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## **Comparison of daylighting simulation workflows and results using plugins for BIM and 3D Modeling programs: application on early phases of design process**

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### **ABSTRACT**

The present paper investigated the application of the daylighting analysis features of the Insight BIM plugin, comparatively to DIVA, a plugin for a 3D Nurbs modeling software. Considering the early phases of the design process, workflows, simulation results and processing times were analyzed, focusing on the prediction of static (illuminance level) and dynamic (sDA<sub>300,50%</sub>) metrics. Simulations on both tools were performed in the context of analyzing the daylight behavior in a deep office room model, with and without light shelves. Results indicate that Insight has limitations compared to DIVA, especially concerning input data configuration flexibility. Simulation results presented significant similarity between Insight and DIVA in most cases, being the direct sun case the one in which illuminance levels differed the most. Insight presented longer processing time for the static metric and similar average time for the dynamic metric. Work findings indicate that Insight has important potential to contribute to daylighting analysis on early phases of design process, and points out to barriers to its adoption and correct use. Authors expect this paper to benefit architects, engineers and students on the comprehension of both tools.

### **KEYWORDS**

Daylighting simulation; Building Information Modeling; Insight; DIVA; design process.

### **INTRODUCTION**

Different work indicates the need for a highly skilled and experienced workforce in the field of high complexity software to have reliability on the results obtained through computational simulation, besides the great financial and time investment (Korolija and Zhang, 2013). Such difficulties reflect on the habit pointed by Dogan and Reinhart (2013) in which computational simulation occurs mainly for code compliance evaluations on final phases of design process. The authors also cite the potential benefit of using simplified easy to use simulation tools at early stages of design process, in which computational analysis exert a great impact on the project's qualification. Furthermore, with the current emphasis on sustainability, including building's energy performance, the multi-disciplinary design solution became more important in initial design stages (Negendahl, 2015).

In this context, Building Information Modeling (BIM) is recognized as a collaborative and information exchange methodology that generates integrated computer models, providing a reliable basis for decision-making regarding the building's design, construction, maintenance and disassemble (Santos et al, 2017). Recent research approaches the use of BIM tools to perform energy and environmental analysis (Chong et al, 2017). According to USGA (2015) these tools have the ability to generate analytical models in an automated or semi-automated

way, creating a simpler process, as simulations can be conducted directly on the modeling program interface. Thus, it can be less prone to errors and demand minimized time and financial investments if compared to current practices.

Insight is a daylighting analysis plugin for Revit, that uses A360 cloud-based rendering service. The tool was designed to be operated by non-daylighting simulation experts professionals (Autodesk, 2015). It presents automated settings for some study types and for others there are customizable input options. Possible analysis includes illuminance levels, daylight autonomy – spatial daylight autonomy ( $sDA_{300,50\%}$ ), studies for LEED credits, and solar access. A360 uses bidirectional ray tracing with multidimensional light cuts algorithm along with secret/patented extensions. The simulation engine has been validated in comparison with Radiance results and measured data (Autodesk, 2017). Such technology has the potential to contribute to the greater adoption of computational simulation, considering that tools difficulty level is a factor of great influence for its adoption (Rogers, 1995). However, although it is possible to increase the accessibility to computational simulations, there is still little research regarding the workflow, results quality and processing time of simulations performed through this methodology, comparable with notably known engines.

Regarding the most used daylighting predictions tools, Radiance, a backward ray tracer simulation engine "enjoys the status of a *gold standard*" (Reinhart and Breton, 2009, p. 1514), being widely validated comparatively to measured data under different sky conditions and complexity of models. Radiance simulates daylighting conditions under one sky condition at a time, and the Radiance-based simulation tool Daysim allows the processing of dynamic simulations under various sky conditions. It is a freeware also extensively used and validated comparatively to measured data (Reinhart and Breton, 2009). Several works that developed Radiance validation studies since 1995 are presented in Reinhart and Anderson (2006).

