Thermal Comfort in Outdoor Classrooms

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Introduction

Communities around the world are re-opening after an extended period of 'lockdown' ordinances, business closures, working from home, and remote education, all intended to curb the exponential spread of COVID-19. As we enter this new phase of the global pandemic, we must strike a balance between maintaining social distancing protocols and restoring key parts of our communities. An idea gaining traction among governments, institutions, and businesses is bringing services outdoors to provide fresh air and reduce disease transmission compared to confined, mechanically ventilated indoor environments. An important factor limiting the feasibility or success of this strategy is whether people will be thermally comfortable in outdoor spaces. There are a variety of program types that are proposed to be outdoors -- restaurants, bars, retail, K-12 and university classrooms. Some of these programs fit within a transient or recreation program type, where people will accept a wider range of thermal conditions.

Outdoor Classrooms

This study focuses primarily on the use case of an outdoor classroom for the 2020 Fall Semester, a setting where occupants will be seated, performing tasks and thus expect a more narrowly defined thermal comfort range. Student and teachers should be provided with a comfortable environment to ensure effective focus and learning. The results presented use historic weather data to demonstrate thermal comfort conditions in outdoor environments for 6 sample climate zones – 5 in California and 1 in New York City.

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Thermal Comfort Model

This analysis uses an adjustment to the ASHRAE 55 Standard Thermal Comfort model. The standard thermal comfort model is typically used for indoor conditioned spaces, and assumes that occupants are not inclined to adapt to wide variations in temperature. This model assumes that people will have a narrow expectation of temperature. It assumes that occupants will feel comfortable between approximately 68°F and 75°F, with an additional expansion to 85°F with elevated air speeds and flexibility to adjust clothing levels. Given the ability of students to increase clothing levels, the lower end of the comfort band was expanded to 65°F.

The ASHRAE 55 Adaptive Thermal Comfort Standard, which allows for seasonal variations in thermal comfort expectations, was considered, but ultimately not used for this study. The Adaptive Standard can be used for naturally ventilated or semi-outdoor spaces and provides for a wider thermal comfort band. However, given that classrooms are highly sensitive spaces where students may already struggle to focus, we thought that conducting this analysis in a more conservative manner would be more appropriate. To account for the impact of direct solar exposure, the UC Berkeley Center for the Built Environment SolarCal function was used. It is important to understand that in reality, thermal conditions are highly specific. Results shown here are intended to provide a general overview of anticipated conditions based on historic climate data. They do not, for example, include the impact on radiant temperatures caused by building materials or the urban heat island effect. Wind control is assumed in all cases to prevent gusty conditions from disrupting classroom materials.

Occupants will feel comfortable between approximately 65°F and 75°F, with an additional expansion to 85°F with elevated air speeds and flexibility to adjust clothing levels.





Hourly Thermal Comfort Results

These graphs chart operative temperatures relative to the established thermal comfort range for **2 cases**:

- an outdoor classroom that has wind protection but is exposed to sun
- an outdoor classroom that has wind protection and is shaded from sun

Red dots show frequency and intensity of hours that are too warm, while **darker blue** dots show colder hours.

Schedule Planner

These 'schedule planner' tables show time periods with the highest frequency of comfortable conditions for each case. For example, the typical 3PM in September in this climate has a 70% chance of being comfortable (in the shade).



Key Takeaways

Shade is critical to providing a comfortable space for occupants, even in temperate San Francisco. The most comfortable period for outdoor classes (in shade) in San Francisco is between **12PM and 3PM**, **August-September**. The cooler, marine-influenced summer temperatures create periods with cold stress in the shade, especially during foggy mornings in July and August. During these times, full shade coverage is undesirable. Partial shade or collapsible/moveable shade devices are recommended to address these fluctuations in comfort conditions. Outdoor classrooms without shade coverage will be comfortable once outdoor air temperatures fall in late October, though this is also the start of the region's rainy season.

Legend

°F Outside of ASHRAE 55 Comfort Band





Schedule Planner

SF Bay Area, CA

OAKLAND, CA





Key Takeaways

While the marine climate of Oakland is also influenced by its proximity to the Bay, it is warmer than San Francisco and more susceptible to short periods of heat stress. Shade is critical to improving comfort. The most comfortable period for shaded outdoor classes in Oakland is between **12PM and 3PM**, **July-September**. Cooler summer temperatures create periods with cold stress in the shade during July and August mornings; partial shade or collapsible/moveable shade devices are recommended to address hourly changes in comfort conditions in the East Bay.

Schedule Planner

Increased comfort probability (%)



Key Takeaways

San Jose has a warmer microclimate compared to Oakland and San Francisco, with both marine and inland valley influences. It is more susceptible to heat waves than those other cities. Shaded classrooms will be consistently comfortable between **11AM and 3PM**, **July-October**, with the exception of particularly hot days, which typically occur between late August and mid-October. On these hot days, there are limited tools to improve comfort -- fans and evaporative cooling (misters), though both may not fit functionally with an academic program.

Schedule Planner



Los Angeles County, CA

COASTAL LOS ANGELES, CA



Key Takeaways

The marine influenced coastal Los Angeles climate provides comfortable conditions for shaded outdoor classrooms throughout the summer and early fall. It is important to note that the region is susceptible to heat waves, especially in areas that are further from the ocean. The impact of the surrounding materials on radiant comfort is important to consider in sunny Los Angeles, which can face localized warming from the urban heat island. The most comfortable period for outdoor classes (in shade) in coastal Los Angeles is between **9AM and 4PM**, **July-October**.

Schedule Planner

Increased comfort probability (%)

139 6% 139

> 0% 0%

429

61%



Key Takeaways

The inland, valley microclimates of Los Angeles are susceptible to hot temperatures and heat waves that preclude the use of outdoor classrooms during afternoon periods in the summer and fall. Shade is critical to improving comfort. The most comfortable periods for outdoor classes (in shade) in inland Los Angeles are the mornings, between **9AM and 12PM**, **July-August, 8AM - 10AM, September.** By October, cooler temperatures arrive, allowing for comfortable shaded outdoor classrooms between **10AM - 3PM**, **October-November**.

Schedule Planner











Key Takeaways

Canopy coverage is critical to improving comfort and protecting from rain in New York City. Hot summer temperatures mean that outdoor classrooms may not be appropriate for afternoon periods in July and August. The urban heat island is likely to exacerbate warm conditions shown in this analysis. Early autumn provides a brief comfortable period before cooler temperatures arrive in mid-October. The most comfortable periods for outdoor classes (in shade) are **9AM and 11AM**, July-August, 10AM to 2PM, September.

Schedule Planner



Affordable Wind & Solar Protection Strategies

Wind Protection

Wind protection is an important element of an outdoor classroom. Wind is a highly local condition and selecting an appropriate location with adequate protection is key. If adequate wind protection is not provided by trees or surrounding buildings, constructed wind barriers can be used to mitigate undesireable gusts and breezes.



Shade Coverage

As seen in the thermal comfort analysis, providing protection from direct solar exposure is the single most important element to providing a comfortable outdoor classroom space. Shade can be provided in a number of ways -- through existing conditions such as natural tree canopy and local overshadowing or with constructed shade structures such as tents, canopies, or trellises.



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