Fall 2013

Post-Occupancy Daylight Analysis: Vernonia K-12 School

Portland State University. School of Architecture

Post-Occupancy Daylight Analysis: Vernonia K-12 School

PROJECT BACKGROUND

Completed July 2012
Area: 134,438 sq. ft

"This is a new K-12 school to replace the flood damaged schools for the City of Vernonia. The project is targeting LEED Platinum. Natural day-lighting, in-floor radiant heating and cooling and a bio-mass boiler are among the schools features."

CLASSROOM BACKGROUND

The classroom is located on the second floor on the southern most wing of the building. It accounts for (2) floor-to-ceiling windows utilizing (2) glazing types, an interior light shelf, and an exterior light shade. The classroom also has (2) 2' x 2' skylights located deeper into the space and (1) clerestory window that connections with the central hallway allowing the classroom to gain daylight from the hallway skylight.

ABSTRACT

Early design approaches are becoming increasingly important in the architectural design process. Studying the buildings performance after occupancy has allowed our field to study the accuracy of design modeling. This has been especially true with daylight analysis. Specifically in school settings, daylight is not only desirable but crucial to the health and performance of children. Analysis of daylight in the architectural field has increased as the opportunity to perform more accurate simulations during the design process. Alongside this development, there is a move to explore the efficiency of software analysis to real world projects.

This research examines the effectiveness of digital daylight analysis against post-occupancy daylight field measurements for the Vernonia K-12 School. The two software programs analyzed in their accurate simulation of daylight are 3ds Max and the Rhino Radiance Plug-in Diva. This study focused on two primary influence factors; material specifications and sky modeling. Through a series of digital iterations and two sets of field measurements (one from Boora Architects, the other from our research), the comparison between software and real data exposed a consistent error in both programs.

This analysis was also compared with the initial digital and field data of Boora Architects. Results show that 3ds Max is more suitable for design during early stages of design, while Diva provides a more accurate relationship to material representation. Further, this study provides a sufficient starting point for additional exploration of post-occupancy utilization of the primary users and more in depth analysis of digital programming factors.

PROCESS

In this study, we began with an initial research on daylight techniques and conversations with the design team to understand what field data and analysis has already been gathered. To understand the software parameters and constraints, we tested a generic classroom model. The purpose of the previous parameter testing is to compare and compile daylight data to analyze the accuracy of early design modeling software. Research was conducted using two daylight simulation programs; 3ds Max and Rhino's Radiance Plug-in Diva.

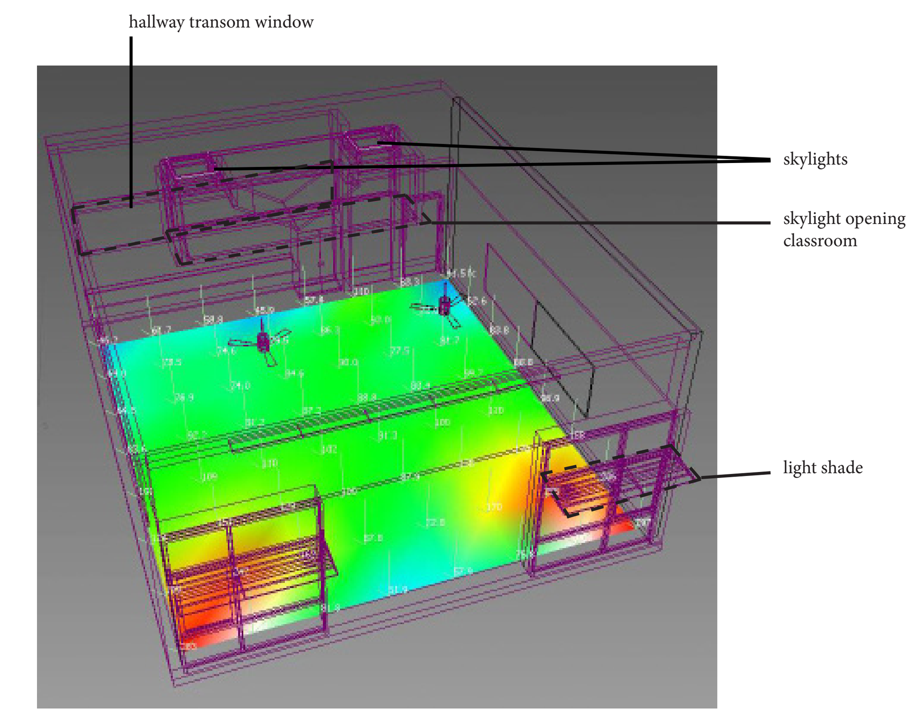
The first step of the process was to analyze the software and determine factors that would have a significant effect on daylight analysis. The two factors that have the most effect on daylight simulation are material specification and the sky model used; CIE versus Perez sky model. These factors were the primary focus of analysis. We use the software to analyze and test parameters of one second floor classroom in the Vernonia K-12 School. This analysis will take into account cloud coverage, surface (material) reflectance, and exterior reflectance of surrounding surfaces.

