Report:

Reflectivity Analysis

Project:

Lismore Base Hospital

For:

John Holland

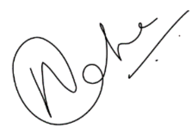
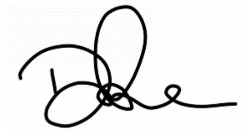
By:

Inhabit Australasia Pty Ltd.

Doc. No: 7254-RPT-ES0001
Date: 2018-04-12
Revision: 00

Inhabit Group
Brisbane | Melbourne | Perth | Sydney
www.inhabitgroup.com contact@inhabitgroup.com
Australia | China | Hong Kong | India | Indonesia | New Zealand | Qatar | Singapore | United Arab Emirates | United Kingdom

Table of Contents

Revision	**Date**	**Filename**	7254-RPT-ES0001(00) External Glare Assessment		
00	2018-04-12	**Description**	Reflectivity assessment for north tower (NTX) 3C.		
			Prepared by	**Checked by**	**Approved by**
		Name	Neha Yadav	Samantha Anderson	Darren O'Dea
		Signature			

Limitations

Inhabit Australasia Plc will not be held liable for predicted glass transmission light colour estimates, nor for the reliance by any party on those results, for any purpose. Simulations of façade performance are idealised representations of the actual façade that cannot fully represent all of the intricacies of the building once built. As a result, simulation results only represent an interpretation of the façade performance. No guarantee or warrantee for the occurrence of glare in practice can be based on simulation results alone.

Executive Summary

An external glare study has been undertaken to determine the risk of direct solar reflections off the building's façade and onto the traffic around the Lismore Base Hospital.

The methodology used within this study has been conducted by geometrical modelling of the proposed building design of Lismore Base hospital along with the context, identification of sources of reflective glare from the façade and its effects on the critical identified locations around the development.

The glare assessment has been undertaken at 5 critical view locations around the proposed north tower of the hospital that were identified to have a high risk of glare.

The results indicate that the proposed façade will have minimal glare issue (1% in a year) provided the specified material (refer section 4.6) or similar material properties are used with the current material application ratios. There are three occurrences where the glare risk has the potential to be an issue at location 3 and 4. These occur on the 21st June at 4pm, 21st August at 5pm for location 3 and 21st March at 7am for location 4, where the glare is a direct result of reflection of the glazed façade.

All other predicted intolerable glare experienced in this analysis were due to direct sunlight being in the field of vision. The summary of the daylight glare index (DGI) for all the identified locations and all the months are shown in Table 1 and Figure 1.

Table 1: Daylight Glare Index results summary

	DGI Score	Location 1	Location 2	Location 3	Location 4	Location 5
Imperceptible - Acceptable	< 22	84%	92%	92%	82%	84%
Borderline between Comfort and Discomfort	≥ 22 & < 24	2%	1%	0%	1%	0%
Uncomfortable	≥ 24 & < 28	6%	6%	4%	6%	6%
Intolerable Direct Sun	≥ 28	8%	2%	3%	12%	9%
Intolerable Due to Reflectivity	≥ 28	0%	0%	1%	1%	0%

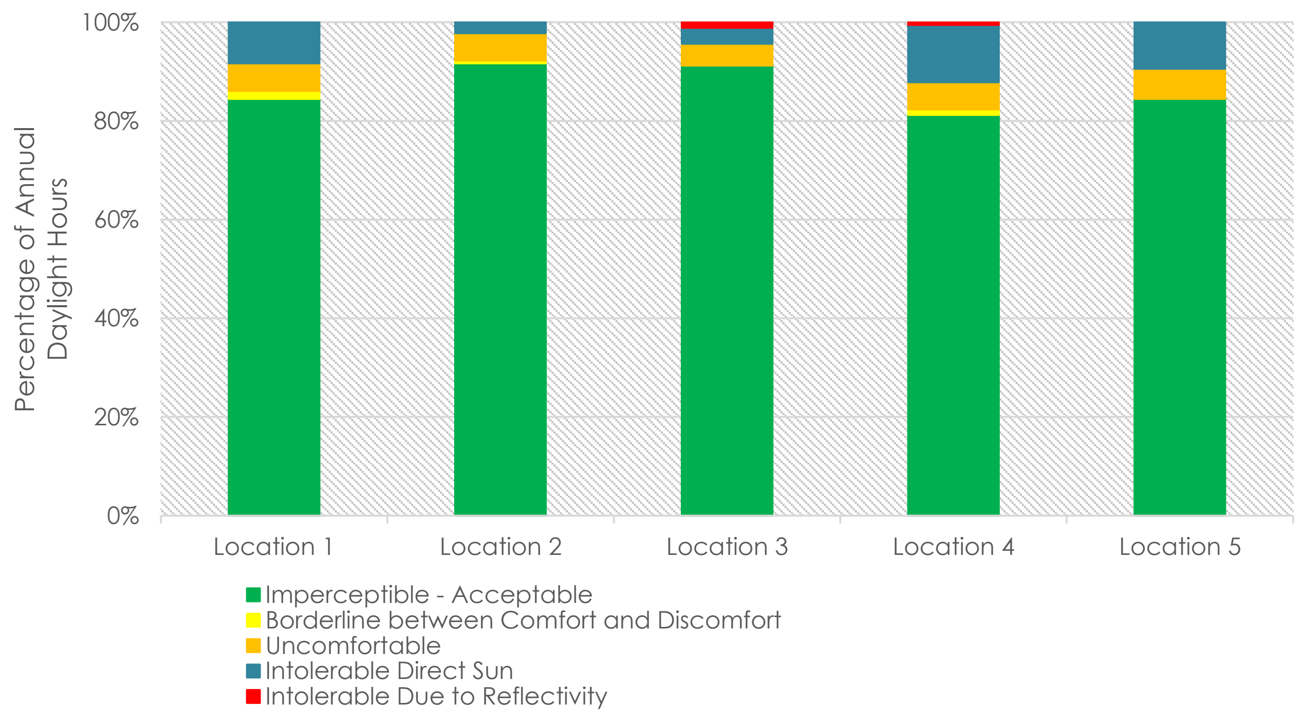


Figure 1: Summary of results % of occurences in each comfort band

1. Introduction

A new northern tower (phase 3c) adjoining the southern tower (phase 3a) is undergoing development at Lismore Base Hospital, 60 Uralba St, Lismore. The proposed development will consist of ten storeys above ground level and consists of additional emergency, ICU facilities along with car parking areas.

Inhabit has been appointed to determine the risk of direct solar reflections off the north tower's façade onto the traffic around the development. The Figure 2 below illustrates an architectural render of the proposed design.

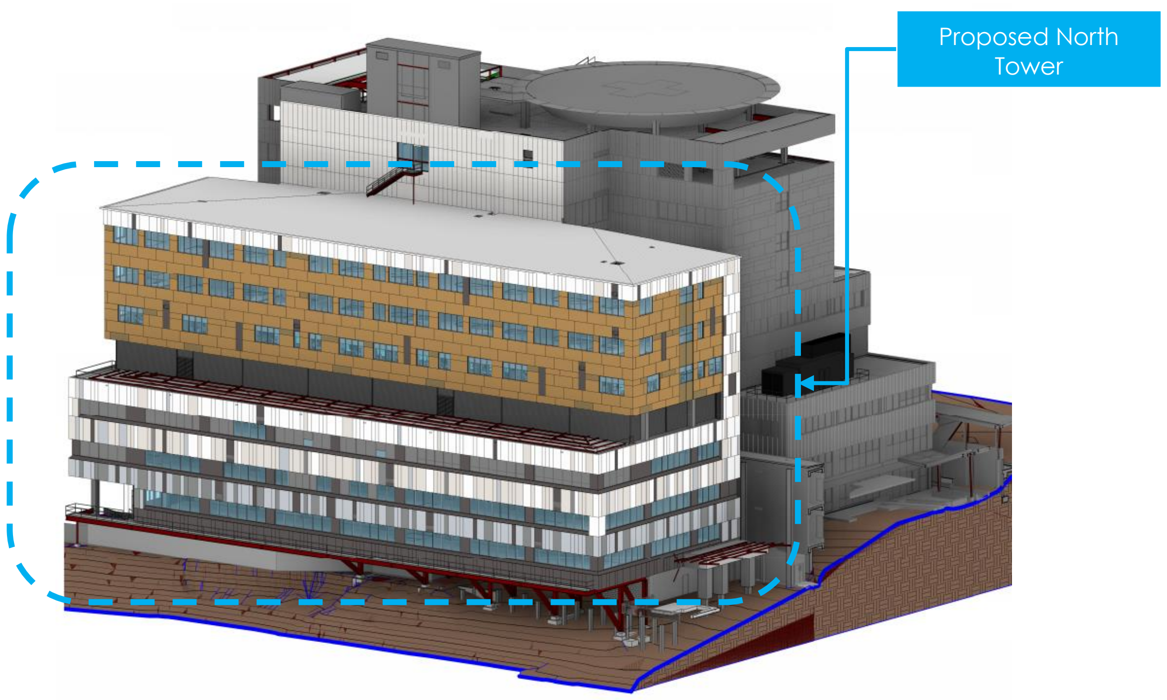


Figure 2: Architectural Render of the Proposed Development

The aim of this study has been to identify the possible causes of visual impairment to the people in the external environment within the context of the proposed façade. Computational techniques have been used to quantify the degree to which the people are likely to be affected.

