View Clarity Index

Define view clarity through solar shades

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Introduction

Connection to the outdoors through window views has been related to occupant satisfaction by several studies. Green building rating systems such as LEED (Leadership in Energy and Environmental Design) offer credits for outdoor views, without elaborating on details. While *view "quality"* depends on outdoor scenery, *view "clarity"* can be quantified according to fenestration properties and visual conditions. The clarity of view through actual windows or glass facades depends on the layers of fenestration (glazing and shading systems) and their optical properties.

Most modern glazing products have a high visible transmittance to allow more daylight into the space, thus the impact on view clarity is not substantial. In contrast, shading devices (e.g., venetian blinds, roller shades, and draperies) significantly affect the clarity of outside view, since they block part of the window and influence the direct and diffuse light transmission. All window shades (*fabrics*) allow direct outdoor view when they are partially open. However, unlike other types of shading, due to their perforations, solar screens allow some outside view even when fully closed.

A key performance feature of solar screens is their ability to simultaneously provide glare control while allowing daylight into the space and preserving view to the outdoors. These benefits are greatly affected by the fabric properties. Specifically, Openness Factor (OF)[1] and Visible Light Transmittance (Tv)[2] are critical to this performance. Although recent studies comment on shading properties with respect to glare and daylight provision, view clarity through shading fabrics has not been studied.

For these reasons, Lutron and Purdue University conducted a research project in fall 2014 to investigate and evaluate the clarity of view through windows with solar screen fabrics.

The outcome of this comprehensive research is directly integrated into the Lutron Fabric Wizard (www.performanceshadingadvisor.com), a web-based tool that can help designers choose shading fabrics based on their project requirements in order to achieve the optimized glare, daylight, and view clarity performance.

The principal investigators from Purdue University were: Thanos Tzempelikos (Associate Professor of Civil Engineering) and Robert Proctor (Distinguished Professor of Psychological Sciences).

[1] Openness Factor (OF): The percentage of light that transmits directly through a solar screen without being redirected or diffused.
[2] Visible Transmittance (Tv): The percentage of light that transmits through a solar screen, including both direct and diffuse light.

Methodology to Assess View Clarity through Window Shades

In the absence of an existing view clarity metric, the goal of this project is to develop a new metric for characterizing view clarity through windows with shading fabrics. A full-scale field study with 18 human subjects was conducted to measure view clarity preferences in two offices equipped with 14 shading fabrics of different properties (OF, Tv and color). The tests were conducted with different sky conditions and viewing positions. 6912 data points from questionnaires were collected and used to create a scoring system/fabric rankings and a new metric, the View Clarity Index (VCI).

Test Facility

The field study was conducted in two identical, side-by-side test office spaces at Purdue University (Fig. 1). These spaces are designed with reconfigurable façade systems and are ideal for comparing the impact of different technologies on indoor environmental conditions, occupant impressions and energy use under real weather conditions. The curtain wall glass façades are facing south (60% window-to-wall ratio) and have a high performance glazing unit with Tv = 65%.

For the purpose of this study, each room was reconfigured with the addition of two vertical panels (Fig. 1) in order to form six total partitioned areas. Each partitioned area would host a different shade product. The study included objective observations; for that reason, six visual targets with modified Landolt-C charts were installed on a vertical fence outside the rooms, at a distance of 14.8 ft from the windows (Fig. 1). Each chart was on the direct line of sight from each partitioned section. The general outdoor view is open and unobstructed, with visible green areas and a nearby street with traffic.

Figure 1: Exterior view of test offices (left), interior partitioning (middle) and Landolt C boards installed outside (right)

Experimental Procedure

Eighteen participants (six female and twelve male), between ages of 23 and 55 years, participated in the field study. All participants reported to having satisfactory visual acuity. A questionnaire (see Appendix) with eight basic questions, developed to assess the subjects' clarity of view, was given to each participant before testing each fabric. Data collected from the first six questions were considered in the quantitative part of this study (fabric ranking and view clarity index/score). The last two questions were qualitative feedback from the participants.

