Applying a composite indoor environmental quality indicator to Danish office spaces: The TAIL rating scheme

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SUMMARY

A composite rating scheme for indoor environmental quality (IEQ) can help provide a summary picture of buildings for occupants, inform the building managers regarding IEQ performance that need attention, and raise awareness on regarding the importance of IEQ parameters. The TAIL IEQ rating scheme has been designed to communicate such aspects in a simple, easy to use manner.

KEYWORDS

indoor environmental quality; IEQ rating scheme; composite index; multidomain effects; office space

1 INTRODUCTION

Indoor environmental quality (IEQ) impacts occupant wellbeing and work performance. A considerable amount of research effort has been devoted to IEQ rating schemes, encompassing the different domains, viz., Thermal, Acoustic, Indoor Air, and Lighting. Building rating schemes like LEED, BREEAM have a scoring system that includes certain IEQ aspects. To create IEQ rating schemes, researchers have used subjective feedback from occupants, objective measurements of IEQ, and combinations of these two approaches. They have used methods such as regression analysis, multi-criteria decision analysis, and analytical hierarchical processing to analyse the data (Roumi et al. 2022). There currently exists little concurrence regarding relative importance of different domain and the parameters to use.

Apart from accuracy and repeatability of an IEQ rating scheme, there are practical considerations. Ease of communication, cost of the measurements/surveys involved, and how informative it can be for the stake holders are important. This is particularly important for buildings where there are stake holders with different perspectives and levels of understanding of IEQ. To address some of these challenges, as part of the EU ALDREN project, the TAIL (Temperature, Acoustic, Indoor air, and Lighting) rating scheme was developed (Wargocki et al. 2021). TAIL was created in form of a framework linking existing regulations related to occupant comfort and health – EN16798, WHO Air Quality Guidelines, Level(s) – so that they could be used together to rate IEQ. Initial applications of TAIL focused on building energy retrofits. However, it is suitable for a wide range of use cases and building types.

The twelve components of TAIL are – **Thermal environment**: Air temperature; **Acoustic environment**: Sound pressure level; **Indoor air environment**: Ventilation rate, CO_2 concentration, Formaldehyde concentration, Benzene concentration, $PM_{2.5}$ concentration, Radon concentration, Air relative humidity, & Visible mould area; **Luminous environment**: Illuminance, & Daylight factor. The TAIL rating is shown as a roman numeral (I-IV), with the component exhibiting the poorest performance being used to determine the overall rating. This motivates action by building management and operations, indicating which renovation strategies should be prioritized. In this work we report the application of TAIL to office buildings in the campus of the Technical University of Denmark (DTU).

2 STUDY METHOD

The study was undertaken in five buildings of DTU, in the Lyngby campus. These primarily house single occupancy offices (~60%). To ensure representation, 60-70% of the available monitors were deployed in single-person offices. Offices from all floors were selected, with approximately 10% of the total office floor area in each building being covered. Measurements typically spanned a full working week (Monday morning through Friday afternoon).

We used 15 AtmoCube monitors (AtmoCube 2024). The monitors were placed on the desks of the occupants, about 0.8-1m from ground, at least one meter from window, walls, radiators or ventilation grilles. They were positioned about 0.5 m from the occupants so as not to be affected by their body heat or the exhaled air. The AtmoCubes measured temperature, sound pressure level, illuminance, humidity, formaldehyde, CO_2, and $PM_{2.5}$ concentration. One-year dynamic daylight simulations were conducted in IDA Indoor Climate and Energy, with an overcast sky. The building classification was through a two-step process. First, a classification is given for I and L, based on the simulated or logged values for the parameters within the domain. Then, the classification of the worst performing domain is given to the building.