A method of identifying times and locations that are considered at high risk of glare have been established. This study has effectively reviewed the levels of potential risks of glare from the proposed façade to the identified five locations (vehicular & pedestrians) at various critical times of the year.

2. Potential Sources of Visual Impairment

2.1 Solar Reflections

The human eye can only tolerate a certain level of light luminance. Glare issues occur when too much light strikes the observer's field of vision, and can be caused by direct sunlight, or reflected sunlight. The reflective nature of the material, in addition to the specularity and the roughness of the surface determine the intensity of the reflective light. The law of reflection is indicated in Figure 3 indicating that a reflection back to the observer is on a point by point basis.

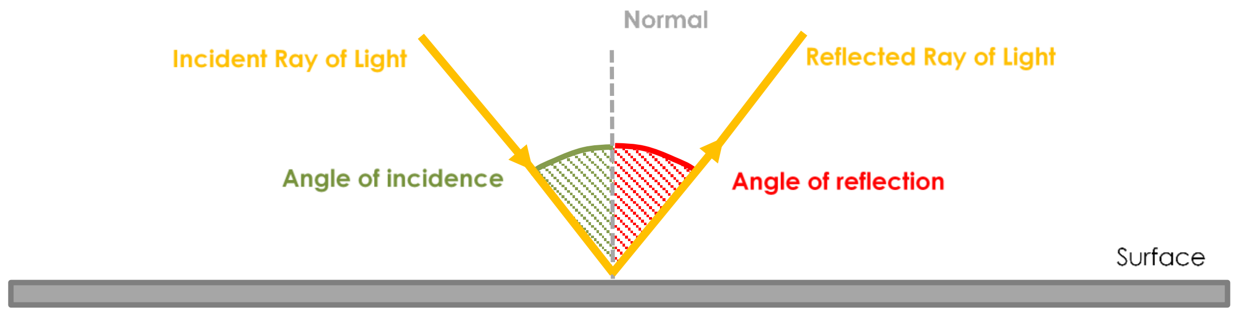


Figure 3: Light Reflections off Surfaces

2.2 Glare

This section of the report discusses the phenomena defined as both disability and discomfort glare, and also identifies other potential sources of visual impairment that could occur in the environment surrounding the proposed Landmark Development. Factors that affect visual comfort include:

- Location of person;
- View direction of person;
- Position of sun;
- Geometry of built environment;
- Reflectivity, specularity & roughness of surfaces in the built environment.

2.2.1 Daylight Glare Index

The glare sources and field are analysed using the Daylight Glare Index (DGI) over a field of view 90° in each direction on the horizontal plane. The DGI is a glare index that is adapted to relatively large sources of glare and accounts for the eye's greater tolerance to glare from daylight sources rather than artificial sources (Daylight Glare: A Review of Discomfort Indices, L Bellia et al, 2007). Although the evaluation of visual performance and comfort is still subject to research and discussion, the DGI is the most relevant to this instance. The degree of perceived glare using the DGI is shown in Table 2 below.

Table 2: The Degree of Perceived Glare using the DGI Scale

Glare Response	DGI
Imperceptible	< 16
Perceptible	≥ 16 & < 20
Acceptable	≥ 20 & < 22
Borderline between Comfort and Discomfort	≥ 22 & < 24
Uncomfortable	≥ 24 & < 28
Intolerable	≥ 28

3. Methodology

3.1 General

The analysis will be conducted in a three stage process. The first step involves the development of a massing model of the site. This is to be sourced from the project architect in order to ensure that the geometry is as close to the proposed design as possible. The second stage involves an analysis of how sunlight interacts over the course of a year, in order to identify any 'critical' locations which have a high frequency of direct solar reflections. The final step of the analysis is to quantify the expected glare level at these locations at representative times of the year. Further details on the proposed methodology are included below.

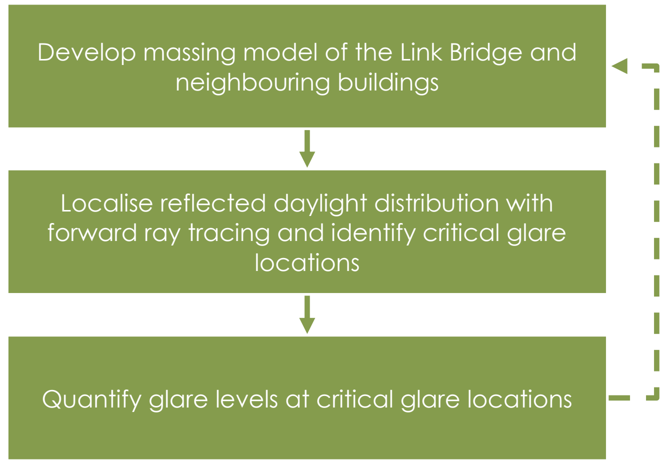


Figure 4: Flowchart of the reflected daylight evaluation procedure

If there are any issues identified in the glare assessment, an iterative workflow can be employed in order to confirm that risks have been eliminated.

3.2 Quantification of Glare Risk

With the critical locations identified, images were rendered using the Radiance plug-in for Rhinoceros. Radiance is a high-detail ray-tracing software system that is licensed in open-source form. It was developed with primary support from the U.S. Department of Energy and additional support from the Swiss Federal Government, and is widely considered the industry standard tool for lighting simulation and glare calculations.

The Rhinoceros plug-in was used to generate high quality fish-eye images with a 180° field of view. This very wide angle allows the glare calculation to sample areas in the entire field of view of people in the surrounding environment.

From Grasshopper, the Radiance programme named 'evalglare' was used to automatically identify glare sources for the fisheye image at each location, where the risk of glare will be calculated using the DGI scale.

The evalglare programme creates a 'check-picture' where the glare sources are detected and colour-coded, with each different glare source given a unique colour.

An example fish-eye image, and the analysis of that image by evalglare is included in Figure 5 below. No direct solar glare is identified in the image; however some reflective glare is highlighted in the areas shaded in blue.

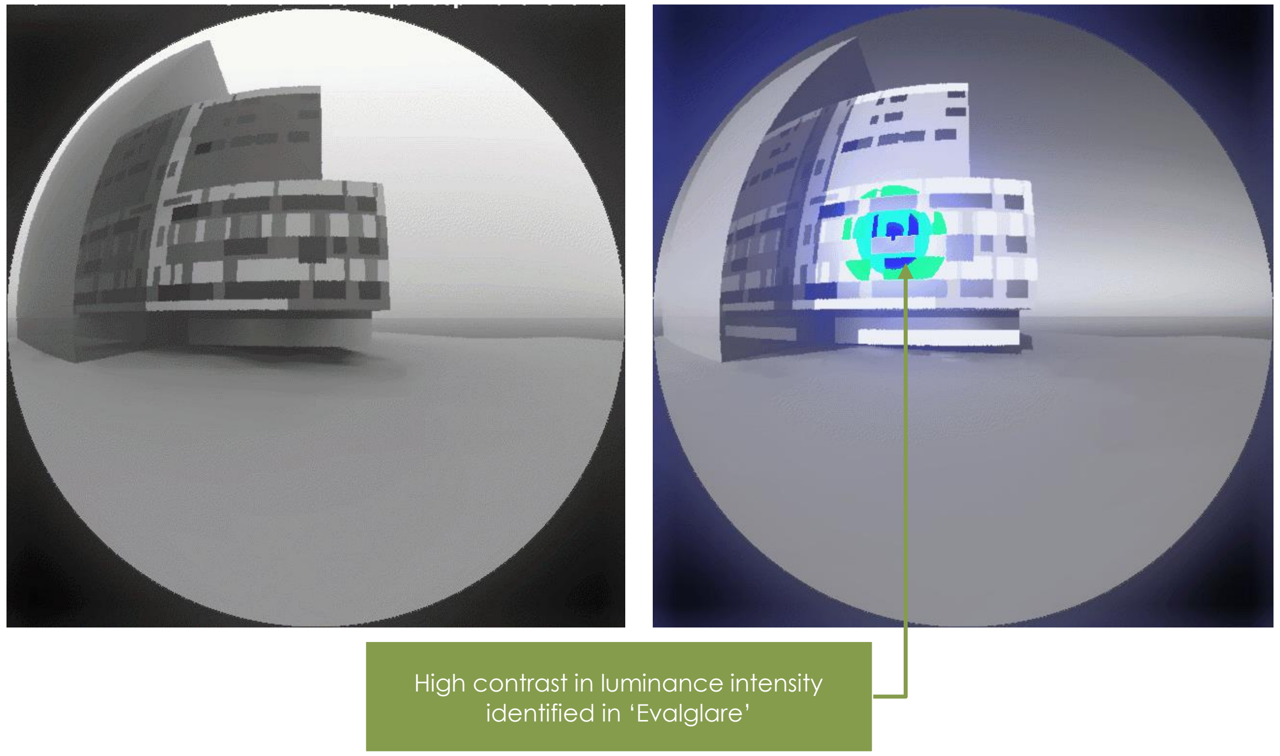


Figure 5: Example of fish-eye image (Left) and output from Evalglare (right)

The example glare images provided above were analysed on the 21st March at 07:00. The viewpoint was arbitrarily located 2m above street level facing west. The analysed image had a Daylight Glare Index of 29.43, which translates to an intolerable level of glare.