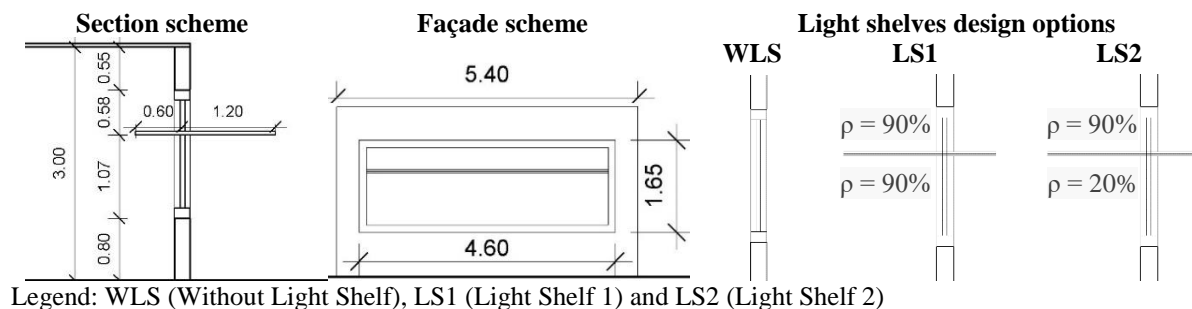
Over the last years, the adoption of DIVA, a plugin that incorporates Radiance and Daysim into the 3D Nurbs modeling program Rhinoceros has been noticed. From this plug-in, it is possible to analyze the performance of different design options without manually exporting the architectural model to another software. International researches have been using DIVA for daylighting and energy consumption studies (Sharma et al. 2017, Tabadkan et al. 2018 and Villalba et al., 2018). DIVA was initially developed at the Graduate School of Harvard University and is now distributed and developed by Solemma LLC. Free use is available through educational licenses for students and educators (Solemma LCC, 2018). Due to its validated simulation engines and acceptance among the academic community, DIVA will be considered in this study as a reference program.

In the search for a better distribution of daylight in laterally daylit rooms, light redistribution elements such as light shelves and daylight harvesting louvers have been widely studied (Berardi et al. 2018, Villalba et al. 2018 and Tabadkan et al. 2018). This article aims then to investigate the plugin Insight, focusing on its application on daylighting simulations analysis during the early phases of a design process. For that, the daylight behavior in a deep office room model with a 1:2 proportion with and without light shelves was analyzed. Workflows, static (illuminance levels) and dynamic ( $sDA_{300,50\%}$ ) results and processing time were studied comparatively to DIVA.

## **METHODS**

The study was developed in two phases. In the first phase Insight and DIVA workflows were apprehended, and in the second one, the study focused on simulation results and processing

time. A design process was assumed within the context of analyzing daylight behavior in a deep office room model with a 1:2 proportion with and without light shelves. The model is not obstructed by neighbouring building and has a depth which corresponds to nearly 4 times the aperture height. Its internal dimensions are 5.0m x 9.9m; 3.0m height, with a 15° Azimuth. This office configuration is commonly found in commercial buildings in Belo Horizonte, Brazil as stated by Alves et al. (2017). Three design options were tested: the basic model (without light shelf) and two models with light shelves with varied inferior surface reflectance ( $\rho$ ) (Figure 1). A 0.2m wall thickness was assumed and the reflectance of interior walls, interior ceiling, interior floor and exterior ground was 50%, 80%, 20% and 20%, respectively. The outer frame represented a framing factor of 20% of the rough opening area of the window, which included a single glazing with a 90% direct visual transmittance.



Legend: WLS (Without Light Shelf), LS1 (Light Shelf 1) and LS2 (Light Shelf 2)  
Figure 1. Schematic models description.

Daylighting simulations were performed with Insight (v. 3.0.0.1 for Revit 2018) and DIVA (v. 4.0 for Rhinoceros5.0) for Belo Horizonte (lat.: -19.85, long.: -43.95). Simulated metrics and parameters were: illuminance levels for winter solstice at 12:00h with analysis plan height of 0.75m and nodes distance of 0.35m; and sDA<sub>300,50%</sub> with 0.8m plan height and 0.6m node distance. For illuminance analysis the Perez sky model was used in both software, using weather data as sources for sky condition information. The one considered for Insight simulations was automatically assigned from the project location indication through a default city list, and for DIVA simulations a SWERA file was considered (Table 1). Table 2 presents DIVA advanced simulation parameters - at Insight, it is not possible to access such settings.

