Application of ALDREN-TAIL index

for rating the indoor environmental quality of buildings undergoing deep energy renovation

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One of the limitations for advancing indoor environmental quality (IEQ) in buildings is the lack of a common metric or a set of agreed indicators for IEQ. Wei et al. (2020) showed that nearly 100 different parameters are used to monitor and express IEQ in different standards and certification schemes worldwide. Still, no standard, uniform, and agreed metric have been developed so far. Deep energy renovation (DER) of buildings intentionally or not intentionally affect IEQ. DER, as a consequence, may have adverse effects resulting in discomfort, increased risk for health, or reduced productivity, which needs to be detected and immediately mitigated. But DER can also provide benefits of improved comfort, health, and productivity that are not accounted for when the cost-benefit analyses of building renovations are made. A fair conclusion will be that IEQ is inadequately addressed during energy renovations because of the lack of this standard metric.

ALDREN project consequently developed an index that allows rating of IEQ in buildings that are in operation and undergo DER as well as a method for predicting IEQ during the design of DER (Wargocki et al., 2019a, 2019b, 2020). The former is called ALDREN-TAIL, in short TAIL, the latter is called predicTAIL. In both cases, TAIL describes four components of IEQ, i.e., thermal environment (T), acoustic environment (A), indoor air quality (I), and luminous (visual) environment (L), as well as the overall quality of the environment.

TAIL index

The TAIL index consists of 12 parameters describing IEQ (**Table 1**). The parameters are defined based on a review of the state-of-the-art of IEQ indicators proposed by Green Building (GB) schemes, European standards, research projects and scientific publications (Wei et al., 2020). They are also aligned with the requirements of standards supporting the European Energy Performance of Buildings Directive (EPBD). For each parameter, four ranges are defined describing their four quality levels aligned with the quality levels included in the standard

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EN16798-1. The four quality levels of the 12 parameters and the four IEQ components defining the ALDREN-TAIL index are depicted with one of the four colors: green representing high-quality level, yellow indicating medium quality level, orange showing moderate quality level, and red representing low-quality level. The Roman numbers indicate the overall IEQ level, i.e., I, II, III, and IV, corresponding respectively to green, yellow, orange, and red quality levels (**Figure 1**). The twelve parameters are determined before and after energy renovation using measurements in buildings, observations (only visible mold), or simulations (only daylight factor). The detailed protocol for measurements has been developed. The quality level of each component of TAIL and the overall IEQ level is determined by the lowest quality to create incentives for improvement and not to compromise any of the major components of IEQ.

Application of TAIL in buildings before or after energy renovation

With the ALDREN project, the TAIL has been applied in six buildings before or after having been retrofitted to determine the quality of the indoor environment. Below there is an example of measurements from one office building performed in November 2019. According to the measuring protocol and given the size of the building, eight representative rooms were selected for measurements. In each room, the parameters defining TAIL (**Table 1**) were determined; measurements were performed for one week using on-line instrumentation and passive samplers. For temperature, the measurements were performed over one month. The daylight factor was modeled. There were no visible signs of mold.

Table 1. *ALDREN-TAIL indicators.*

T (thermal envir.)	A (acoustic envir.)	I (indoor air quality)	L (luminous envir.)
Air temp.	Sound pressure level	CO_2	Daylight factor
		Ventilation rate	Illuminance
		Air relative humidity	
		Visible mold	
		Benzene	
		Formaldehyde	
		$PM_{2.5}$	
		Radon	

The measured values at each measuring point during working hours were compared with their defined ranges (Wargocki et al., 2020), and their quality levels were determined. The quality level of each parameter defining TAIL was obtained by calculating the interim rating at each of the eight measuring locations:

$$\text{Interim rating} = \frac{\sum_1^k R_k * O_k}{n} \quad (1)$$

where R is the rank for the specific quality level k (R = 1 for green level, R = 2 for yellow level, R = 3 for orange level and R = 4 for red level); O is the number of observed rooms for the specific quality level k; k is the number of quality levels ($k \leq 4$); n is the total number of the rooms where measurements are performed.

The final quality level of each of the four TAIL components at the building level was determined by the worst interim rating for the thermal environment (T), acoustic environment (A), indoor air quality (I), and the luminous environment (L). The overall rating of IEQ was determined by the worst level of the four TAIL components.

Figure 1 shows the TAIL level of the building. The thermal environment in the building (T) was qualified at the yellow level because the indoor air temperature varied between 20 and 24°C during more than 94% of the working hours in 5 rooms. The thermal environmental quality could be improved to the green level if the indoor temperature had been reduced to 23°C during midday. The acoustic environment in the building (A) was qualified at the green level because the sound pressure was lower than 35 dB(A). The indoor air quality in the building (I) was qualified at the orange level mainly because CO_2 concentrations in the measured rooms often exceeded 1200 ppm, and there were high concentrations of formaldehyde. The indoor air quality could be improved by increasing the air change

Figure 1. TAIL level of an office building.

rate in highly occupied spaces. The luminous environment in the building (L) was qualified at the orange level because the median daylight factors in the selected rooms were between 1.7% and 3%, and the illuminance levels in the measured rooms were often higher than 500 lux at the desk height. The visual environment could be improved by renovating sun protection systems and reducing artificial lighting.

Since the lowest quality level among TAIL components was orange, the overall quality level of IEQ and the overall rated TAIL level was also orange, which is represented by the Roman III in the middle of the TAIL indicator for this building (**Figure 1**).