4. Analysis Inputs

4.1 Climate & Location

The analysis has used the coordinates of the Lismore (New South Wales) for the solar analysis. The following details were used to locate the development with respect the sun:

- Latitude: -28.8° South
- Longitude: 153.29° East
- Elevation: 9.13m above sea level

The data used for this assessment of the building is: AUS_NSW_Lismore.epw, and was sourced from Global Energy Balance Archive Data (GEBA).

4.2 Sky Conditions

A sunny clear sky condition was used in the glare analysis, which represents a worst-case scenario for the risk of glare. In reality, an overcast (or polluted) sky will reduce the intensity of direct solar reflections thereby reducing the risk of glare.

The location of the sun in the sky for each time and date throughout the year is based on the actual celestial path for Lismore in NSW was used.

4.3 Hospital Model

The figures below illustrate the north tower geometry that was used in the glare analysis. This geometry was provided by the project architects, Conrad Gargett, on 16/01/2018.

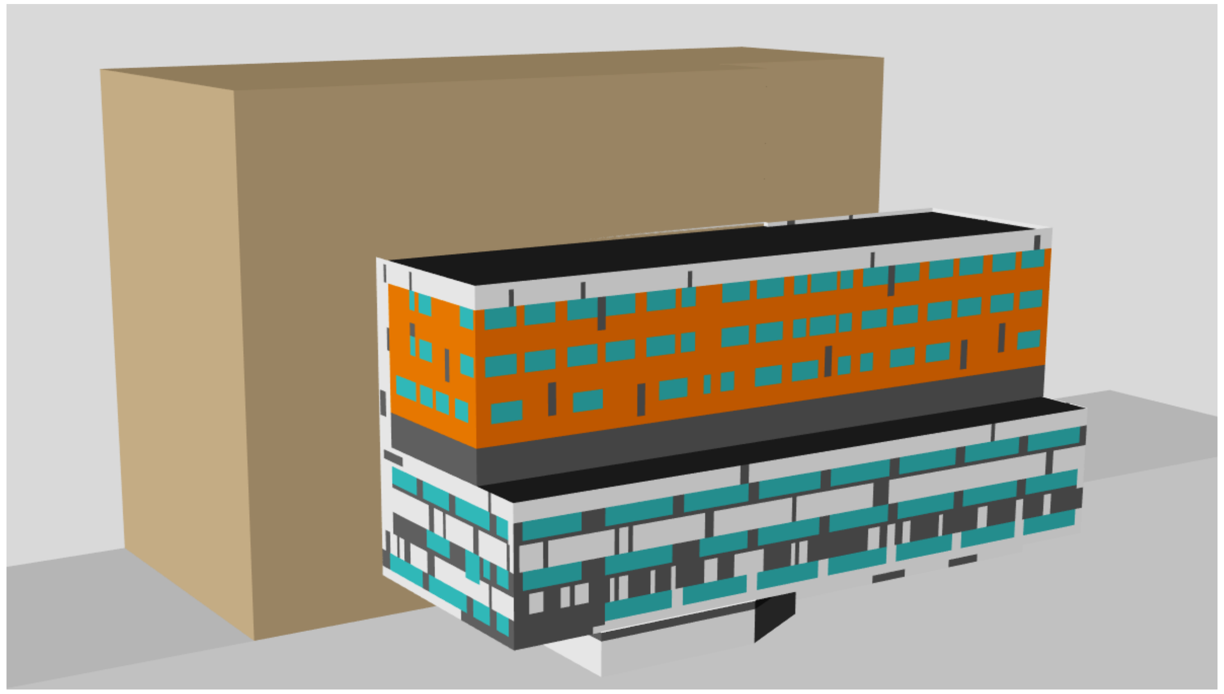


Figure 6: Proposed north tower at Lismore Base Hospital.

4.4 Surrounding Context

The surrounding context has been included in the glare analysis as it will overshadow and reflect light in the field of view. The proposed design is only affected by the southern tower of the hospital and surrounding small residential developments have negligible effect. Also the proposed development is located on the higher side of the site elevation as compared to the surrounding dwellings.

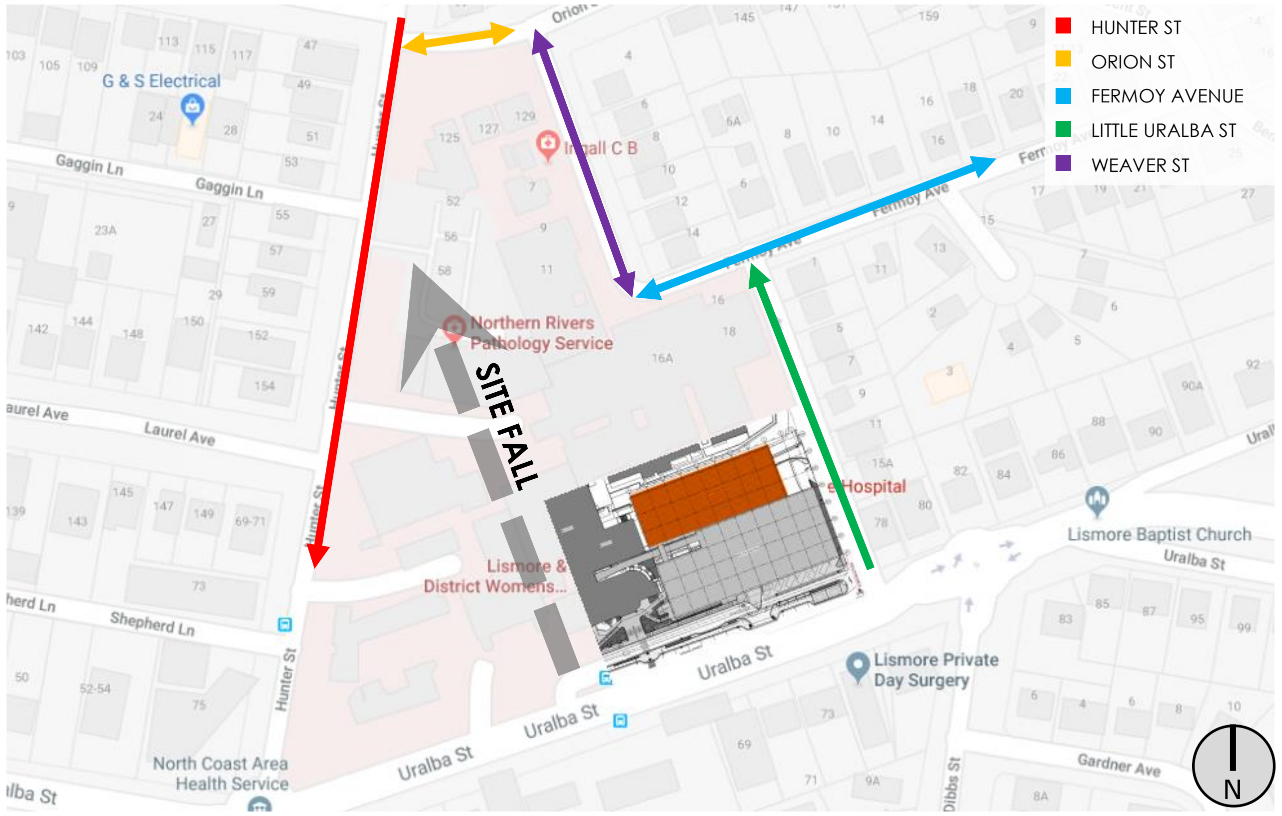


Figure 7: Surrounding context of the proposed development.

4.5 Identification of Critical Glare Locations

With Lismore's sun path throughout the year, locations with a high risk of glare to the travellers critical points around the proposed development have been identified and illustrated in Figure 8 below.

