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Validation of *DIALux* 4.12 and *DIALux evo* 4.1 against the analytical test cases of CIE 171:2006

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Abstract

The practical use of lighting simulation programs has significantly increased particularly during the last decades. To verify the accuracy of those programs, the CIE has published technical report of CIE 171:2006 - Test Cases to Assess the Accuracy of Lighting Computer Programs, which has been applied ever since to validate a number of available lighting simulation tools. This article reports the performance of *DIALux* 4.12 and *DIALux evo* 4.1 against the analytical test cases of CIE 171:2006. Both programs show a very good agreement with the reference values in cases with point source. *DIALux* 4.12 yields noticeably errors at receiving points with small configuration factors, in cases with area source. Both programs show a good agreement with the reference values in cases with diffuse reflection, respect luminous flux conservation, but do not respect variation of relative angular transmission due to varying incidence angles. Inaccuracies are found in daylighting scenes, particularly in the calculation of sky and externally reflected components. It may be of common interest for the CIE to amend the current document and publish a new version with possibly a new series of test cases.

Keywords: CIE 171:2006, *DIALux* 4.12, *DIALux evo* 4.1, simulation, test cases, validation

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1. Introduction

The practical use of lighting simulation software has significantly increased particularly in the building sector, due to the emerging requirement for achieving energy efficiency while maintaining indoor environment quality and comfort. In the specific field of lighting in buildings, the application of software can help, among others, in balancing the use of daylight and artificial lighting in search of reducing the electrical energy consumption.

A large number of lighting simulation software has been made available, either in the forms of open source, free, or proprietary, of which a thorough review has been provided by Ochoa et al [2012]. It is therefore important for the users to understand the level of accuracy and precision of the produced outcomes or information, in order to avoid mistaken evaluations of the constructions when compared to the original goal of the project [Donn et al. 2007].

To verify the accuracy of these tools, the CIE has published technical report of CIE 171:2006 - Test Cases to Assess the Accuracy of Lighting Computer Programs [CIE 2006], which has been applied ever since to validate a number of available lighting simulation programs. This CIE document was preceded by several publications [Maamari et al. 2005, Maamari et al. 2006] introducing the (initial) concept of the test cases, validating a number of programs. In the final version of the CIE document, there exist some slight changes, particularly in the order of the test cases.

This article reports the performance of *DIALux* 4.12 and *DIALux evo* 4.1 against the analytical test cases of CIE 171:2006. Both programs are created by DIAL GmbH, Germany, and are free to download and install from the company's website, but are not open source. The first version of *DIALux* was released in 1994, whereas *DIALux evo* was released in 2012. The former program implements radiosity method in its working algorithm [DIAL 2015a], while the latter implements photon mapping algorithm that is said to be capable for handling more complex and irregular geometries [DIAL 2015b].

There is an increasing number of published scientific works using *DIALux* (mostly with the radiosity version), for both indoor and outdoor application, e.g. Ashdown [2005], Saraiji and Oommen [2012], Gómez-Lorente et al. [2013], Ylinen et al. [2013], Chowdhury and Tripathy [2014], Mavromatidis et al. [2014], Chueco et al. [2015], Son et al. [2015]. Despite the fact, a complete validation of the program against all test cases of CIE 171:2006 has never been reported, to the best of the author's knowledge. There are, however, some reports of partial validation of *DIALux*, i.e. against the experimental test cases of CIE 171:2006 [DIAL 2015a, 2015b] and against a number of author-defined daylighting cases [e.g. Acosta et al. 2011, Iversen et al. 2013]. Moraes et al. [2013] evaluated *DIALux*, as well as other programs, to validate *LightTool* and APOLUX, but not against all test cases. It is therefore the intention of this investigation to fill in the gap by performing the analytical test cases in both programs of *DIALux*.

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2. Method

In this article, only the analytical test cases (i.e. test cases 5.2 until 5.14) were performed, since the experimental test cases (i.e. test cases 4.1 until 4.6) for both *DIALux* and *DIALux evo* have been reported, although a few selected analytical test cases have been performed as well [DIAL 2015a, 2015b]. To date, *DIALux* 4.12 can simulate both artificial lighting and daylighting scenes, but *DIALux evo* 4.1 can do only artificial lighting scenes, since *DIALux evo* 4.1 does not consider exterior daylight scenes and reflection from exterior objects in daylight scenes into account. Even though there is an option to include daylight (from overcast, clear, or mixed sky) in the scene, *DIALux evo* 4.1 currently can only create the daylight visualization in the scene, but cannot actually calculate the numerical values, i.e. it cannot return the values of daylight parameters (at least) as required in the CIE 171:2006 document. Therefore, the test cases that include daylight (i.e. test cases 5.9 until 5.14) were performed for *DIALux* 4.12 only.

For all test cases, the simulation setting in *DIALux* 4.12 was set to be "very accurate (longer calculation time)", while the default simulation setting was used *DIALux evo* 4.1. In both programs, the light loss factor was set to 1.0, i.e. no loss of light due to any factors other than geometrical distance and specified reflection or transmission.

2.1. Test case 5.2

This test case is to assess direct illuminance values from a point light source at 3 m height above the center of a horizontal surface (4 m × 4 m). Both diffuse and asymmetrical intensity distributions are used in CIE 171:2006, but in this article only the diffuse distribution was tested, as the intensity values can be obtained analytically, knowing that the source has a maximum intensity of 1000 cd. The position of the receiving points is described in Fig. 1. The illuminance values can be obtained by the following equation:

$$E = \frac{I_\theta}{R^2} \cos \alpha \tag{1}$$

where E is the direct illuminance at a given point [lx]; I_θ is the intensity of the point light source in the direction of the receiving point [cd]; θ is the incidence angle of the light with respect to the normal of the source [rad]; α is the incidence angle of the light with respect to the normal of the receiving plan [rad]; and R is the distance between the light source and the receiving point [m].

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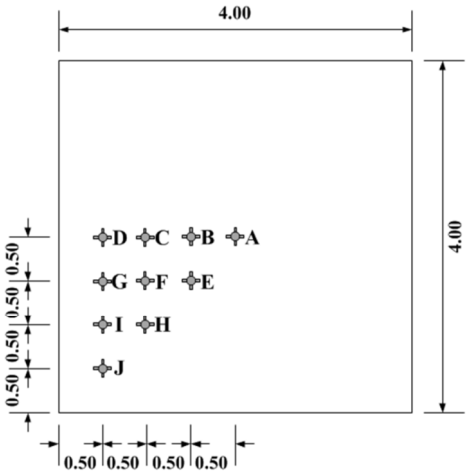


Fig. 1. Plan view of the receiving points in test case 5.2

2.2. Test case 5.3

This test case is to assess direct illuminance values from an area light source (1 m × 1 m) at the center of the ceiling of a black room (0% reflectance) of 4 m × 4 m × 3 m. Both diffuse and asymmetrical intensity distributions are used in CIE 171:2006, but in this article also only the diffuse distribution was tested, given the maximum intensity of 1000 cd. The position of the receiving points is described in Fig. 2. The illuminance values can be obtained by the following equation:

$$E = M \times F_{12} \tag{2}$$

where E is the direct illuminance at a given point [lx]; M is the luminous exitance of the area light source [lm/m^2]; and F_{12} is the configuration (or view) factor between the receiving area dS_1 and the area light source S_2 [-].

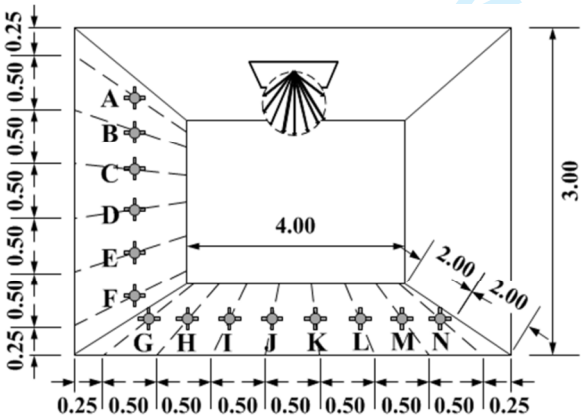
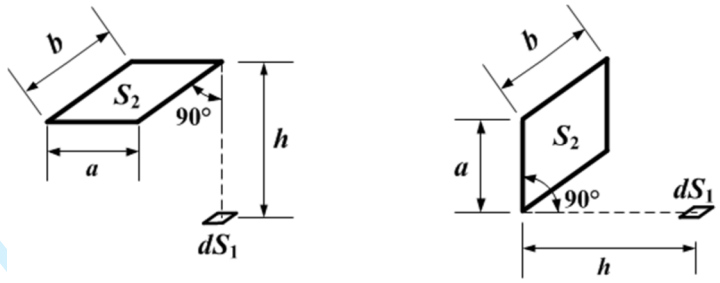


Fig. 2. Perspective view of the receiving points in test case 5.3

For any receiving point in a plan parallel to the area light source and opposite to one of its corners (Fig. 3a), the configuration factor $F_{12,H}$ can be obtained analytically from Equation 3, whereas for any receiving point in a plan perpendicular to the area light source and opposite to

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one of its corners (Fig. 3b), the configuration factor $F_{12,V}$ can be obtained analytically from Equation 4.



(a) **(b)**

Fig. 3. Configuration of a receiving point in a plan (a) parallel to the area light source, and (b) perpendicular to the area light source

$$F_{12,H} = \frac{1}{2\pi}\left[\frac{X}{\sqrt{1+X^2}}\arctan\frac{Y}{\sqrt{1+X^2}} + \frac{Y}{\sqrt{1+Y^2}}\arctan\frac{X}{\sqrt{1+Y^2}}\right] \quad (3)$$

$$F_{12,V} = \frac{1}{2\pi}\left[\arctan Y - \frac{1}{\sqrt{1+X^2}}\arctan\frac{Y}{\sqrt{1+X^2}}\right] \quad (4)$$

where $X = a/h$ and $Y = b/h$.

2.3. Test case 5.4

This test case aims to assess the luminous flux on the exterior surface of an aperture, which is a roof opening (1 m × 1 m) or a façade opening (2 m × 1 m), and the total luminous flux on the interior surface of a black room (0% reflectance) of 4 m × 4 m × 3 m, which analytically should be equal.

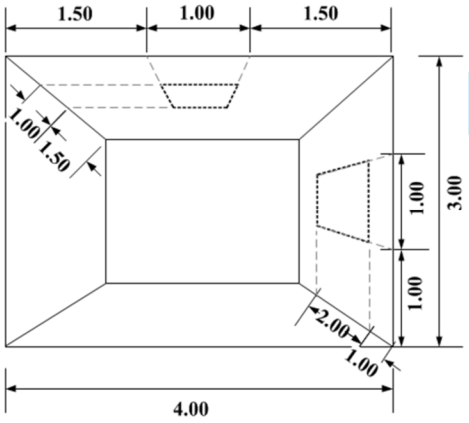


Fig. 4. Perspective view of the scenario in test case 5.4, with either a roof or a façade opening

The light source in this test case is the CIE Overcast Sky (type 16) or the CIE Clear Sky (type 12), both of which were applied in *DIALux* 4.12. For the clear sky scene, location was defined at 0° latitude and 0° longitude, on 21 March at 10.06 hrs, corresponding to the sun

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elevation angle of 60°. Since *DIALux evo* 4.1 is not yet able to simulate daylight, an array of 3 × 12 luminaires was applied instead, at 1 m height above the roof.

2.4. Test case 5.5

This test case aims to assess the angular transmittance of a clear glass (with negligible bi-directional effects) at various incidence angles, relative to its transmittance at normal incidence angle. The tested scenario was a black room of 4 m × 4 m × 3 m with a 1 m × 1 m roof opening. The light source was a point source with a very narrow intensity distribution of maximum 1000 cd. Total luminous flux on the interior surface was calculated with and without glazing (of 96% normal transmittance) at incidence angle of 0° (normal) until 90°, with a step of 10°. It is found however that the public released version of *DIALux evo* 4.1 requires a minimum thickness of 0.1 m for the ceiling; therefore the incidence angle of 80° could not be tested without obtaining zero value at all surfaces, since the light was already blocked by story's thickness.

The reference values for the relative angular transmittance are given in the CIE document [CIE, 2006].

2.5. Test case 5.6

This test case aims to assess the light reflection from a diffuse surface of a certain reflectance. The diffuse surface had a size of 0.5 m × 0.5 m or 4 m × 4 m, with a fixed reflectance of 30%. Note that a surface size of 500 m × 500 m was also proposed in the CIE document, but was not tested in this article for calculation efficiency. The light source was an array of point sources with a very narrow intensity distribution, put in a way so that the diffuse surface received a uniform illumination. The incidence angle was 45° and 35° for the diffuse surface size of 0.5 m × 0.5 m and 4 m × 4 m, respectively (Fig. 5). The receiving points were illustrated in Fig. 6.

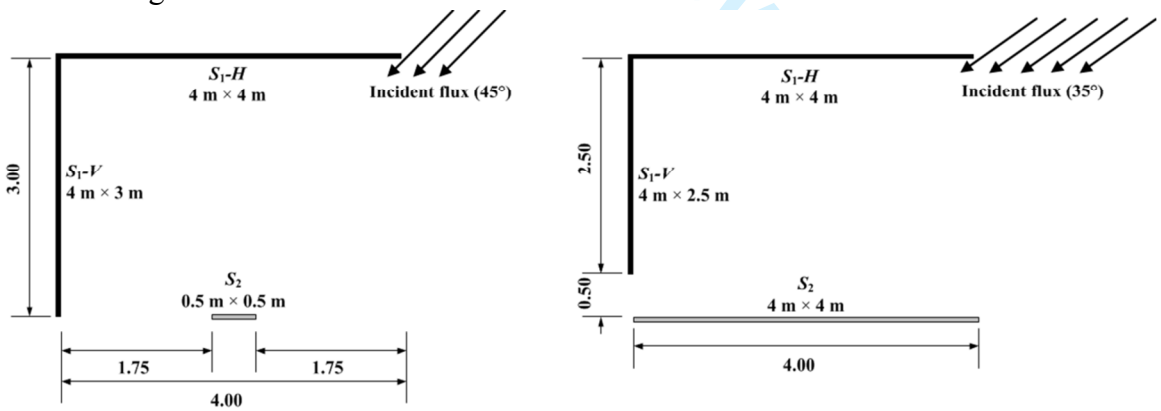


Fig. 5. Elevation views of the space in test case 5.6, with (a) 0.5 m × 0.5 m and (b) 4 m × 4 m diffuse surface

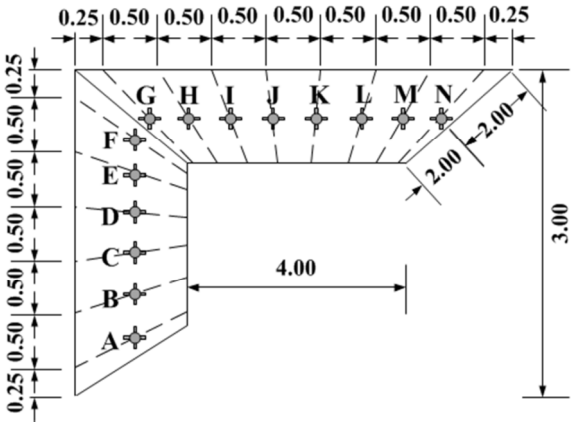


Fig. 6. Perspective view of the receiving points in test case 5.6. Note that in the scenario with 4 m × 4 m diffuse surface, the vertical wall is 2.5 m high and point A does not exist.

