projected area per skylight: 39.78 ft × 43.78 ft ≈ 1,742.5 ft²
- Number of skylights required: 22,048 ft² ÷ 1,742.5 ft² ≈ 13 skylights

Based on the projected coverage area per skylight, a total of 13 skylights is needed to illuminate the entire production line area. The material cost for each skylight is $1,400, while the labor cost for installation is $700 per unit. The combined cost for both materials and labor for all 13 skylights amounts to $27,300. This figure represents the total cost to install the skylights and achieve the desired lighting conditions within the facility.

5.3 Comparison Analysis: Artificial Lighting vs. Skylight Installation

While artificial lighting installation is significantly cheaper at $2,580 for 12 stations, skylights offer a more sustainable and natural lighting solution but come at a considerably higher cost of $27,300 for 13 units. The artificial lighting solution has the immediate advantage of lower cost, but skylights, though more expensive, can provide long-term benefits such as reduced energy consumption and a healthier work environment by utilizing natural light. Table 1 summarizes the costs and advantages of these two alternative solutions.

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Table 1: Comparison Summary

Lighting Option	**Artificial Lighting**	**Skylights**
Quantity	12 stations	13 units
Total Cost	$2,580	$27,300
Advantages	● Energy efficiency through use of natural light, reducing energy costs ● Enhances worker well-being by improving mood and reducing stress ● Supports sustainability goals by utilizing renewable sunlight	● Lower initial cost, making it budget-friendly ● Provides consistent, controllable lighting regardless of time or weather

6. Conclusion

This study underscores the importance of adequate lighting in promoting employee productivity, safety, and well-being. While artificial lighting provides a more affordable and immediate solution at a total cost of $2,580, the installation of skylights, though more costly at $27,300, offers long-term advantages such as reduced energy consumption, improved mood, and alignment with sustainability goals. Our findings clearly show that lighting levels across the facility are inconsistent, and several workstations fall below the optimal illumination range. As a result, it is essential to address these deficiencies by strategically enhancing lighting conditions. Artificial lights should be installed or repositioned to avoid shadows or obstruction, while skylights should be considered in areas where natural light can be fully utilized. In parts of the facility that are isolated from natural light, artificial solutions will remain necessary. Future efforts will include a detailed review of each station's lighting needs to ensure improvements are effective and tailored. Ultimately, creating a well-lit work environment not only enhances productivity but also supports a healthier and more satisfied workforce.

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Biographies

Dr. Shahriar Hossain is the Department Head and Associate Professor of Engineering Technology at Northwestern State University. With over 16 years of experience, he specializes in manufacturing systems optimization. He has published extensively, earned multiple awards, and holds certifications in industrial robotics and PLC systems.

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