The participants were randomly separated into three groups of six, to conduct the field study efficiently using the six partitioned areas. Each group was tested under sunny and cloudy conditions and two viewing positions (close to and further away from the windows), for all selected fabrics. In the beginning of each testing day, a short presentation of the procedure was made, and shades were removed from one of the partitioned sections, to provide the participants with a baseline of "maximum" view clarity. First, all six participants in each group completed the questionnaires for the two viewing positions with each fabric. After finishing the test with the first fabric, they rotated clockwise (moved to adjacent partitioned area with a different fabric), and repeated the procedure until all six shades had been experienced by all six participants. Then, the next set of six shades were installed on the windows and the entire procedure was repeated. The order of participants and fabrics was random (Fig. 2).

Fig. 2: Simultaneous observations of different fabrics installed on the same façade –random order

Shading fabrics

Fourteen different fabrics were used in this study (Table 1), representative of commonly used products in commercial buildings. They cover a wide range of Openness Factors (1% - 13%) and Visible Light Transmittance values (3% - 25%). Horizontal and vertical fabric threads had combinations of white, black, grey and brown colors. Although the basic fabric properties were provided by the manufacturer, integrated sphere measurements were conducted to obtain accurate value of the properties.

Results

Overall, 1152 questionnaires were used in the analysis (18 participants, 14 shade test cases, 2 viewing positions and 2 sky conditions), with 6912 data points (total responses for all questions) collected. Since different questions had different numbers of possible answers, all answers were normalized to a scale from 0 to 1. The total responses from the six main questions were weighted equally. The averaged normalized scores for the two sky conditions and the two viewing positions were used to develop a total view clarity score. This number was then corrected to account for the glazing properties, using all the scores of the objective test results without shading.

View clarity scores and fabric rankings

The fabrics were given code names from A to N for reasons of procedural flexibility. Table 1 presents the overall rankings for all studied fabrics (including their measured optical properties and code names) and the ***measured total normalized view clarity score***.

Table 1. Measured View clarity score and ranking of different fabrics

Rank	Fabric code	Fabric Color	Measured *OF*	Measured T_v	Normalized view clarity score
1	L	Black	11.3%	12%	0.893
2	I	Black	7.0%	7.3%	0.817
3	D	Black	3.7%	4.1%	0.730
4	M	Grey	12.6%	19.9%	0.682
5	N	White	12.5%	25.1%	0.585
6	J	Grey	6.7%	13.0%	0.560
7	G	Brown	3.9%	5.9%	0.531
8	A	Black	2.6%	2.8%	0.527
9	F	Brown	3.0%	4.5%	0.420
10	K	White	5.9%	18.2%	0.298
11	E	Grey	2.3%	6.6%	0.212
12	H	White	3.9%	15.9%	0.187
13	C	White	1.6%	13.7%	0.026
14	B	Grey	0.7%	6.4%	0.013

The results show that: **darker fabrics with higher OF** generally achieve higher clarity scores, followed by **light-colored fabrics with high *OF* and *Tv***, and then dark or colored fabrics with small *OF*; light-colored fabrics with low OF received the lowest view clarity scores.

Normalized view clarity score distributions

To illustrate view clarity preferences in graphical form, Fig. 3 shows the distribution of view clarity index for each fabric during sunny and cloudy days. Bar colors reflect actual fabric colors and bar texture density indicates fabric knit/weave density. For example, for black fabric A, the view clarity score during sunny days ranged between 0.2 and 0.8 between all subjects with the distribution shown in the figure. For Fabric B, the dispersion of preferences was minimal and all scores were around 0 –this was the lowest ranked fabric for view. The results of Fig. 3 were statistically processed to obtain the final scores listed in Table 1.