The indirect illuminance at the receiving points can be obtained analytically as follows:

$$E_i = E_{hz} \times \rho \times F_{12} \quad (5)$$

where E_i is the indirect illuminance at the receiving point [lx]; E_{hz} is the average direct horizontal illuminance at the diffuse surface [lx]; ρ is the reflectance of the diffuse surface [-]; and F_{12} is the configuration factor between the receiving area dS_1 and the diffuse reflecting surface S_2 [-]. Here, the configuration factor F_{12} [in %] is the quantity to be assessed, with reference to the CIE document.

2.6. Test case 5.7

This test case aims to assess the influence of an internal obstruction to a diffuse reflection. The light source was an array of point sources with a very narrow intensity distribution, put in a way so that a vertical, diffuse surface of 3 m × 4 m and 60% reflectance received a uniform illumination, with an incidence angle of 60° (Fig. 7).

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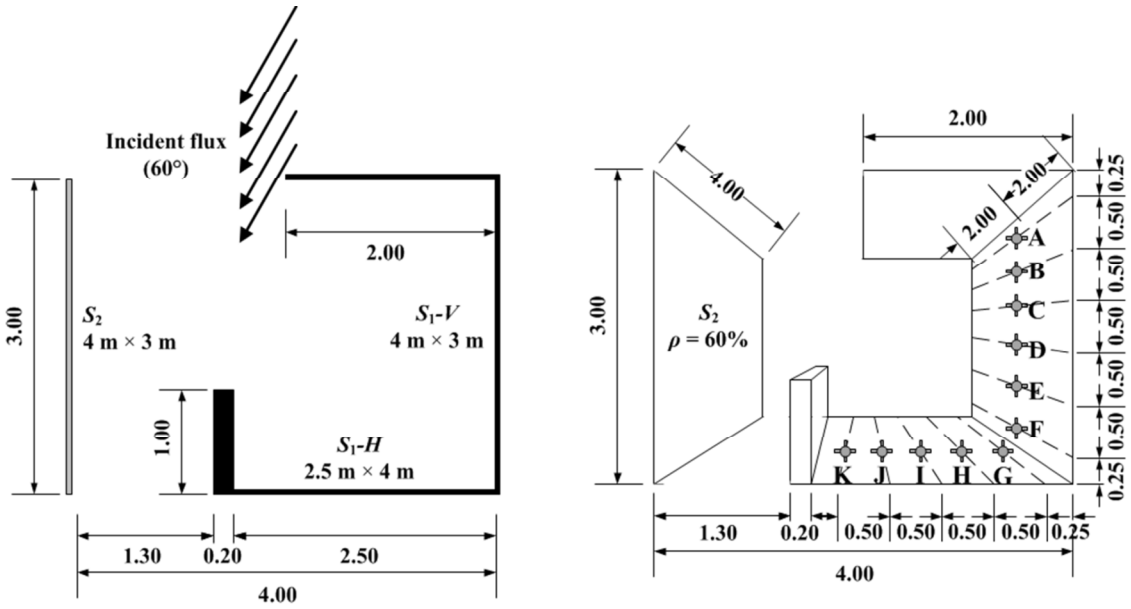


Fig. 7. (a) Elevation and (b) perspective views of the scenario in test case 5.7

The indirect illuminance at the receiving points can be obtained analytically using Equation 5, in which the configuration factor F_{12} [in %] is the quantity to be assessed. It is noticed however that reference values in the CIE document might be incorrect [Geisler-Moroder and Dür, 2008]. Therefore, the analytical values were referred instead.

2.7. Test case 5.8

This test case aims to assess the average indirect illuminance due to inter-reflection on the interior surface of a 4 m × 4 m × 4 m room with varying reflectance values (Fig. 8). The light source was a point source with an isotropic intensity distribution and a given luminous flux of 10000 lm, positioned in the center of the room. The interior surface reflectance was set all equal, varying from 5%, 10%, 20%, and so forth until 90%. It is found that both programs cannot model a surface reflectance of higher than 90%, therefore the reflectance value of 95% was not assessed.

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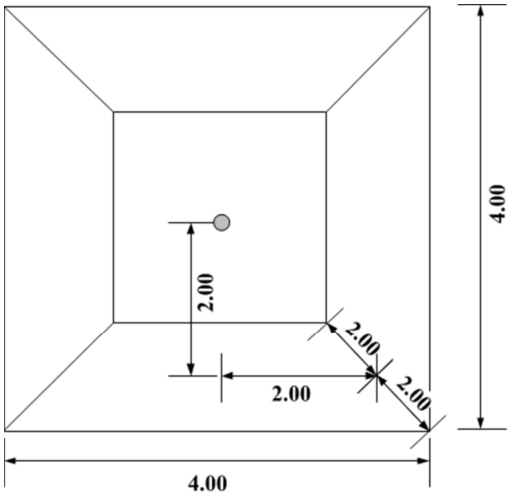


Fig. 8. Perspective view of the scenario in test case 5.8

The average, indirect illuminance values on the interior surface can be obtained analytically as follows:

$$E_{i,av} = \frac{\Phi}{S_T} \times \frac{\rho}{1-\rho} \tag{6}$$

where $E_{i,av}$ is the average indirect illuminance at the interior surface [lx]; Φ is the luminous flux of the point light source [lm]; S_T is the total area of the interior surface [m^2]; and ρ is the average reflectance of the interior surface [-]. Both programs cannot directly calculate indirect illuminance values, therefore the values were obtained by subtracting total illuminance values under a certain reflectance with the total illuminance values under 0% reflectance (i.e. the direct illuminance).

2.8. Test case 5.9

This test case aims to assess the sky component on the receiving points in a 4 m × 4 m × 3 m black room with an unglazed roof opening of 1 m × 1 m (Fig. 9). The light source was the CIE Overcast Sky (type 16). The reference values are given in the CIE document, whereas the analytical values can be referred to, e.g., Seshadri [1960] and Andersen [2004].

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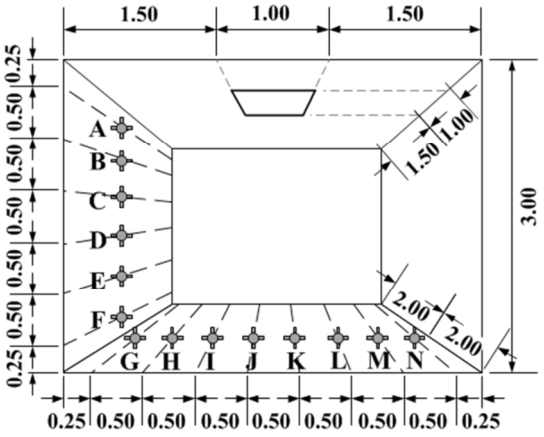


Fig. 9. Perspective view of the scenario in test case 5.9

2.9. Test case 5.10

This test case is similar to test case 5.9, with the only different is the use of 6 mm clear glass (91% normal transmittance) on the roof opening. The reference values are given in the CIE document.

2.10. Test case 5.11

This test case aims to assess the sky and externally reflected components on the receiving points in a 4 m × 4 m × 3 m black room with an unglazed façade opening of 2 m × 1 m (Fig. 10). The external ground was assumed to have a reflectance of 30%. The light source was the CIE Overcast Sky (type 16). The reference values are given in the CIE document, whereas the analytical values can be referred to, e.g., Seshadri [1960] and Andersen [2004].

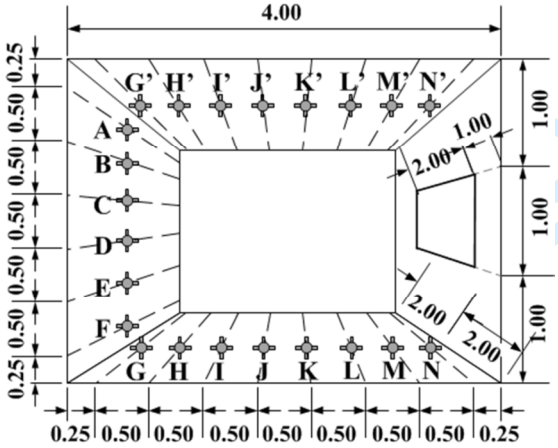


Fig. 10. Perspective view of the scenario in test case 5.11

2.11. Test case 5.12

This test case is similar to test case 5.11, with the only different is the use of 6 mm clear glass (91% normal transmittance) on the façade opening. The reference values are given in the CIE document.

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2.12. Test case 5.13

This test case aims to assess the sky and externally reflected components on the receiving points in a 4 m × 4 m × 3 m black room with an unglazed façade opening of 2 m × 1 m, and a continuous external horizontal mask (i.e. a canopy) above the façade (Fig. 11). The canopy width was 0.5 m, 1 m, or 2 m; the reflectance was assumed to be 50% [Dau Design and Consulting, 2007]. The external ground was assumed to have a reflectance of 30%. The light source was the CIE Overcast Sky (type 16). The reference values are given in the CIE document.

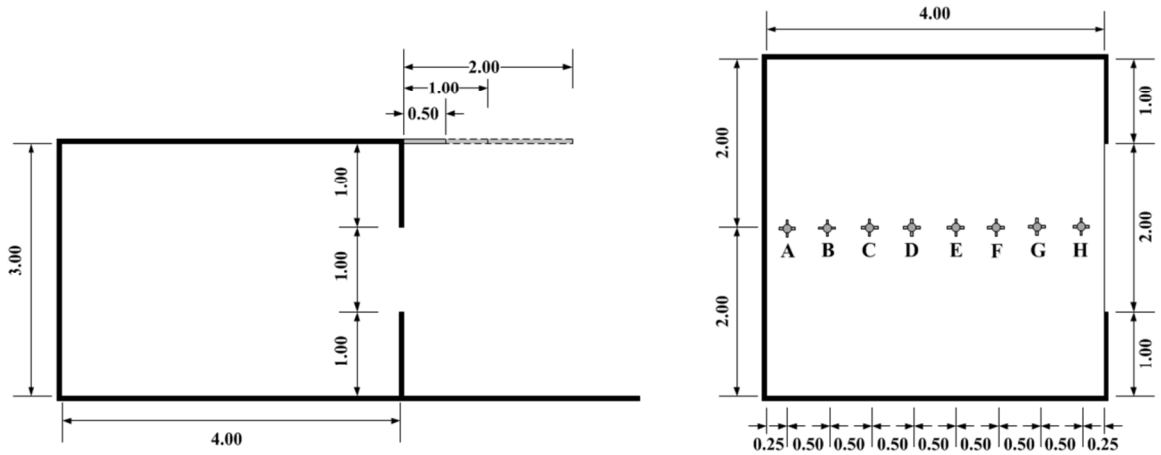


Fig. 11. (a) Elevation view of the scenario and (b) plan view of the receiving points in test case 5.13

2.13. Test case 5.14

This test case aims to assess the sky and externally reflected components on the receiving points in a 4 m × 4 m × 3 m black room with an unglazed façade opening of 2 m × 1 m, and a continuous external vertical mask (i.e. a barrier) at 6 m distance in front of the façade (Fig. 12). The barrier height was 3 m, 6 m, or 9 m; the reflectance was assumed to be 50% or 90%. The external ground was assumed to have a reflectance of 30%. The light source was the CIE Overcast Sky (type 16). The reference values are given in the CIE document.

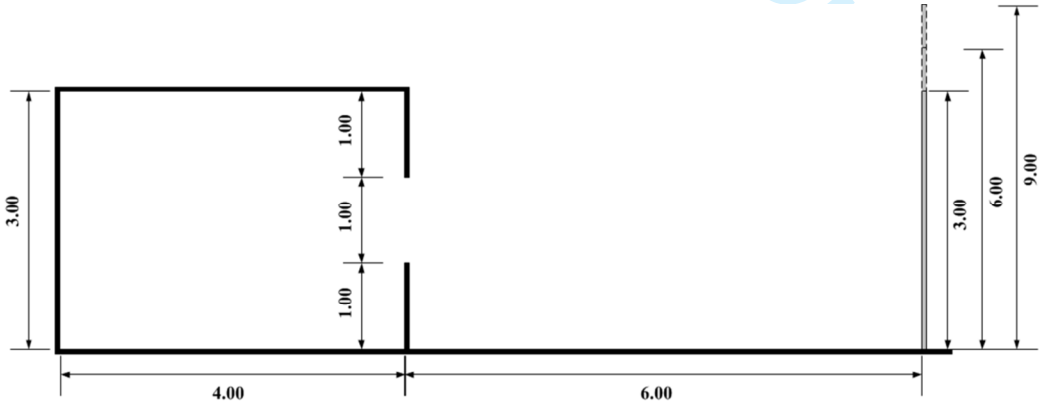


Fig. 12. Elevation view of the scenario in test case 5.14. The receiving points are at the same positions as in Fig. 11.

3. Results and Discussion

The simulation result of test case 5.2 is displayed in Fig. 13. Both *DIALux* 4.12 and *DIALux evo* 4.1 show a very good agreement with the analytical values; the largest relative error is –0.5% for *DIALux* 4.12 and 0.1% for *DIALux evo* 4.1.