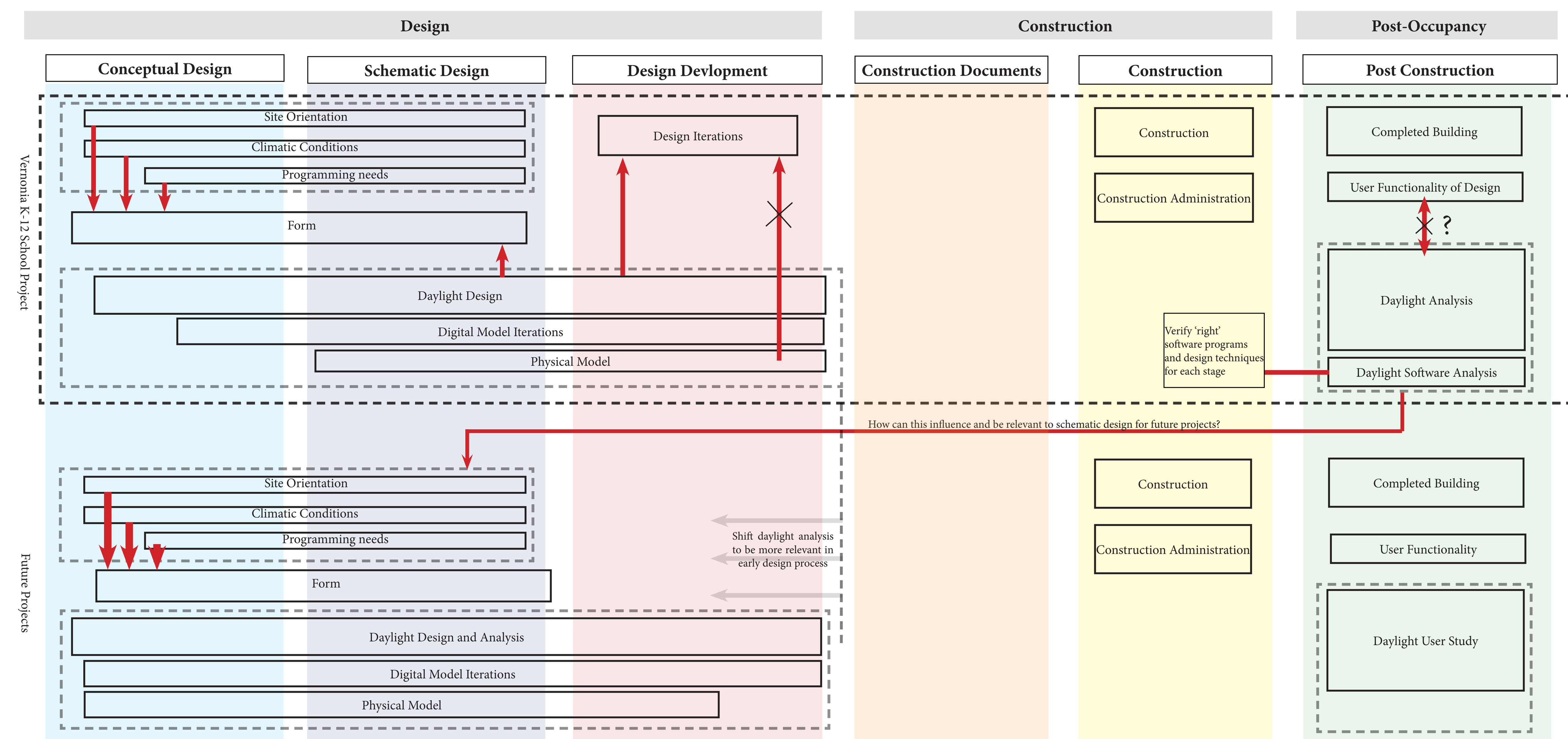
PROCESS CONTINUED

Iterations were preformed through 3ds Max and Diva to understand significance of changes in these two factors. We then were able to focus on the comparison of the programs and were analyzed in their performance on daylight accuracy to real world data from Boora Architects and our own measurements.

The next step was to go into the field and preform light meter readings on the same classroom to compare results to Boora's initial measurements. Equipment used were two light meters and a Reflectometer to measure the reflectance of opaque surfaces in the classroom. These measurements provided accurate data to input into Rhino and utilize the Diva Plug-in.

BASE MODEL CASE STUDY





METHODOLOGY

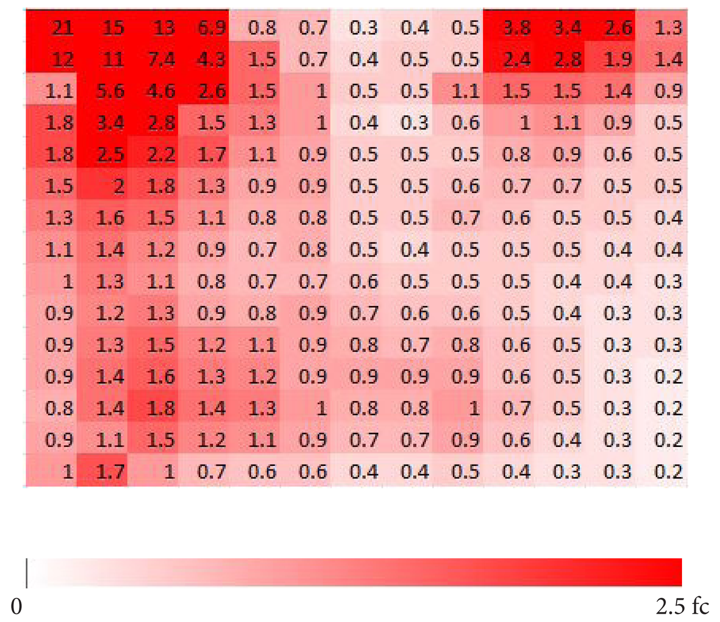
The goal of this study was to determine what digital software provides the most accurate data during the schematic and design development stages. The methodology used by Boora Architects on this project shows that digital and physical modeling for daylight analysis happened primarily during the design development phase (shown above). However, in communication with Boora Architects, it is understood that their daylight analysis did have a critical role from the beginning of the design process and had an effect on their massing and construction design. The study of daylight strategies throughout the project began with site orientation and massing and remained important through the choice on finishes and the design of the light shelves. Boora Architects used 3ds Max as their analysis tool and sought to use it to progress their own knowledge and methods of analysis. For instance, due to budget restraints the building has to be revised.