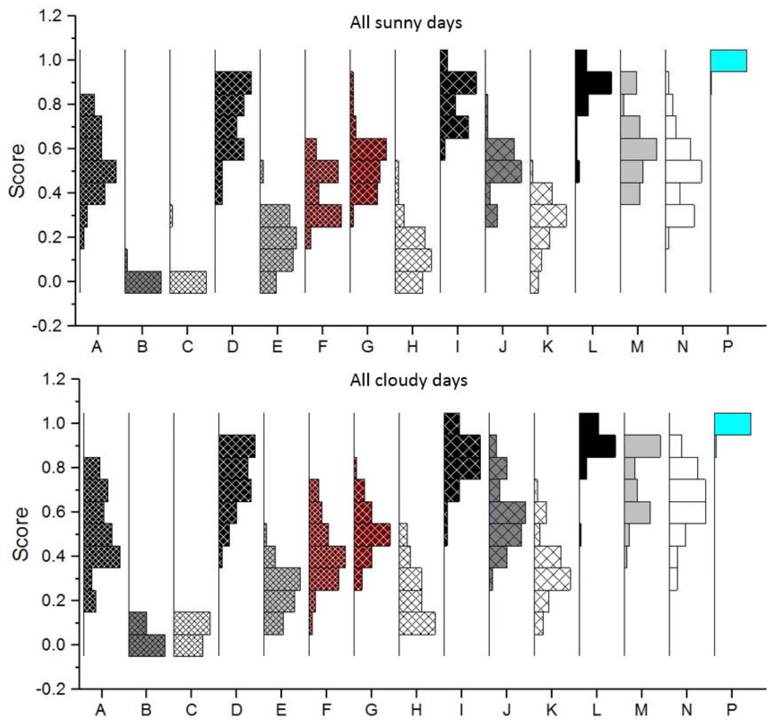

Figure 3: Distributions of normalized view clarity score for each fabric (all measurements) during sunny days (top) and cloudy days (bottom).

Effect of viewing distance

Occupants seated right next to the windows might have a less clear view to the outside (through fabrics). To investigate this parameter, the experiments on rated view preferences were repeated for two positions: for occupants located near the windows (1-2 ft) and further away (5-6 ft) from the windows. It was found that occupants seated right next to the windows have a slightly reduced clarity of view (for all fabrics) as shown in Fig. 4. However, this factor did not affect the fabric ranking order.

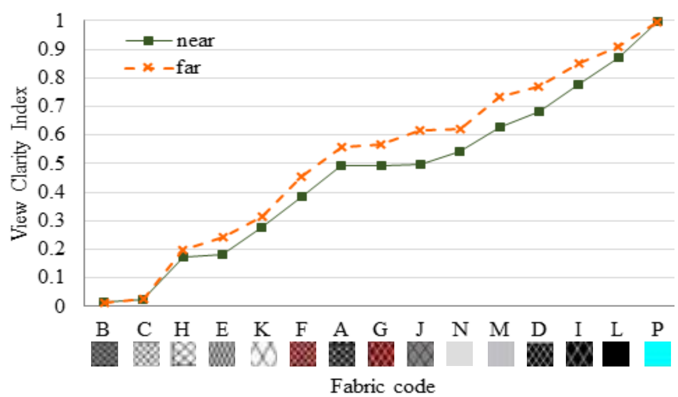

Figure 4: The effect of viewing distance from the window on view clarity score for all fabrics.

Predicting View clarity based on the experiment results

Based on the experiment results above, a new metric, ***View Clarity Index (VCI)*** can be predicted for any shading fabric using only the two basic shade properties (OF and Tv). The value of this index can be found from Fig. 5 (listed values in the figure and in the legend) for given fabric OF (x-axis) and Tv (y-axis). Alternatively, the equation below can be used to calculate VCI as a function of OF and Tv:

$$VCI = 1.36 \cdot (OF)^{0.51} + 0.68 \cdot \left(\frac{OF}{T_v}\right)^{1.19} - 0.18$$