Table 1. Sky condition information.

	GHI <sup>1</sup>	DNI <sup>1</sup>	DHI <sup>1</sup>	Sky cover	Weather file
Insight	890Wh/m <sup>2</sup>	810Wh/m <sup>2</sup>	93Wh/m <sup>2</sup>	0%	GBS_04R20_299004
DIVA	623Wh/m <sup>2</sup>	616Wh/m <sup>2</sup>	179Wh/m <sup>2</sup>	5%	Belo Horizonte/Pampulha-SWERA

<sup>1</sup>GHI: Global Horizontal Irradiance, DNI: Direct Normal Irradiance, DHI: Diffuse Horizontal Irradiance.

Table 2. Advanced Radiance simulation parameters used in DIVA.

Model	ab	ad	as	ar	dt	ds
Without light shelf	5	1000	20	300	0	0
With light shelves (1 and 2)	7	1500	100	300	0	0

## RESULTS

Figure 2 displays workflows schemes of Insight and DIVA. Key aspects of Insight operation mode involve the use of a BIM model to perform cloud-based daylighting analysis and having the option to configure or not analysis parameters, as the tool presents default values for material, nodes and analysis information. DIVA uses a scene modeled in Rhinoceros and processes simulations on user's computer. There are also default parameters for numerous daylighting analysis, but nodes and materials properties must be configured manually.

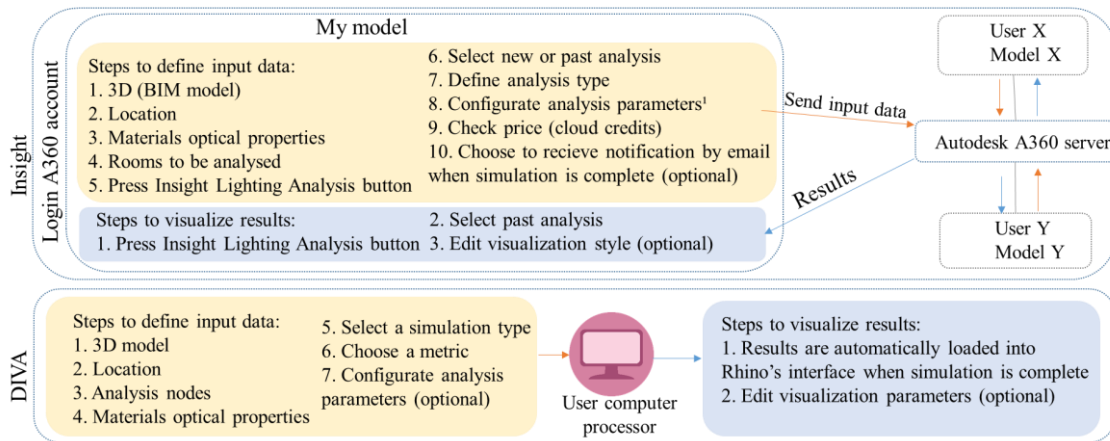


Figure 2. Schematic operating mode of Insight and DIVA.

Important workflow differences rely on material's optical properties configuration: on Insight it is set by color or by specific Red, Green and Blue (RGB) values, defined by equations presented in Autodesk (2017); while in DIVA it is set by a default list, which can be altered in a .rad file. In Insight it is viable to load past simulation results, as a simulation historic is stored in the A360 user account. Also, it provides users with design tips for lighting performance improvement. Both tools allow configuring result scale appearance, an important aspect of comparing design options. In Insight users can manually change color schemes and define intervals between the maximum and minimum thresholds, which are fixed on the scale; while in DIVA it is viable to choose between three color schemes and to define scale's maximum and minimum thresholds, but quantity and value of intermediate intervals are automatically set. Figure 3 presents both tools results and its processing time.