"By far the biggest example of such input was to switch the exterior wall system from CMU with brick veneer to structural tilt-up concrete panels. The design team then had to make big revisions to refashion the building within the constraints (and opportunities) of the new wall/structural system. However, most factors that influence daylight remained unchanged. The tilt-up system did enable the corner windows we used throughout the building but their impact probably relates more to views than daylight." [Boora Architects, 2013]

From Boora Architects' study, the data provided conclusions into the inconsistency of 3ds Max simulation to their field measurements, which prompted an additional need to understand the function and accuracy of digital daylight software.

FIELD MEASUREMENTS AND DATA

On November 14th, 2013 daylight field measurements were collected at the Vernonia K-12 School from the designated classroom. For a greater understanding of daylight analysis of the built project, two light meters were used. Equipment used included a Reflectometer, Ligth Meter, and Transmissivity Meter. We began the process at 4:00pm and finished at 4:50pm and used a two foot measuring grid. The results are as follows:



The time of day we were allotted to do our readings unfortunately coincided with the setting of the sun; so in the 50 minutes we were in the classroom, it transitioned from dim to full dark. This created apparent issues with the field data we collected. The largest concern was the time of year and then, the school's hours which prevented us from visiting the classroom between 8:00am and 3:00pm.

This had the unfortunate effect of skewing our field data to the point that it prevented us from accurately comparing it to any other field readings or digital modeling. For example, the readings we logged by the first window around 4:10pm showed a range in foot-candles between 20.8 fc and 6.9 fc. Already dim due to the time and overcast sky, by the time we took readings by the other window, the readings were between 3.8 fc and 1.3 fc. There were no blinds, trees, or other factors that would have affected these readings to the extent documented other than the setting sun and cloud cover. At the end of our field measurements, the data was inconclusive and lacked the rigor to add to the initial field data by Boora Architects.

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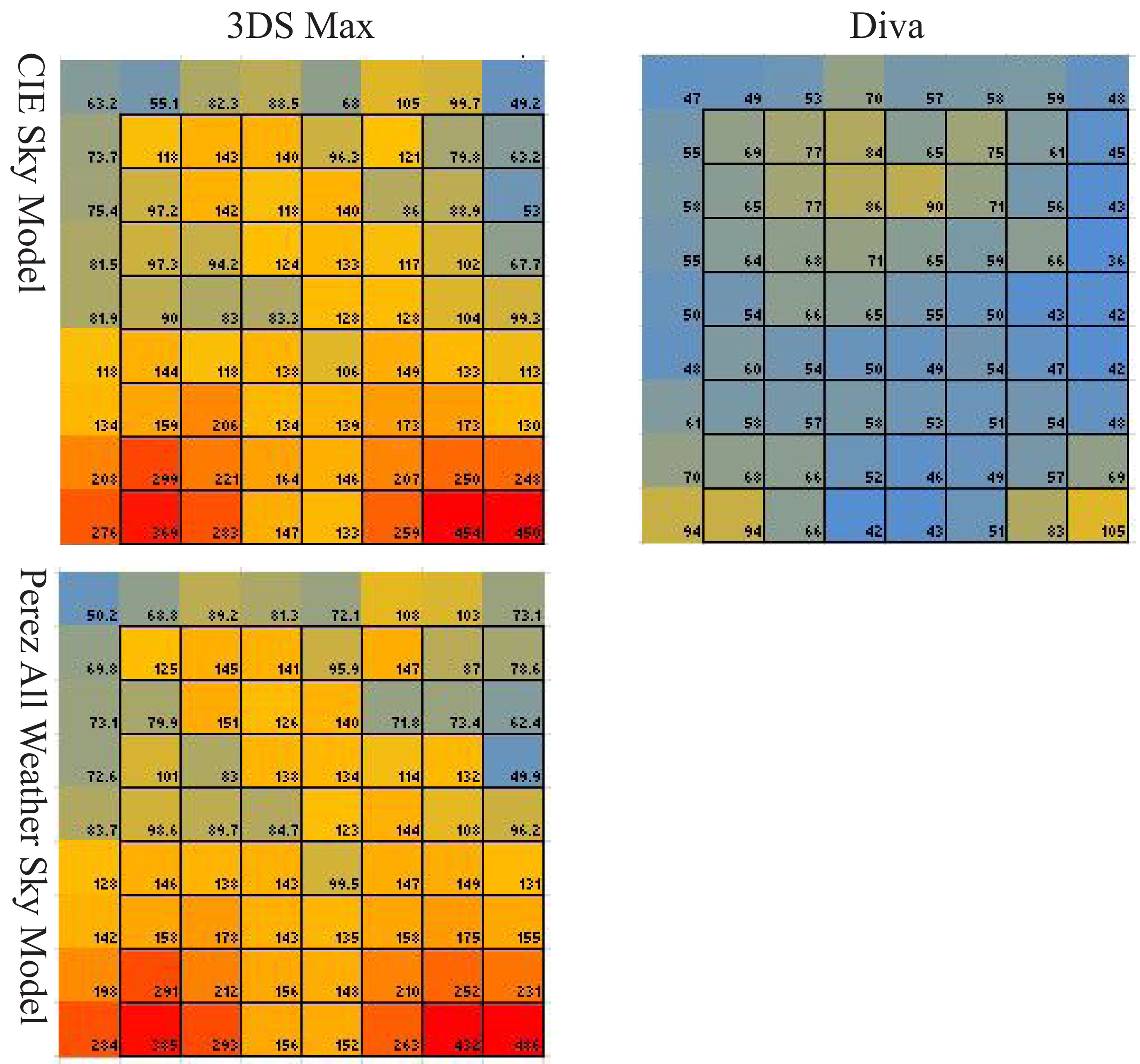
DIGITAL SIMULATION DATA