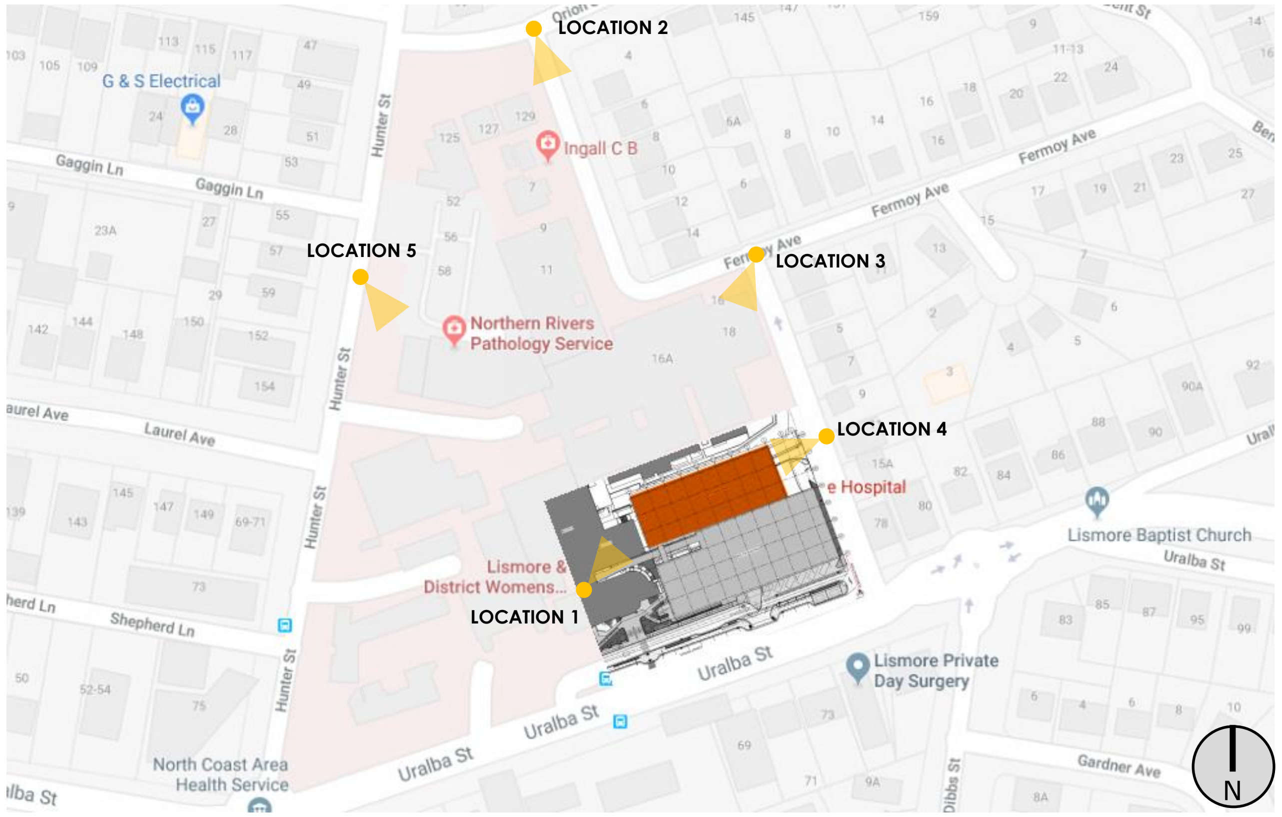


Figure 8: Hospital location with identified locations in the context.

A line of sight has been taken from each of these locations to the proposed development façade to obtain meaningful results, as close to the observer's vision angle.

Following are the assumptions taken for eye level elevations for each of the locations identified.

Table 3: Analysed locations.

	Travellers	Elevation (above G.L)
Location 1	Pedestrians on the hospital link bridge.	16m
Location 2	Pedestrians & drivers heading south (Weaver St)	2m
Location 3	Pedestrians & drivers heading west (Fermoy Ave)	2m
Location 4	Pedestrians & drivers heading north (Little Uralba St)	2m
Location 5	Drivers heading south. (Hunter St)	2m

4.6 Material Definitions

The opaque materiality values listed in the table below are based on typical properties.

Table 4: Opaque Material Properties

Element	Reflectivity	Specularity	Surface Roughness
Alpolic M774 Milk White (G30)	80%	0.05	0.15
Alpolic M9221 Medium Bronze Metallic (G30)	30%	0.05	0.15
Alpolic M7788 Stainless Steel Metallic (G30)	80%	0.05	0.15
Alpolic M9177 Champagne Metallic (G30)	40%	0.05	0.15
Alpolic MB080 Medium Gray Metallic (G30)	30%	0.05	0.15
Alpolic MB542 Light Brown Metallic (G30)	30%	0.05	0.15
Ground	60%	0	0.2
Roof	20%	0.2	0
Context Buildings	20%	0	0.1

Table 5: Glass Material Properties

Parameter	Value
Specular Visual Light Reflection	12%
Surface Roughness	0

4.7 Radiance Parameters

The Radiance Parameter table in Appendix A of this report details the parameters used in the daylighting analysis. These values are at the 'accurate' level that Radiance recommends for rendering.

5. Results

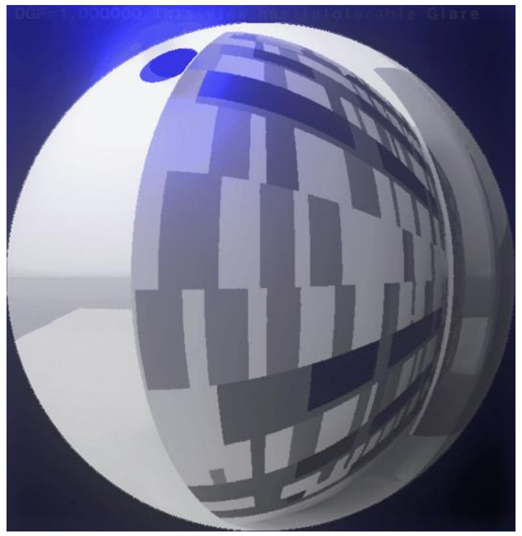
5.1 Location 1

	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
21st January	0.00	0.00	-12.93	-3.64	2.28	26.86	26.75	26.60	26.20	7.35	-1.23	5.02	-1.55	-2.79	0.00
21st February	0.00	0.00	7.40	1.73	18.74	28.13	27.97	9.57	15.24	15.13	9.93	8.07	-1.94	0.61	0.00
21st March	0.00	0.00	9.16	-2.54	2.96	5.37	5.52	5.80	17.50	17.65	22.45	21.18	9.88	0.00	0.00
21st April	0.00	0.00	0.00	0.00	0.00	4.11	4.12	8.84	17.22	23.15	0.00	0.00	7.55	0.00	0.00
21st May	0.00	0.00	0.00	-3.73	-0.55	-0.24	-2.26	12.39	31.78	27.40	26.19	29.01	0.00	0.00	0.00
21st June	0.00	0.00	0.00	3.99	-1.10	-0.95	5.18	13.47	17.28	33.93	31.79	30.91	0.00	0.00	0.00
21st July	0.00	0.00	0.00	-3.81	16.30	19.18	12.77	0.00	6.20	35.48	34.84	33.47	0.00	0.00	0.00
21st August	0.00	0.00	0.00	-1.91	1.14	1.35	-0.64	6.73	31.79	30.75	29.89	28.49	26.36	0.00	0.00
21st September	0.00	0.00	10.34	18.11	20.15	20.64	0.00	-14.75	28.69	28.43	27.84	23.90	8.01	0.00	0.00
21st October	0.00	0.00	-3.71	3.26	7.69	21.87	19.62	14.64	15.35	5.22	0.00	-7.11	5.64	0.00	0.00
21st November	0.00	-9.17	-2.94	2.67	7.48	27.26	21.11	20.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st December	0.00	0.00	0.00	0.00	0.00	3.07	6.26	7.27	-10.32	0.00	0.00	-7.77	0.00	0.00	0.00

	DGI
Imperceptible	< 16
Perceptible	≥16 & <20
Acceptable	≥20 & <22
Borderline between Comfort and Discomfort	≥22 & <24
Uncomfortable	≥24 & <28
Intolerable	≥ 28

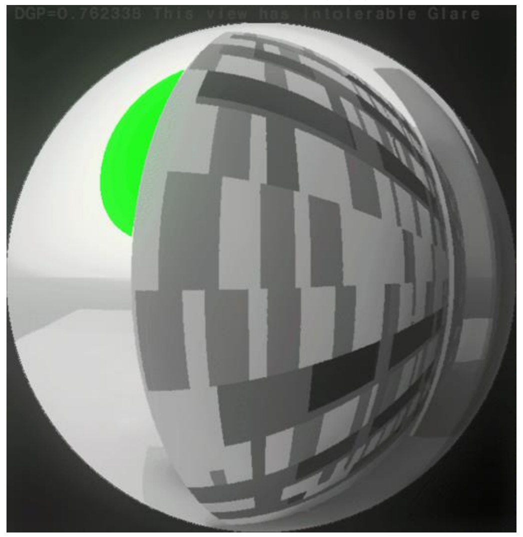
The intolerable DGI values observed for all the months at this location point are due to direct exposure of sun and not due to reflectivity from the façade.