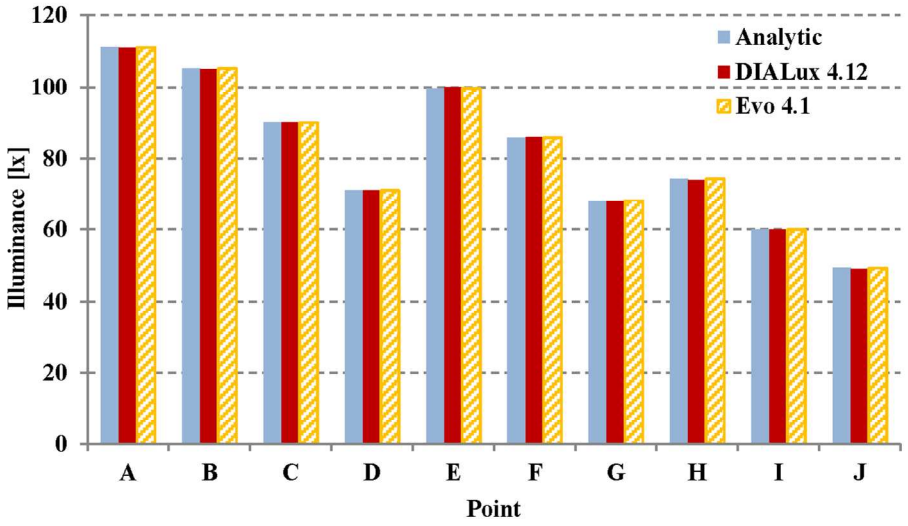


Fig. 13. Result of test case 5.2: point source – direct illuminance

The simulation result of test case 5.3 is displayed in Fig. 14. *DIALux evo* 4.1 yields a very good agreement with the analytical values; the maximum relative error is 0.2%. The largest relative error in *DIALux* 4.12 is noticeably high, i.e. 35% at point A, which is the closest to the area light source but with a very small configuration factor. At the rest of the receiving points, the relative error in *DIALux* 4.12 is within the range of –5% until 6%. The difference performance of both programs may suggest the capability of photon mapping algorithm to predict better illuminance values under area light source, as compared to radiosity algorithm.

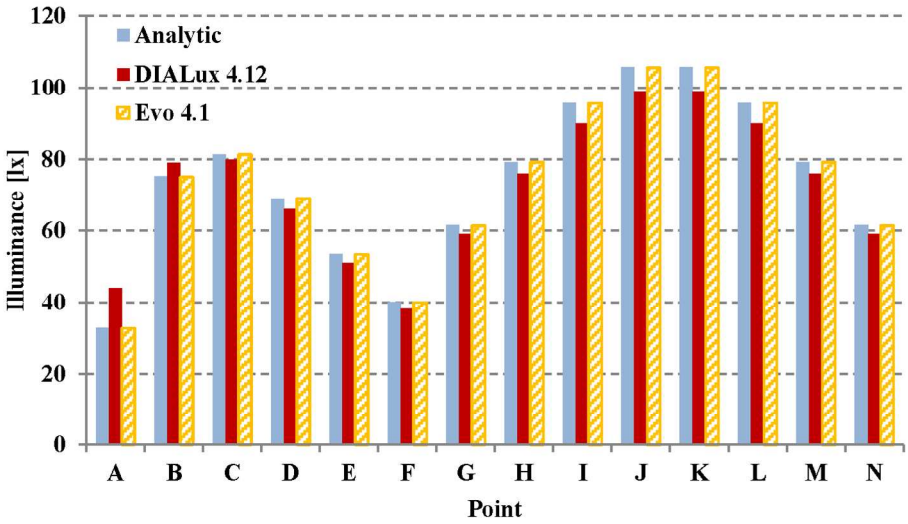


Fig. 14. Result of test case 5.3: area source – direct illuminance

The simulation result of test case 5.4 is displayed in Fig. 15, in which the values with overcast and clear skies were obtained with *DIALux* 4.12, and those with lamps were obtained with *DIALux evo* 4.1. *DIALux* 4.12 yields smaller differences between internal and external luminous flux, being around 1% for the roof opening and 8% for the façade opening. In *DIALux evo* 4.1, the differences are 4% for the roof opening and 7% for the façade opening. As expected, the total luminous flux is less conserved in the façade opening scenarios, since random reflection can occur from the external ground, despite having set the reflectance to zero.

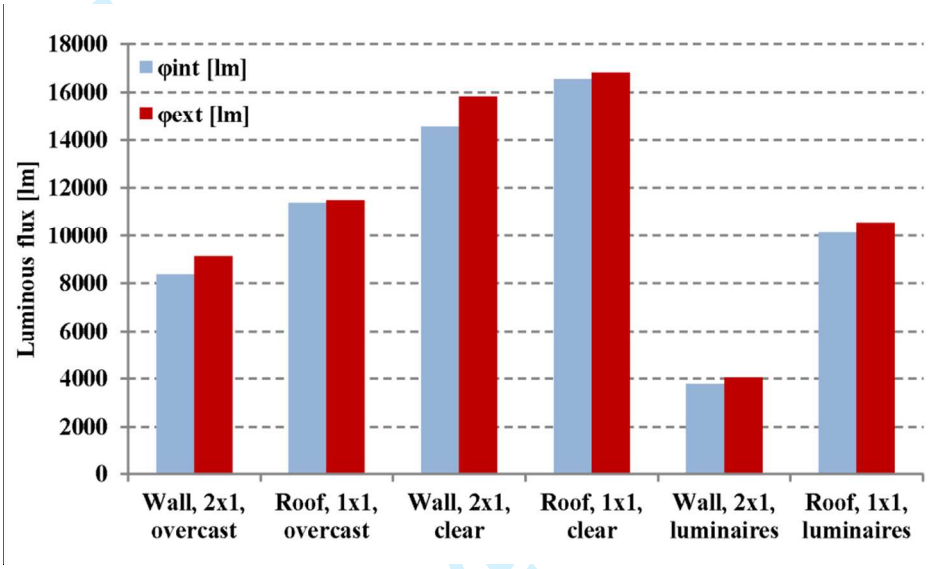


Fig. 15. Result of test case 5.4: daylighting – luminous flux conservation. The values with overcast and clear skies were obtained with *DIALux* 4.12, those with luminaires were obtained with *DIALux evo* 4.1

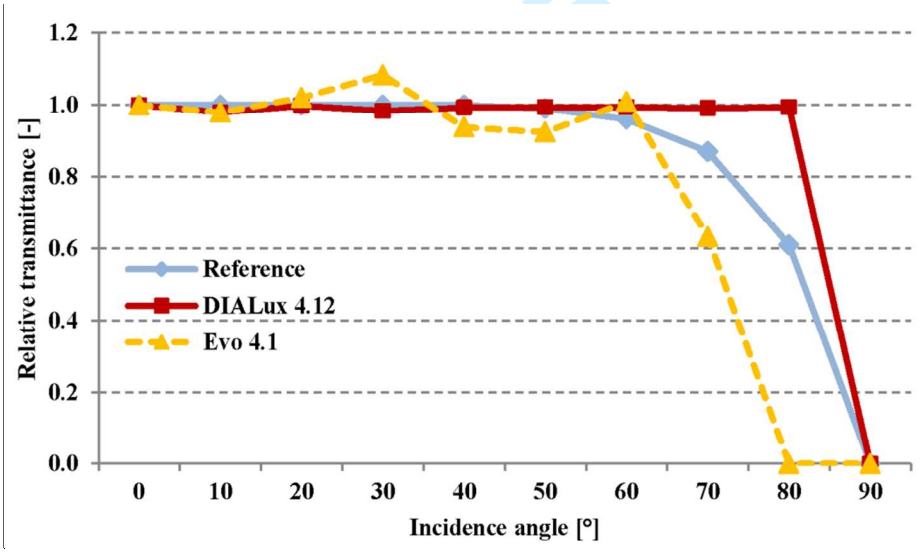


Fig. 16. Result of test case 5.5: directional transmission of clear glass

The simulation result of test case 5.5 is displayed in Fig. 16. *DIALux* 4.12 clearly assumes no variation of transmittance values with respect to the incidence angle; the relative transmittance

values stay between 0.98 and 1.00 for 0°~80° incidence angle. *DIALux evo* 4.1 presumably applies a similar assumption; it is found however that at 20° and 30° incidence angles, the relative transmittance is respectively 2% and 8% higher than the value at 0° angle.

The simulation result of test case 5.6 is displayed in Figs. 17 and 18. For diffuse surface size of 0.5 m × 0.5 m, *DIALux* 4.12 shows a good agreement with the reference values, with the largest relative error of 2%, whereas *DIALux evo* 4.1 yields relative errors of within ±5%. For diffuse surface size of 4 m × 4 m, *DIALux* 4.12 yields the largest relative error of 3%, whereas *DIALux evo* 4.1 yields 5%.

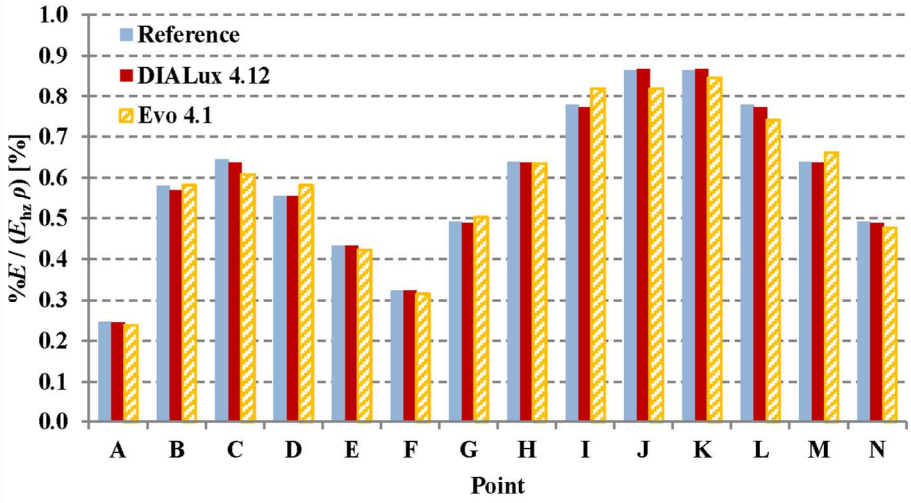


Fig. 17. Result of test case 5.6: indirect lighting – diffuse reflection, for diffuse surface size of 0.5 m × 0.5 m

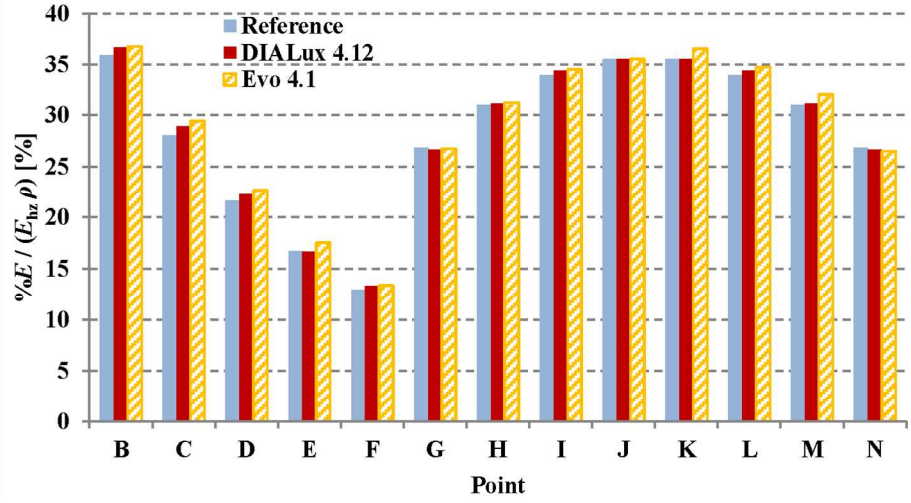


Fig. 18. Result of test case 5.6: indirect lighting – diffuse reflection, for diffuse surface size of 4 m × 4 m

The simulation result of test case 5.7 is displayed in Fig. 19. *DIALux* 4.12 shows relative errors between –6% and 4%, whereas *DIALux evo* 4.1 yields those between –4% and 2%. Note that the reference here is the analytically calculated values, since the given reference values in the CIE document are most likely incorrect [Geisler-Moroder and Dür, 2008].

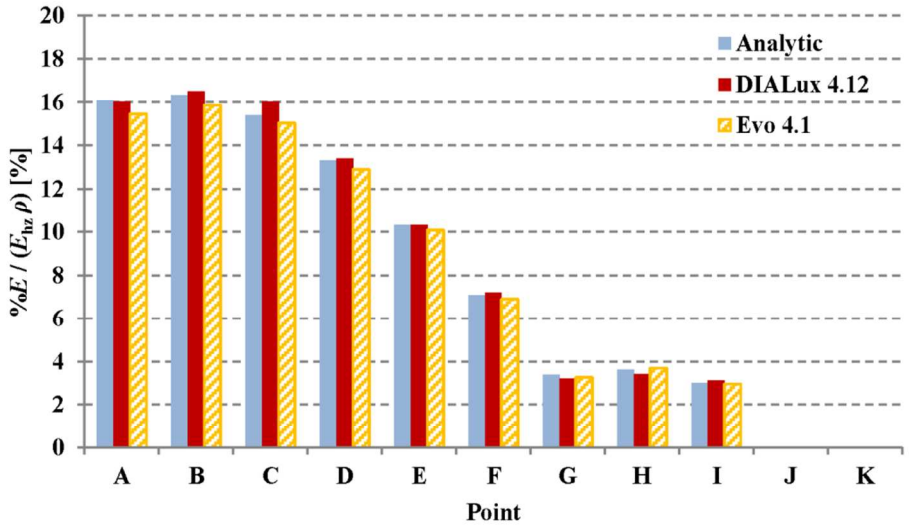


Fig. 19. Result of test case 5.7: indirect lighting – internal obstruction

The simulation result of test case 5.8 is displayed in Fig. 20. Both programs yield a relative error of –9% at 5% reflectance. In *DIALux* 4.12, the relative errors become smaller as the reflectance increases, however, for reflectance vales of 60% and higher, the errors rise again until +9% at 90% reflectance. In *DIALux evo* 4.1, the second largest error is +4% at 10% reflectance; at 90% reflectance the relative error is –2%.