FACTORS IMPACTING DIGITAL SIMULATION

Material	Emissivity Field Measurement	Reflectance
White Wall	0.242	0.758
Yellow Wall	0.367	0.633
White Board	0.336	0.664
Floor	0.354	0.646
Ceiling	0.032	0.968
Brown Desk	0.57	0.43
Cabinet	0.267	0.733
Countertop	0.29	0.71
Blue Plastic Chairs	0.872	0.128
Fabric Board	0.151	0.849

The factors that have the most significant role in altering digital results in 3ds Max are the dependency on RGB classification and Revit settings, and complexity of the material editors. For Diva, the most significant factors include the need for detailed material specifications. Thus field measurements were gathered for all significant materials (see left). Both programs are user friendly that provide settings for advanced settings that provide more accurate results to real field data.

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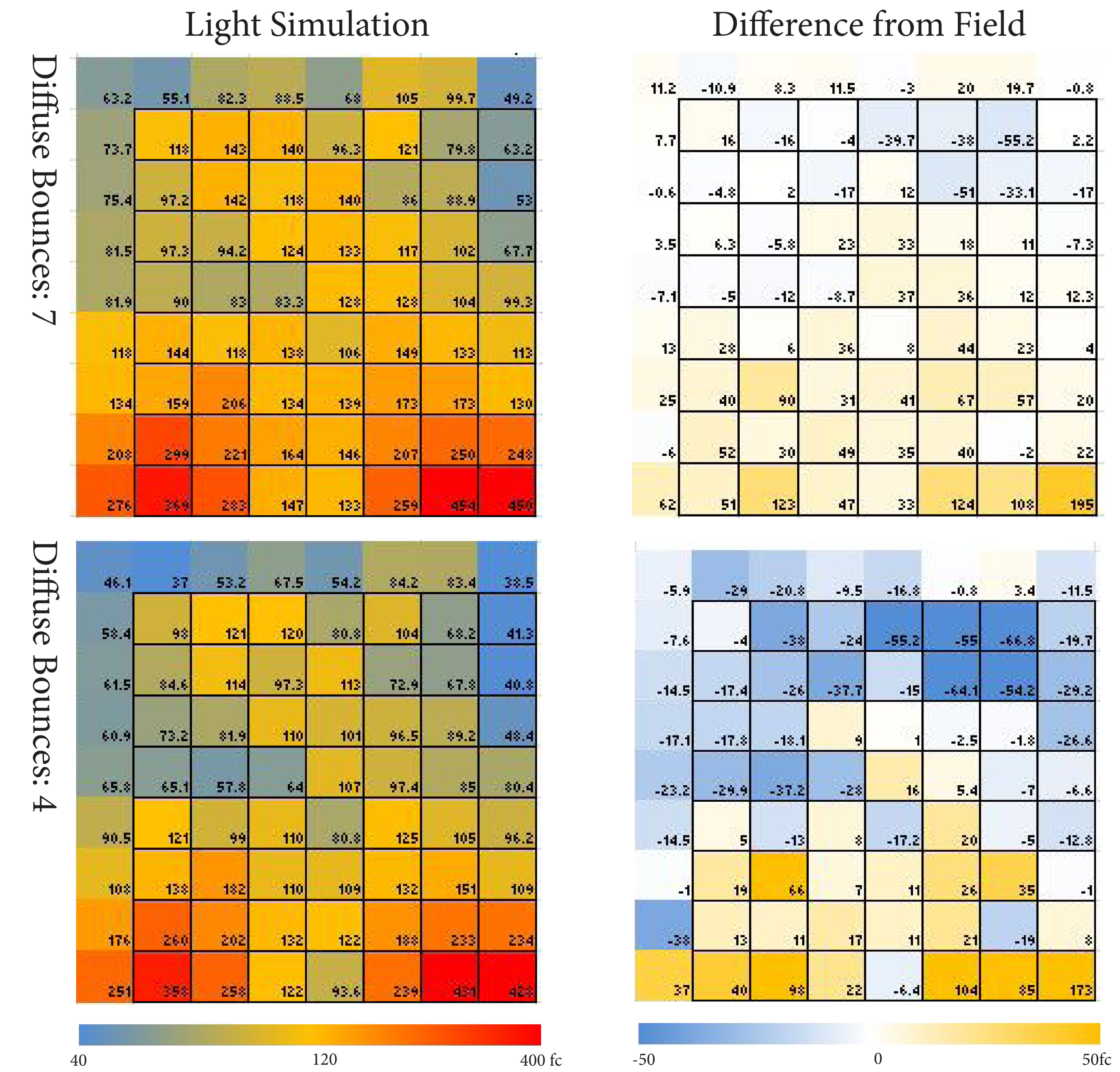
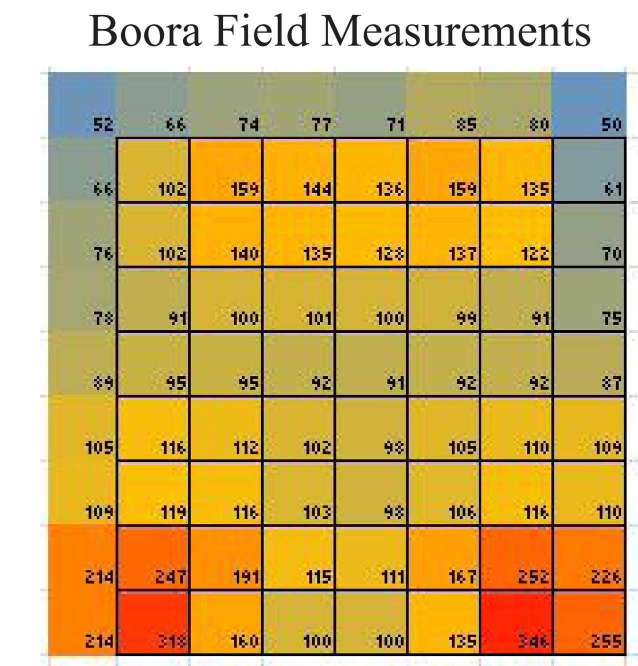
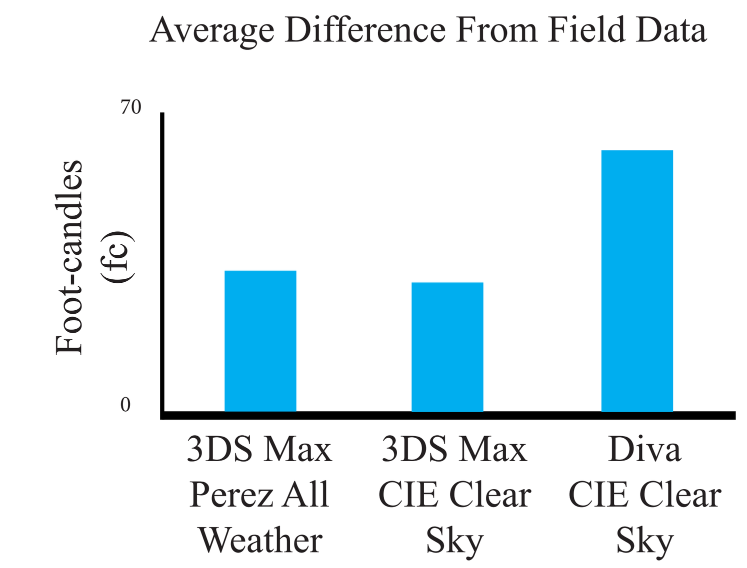
3DS MAX SIMULATION: DIFFUSE BOUNCES