21st June 12:00



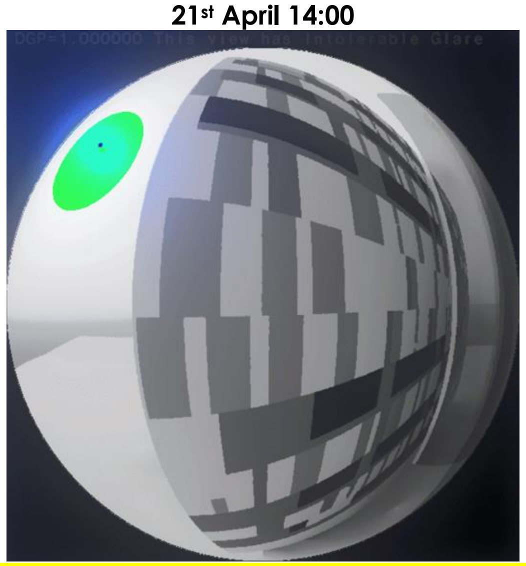
13.47 – Acceptable

21st March 13:00



17.50 – Accpetable

21st April 14:00

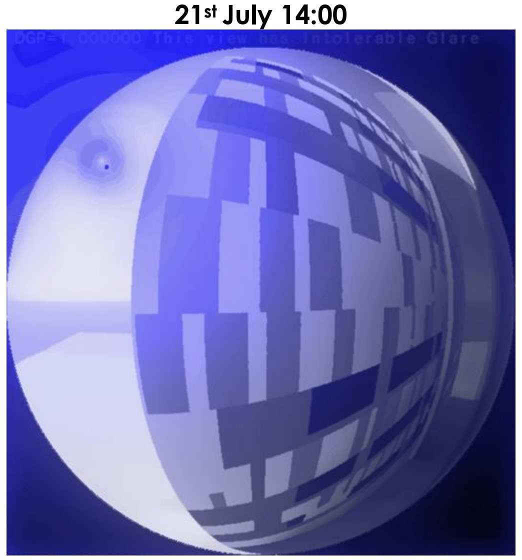


22.45 – Borderline

21st November 10:00

27.26 – Uncomfortable

21st July 14:00



35.48 – Intolerable

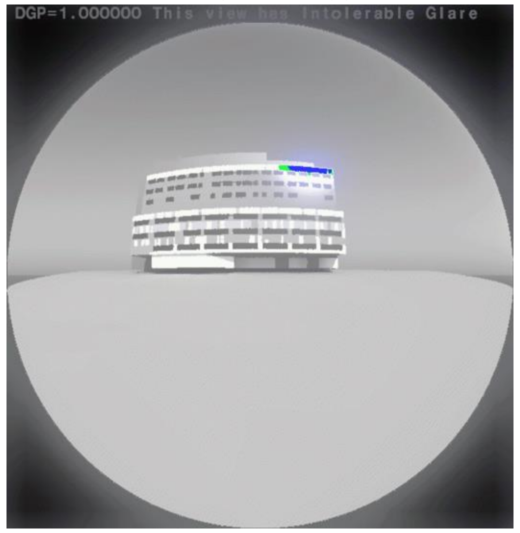
5.2 Location 2

	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
21st January	0.00	0.00	32.06	28.10	26.75	25.35	0.00	0.00	0.00	0.00	0.00	0.00	-0.40	8.00	0.00
21st February	0.00	0.00	31.22	27.23	26.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-18.19	0.00
21st March	0.00	0.00	27.73	24.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st April	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st May	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	5.69	0.00	0.00	0.00	0.00	0.00
21st June	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	12.37	0.36	0.00	0.00	0.00	0.00
21st July	0.00	0.00	0.00	-6.64	0.00	0.00	0.00	0.00	0.00	11.27	4.67	10.66	0.00	0.00	0.00
21st August	0.00	0.00	0.00	2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.37	0.00	0.00
21st September	0.00	0.00	27.73	12.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.88	0.00	0.00
21st October	0.00	0.00	22.31	19.28	3.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.00	0.00	0.00
21st November	0.00	33.42	27.55	25.56	26.87	10.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st December	0.00	0.00	0.00	0.00	0.00	-0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	DGI
Imperceptible	< 16
Perceptible	≥16 & <20
Acceptable	≥20 & <22
Borderline between Comfort and Discomfort	≥22 & <24
Uncomfortable	≥24 & <28
Intolerable	≥ 28
Intoleable Glare Reflelecitivty	

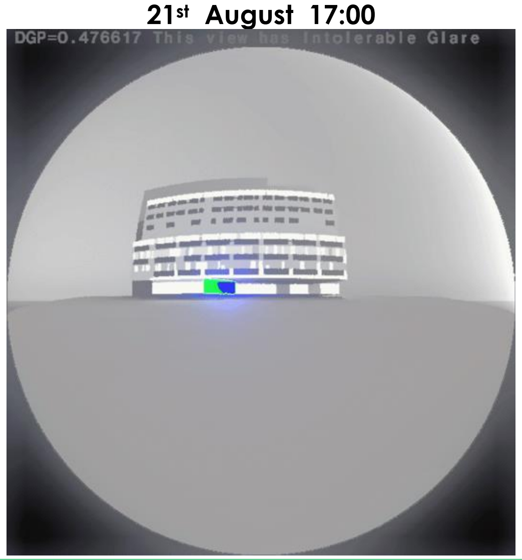
The intolerable DGI values observed for all the months at this location point are due to direct exposure of sun and not due to reflectivity from the façade.

21st June 14:00



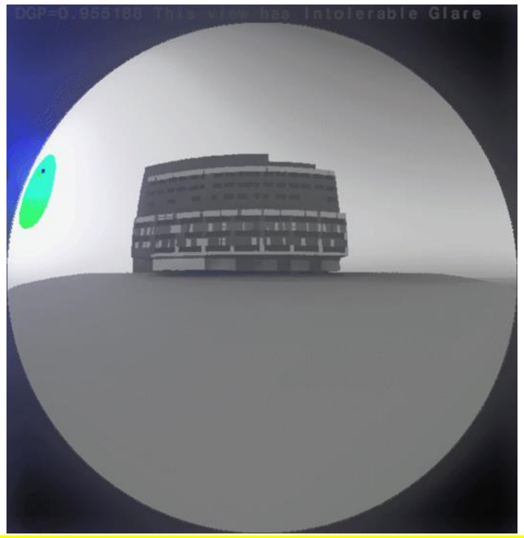
12.37 – Acceptable

21st August 17:00



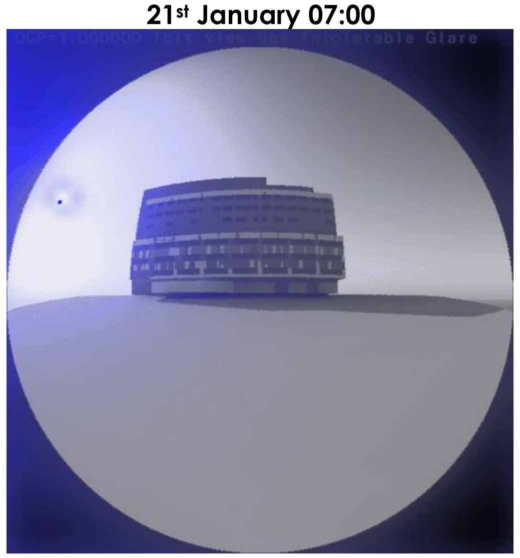
21.37 – Acceptable

21st October 07:00



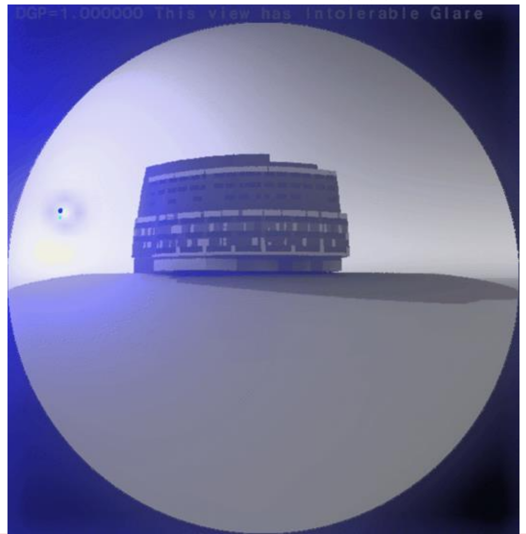
22.31 – Borderline

21st January 07:00



32.06 – Intolerable

21st November 06:00



33.42 – Intolerable

5.3 Location 3

	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
21st January	0.00	0.00	2.71	0.00	0.00	0.00	0.00	0.00	0.00	25.82	26.70	28.88	34.20	37.33	0.00
21st February	0.00	0.00	-1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.09	11.20	20.63	7.32	0.00
21st March	0.00	0.00	2.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-3.88	24.31	27.05	0.00	0.00
21st April	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.98	0.00	0.00
21st May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.08	24.12	0.00	0.00	0.00
21st June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.96	28.60	0.00	0.00	0.00
21st July	0.00	0.00	0.00	10.47	0.00	0.00	0.00	0.00	0.00	0.00	15.46	25.22	0.00	0.00	0.00
21st August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.26	19.78	33.81	0.00	0.00
21st September	0.00	0.00	10.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.17	31.73	0.00	0.00
21st October	0.00	0.00	-6.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.38	16.06	26.09	0.00	0.00
21st November	0.00	6.54	-3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-9.18	6.95	10.55	10.38	7.65	0.00	0.00