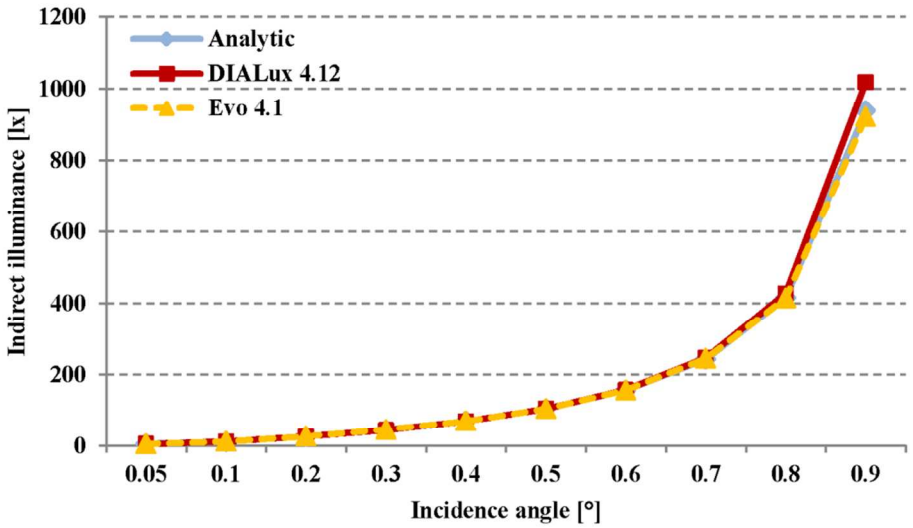
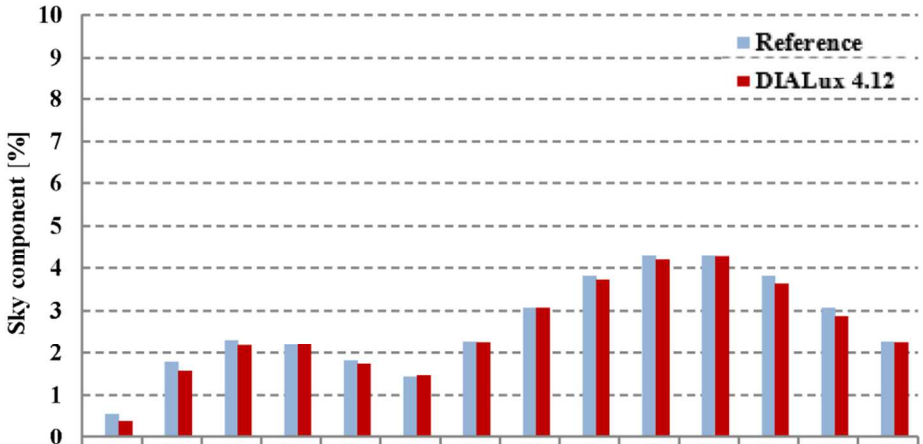


Fig. 20. Result of test case 5.8: point source – indirect illuminance

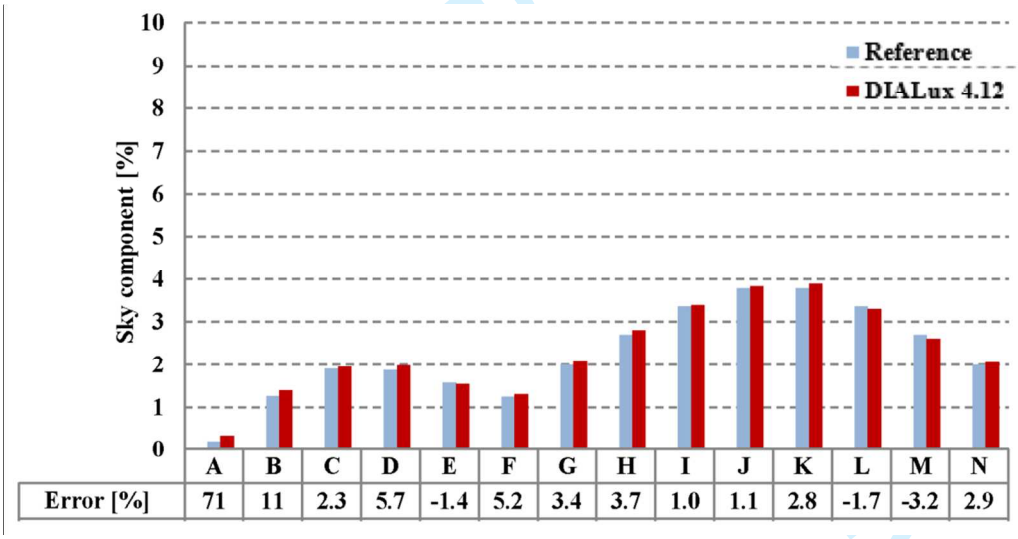
The simulation result of test case 5.9 is displayed in Fig. 21. Note that, only results from *DIALux* 4.12 are shown, since *DIALux evo* 4.1 is not yet able to handle daylighting simulation. The largest relative error is –30%, found at point A, which is again the closest to the aperture but with the smallest configuration factor, as observed in test case 5.3. The second largest relative error is –12% at point B.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Error [%]	-29	-11	-6.0	0.4	-4.5	2.2	-0.7	0.2	-2.4	-2.1	-0.4	-5.0	-6.4	-1.2

Fig. 21. Result of test case 5.9: direct daylighting – unglazed roof opening

The simulation result of test case 5.10 is displayed in Fig. 22. The largest relative error is remarkably high, i.e. 71% at point A. The second largest relative error is again at point B, 11%. It can be therefore concluded that *DIALux* 4.12 has a weakness in predicting illuminance at positions with relatively small configuration factors, under an area light source.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Error [%]	71	11	2.3	5.7	-1.4	5.2	3.4	3.7	1.0	1.1	2.8	-1.7	-3.2	2.9

Fig. 22. Result of test case 5.10: direct daylighting – glazed roof opening

The simulation result of test case 5.11 is displayed in Fig. 23. It is observed that the simulated values of sky and externally reflected components in *DIALux* 4.12 are not sufficiently accurate. Among the vertical points, the largest relative error is –20% at point C; among the horizontal points on the floor, the largest relative error is –24% at point N; whereas among the horizontal points on the ceiling, the largest relative error is –47% at point N'. Points N and N' are again those with the smallest configuration factor, i.e. re-confirming the finding from test cases 5.3, 5.9, and 5.10.

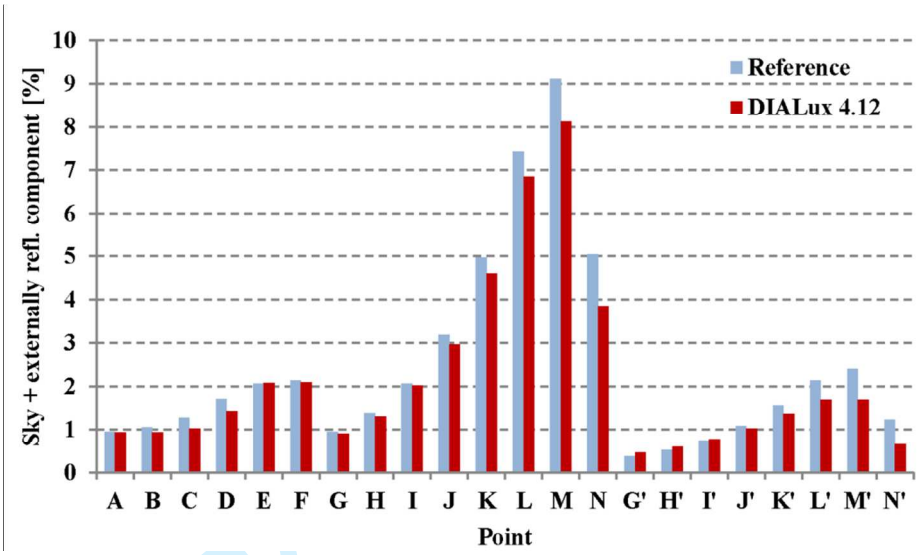


Fig. 23. Result of test case 5.11: direct daylighting – unglazed façade opening

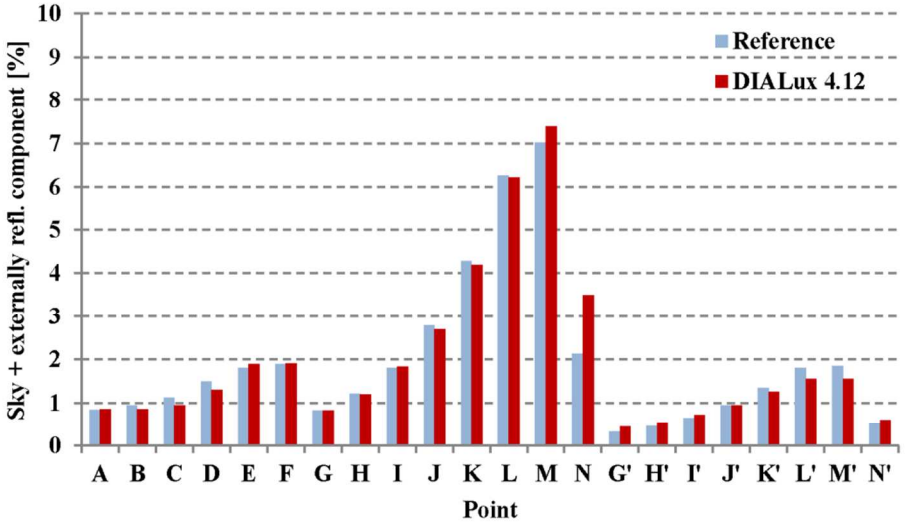


Fig. 24. Result of test case 5.12: direct daylighting – glazed façade opening

The simulation result of test case 5.12 is displayed in Fig. 24. Among the vertical points, the largest relative error is –16% at point C; among the horizontal points on the floor, the largest relative error is 64% at point N; whereas among the horizontal points on the ceiling, the largest relative error is 33% at point G'.

The simulation result of test case 5.13 is displayed in Fig. 25. Among all tested scenarios, the most remarkable error is found at point H, whose simulated values can be as large as three times the reference ones. At other points in all scenarios, except at points F and G in 2 m wide canopy scenario, the errors are arguably small, between –4% and 7%.

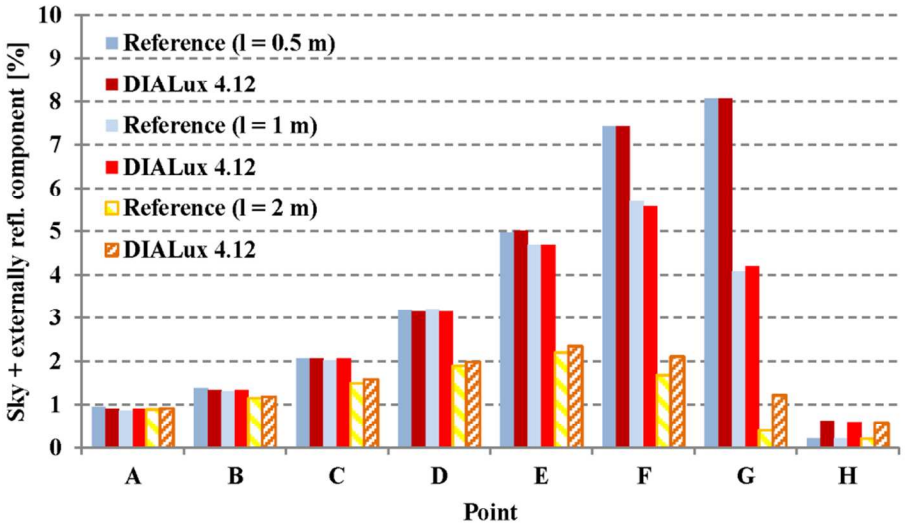


Fig. 25. Result of test case 5.13: daylighting – external horizontal mask

Finally, the simulation result of test case 5.14 is displayed in Fig. 26, for assumed barrier reflectance of 50%, and in Fig. 27 for that of 90%. It is observed that at points G and H, the simulated sky and externally reflected component is insensitive to variation of barrier reflectance. This value is found to be respectively 9.00% and 5.02% in all scenarios, as compared to the reference of 9.11% and 5.04%.

In the scenario of 3 m high barrier, the obtained results are highly accurate, having the largest error of –2% (assuming 50% barrier reflectance) or +2% (assuming 90% barrier reflectance). However, the errors increase significantly in the other two scenarios, with the largest is found at point E. In the scenarios of 6 m and 9 m high barrier, assuming 50% barrier reflectance yields smaller relative errors. Most of the simulated values in the last two scenarios are higher than the reference ones. This may suggest an overestimation of the reflected light off the barrier, while the sky component is being partially blocked. There is also a possibility, though, that the blocking may be underestimated in the reference values [Dau Design and Consulting 2007].

Having seen the results with the daylighting test cases, it is concluded that in general, *DIALux* 4.12 has low accuracy in calculating sky and externally components in daylight scenes.

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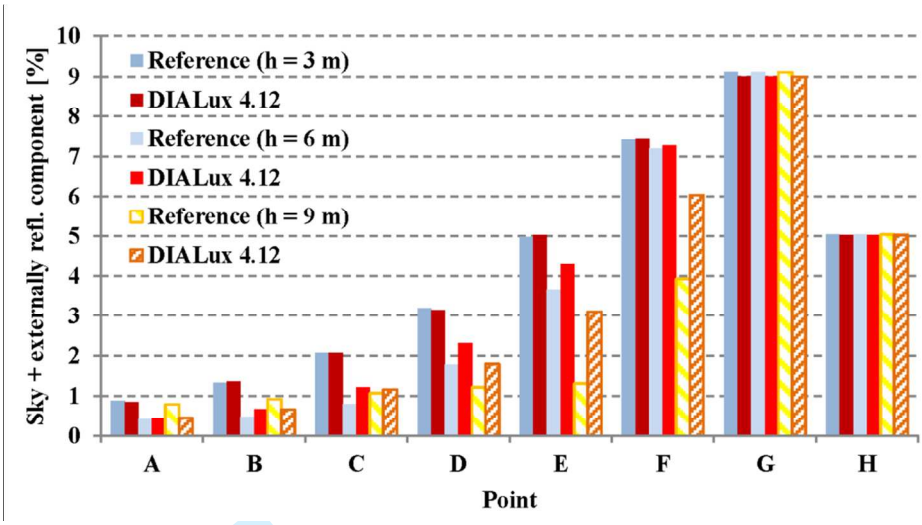


Fig. 26. Result of test case 5.14: daylighting – external vertical mask, of 50% reflectance

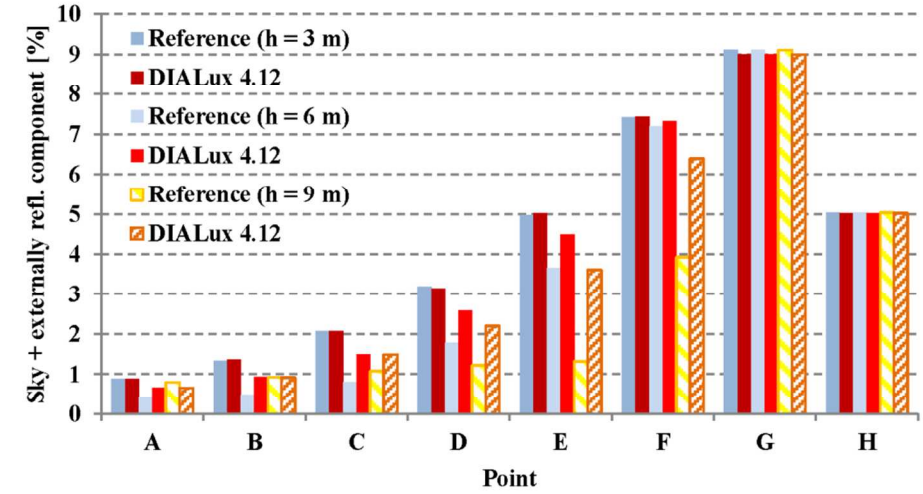


Fig. 27. Result of test case 5.14: daylighting – external vertical mask, of 90% reflectance

The strength and weakness of both tested programs, in view of the validation results, can be summarized as follows:

- *DIALux* 4.12
  - Strength: high accuracy in simulating point light source, diffuse reflection and inter-reflection.
  - Weakness: low accuracy in simulating area light source, in particular at locations with small configuration factors; low accuracy in calculating sky and externally reflected components in daylight scenes; incapable of simulating directional transmission of clear glass.
- *DIALux evo* 4.1
  - Strength: high accuracy in simulating point light source, area light source, diffuse reflection and inter-reflection.