	Without light shelf (WLS)	With light shelf 1 (LS1)	With light shelf 2 (LS2)
<b>Insight</b>	<p>Illuminance - Max.: 6,000lx / Min.: 214 lx                      Illuminance processing time: 3 minutes                      sDA<sub>300,50%</sub>: 68% / Processing time: 39 min.</p>	<p>Illuminance - Max.: 6,000lx / Min.: 161 lx                      Illuminance processing time: 10 minutes                      sDA<sub>300,50%</sub>: 65% / Processing time: 9 min.</p>	<p>Illuminance - Max.: 3,010lx / Min.: 173 lx                      Illuminance processing time: 1 minute                      sDA<sub>300,50%</sub>: 62% / Processing time: 3 min.</p>
<b>DIVA</b>	<p>Illuminance: Max.: 53,700 lx / Min.: 358 lx                      Illuminance processing time: &lt; 1 minute                      sDA<sub>300,50%</sub>: 65% / Processing time: 20 min.</p>	<p>Illuminance: Max.: 5,549lx / Min.: 179 lx                      Illuminance processing time: &lt; 1 minute                      sDA<sub>300,50%</sub>: 61% / Processing time: 13 min.</p>	<p>Illuminance: Max.: 4,117 lx / Min.: 179 lx                      Illuminance processing time: &lt; 1 minute                      sDA<sub>300,50%</sub>: 60% / Processing time: 14 min.</p>

Figure 3. Results and processing time of Insight and DIVA simulations.

Maximum and minimum resulting illuminance levels were similar on both tools in the cases of light shelves use (LS1 and LS2). Most discrepant illuminance result was in the case with direct sun exposure (WLS), being the maximum level in DIVA approximately 9 times higher than in Insight. In what concerns the three design options, both tools demonstrated decreasing illuminance levels in the area next to the opening and more uniform daylight distribution when WLS, LS1 and LS2 were tested, respectively. Medium illuminance simulation time in Insight was 4.7 minutes, while in DIVA it was less than 1 minute. In what concerns the  $sDA_{300,50\%}$ , both tools presented similar results in all cases, being the bigger difference in case LS1 (4%). Medium  $sDA_{300,50\%}$  simulation time was 17 minutes for Insight and 15.7 minutes for DIVA. Authors point out that there were occasions when Insight simulations were impaired due to connection problems with Autodesk's server.

## DISCUSSIONS

With the workflows study, characteristics that can favour Insight adoption on early phases of design process were noticed. Firstly, there is the possibility to use a BIM model to perform daylighting analysis, for all benefits of BIM design process cited by Santos et al (2017). Secondly, the indication of design tips can assist the development of project solutions. Thirdly, default values configured for material properties, analysis nodes and metrics parameters enables simulations execution by nonexperts professionals, in congruence with Insight developers objectives, as stated in Autodesk (2015). As indicated by Rogers (1995) those simplifications can contribute to the tools higher adoption. Also, the storage of simulation historic facilitates results comparison between design options. On the other hand, with the experience of this work, authors encountered aspects that can be considered barriers to Insights adoption and correct use. Among them, there is the occurrence of errors with Autodesk's server connection. Also, when consulting the design tips, which was based on studies developed in the USA, users should attempt to their specific project climate characteristics. Further, fixed input values encountered in Insight may represent an obstacle for more detailed analysis. An example is the impossibility to specify the desired weather file and although it is possible to inform GHI, DNI and DHI values for illuminance analysis, it is not viable to inform a sky cover percentage. Additionally, the configuration process of the desired material reflectivity or visible transmittance is unintuitive compared to DIVA's, due to the necessity of informing the RGB values. Since calculated values presented in Autodesk (2017) are not available in Revit or Insight interfaces, users must search for this reference.