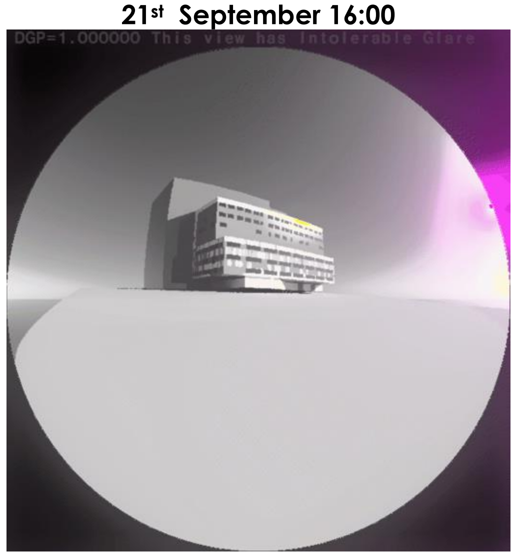
	DGI
Imperceptible	< 16
Perceptible	≥16 & <20
Acceptable	≥20 & <22
Borderline between Comfort and Discomfort	≥22 & <24
Uncomfortable	≥24 & <28
Intolerable	≥ 28

It is observed that there is glare caused from the reflectivity of the northern façade at this location on 21st June 4pm and 21st Aug 5pm. However, DGI value exceeds the limit by a minor difference and the intersecting road i.e. Little Uralba St is a one-way road heading north, in the opposite direction of the façade. Hence this glare will have minimal effect on the travellers. All the other intolerable DGI values observed at this location point are due to direct exposure of sun.

21st February 17:00

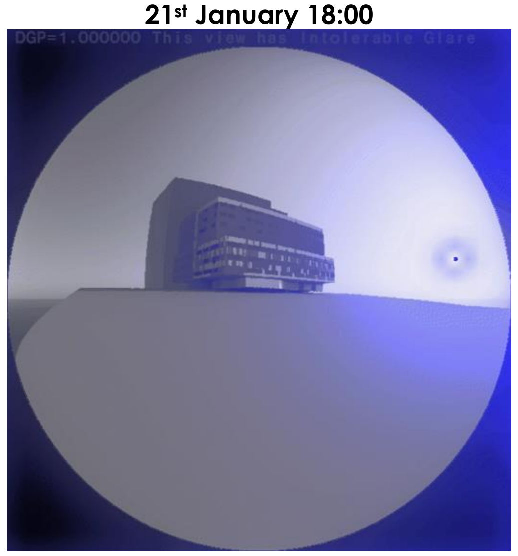
20.63 – Acceptable

21st September 16:00



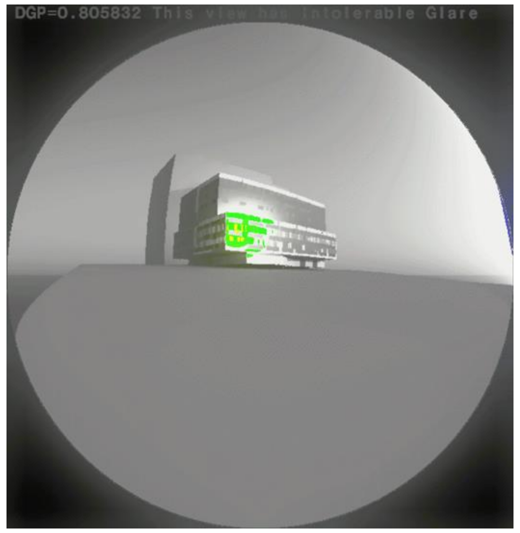
27.17 – Uncomfortable

21st January 18:00



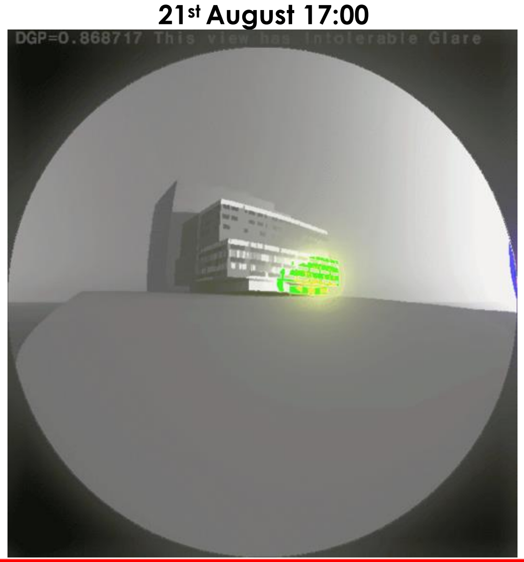
37.33 – Intolerable

21st June 16:00



28.60 – Intolerable

21st August 17:00



33.81 – Intolerable

5.4 Location 4

	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
21st January	0.00	0.00	0.00	6.95	10.54	0.00	0.00	0.00	26.68	27.65	32.44	37.72	20.09	19.06	0.00
21st February	0.00	0.00	19.39	17.58	14.57	-7.38	0.00	-7.76	17.39	20.62	21.09	21.45	31.17	15.06	0.00
21st March	0.00	0.00	29.43	20.16	0.00	0.00	0.00	0.00	22.50	24.07	31.35	36.82	39.37	0.00	0.00
21st April	0.00	0.00	0.00	0.00	0.00	-11.19	0.00	0.00	9.41	18.90	0.00	0.00	12.03	0.00	0.00
21st May	0.00	0.00	0.00	16.37	0.00	-6.65	0.00	0.00	13.44	25.03	25.52	34.25	0.00	0.00	0.00
21st June	0.00	0.00	0.00	14.03	0.00	0.00	0.00	0.00	1.49	25.59	29.79	34.10	0.00	0.00	0.00
21st July	0.00	0.00	0.00	22.81	4.69	6.63	-5.06	0.00	0.00	27.87	33.41	37.64	0.00	0.00	0.00
21st August	0.00	0.00	0.00	20.62	4.72	1.43	0.00	0.00	21.97	26.77	32.85	37.19	39.60	0.00	0.00
21st September	0.00	0.00	24.28	19.86	-8.70	0.00	0.00	0.00	27.59	29.27	35.75	40.81	43.26	0.00	0.00
21st October	0.00	0.00	7.74	0.00	0.38	0.00	0.00	-11.50	14.51	7.32	19.68	28.17	33.68	0.00	0.00
21st November	0.00	0.00	0.00	8.00	2.26	0.00	0.00	10.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.80	9.96	10.59	18.21	18.94	0.00	0.00	0.00

	DGI
Imperceptible	< 16
Perceptible	≥16 & <20
Acceptable	≥20 & <22
Borderline between Comfort and Discomfort	≥22 & <24
Uncomfortable	≥24 & <28
Intolerable	≥ 28

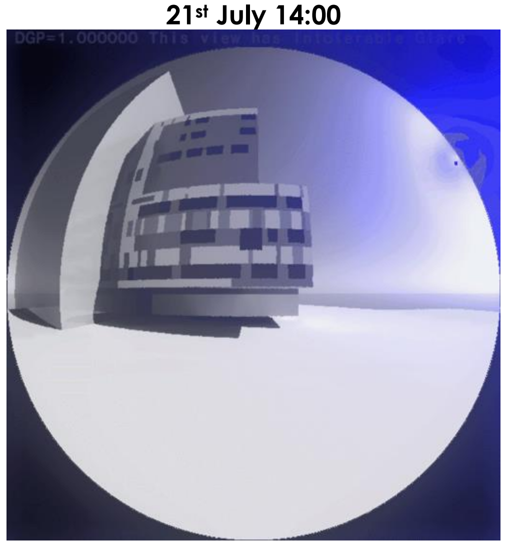
It is observed that there is glare caused from the reflectivity of the eastern façade at this location on 21st March 7am. However, the DGI value exceeds the limit by a minor difference for a small portion of the facade. Hence this glare will have minimal effect on the travelers. To remediate the issue, façade reflectivity value to be optimized.