- Weakness: incapable of calculating exterior daylight scenes and reflection from exterior objects in daylight scenes; incapable of simulating directional transmission of clear glass.

Remarks should be noted however, that the results presented in this article were obtained by applying the defined simulation settings in the currently available version of the programs; observed accuracy may vary for any other settings and for past or future versions of the programs. This may explain the difference between results of the overlapped test cases in the reports of DIAL [2015a, 2015b] and this article, since the former might have used the earlier version of *DIALux*. On the other hand, inaccuracies are also found in some of the reference values given in the CIE document, as pointed out by e.g. Dau Design and Consulting [2007]. Various new analytical cases, particularly for daylighting scenes, have also been proposed [e.g. Acosta et al. 2011, Iversen et al. 2013]. Acosta et al. [2013] proposed cases with various orientations, time on a day, and geometry (ratio of height and width). Iversen et al. [2013] proposed cases of five types of room, i.e. simple room, deep room, room with obstruction from the building's opposite, room with light shelf, and room with borrowed light. In both articles, daylight factor is the quantity to be assessed. While the current CIE document has been put in practice for almost ten years, it may be the time now to revise of the current version of the document, with possible introduction of some of those new cases to be tested.

4. Conclusion

This article reports the validation of *DIALux* 4.12 and *DIALux evo* 4.1 against the analytical test cases of CIE 171:2006. To date, *DIALux evo* 4.1 can calculate only artificial lighting scenes, therefore test cases 5.9 until 5.14 that include pure daylight scenes were performed for *DIALux* 4.12 only. Both programs show a very good agreement with the reference values in cases with point source (test cases 5.2 and 5.8). *DIALux* 4.12 yields noticeably errors at points with small configuration factors, in cases with area source (test cases 5.3 and 5.9 until 5.12). Both programs show a good agreement with the reference values in cases with diffuse reflection (test cases 5.6 and 5.7). Both programs are capable to yield small error in luminous flux conservation (test case 5.4), but does not respect variation of relative angular transmission due to varying incidence angles (test case 5.5). Inaccuracies are found in daylighting scenes, particularly in the calculation of sky and externally reflected components.

Inaccuracies are also found in some of the reference values in the CIE document. Meanwhile, various new analytical cases have been proposed, particularly for daylighting scenes. It may be of common interest for the CIE to amend the current version of the document and publish a new version with possibly a new series of test cases.

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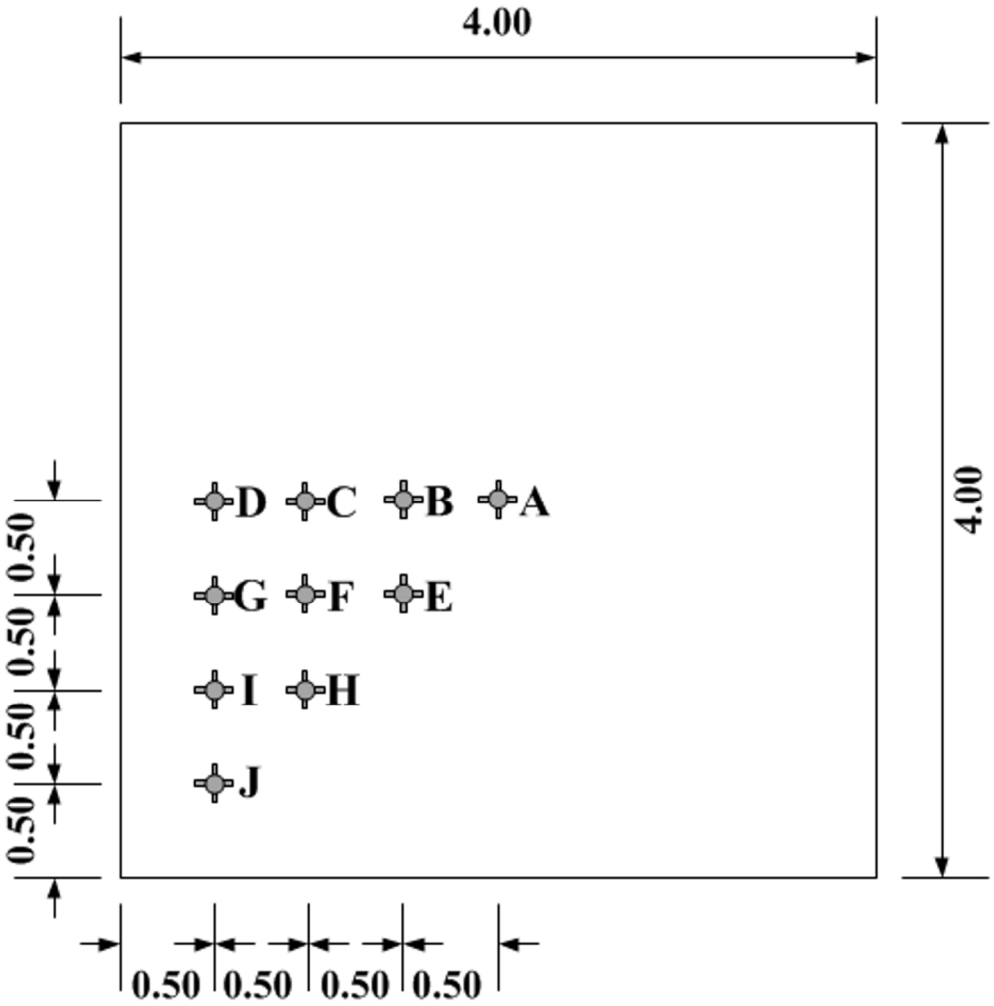


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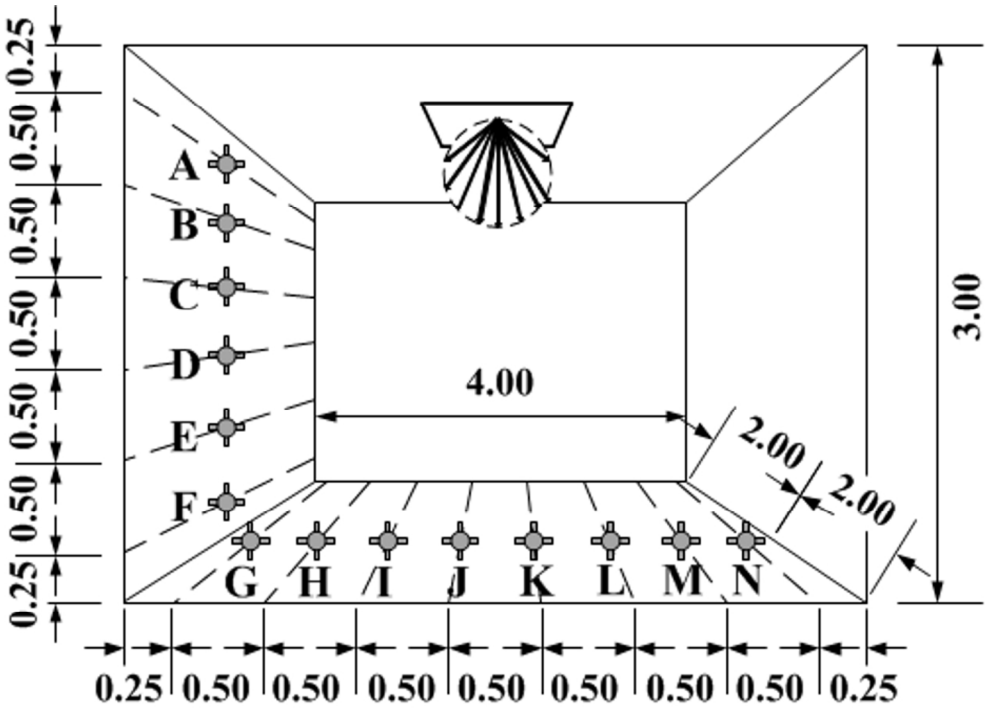


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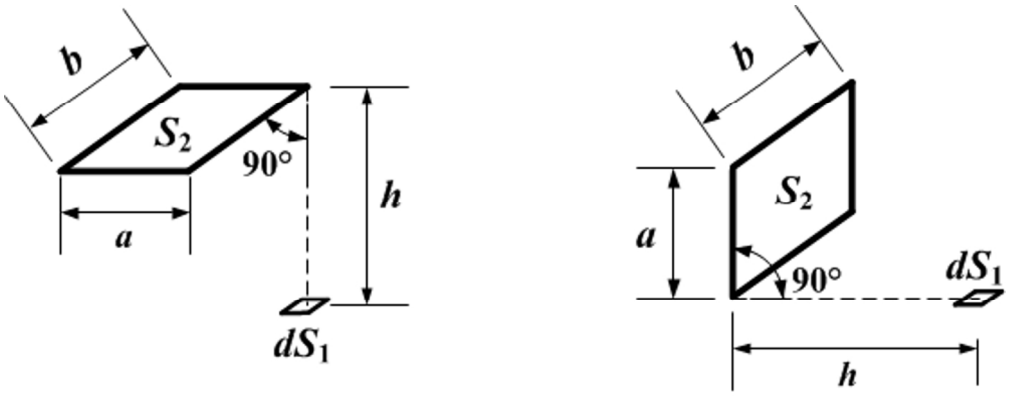
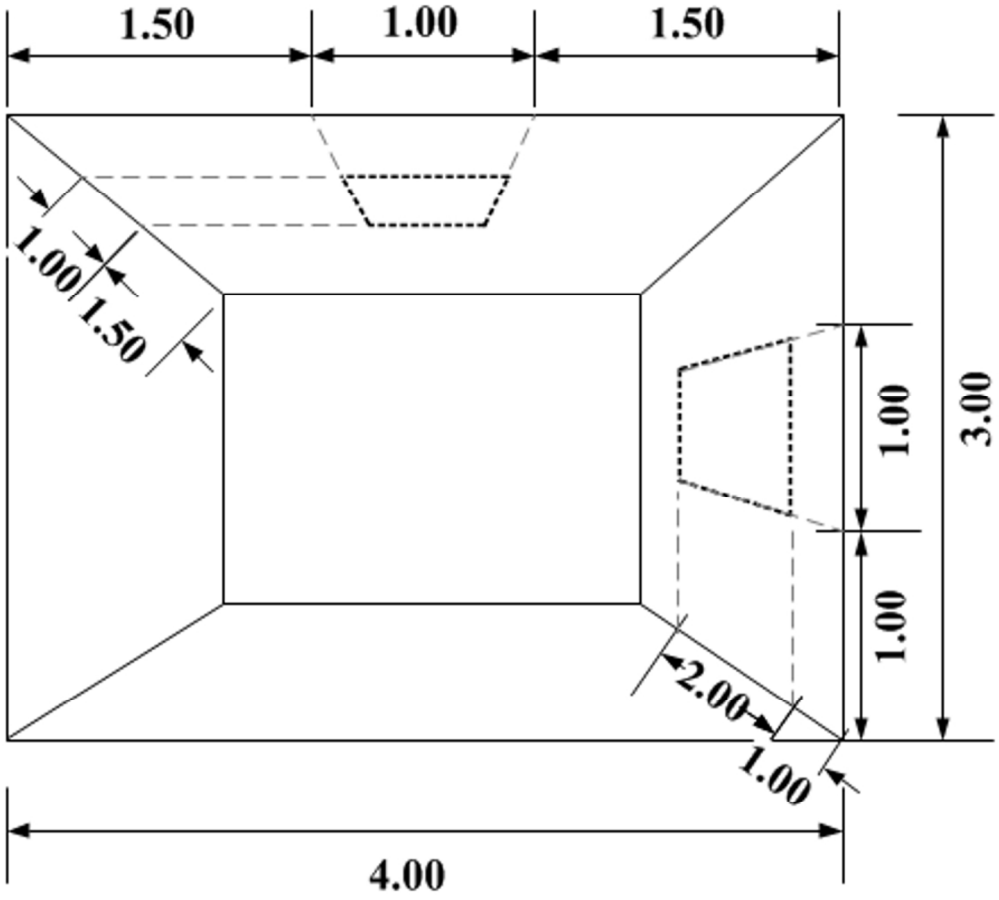