Illuminance levels and  $sDA_{300,50\%}$  results of both tools presented similarity, mostly in cases with a predominance of diffuse light, when LS1 and LS2 were used. The case with direct sun exposure (WLS) presented illuminance significant discrepancy among both tools, and based on weather files sky condition information, authors infer this was due to Insight's maximum threshold specification. Authors could not confirm this hypothesis because this configuration could not be accessed. Still, transposing this results to a design process practice, such difference may not imply great prejudice, for illuminance levels in both cases were above comfortable desired levels if a 3,000lx limit is considered - so both of them indicated the necessity to develop sun protection solutions. In this study, illuminance simulation processing time was notably shorter when using DIVA than when using Insight, and this may be caused by the low computing capacity necessary for such static metric along with the low complexity of the model. The average processing time for  $sDA_{300,50\%}$ , in its turn, was similar in both tools.

## CONCLUSIONS

This work investigated the application of Insight daylighting features on design process, comparatively to DIVA. Workflows, simulation results and processing time were analyzed.

Results indicate that Insight has limitations, mostly on what concerns input data configuration flexibility, but it still has significant similarity in results with DIVA, mainly in cases with a predominance of diffuse daylighting. Findings demonstrate Insight has important potential for contributing to daylighting analysis on early phases of design process, assisting A&E professionals on developing more based solutions in conjunction with the use of a BIM platform. Authors intend this paper to benefit architects, engineers and students on the better comprehension of both studied tools. Future research could approach simulations with other metrics, model complexities, and the use of DIVA along with Rhinoceros BIM plugins.

## ACKNOWLEDGEMENT

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## REFERENCES

- Alves T, Machado L, Souza R.G, De Wilde P.2017. A methodology for estimating office building energy use baselines by means of land use legislation and reference buildings. *Energy and Buildings*,143,100-113.
- Autodesk. 2015. *Light Analysis for Revit*.Autodesk, Inc.
- Autodesk. 2017. *Insight Lighting Analysis Help*.Autodesk, Inc.
- Berardi U, Anaraki H. 2018. The benefits of light shelves over the daylight illuminance in office buildings in Toronto. *Indoor and Built Environment*, 27, 244-262.
- Chong H-Y, Wang X, Lee C-Y. 2017. A mixed review of the adoption of Building Information Modelling (BIM) for sustainability. *Journal of Cleaner Production*, 142, 4114-4126.
- Dogan T, Reinhart C. 2013. Atmosphères: proof of concept for web-based 3D energy modeling for designers with WebGL/html5 and modern event-driven, asynchronous server systems. In: *Proceedings of the 13th Conference of International Building Performance Simulation Association (IBPSA)*, Chambéry, pp. 1039-1044.
- Korolija I, Zhang I. 2013. Impact of model simplification on energy and comfort analysis for dwellings. In: *Proceedings of the 13th Conference of International Building Performance Simulation Association (IBPSA)*, Chambéry, pp. 1184-1192.
- NegendahlK. 2015. Building performance simulation in the early design stage: An introduction to integrated dynamic models. *Automation in Construction*, 54, 39-53.
- Reinhart C, Anderson M. 2006. Development and validation of a Radiance model for a translucent panel. *Energy and Buildings*, 38, 890-904.
- Reinhart C, Breton P. 2009. Experimental validation of 3DS max® design 2009 and Daysim 3.0. In: *Proceedings of the 11th Conference of International Building Performance Simulation Association (IBPSA)*, Glasgow, pp. 1514-1521
- Rogers E M. 1995. *Diffusion of Innovations*. 3° Ed. New York. The Free Press.
- Santos R, Costa A, Grilo A. 2017. Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015. *Automation in Construction*, 80, 118-136.
- Sharma L, Lal K, Rakshit D. 2017. Evaluation of impact of passive design measures with energy saving potential through estimation of shading control for visual comfort. *Journal of Building Physics*, 1-19.
- SOLEMMA LCC. *Diva-for-Rhino*. 2018.
- Tabadkan A, Banihashemi S, Hosseini M. 2018. Daylighting and visual comfort of oriental sun responsive skins: A parametric analysis. *Building Simulation*, 11, 663-676.
- U. S. General Services Administration (USGSA). 2015. GSA BIM Guide 05 - Energy Performance.
- Villalba A, Monteoliva J, Rodríguez R. 2018. A dynamic performance analysis of passive sunlight control strategies in a neonatal intensive care unit. *Lighting Research & Technology*, 50, 191-204.