All the other intolerable DGI values observed at this location point are due to direct exposure of sun.

21st March 13:00

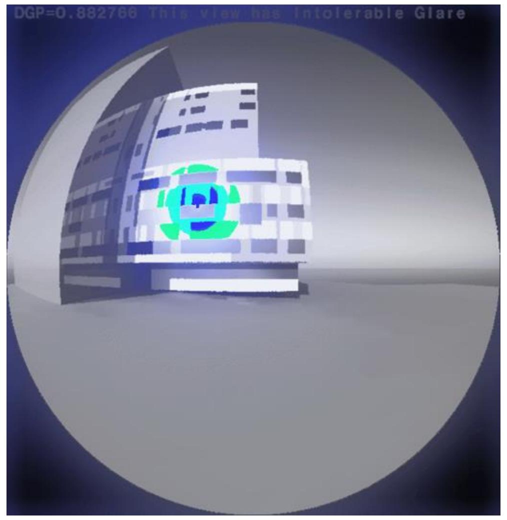
22.50 – Borderline

21st July 14:00



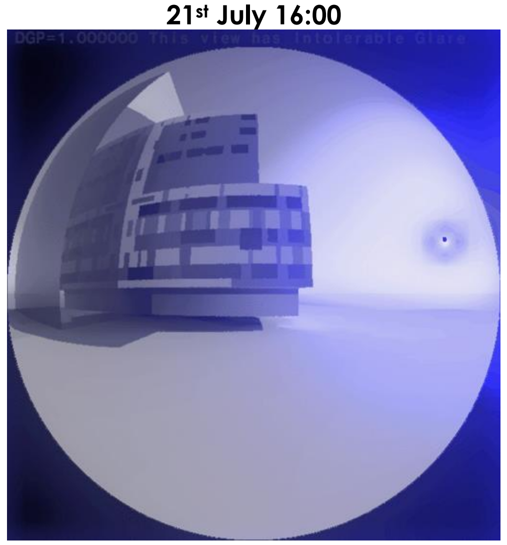
27.87 – Uncomfortable

21st March 07:00



29.43 – Intolerable

21st July 16:00



37.64 – Intolerable

21st September 17:00

43.26 – Intolerable

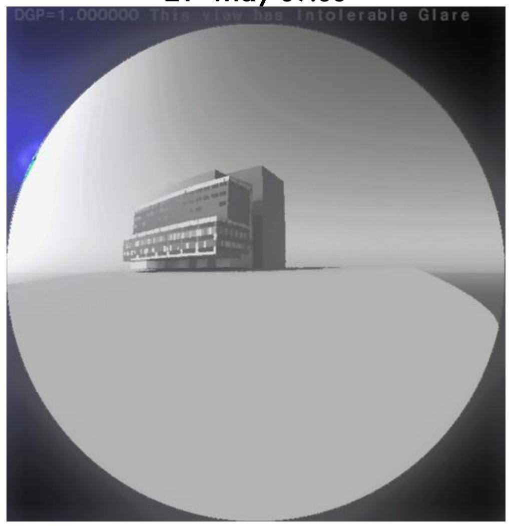
5.5 Location 5

	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
21st January	0.00	0.00	38.46	35.06	29.41	27.22	26.04	0.00	0.00	0.00	0.00	0.00	0.00	5.14	0.00
21st February	0.00	0.00	38.69	35.13	29.63	27.59	7.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st March	0.00	0.00	36.88	32.98	26.77	26.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st April	0.00	0.00	0.00	0.00	10.39	-3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st May	0.00	0.00	0.00	25.85	21.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st June	0.00	0.00	0.00	26.01	14.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st July	0.00	0.00	0.00	29.75	26.50	0.00	0.00	0.00	0.00	0.00	4.75	8.04	0.00	0.00	0.00
21st August	0.00	0.00	0.00	29.64	25.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st September	0.00	0.00	37.32	33.13	28.02	18.83	0.00	0.00	0.00	0.00	0.00	3.14	12.51	0.00	0.00
21st October	0.00	0.00	30.21	24.98	16.71	19.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st November	0.00	17.31	33.92	31.37	28.02	27.37	-4.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21st December	0.00	0.00	0.00	0.00	0.00	1.44	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	DGI
Imperceptible	< 16
Perceptible	≥16 & <20
Acceptable	≥20 & <22
Borderline between Comfort and Discomfort	≥22 & <24
Uncomfortable	≥24 & <28
Intolerable	≥ 28

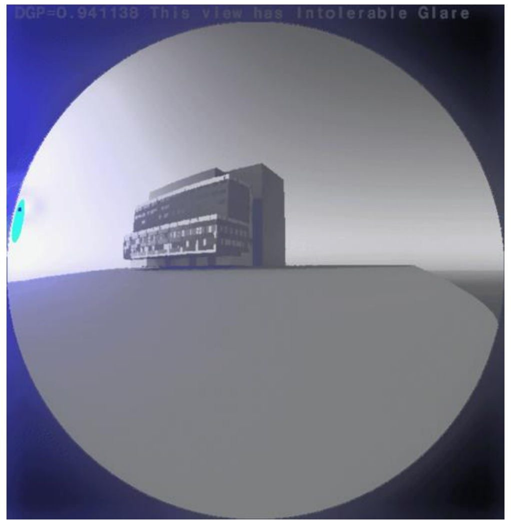
The intolerable DGI values observed for all the months at this location point are due to direct exposure of sun and not due to reflectivity from the façade.

21st May 09:00



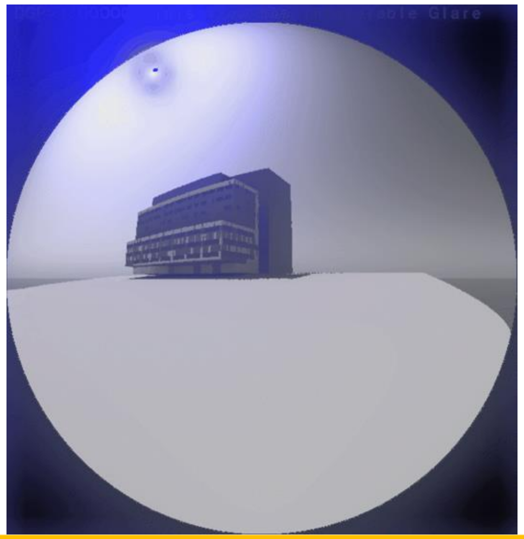
21.75 – Acceptable

21st June 08:00



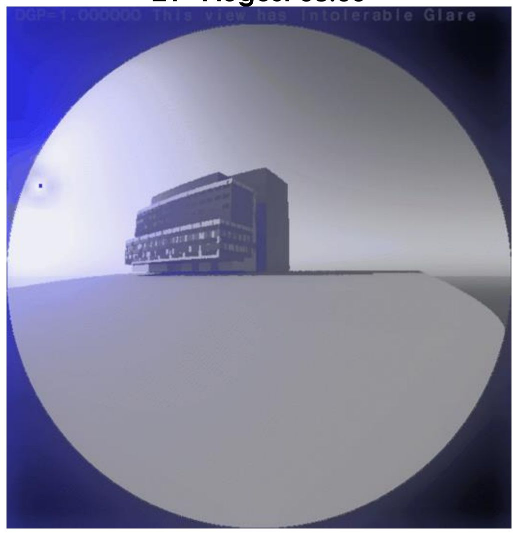
26.01 – Borderline

21st November 07:00



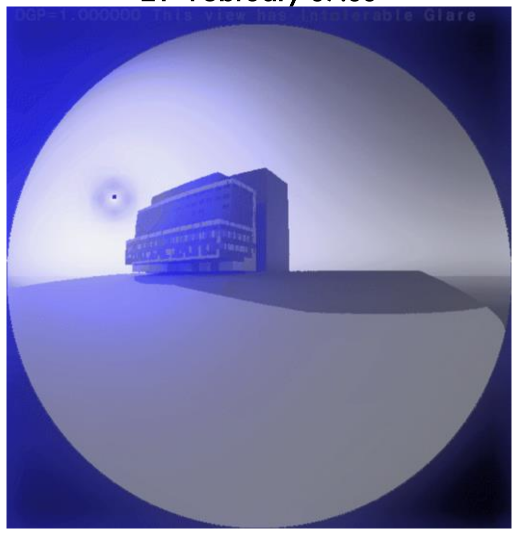
28.02 – Uncomfortable

21st August 08:00



29.75 – Intolerable

21st February 07:00



38.69 – Intolerable

6. Conclusion

The methodology used within this study has been conducted by geometrical modelling of the proposed building design of Lismore Base hospital along with the context, identification of sources of reflective glare from the façade and its effects on the critical identified locations around the development.

The glare assessment has been undertaken at 5 critical view locations around the proposed north tower of the hospital that were identified to have a high risk of glare.

