ABSTRACT

Konstantzos, Iason. Ph.D., Purdue University, December 2016. A Human-Centered Approach for the Design of Perimeter Office Spaces Based on Visual Environment Criteria. Major Professor: Athanasios Tzempelikos.

With perimeter office spaces with large glazing facades being an indisputable trend in modern architecture, human comfort has been in the scope of Building science; the necessity to improve occupants' satisfaction, along with maintaining sustainability has become apparent, as productivity and even the well-being of occupants are connected with maintaining a pleasant environment in the interior. While thermal comfort has been extensively studied, the satisfaction with the visual environment has still aspects that are either inadequately explained, or even entirely absent from literature. This Thesis will investigate most aspects of the visual environment, including visual comfort, lighting energy performance through the utilization of daylight and connection to the outdoors, using experimental studies, simulation studies and human subjects' based experiments.

Visual discomfort is mostly associated with discomfort glare, which can be evaluated using a variety of available different indices with known strengths and weaknesses. Most of the latter are based on the luminance distribution of the visual field. Obtaining the luminance distribution is a complex procedure, either on an experimental or simulation level; experimental acquisition involves the use of dSLR cameras and HDR imaging, along with a series of image processing, calibrations and calculations, while it faces challenges in cases of measuring the solar corona, due to its extreme peak luminance level. This leads to time consuming procedures with questionable accuracy. Also, when it comes to simulations, a detailed luminance mapping of the interior

involves time consuming renderings, which makes annual simulations slow and inefficient. This Thesis uses three different experimental methodologies for luminance acquisition in order to provide accurate and fast measurements, even for the case of the sun being included in the field of view, and also utilizes a hybrid ray-tracing and radiosity lighting model to improve the effectiveness of annual discomfort modeling with the minimal compromise in terms of accuracy. The experimental methodology has been evaluated in preliminary human subjects testing in real office spaces in order to validate its effectiveness and also give some preliminary results and directions for the next parts.

Daylight Glare Probability is the most recent visual discomfort index, and currently considered to be the most reliable, as it is extracted by human subjects experimentation. However, the specific conditions under which it was proposed and the form of the equation itself have raised some concerns in terms of its effectiveness in different conditions, especially when it comes to roller shades and the sun being included in the field of view . This Thesis used experimental and simulation analysis to evaluate the behavior of Daylight Glare Probability under different shading controls, investigate the effectiveness of the simplified index DGPs, and pointed out inconsistencies in special cases, like facing the sun through roller shades.

In order to address the inconsistencies identified, an extended human subjects study has been performed in order to evaluate visual discomfort in the special case of the sun being visible through shading fabrics. Discomfort thresholds are extracted for important interior illuminance and luminance metrics, and a variety of widely used glare indices are evaluated in terms of their prediction performance. Two new discomfort metrics are proposed, DGPmod and GlareEV, to be used in a dual function form only for the cases of the sun being visible through shading fabrics.

As the quality of view is highly subjective and connected to a lot of non-quantifiable parameters, its only measurable aspect, the visual clarity has been investigated. By developing a scoring system based on a combination of subjective and objective questions, human subjects' surveys have been used to find that visual clarity is a function of the fabrics' most common properties, the openness factor and visible transmittance. Through the use of the developed equation, the View Clarity Index (VCI), architects can have an understanding about the visual clarity in the design phase.

Finally, in the lack of a unified design methodology based on the visual environment, the newly obtained knowledge of this Thesis has been combined to propose the Visual Environment Index, a design framework based on three main visual environment factors: visual comfort, lighting energy performance and connection to the outdoors. In that scope, a suite of three metrics are introduced, the Visual Comfort Autonomy (VCA), to account for the portion of annual working hours under conditions of comfort, the Continuous Daylight Autonomy to cover the lighting energy savings, and the Effective Outside View (EOV), to quantify the connection to the outdoors. Using these three metrics in the framework of VEI can help architects make decisions in terms of façade configurations, shading controls or even positional layouts in private or open plan offices.