CONCLUSION

In conclusion, our software analysis and data revealed inaccuracies with material representation in 3ds Max. This software used RGB values which can differ to real materials up to twenty-five percent, depending on material color. The inaccuracies of Boora Architects initial simulations with 3ds Max occurred because it relied solely on Revit material values and luminance. On the other hand, Diva provided a more precise simulation of intended daylight strategies due to its utilization of material specifications. That being stated, 3ds Max allows designers to perform multiple iterations quickly during early design. Diva renders more useful during later stages of design development when specific materials are chosen. Results with the two sky models showed that the Perez All-Weather Sky Model shows consistent averages that are three to four points higher than the CIE Sky Model.

Another conclusion resulted from our field measurements and being at the school was the ability to interview several of the teaching staff on their opinion of the daylighting scheme, and their day to day habits in occupying the space and using the available daylight strategies designed. It quickly became apparent that the classrooms were not being occupied in the way that was imagined during the design process. The overall orientation of the class was not even accurate. When designed, the classes were facing East/West so that the windows would be along one side of the students as they faced the whiteboard. However, with the installation of classroom projectors, the layout was forced to switch orientation toward the windows to take advantage of the only functional open wall space.

This rearrangement caused several effects on the intended daylight strategies. One effect was that the students were now facing toward the windows; so many teachers now considered it a distraction to have the blinds open in certain instances. Another significant effect was the light coming through the windows, particularly the windows above the light shelves that cause glare issues when using the projector. This then resulted in closing the blinds during class time. Several teachers also complained about having to open and close such a large number of blinds if they wanted to adjust the light, or in emergency situations. Further, this resulted in the tendency to default to the artificial lighting available for convenience. Then once closed, the blinds tended to stay in that position, rendering the intended daylighting design largely unutilized.

This brought about the question concerning if the teaching staff was trained or informed about the daylight strategies employed. When asked about their knowledge of the natural light in the classrooms, the best answer given was that they were "aware" of a lighting scheme, but didn't really have specifics. In the absence of information to inform their behavior, the teaching staff simply defaulted to their individual level of comfort in using the blinds. It was concluded that the teaching staff had little to no working knowledge of the daylighting design, or how to effectively utilize it. These findings provide an opportunity for additional research into use of daylight strategies by the primary users of the school, as well as improving current daylight software to reflect more accuracy to constructed, future projects.