Predicting TAIL index: PredicTAIL

Because the TAIL index should guarantee a good IEQ after the energy renovation, it must also be possible for the building owners or investors to assess what could be the influence of the different renovation actions on IEQ. For this purpose, the predicTAIL index was created. PredicTAIL includes the same IEQ parameters, the same quality levels and the same calculation method as TAIL, but is purely based on modeling. PredicTAIL is modeled before renovation to serve as the baseline, and then it is modeled for different renovation strategies. By comparing PredicTAIL after with PredicTAIL before energy renovation, the best renovation strategy can be chosen. PredicTAIL is an additional tool for decision making and is not a verification tool for TAIL. Both should be used independently.

Conclusions

TAIL creates an incentive to improve IEQ as well as the framework that allows qualitative and quantitative assessment of non-energy benefits resulting during the process of a deep energy retrofit. The TAIL index focuses on office and hotel buildings to be aligned with the ALDREN procedure, but the intention is to use it in any type of building.

Being measured before the renovation, the TAIL index helps to identify the possible components to be improved on the occasion of the energy renovation, making the latter even more beneficial for the building and its occupants. In case of measurements done after the energy renovation, the TAIL index 'after' compared to the TAIL index 'before' helps in showing that the renovation has not degraded the IEQ in the building or whether the IEQ improved. ■

Interview with Prof. Francis Allard

Professor Emeritus,
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1. Is there a need for an IEQ indicator, and why?

– The ALDREN initiative is certainly very promising. To have a comprehensive indicator of indoor environment quality corresponds to a real preoccupation of all professionals in the search of complete evaluation of a building quality. The complete evaluation of health and overall comfort conditions indoors is necessary to assess the quality of use of a building, the definition of a first aggregate indicator even if it is not integrating every single aspect of IEQ is a real progress in this way.

2. Does TAIL fulfil this need, and why (benefits of TAIL)?

– In my opinion TAIL answers this need. In order to be efficient and used by professionals, the IEQ indicators need to be as complete as possible, built on solid scientific basis and easy to understand. We already have many environmental quality indicators used by environmental quality assessment methods everywhere in the world but all of them are based on a long list of individual indicators which makes difficult to have a clear vision of the overall quality. For me, the TAIL method fulfills this need.

3. Do you think TAIL would be accepted by building professionals?

– It is always very difficult to predict the acceptability of a method or a concept. However, TAIL is quite attractive by its apparent simplicity. It is complete, easy to understand, and efficient in the overall approach to the assessment of indoor environment quality. I really think it will be accepted easily by our professionals.

4. What should be next step in developing TAIL?

– TAIL needs to be tested in different types of building types (offices, residential, schools, etc.) in a wide range of climates. The testing protocols have to be evaluated carefully to strengthen the method and the limits of such a complete IEQ indicator have to be clearly stated. Then, this indicator could be used easily in the evaluation of rehabilitation projects. Most of the projects are focusing mainly on the energy performance and it will be a real benefit to add this IEQ indicator.

Interview with Dr. Stylianos Kephalopoulos
European Commission, Directorate General Joint Research Centre

1. Is there a need for an IEQ indicator, and why?
– IEQ indicators and other health-based criteria and requirements are given emphasis in a number of building related policy and legislative instruments (e.g. amended EPBD, Construction Products Regulation, European standards and national regulations, etc.). However, a major obstacle for integrating energy and IEQ strategies in the design and optimisation of buildings is the lack of a common, quantitative metrics for IEQ although the worldwide definitions of IEQ generally agree about the main components contributing to the IEQ of buildings and IEQ is considered in existing GBC schemes. Therefore, there is need for a commonly defined and accepted IEQ indicator in EU and worldwide.

2. Does TAIL fulfil this need, and why (benefits of TAIL)?
– TAIL is among the IEQ indicators, indices and tools, which were recently reviewed by EC Services (DG ENER & DG JRC) regarding their potential to be used in the process of IEQ data integration into the EU Building Stock Observatory. TAIL was developed as result of an extensive review process, which can be regarded as a reference for selecting parameters and for development of IEQ indicators that are commonly used in energy performing buildings. Moreover, it is compliant with major certification schemes, EN16798-1 and Level(s). Therefore, the TAIL method can be directly used in the process of defining and applying a common IEQ metric addressing the EU building stock.

3. Do you think TAIL would be accepted by building professionals?
– TAIL has the potential to attract the interest of investors in IEQ and of building professionals, as it can be determined with small extensions to the measuring protocol when performing building certification using major Green Building and Sustainability Certification Schemes. TAIL ranks among the top IEQ concepts and methodologies which were reviewed by EC which present high degree of comprehensive use and affordability to end users, however, needs to undergone validation before it can be effectively applied beyond the purpose for which was developed and after having assessed the feasibility and flexibility of its application at various scales (local, national, EU), buildings' typologies and assessment objectives.

4. What should be next step in developing TAIL?
– Further development of TAIL should be driven by the need of defining and applying a harmonised IEQ indicator at EU level at affordable cost, to assess IEQ in energy performing buildings via a well-balanced and complementary approach of objective (i.e. via measurements) and subjective (i.e. perceived IEQ) assessment which considers the following aspects: variation of IEQ parameters over time (e.g. variation of a calendar year, or different seasons); flexibility for application across different typologies of buildings and different objectives of assessment; need for adjusting IEQ parameters and their weighting according to different national contexts and specificities in EU MS.

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