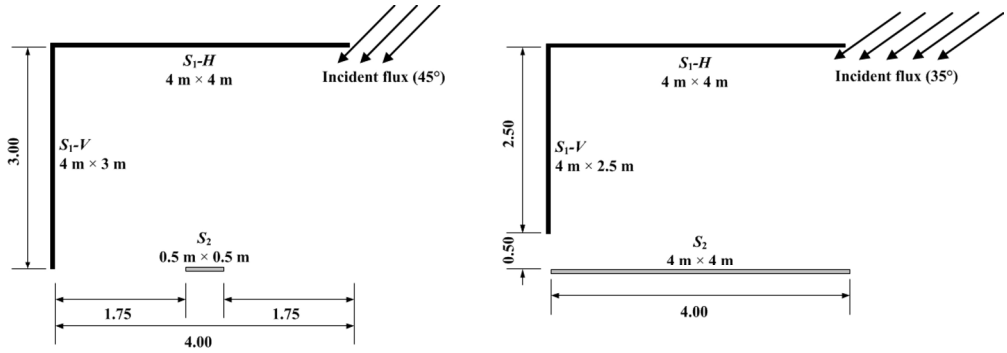
Fig. 3
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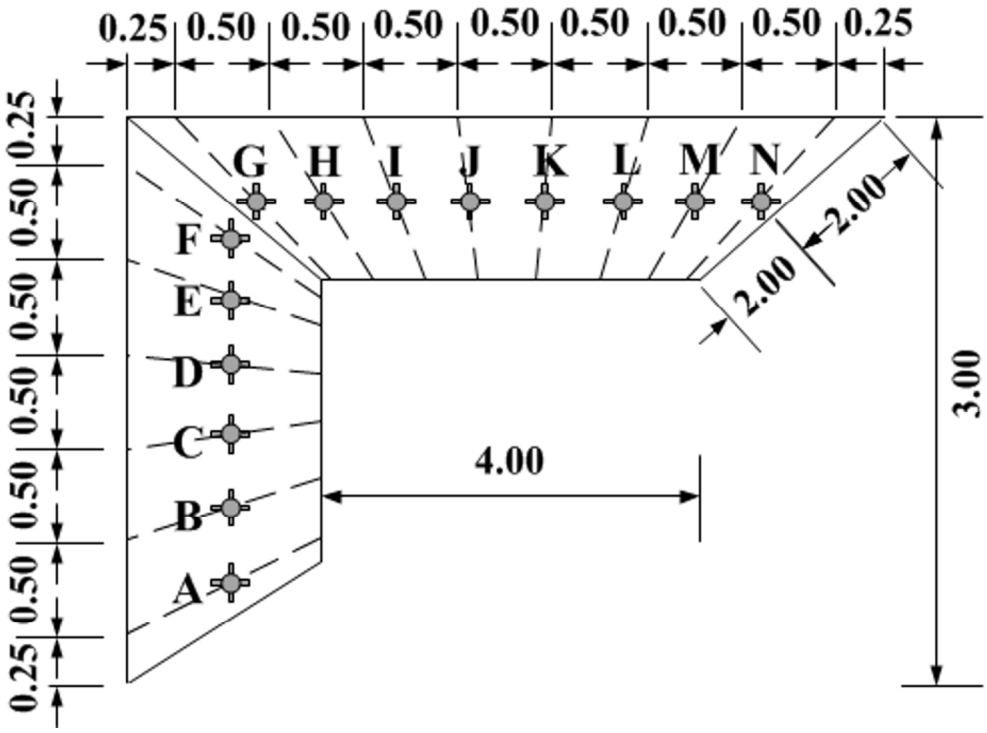
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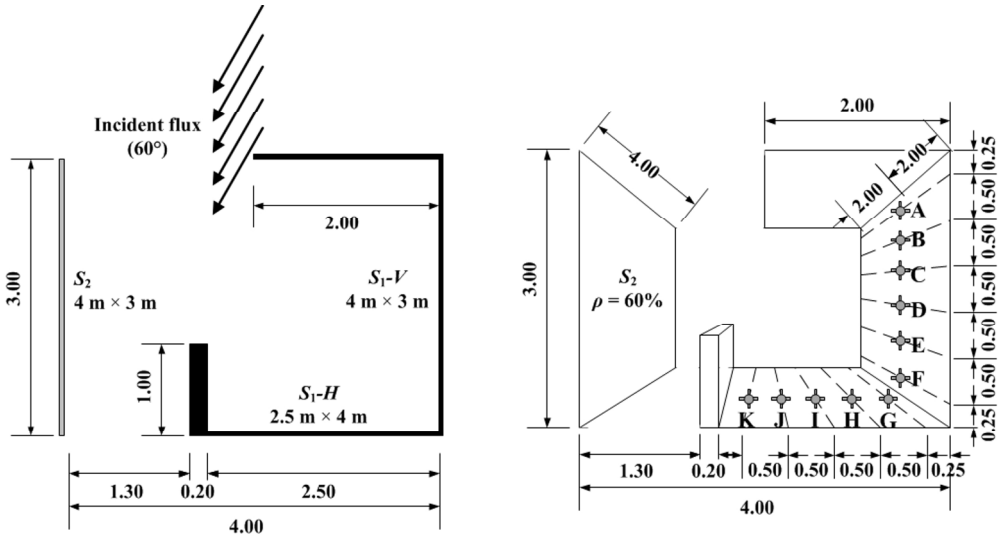
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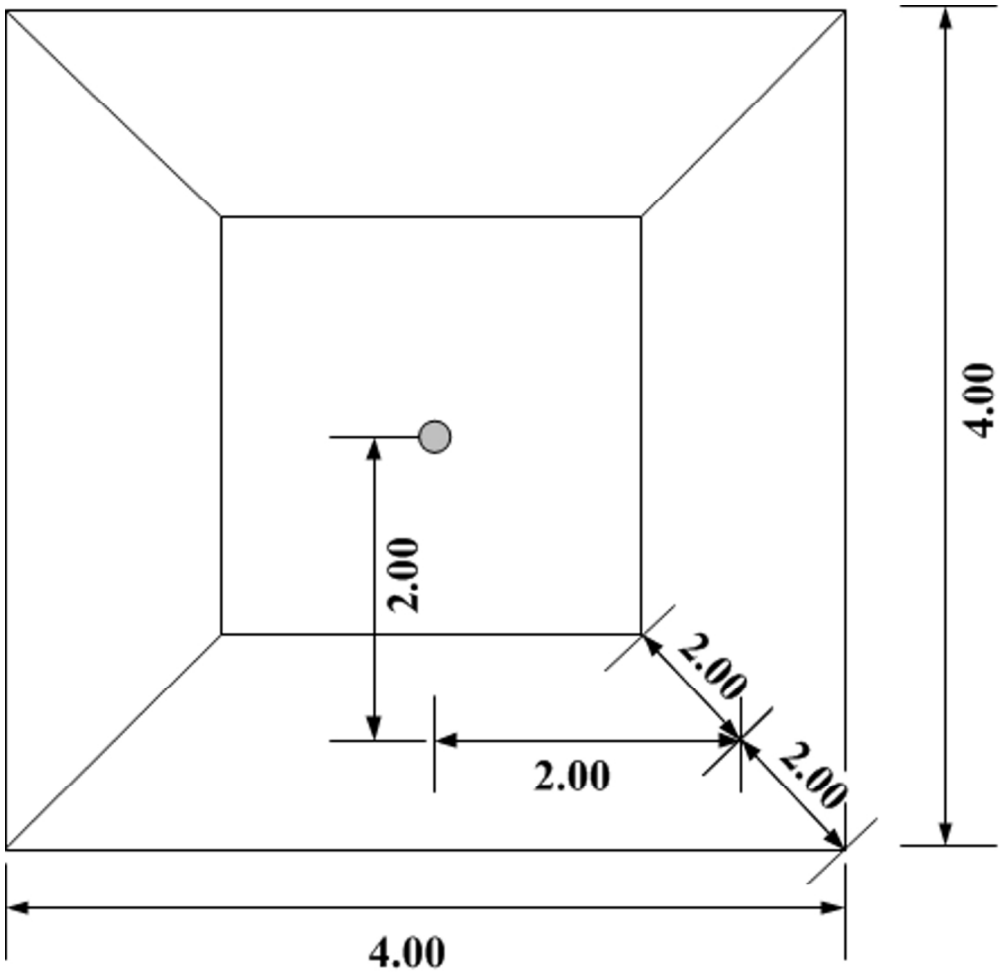
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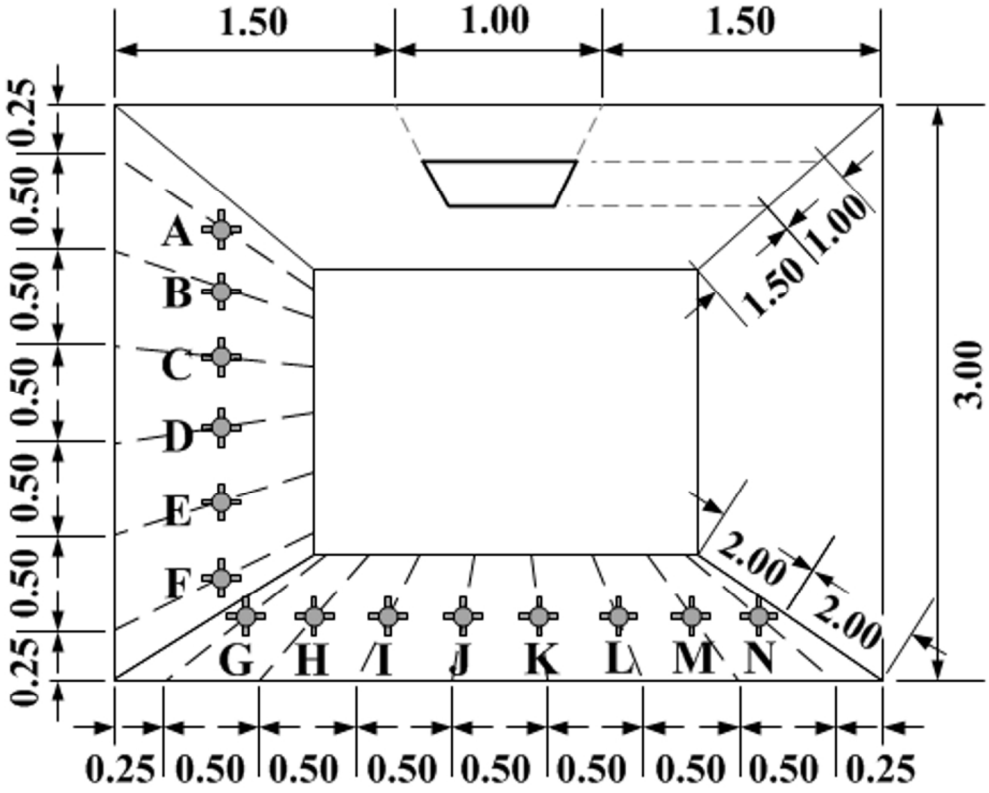
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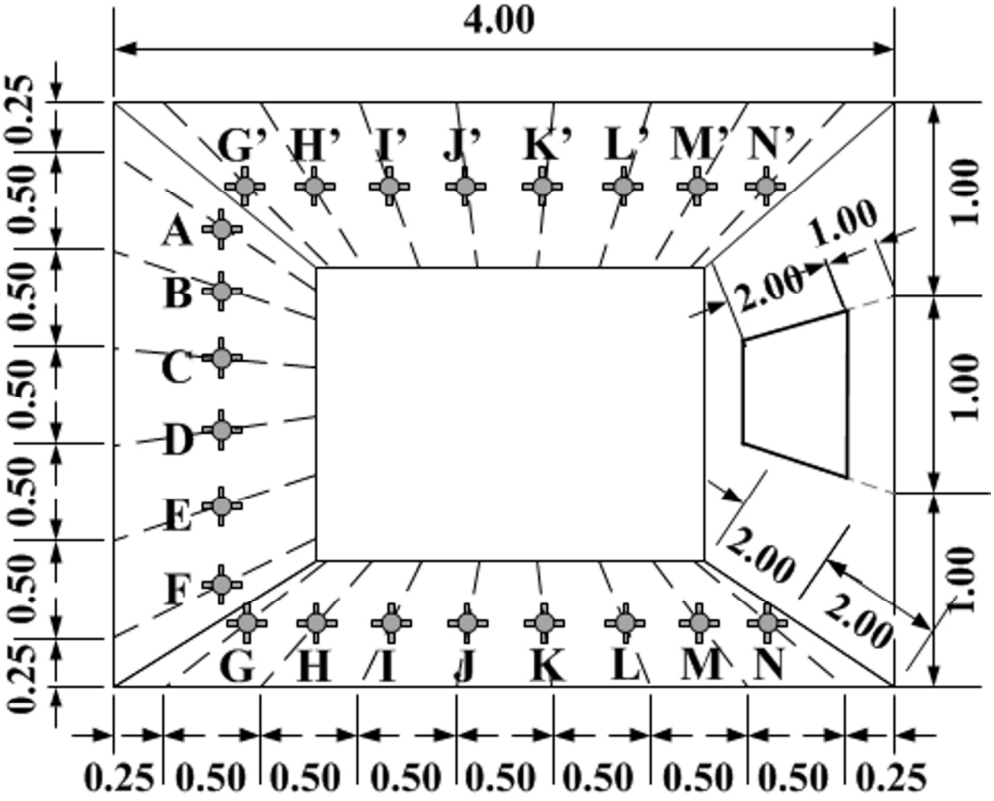
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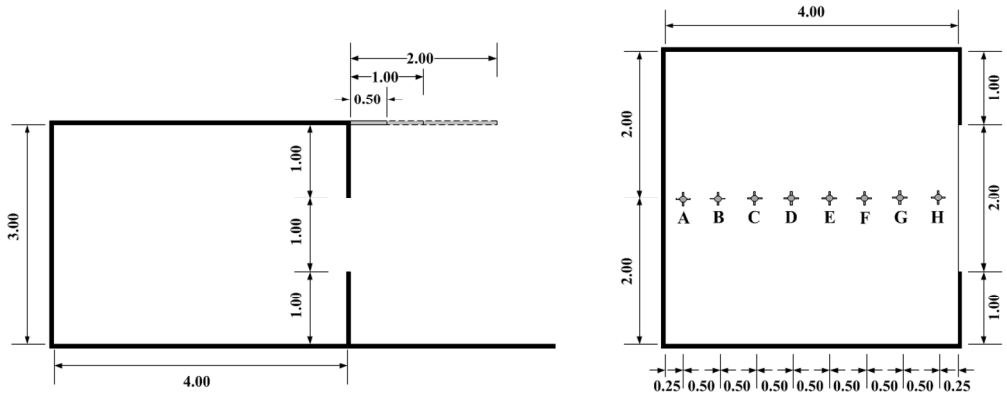
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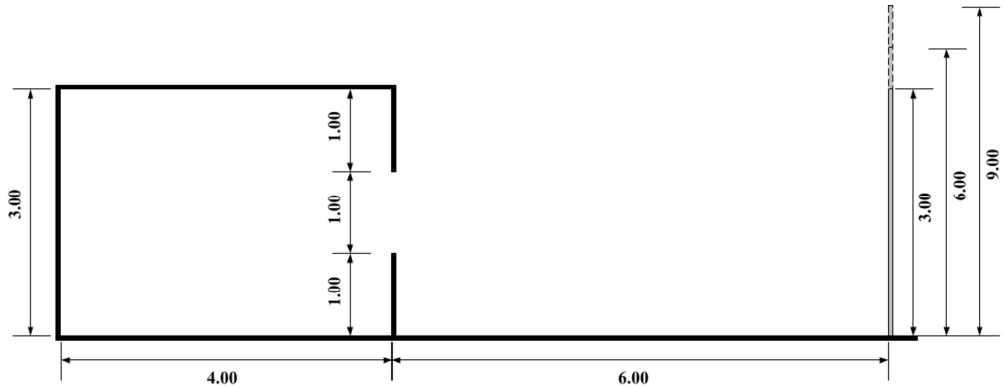
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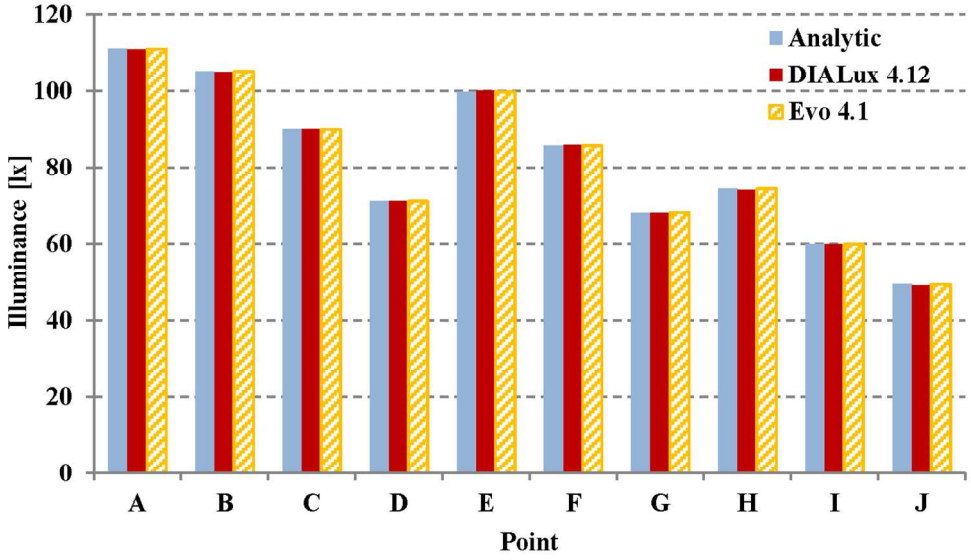
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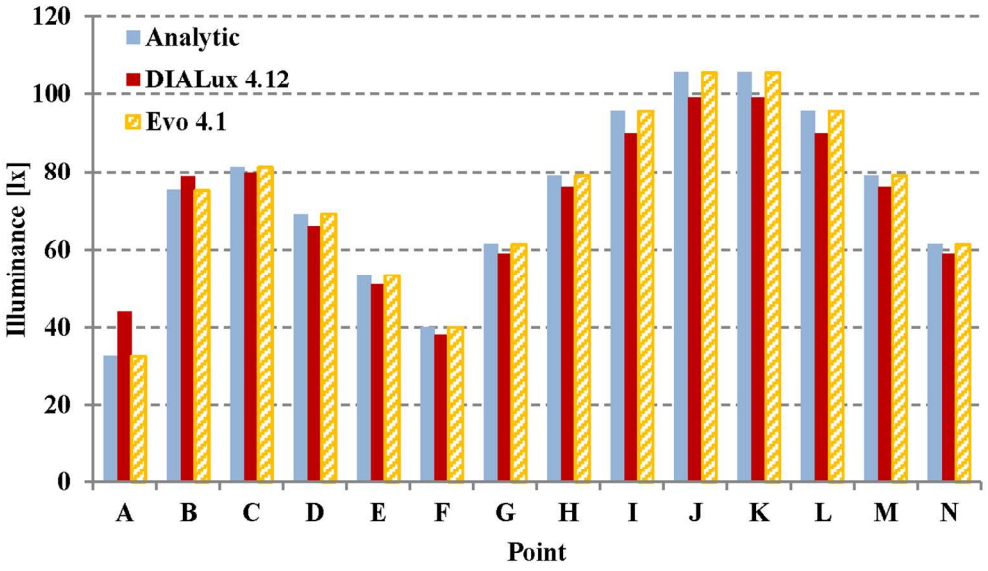
