Atlassian Central
Avenor Pty Ltd
External Reflected Glare Assessment

Final Issue | Revision [03]

Inhabit

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Executive Summary

Inhabit has been commissioned by Avenor on behalf of Atlassian to assess the potential reflected glare impact of the proposed mixed-use development at 8-10 Lee Street, Haymarket, Sydney, NSW (the Site). The proposed development is 38 storeys, with the façade being mostly glazed. As the project is adjacent to a major railway corridor, the impact of glare to train drivers is considered critical in this assessment. Other key areas considered in this study include the Central Station platforms, nearby roads, tram line on Devonshire Street facing the Site, the proposed towers at the Dexus Fraser's site to the south of the Site, as well as public open spaces such as the adjacent Western Forecourt to the north of the Site and Prince Alfred Park on the other side of the railway corridor to the east of the Site.

This study has been carried out in accordance with the SEARs requirements that identifies potential adverse glare conditions. Reflected glare from the proposed development to the surrounding roads and nearby railway line has been assessed against a veiling luminance performance criterion of 500 Cd/m² defined by Hassall (1991) using the Holladay (1927) formula. Public outdoor spaces have been assessed against a performance criterion of 887 Cd/m^2 (Ho et al., 2011). Glare impact to occupants of surrounding buildings have been assessed against the same performance criterion (Ho et al., 2011), however increased to 1267 Cd/m^2 to account for the impact of additional glazing between the observer and glare source, that will reduce the intensity of reflected glare. For surrounding buildings, glazing with a visible light transmittance (VLT) of 70% has been conservatively assumed.

The glazing visible light reflectance considered throughout this study is 20%. This assessment has not identified reflected glare from the proposed façade exceeding the veiling luminance performance criteria. Table 1 summarises the results of the assessment. Refer to Section 7.0 for further discussion on these results.

Table 1: Summary of results.

Region	Performance Criteria	Annual Frequency Criteria Exceeded[1]
A – Northbound Train Perspective (Western Tracks)	< 500 Cd/m²	0%
B – Southwest bound Train Perspective	< 500 Cd/m²	0%
B1 – Platform Perspective (Platform 2)	< 887 Cd/m²	0%
B2 – Platform Perspective (Platform 22)	< 887 Cd/m²	0%
C – Northeast bound Train Perspective (Eastern Tracks)	< 500 Cd/m²	0%
D – Eastbound Motorist Perspective (George Street)	< 500 Cd/m²	0%
E – Southbound Motorist Perspective (George Street)	< 500 Cd/m²	0%
F – Southeast bound Pedestrian Perspective (Quay Street)	< 887 Cd/m²	0%
G – Northwest bound Tram Perspective (Devonshire Street)	< 500 Cd/m²	0%
H – Southwest bound Motorist Perspective (Railway Collonade)	< 500 Cd/m²	0%
I – Northwest bound Motorist Perspective (Moore Park Road)	< 500 Cd/m²	0%
J – Southwest bound Motorist Perspective (Western Forecourt)	< 500 Cd/m²	0%

Region	Performance Criteria	Annual Frequency Criteria Exceeded[1]
K – General Public Perspective - Tennis Courts, Prince Alfred Park[2]	< 887 Cd/m²	0%
L – General Public Perspective - Swimming Pool, Prince Alfred Park[2]	< 887 Cd/m²	0%
M – Occupant Perspective - Tower 1, Dexus Fraser's Site (to the south)	< 1267 Cd/m²	0%
N – Occupant Perspective - Tower 2, Dexus Fraser's Site (to the south)	< 1267 Cd/m²	0%
O – Occupant Perspective – Neighbouring Buildings (to far west)	< 1267 Cd/m²	0%
P – Occupant Perspective - Neighbouring Building (to the west)	< 1267 Cd/m²	0%

[1] Perspectives with direct solar glare in the field of view are considered acceptable because direct glare will always dominate any reflected glare due to the luminance of the sun and the size of the sun as a glare source. This has further been verified using image-based assessment that quantifies glare using the Daylight Glare Probability (DGP) scale.

[2] Result conservatively assumes the observer is facing directly towards the source of glare.

Further, for each of the regions studied, an environmental risk assessment has been undertaken as required by the SEARs. It has been identified that risk levels for the regions vary between 'Low' to 'Very Low'. Refer to Section 6.1 of this report for more details.