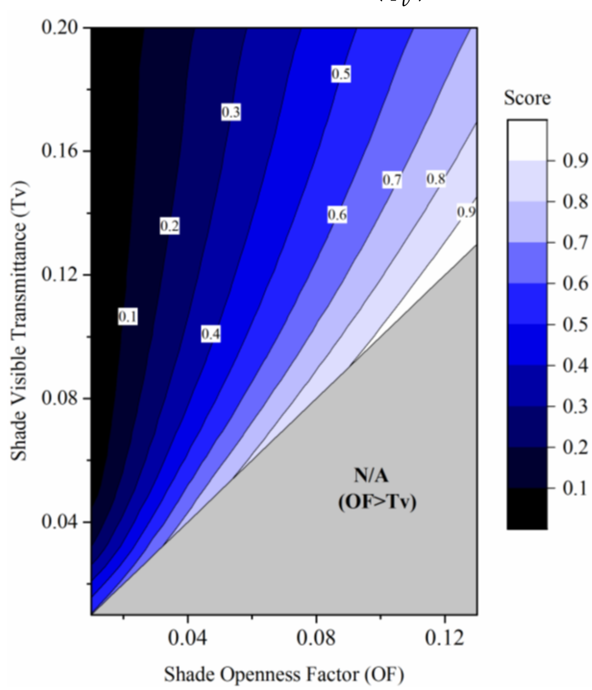

Figure 5: View Clarity Index for various fabric OF and Tv.

The new View Clarity Index predicts view clarity preferences through fabrics with great accuracy. A comparison between predicted and measured (occupant-rated) view clarity is shown in Fig. 6.

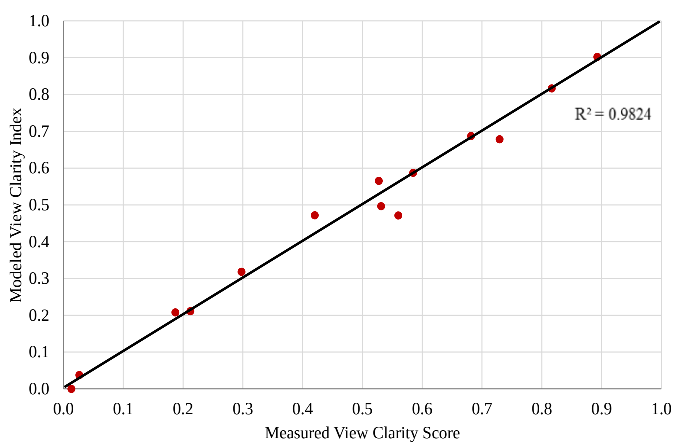

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Figure 6: Comparison between modeled VCI and measured View Clarity Score.

Summary

This paper introduced a new metric (View Clarity Index - VCI) to quantify outside view clarity through window shades, based on a series of occupant experiments. 14 fabrics with different visible transmittance (Tv) and openness factors (OF) were tested in two laboratories by eight participants under sunny and cloudy sky conditions. A regression model was built based on 6912 data points that were collected from the experiment. This model can predict VCI of any given fabric with known Tv and OF. More information can be found at this academic journal article – I. Konstantzos, Y.-C. Chan, J. Seibold, A. Tzempelikos, R.W. Proctor, B. Protzman, "*View Clarity Index: a new metric to evaluate clarity of view through window shades*", Building and Environment, Available online 15 April 2015, ISSN 0360-1323.

This model has been integrated into the Lutron Fabric Wizard (www.performanceshadingadvisor.com), a web-based tool to help designers choose shading fabrics based on their project requirements in order to achieve the optimized glare, daylight, and view clarity performance.

Appendix

Questionnaire provided to every participant for data collection with each studied fabric, viewing position and sky condition

Fabric Code ________

F

1. How clear is your outside view through the window and shade?

   Not clear at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very clear

2. Can you tell the sky conditions outside by what you can see (sunny/cloudy/extends of clouds)?

   Not clear at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very clear

3. How would you grade the vividness of the outside colors?

   Not vivid at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very vivid

4. Which outside objects can you distinguish from the following: Fence, Street, Power cables? Please circle <u>all that apply</u>:

   None Fence Street Power cables

5. Can you clearly distinguish the color of moving cars on the street?

   Yes No

6. Observe the target outside the window, and count how many symbols you can clearly distinguish for each line:

   1st line______ 2nd line______ 3rd line______ 4th line______ 5th line______

7. Are you satisfied with the visual comfort conditions (glare, reflections, etc)?

   Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very much

8. How would you comment about this fabric? (Circle <u>all that apply</u>):

   Too bright Too dark Good color

   Too open Too opaque Good openness/transparency

1-FRONT