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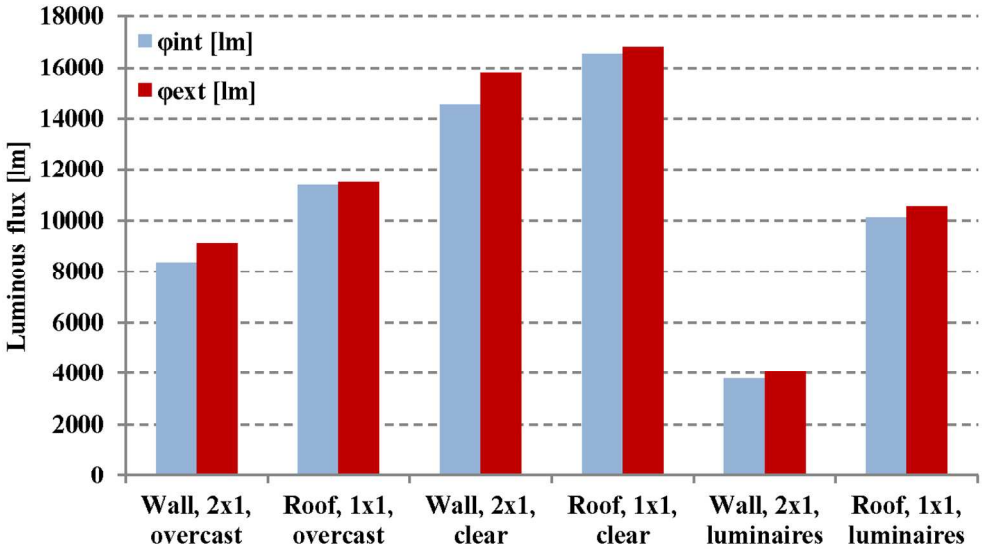
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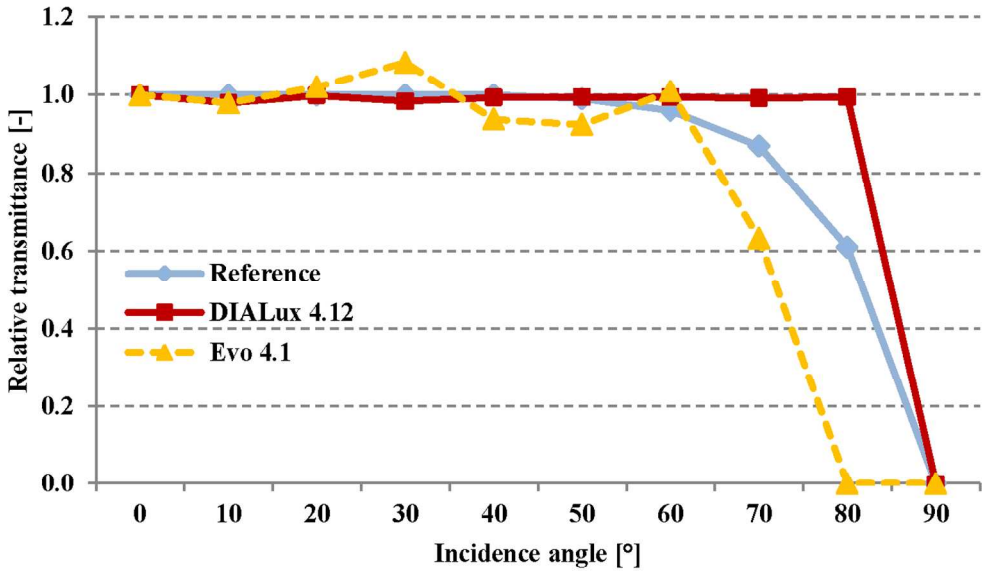
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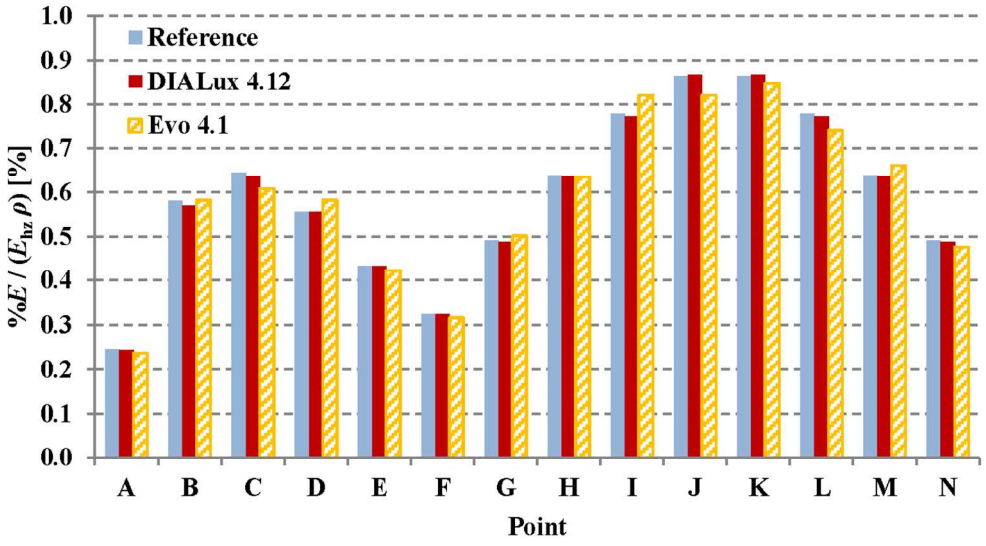
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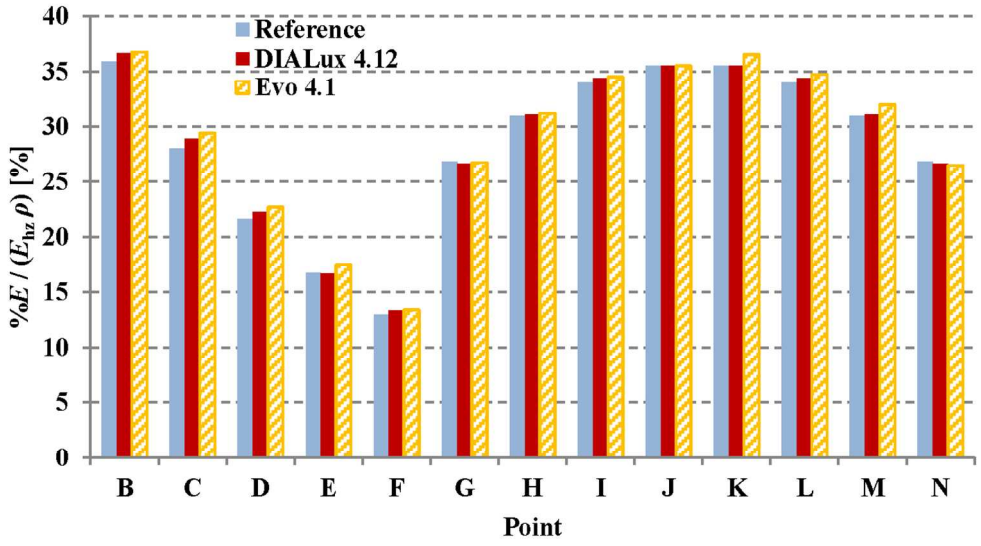
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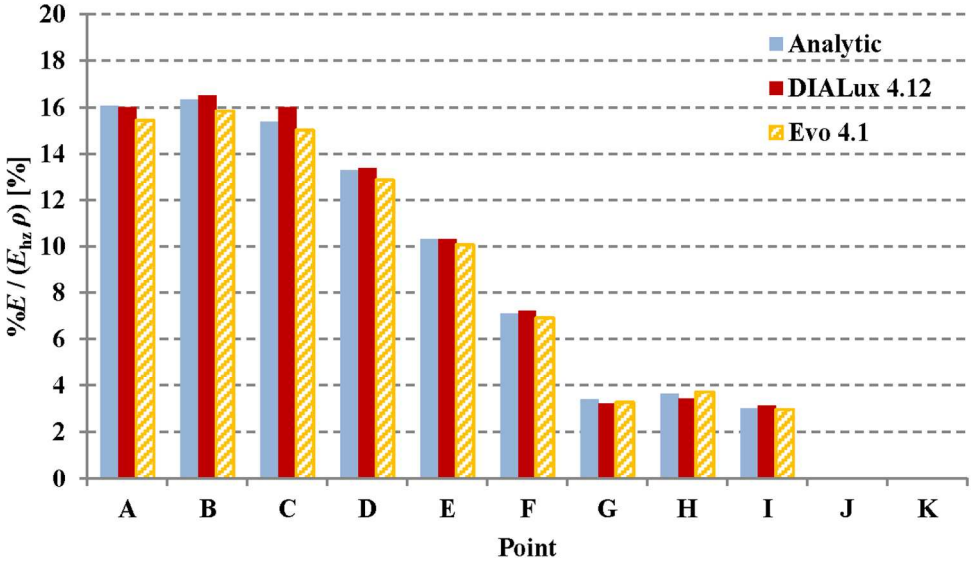
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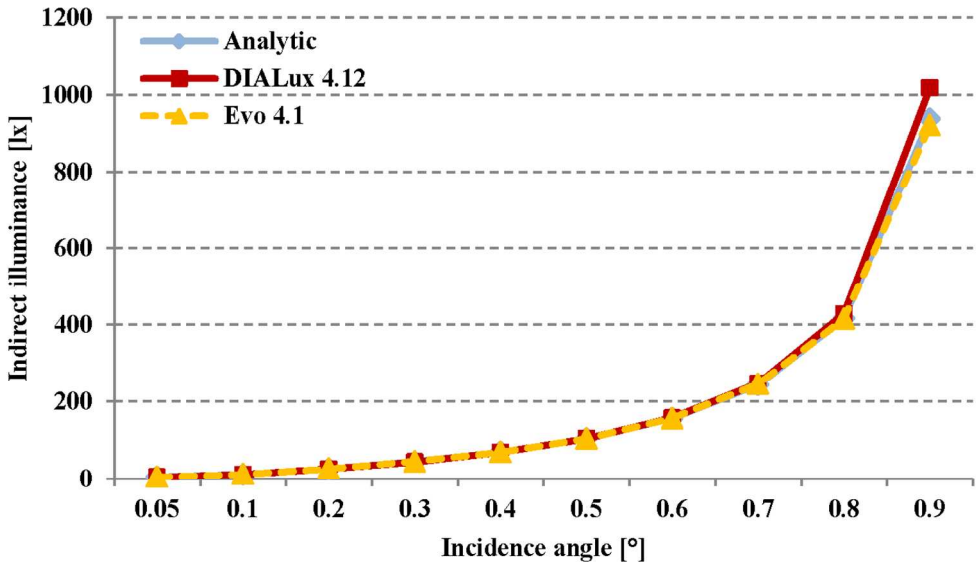
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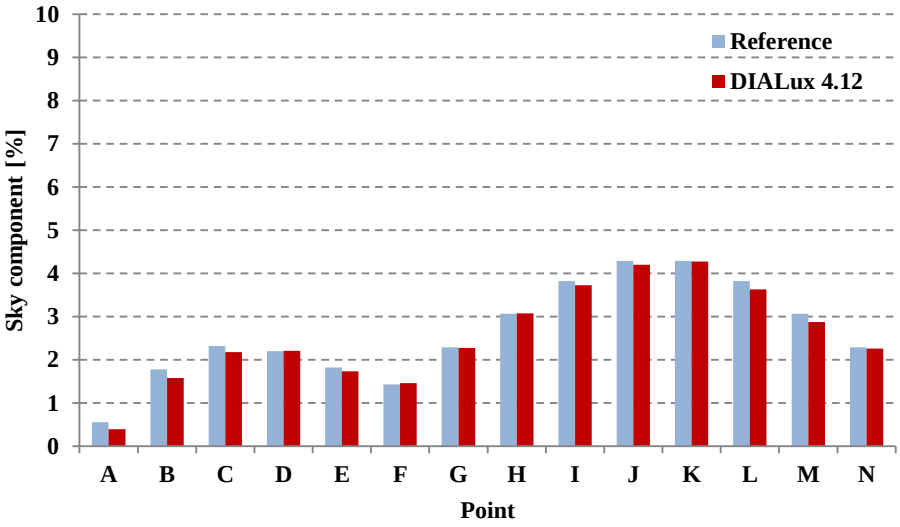
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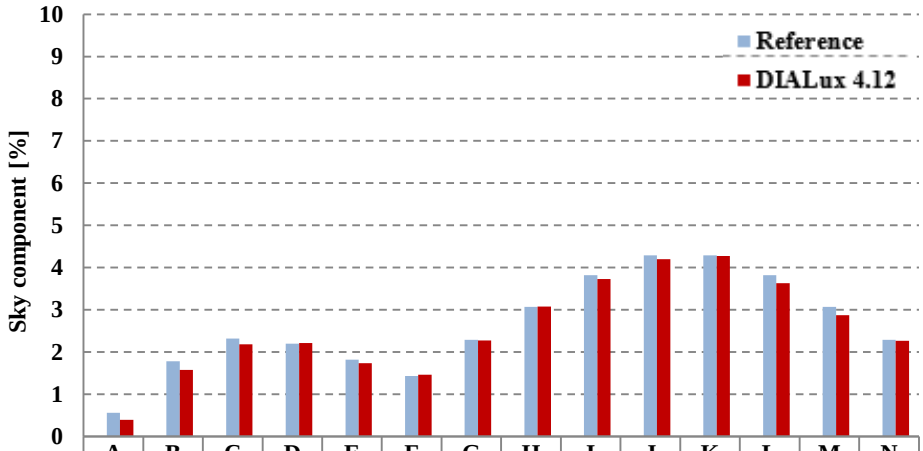
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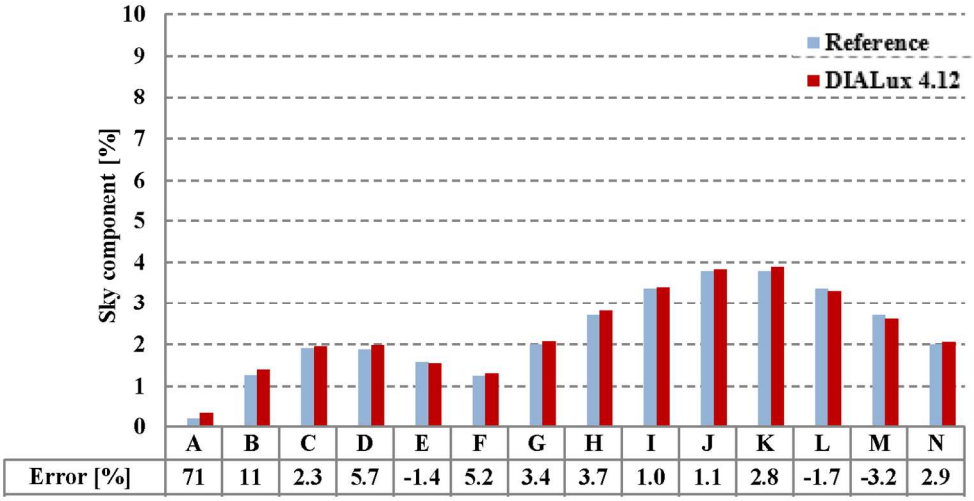