During the months when the physical environment was being monitored, a comprehensive survey was also conducted in the buildings to gauge occupant perception of their workplace IEQ. Occupants were queried regarding their overall perception and sensation on all four domains along with an overall rating of IEQ. The survey also included the questionnaire associated with the Flourishing measure. Developed by the Human Flourishing Program at Harvard University's Institute for Quantitative Social Science, the Flourishing measure examines human flourishing around five central domains: happiness and life satisfaction, physical and mental health, meaning and purpose, character and virtue, and close social relationships (VanderWeele 2017).

3 RESULTS AND DISCUSSION

Figure 1 provides the TAIL ratings of all five buildings monitored during this campaign. As the monitoring period was during a shoulder season when winter heating had not been discontinued but the outdoors was also getting warmer, the buildings had warmer thermal conditions than the winter limits for air temperature in TAIL I and II. Thermal and light sensation votes from the subjective survey showed relatively high correlations with median temperature (r = 0.75) and median illuminance (r = 0.83), respectively, in the buildings. The correlations of odor and noise sensations with physically measured parameters were not as remarkable.

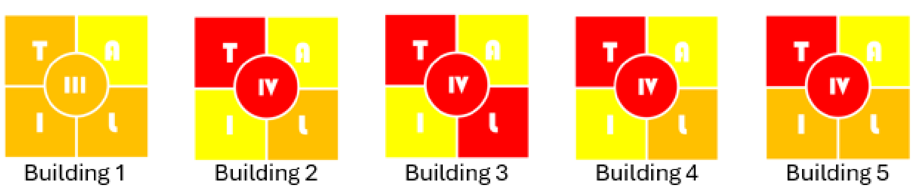

Figure 1: Tail rating schemas for the five monitored buildings.

We observed that the objective measurements and subjective surveys can serve to suitably complement each other, presenting a holistic picture of the IEQ. There are parameters, e.g., local discomfort from radiant asymmetry or drafts, that cannot be easily or economically measured but were easily ascertained from the subjective feedback. Similarly, measured parameters like PM, formaldehyde, daylight factor are not easy for occupants to discern. Our results also suggest that monitoring needs to be carried out in different seasons, different rooms, and for a long enough period to get a picture of the typical use of the building. The AtmoCubes had a logging frequency of one minute. Using one-minute logged data and 10-minute averaged data did not change the ratings to any considerable degree.

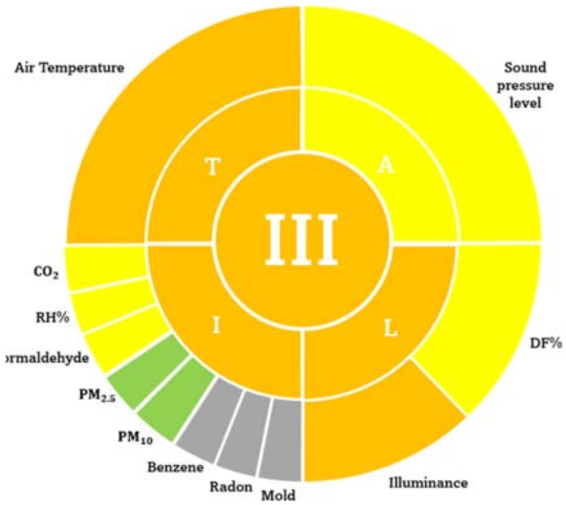

Figure 2: A more detailed representation for TAIL in Building 1. Grey sections indicate parameters that were not evaluated in the current campaign.

Figure 2 provides a more detailed view of the evaluated TAIL for Building 1. As can be seen from this illustration, the quadrants can be expanded or contracted depending on what level of details need to be communicated to a particular audience. At the same time, further parameters can be added to each quadrant without impacting the overall structure of the scheme.

4 CONCLUSION

The TAIL rating scheme provides a good basis for IEQ evaluation. It is easy to communicate to lay occupants yet comprehensive enough to include information relevant for designers and building managers. More studies like the current one, exploring the application of TAIL in different building types and contexts, can help build the utility of TAIL. Our results indicate that specific components defining IEQ can be supplemented with subjective ratings to improve the quality of evaluation and achieve a complete rating scheme.

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