The results indicate that the proposed façade will have minimal glare issue (1% in a year) provided the specified material (refer section 4.6) or similar material properties are used with the current material application ratios. There are three occurrences where the glare risk has the potential to be an issue at location 3 and 4. These occur on the 21st June at 4pm, 21st August at 5pm for location 3 and 21st March at 7am for location 4, where the glare is a direct result of reflection of the glazed façade.

All other predicted intolerable glare experienced in this analysis were due to direct sunlight being in the field of vision. The summary of the daylight glare index (DGI) for all the identified locations and all the months are shown in Table 6 and Figure 9.

Table 6: Daylight Glare Index results summary

	DGI Score	Location 1	Location 2	Location 3	Location 4	Location 5
Imperceptible - Acceptable	< 22	84%	92%	92%	82%	84%
Borderline between Comfort and Discomfort	≥ 22 & < 24	2%	1%	0%	1%	0%
Uncomfortable	≥ 24 & < 28	6%	6%	4%	6%	6%
Intolerable Direct Sun	≥ 28	8%	2%	3%	12%	9%
Intolerable Due to Reflectivity	≥ 28	0%	0%	1%	1%	0%

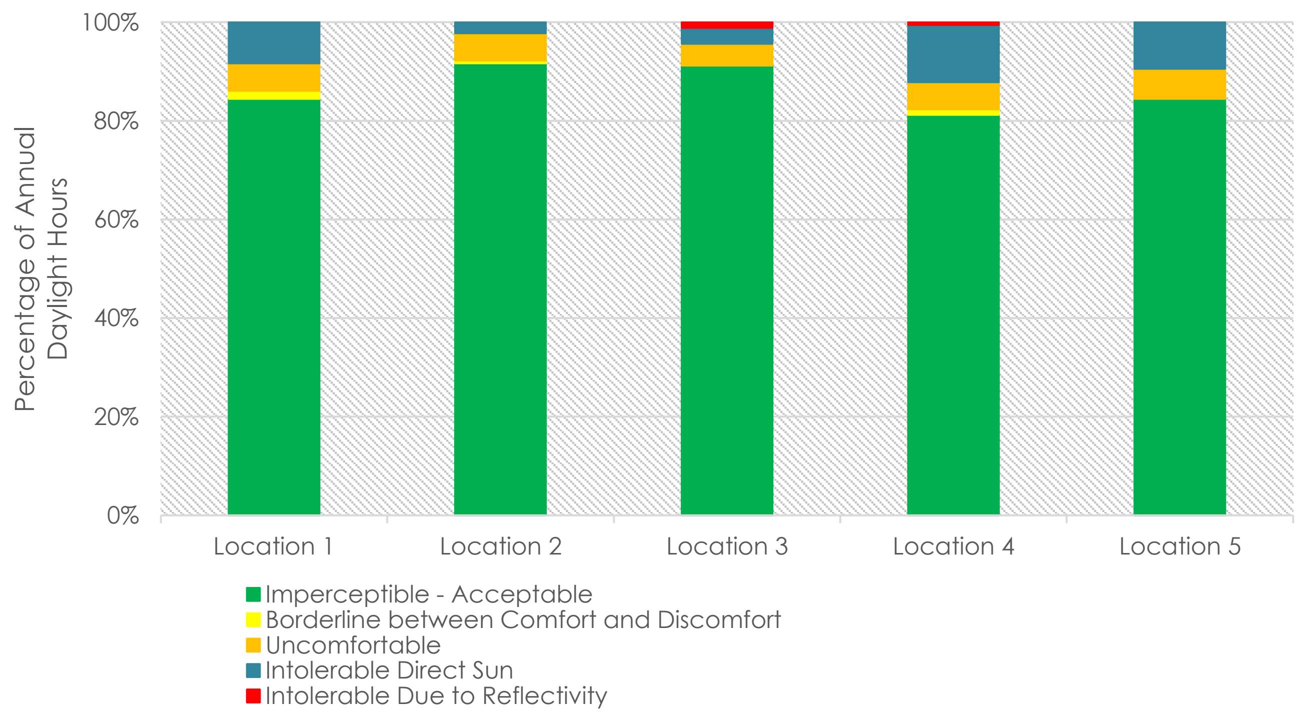


Figure 9: Summary of results % of occurences in each comfort band

7. Appendix A – Radiance Modelling Parameters

Parameter	Parameter Description	Value
-pt	sampling threshold	0.05
-pj	anti-aliasing jitter	0.9
-dj	source jitter	0.7
-ds	source sub-structuring	0.05
-dt	direct thresholding	0.15
-dc	direct certainty	0.75
-dr	direct relays	3
-dp	direct pre-test density	512
-ab	ambient bounces	6
-aa	ambient accuracy	0.15
-ar	ambient resolution	128
-ad	ambient divisions	512
-as	ambient super-samples	256
-lr	limit reflection	8
-lw	limit weight	0.05

8. Appendix B - Glossary of Terms

Reflectivity: the percentage of light that is not absorbed or transmitted by the material, but is reflected

Diffuse: This indicates that a material has a surface roughness or texture, i.e. it scatters the light that it reflects and is non-specular

Specularity: the degree to which a surface has a mirror-like reflection of light. An incoming single ray of light onto a highly specular surface is reflected into a single outgoing direction.

Luminance: describes the amount of light that is emitted or reflected from a particular area, and falls within a given solid angle. This is measured in candela per square metre.

Field of Luminance: the angular extent of the observable world that influences an observer's perception of brightness. In this instance defined as 180° from the centre of view.

Field of View: also known as field of vision, the angular extent of the observable world that is visible.

Glare Threshold: the limiting luminance that defines a glare source from the field of luminance.

Daylight Glare Index (DGI): the established measurement of discomfort glare due to daylight as a function of glare source luminance, field luminance, and solid angle and location glare source.

Solid Angle: the angle in a three-dimensional space that an object subtends at a point. It is a measure of how big that object appears to an observer looking from that point.

Viewing Angle: the angular change in viewing direction from the centre of view in the horizontal plane.

9. Appendix C - Disability glare

Disability glare impairs the vision of objects without necessarily causing discomfort. The disability glare effect is described as an equivalent uniform luminance resulting from the stray light in the eye which superimposes on the location of the vertical image, thus lowering contrast. This equivalent veiling luminance depends mainly on two parameters:

- The illumination on the observer's eye produced by the glare sources in the plane perpendicular to the line of sight;
- The angle between the centre of the glare source and the line of sight.

10. Appendix D - Discomfort Glare

Discomfort glare causes discomfort without necessarily impairing the vision of objects and details. It is the result of high or non-uniform luminance distribution within field or by high contrasts of luminance between the glare source and its surroundings. It is generally agreed that discomfort glare produced by an individual source depends on four main parameters:

- Source luminance in the direction of the observer's eye;
- Solid angle subtended by the source at the observer's eye;
- Angular displacement of the source from the observer's line of sight;
- General field luminance controlling the adaptation level of the observer's eye.

Discomfort glare is often measured in metrics such as Daylight Glare Index.

11. Appendix E - Limitations

Although the methodology developed is considered robust in terms of finding and analysing glare sources, due to the complex nature of the study there are inherent limitations.

The geometry used in this model is believed to be accurate but any excluded geometry, errors in measurements or changes to the surrounding area (such as new developments) could alter the way the sun interacts with the façade and the surrounding environment. Material assumptions have been made that are considered a fair representation of the situation; however a building's façade is made from a variety of materials with a large range of reflectances. The computational model of the façade is unlikely to be a truly accurate representation of the as-built façade as manufacturing tolerances could create discrepancies with the modelled geometry.

As discussed, the scenario analysed in this report contains more than one dynamic variable; people in the surrounding environment and the sun are both in motion. The study highlights extremes of sun brightness and altitude by analysing the solstices. It also focuses on glare resulting from the reflections from the façade and not from direct sunlight. Analysis locations were chosen based on a quantitative assessment of the surrounding environment, which highlighted key locations where glare could be problematic. There are infinite variations in the location of people in the surrounding environment and sun positions and so the presence of further, unidentified periods of glare is possible. As it is not practical to analyse all variations, the study aims to locate and examine critical and extreme examples.

The ray-tracing software used is considered to be highly accurate; however limitations must be made to allow reasonable computation power to be employed, variables such as the number of solar reflections and image resolution are set to produce high quality images, but these can never be true to life.

As the effect of glare itself is a subjective sensation, individuals' perception of glare can vary greatly from one person to another, and factors such as age and eye colour can affect the perceived sensation. The Daylight Glare Index used to measure the glare in this analysis is derived from clinical tests employed to measure glare sensitivity, and is an established tool for the measurement of glare. Several immeasurable phenomena exist that could redirect or scatter light, such as scratched surfaces or incorrectly mounted glazing systems, but these effects are unpredictable and are not included in the study. The dynamic effect of glare, or rather the observer's ability to adapt to changes of light levels over time is also not included in this study.