	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Error [%]	-29	-11	-6.0	0.4	-4.5	2.2	-0.7	0.2	-2.4	-2.1	-0.4	-5.0	-6.4	-1.2

Point	SCref [%]	SCsim [%]	Error [%]
A	0.56	0.395214	-29
B	1.78	1.575443	-11
C	2.32	2.181798	-6.0
D	2.2	2.208868	0.4
E	1.82	1.737859	-4.5
F	1.43	1.461751	2.2
G	2.29	2.273835	-0.7
H	3.07	3.075091	0.2
I	3.82	3.730172	-2.4
J	4.29	4.20118	-2.1
K	4.29	4.271561	-0.4
L	3.82	3.627308	-5.0

M	3.07	2.874777	-6.4
N	2.29	2.263007	-1.2

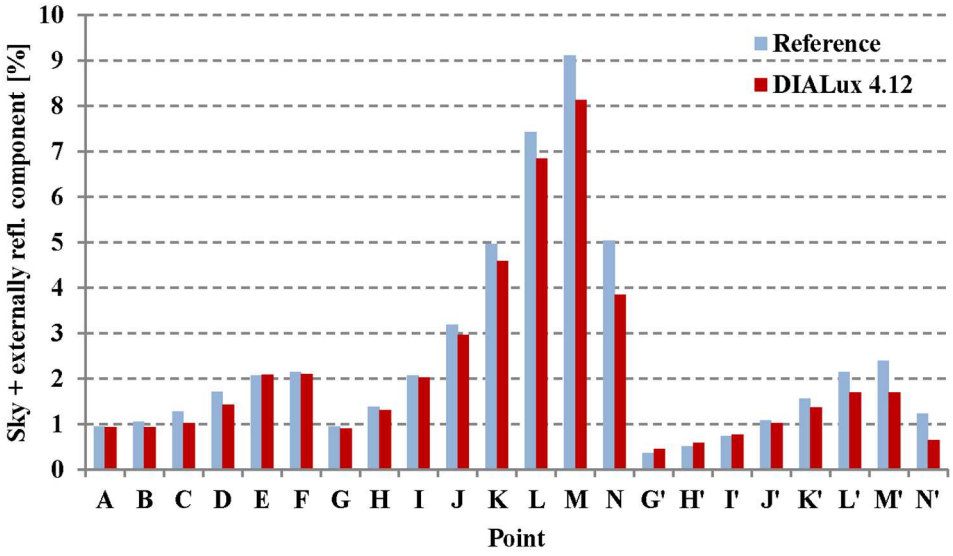
For Peer Review Only



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Error [%]	71	11	2.3	5.7	-1.4	5.2	3.4	3.7	1.0	1.1	2.8	-1.7	-3.2	2.9

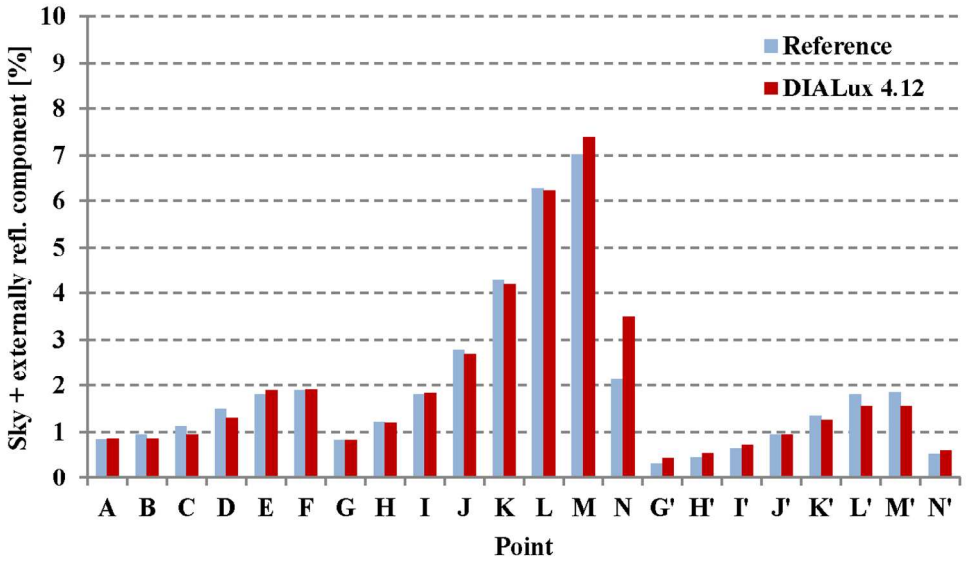
136x70mm (300 x 300 DPI)

For Review Only



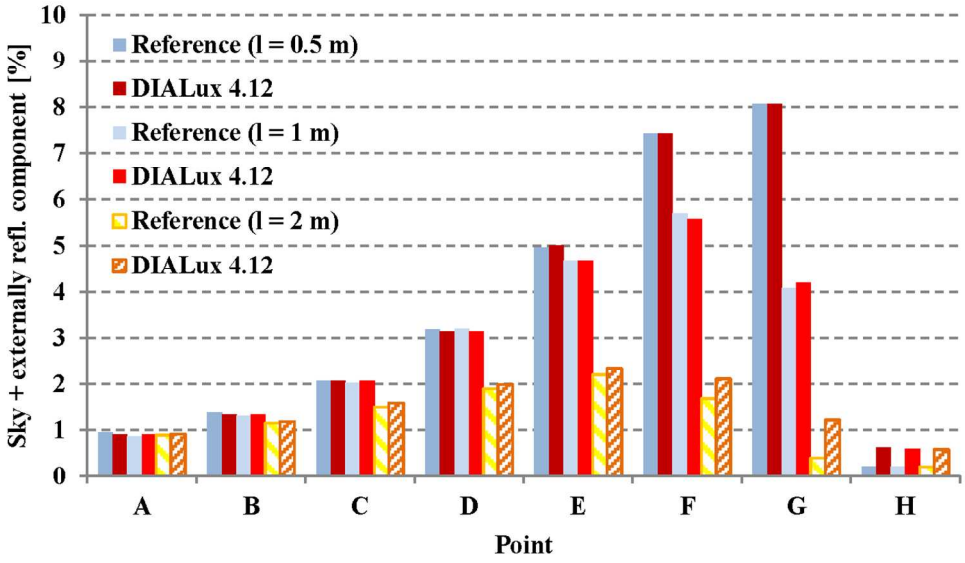
125x72mm (300 x 300 DPI)

Review Only



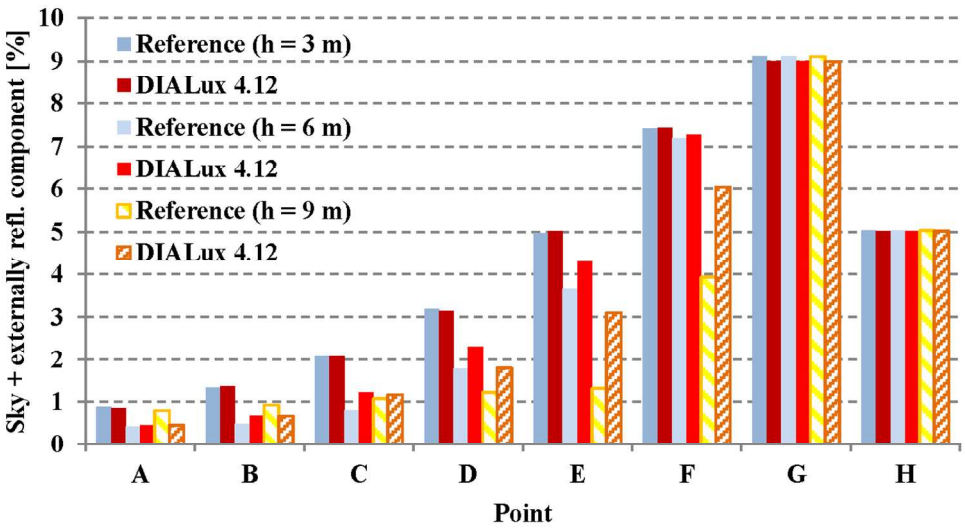
123x71mm (300 x 300 DPI)

Review Only



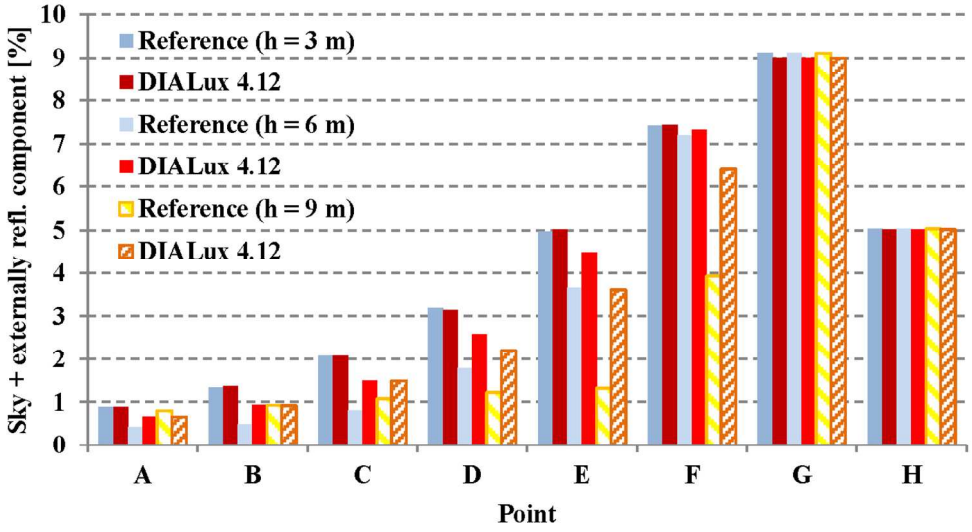
123x75mm (300 x 300 DPI)

Review Only



123x68mm (300 x 300 DPI)

Review Only



123x68mm (300 x 300 DPI)

Review Only