1.0 Introduction

Inhabit has been commissioned by Avenor on behalf of Atlassian (the Applicant) to prepare this report in accordance with the technical requirements of the Secretary's Environmental Assessment Requirements (SEARs), and in support of the SSD-10405 for a commercial and hotel development above the Former Inwards Parcel Shed at 8 – 10 Lee Street, Haymarket, Sydney, NSW.

Specifically, this report addresses the following SEARs (Table 2):

Table 2: SEARs requirements.

Reference Number	Description of Requirement	Report Reference
6. Environmental Amenity	The EIS shall include a reflectivity analysis identifying potential adverse glare conditions affecting, motorists, pedestrians and occupants of neighbouring buildings.	Refer to Section 3.4 for critical observer orientations considered, Section 6.0 for results, Section 7.0 for discussion and Section 8.0 for conclusion.

1.1 Reference Documentation

This assessment has been based on the following sources of information.

- 3D models and architectural drawings developed by project architects, BVN and SHoP, issued 28th August 2020.
- GIS site plans, dated 24th June 2019.

The above information was downloaded from the project BIM360 website on 30th August 2020.

1.2 Glare Background

Reflective glazed façades with modern high-performance coatings will always cause a degree of reflected glare impact to the surroundings. Non-matte surfaces including shiny cladding can also result in reflected glare. The solar reflections off a building façade can lead to numerous visual and thermal issues.

In addition to causing nuisance to pedestrians or occupants of nearby buildings, visual glare can create a safety hazard to motorists, railway drivers and others whose tasks restrict them from simply looking away. Glare can also create undesirable patterns of light throughout the urban environment.

Thermal gains as a result of reflections from a building façade can increase building heat loads and human discomfort, even posing a safety issue to both people and materials when heat is focused on a single location. Such is the case by a parabolic or otherwise curved reflecting surface. This study only assesses radiation in the visible light spectrum and does not consider thermal radiation. To quantify the impact of solar reflections from the development, the following factors must be considered:

- Frequency
- Duration
- Intensity
- Receiving location

1.3 Limitations

This simulation has been based on the methodology and the assumptions included in this report, using material performance values specific to the project. Where specific material performance values are not available, standard industry values have been used as default.

Building performance simulations are idealised representations of the actual building that cannot fully represent all of the intricacies of the building once built. As a result, simulation results only represent an interpretation of the building performance. No guarantee or warrantee for the building performance in practice can be based on simulation results alone. Refer to Appendix E for more details.

2.0 Performance Criteria

The City of Sydney nominates an upper limit for glazing reflectance value of 20%. It is understood that this is a prescriptive requirement and other factors such as the proportion of façade glazing, building form and adjacent sites may require the project to demonstrate compliance via performance-based modelling.

As the impact of glare is subjective and dependent on the duration of exposure, planning requirements do not define a specific performance criterion. This study nominates the following criteria (Table 3) based on Hassall (1991) and Ho et al. (2011).

Table 3: Summary of performance criteria adopted.

Receiver Group	Performance Criteria	Description
Transport (Road, Tram and Rail Drivers)	< 500 Cd/m² [1]	< Safety Limit
General Public	< 887 Cd/m² [2]	< Comfort Limit
Neighbouring Buildings	< 1267 Cd/m² [3]	< Comfort Limit

Note that when the reflected glare exceeds the performance criteria, but direct glare from the sun is also present in the observer's field of view, reflected glare is considered acceptable because direct glare will be the dominant source of visual discomfort. This is verified using image-based assessment that quantifies glare using the Daylight Glare Probability (DGP) scale (Wienold & Christoffersen, 2006). This study nominates the following criteria (Table 4). As the City of Sydney does not nominate a performance criterion for glare, DGP 0.40 and 0.45 were adopted for drivers and general public respectively. These DGP limits correspond to when discomfort and disability glare can occur, and are therefore considered appropriate for this study.

Table 4: Summary of performance criteria adopted – Image-based verification.

Receiver Group	Performance Criteria	Description
Transport (Road, Tram and Rail Drivers)	< 0.40 DGP	< Discomfort Glare
General Public	< 0.45 DGP	< Disability Glare
Neighbouring Buildings	< 0.45 DGP	< Disability Glare

[1] Hassall, David N. H., 1991. Reflectivity: dealing with rouge solar reflections / written and illustrated by David N.H. Hassall [D.N.H Hassall] [Newport, N.S.W]

[2] Ho, C. K., Ghanbari, C. M., and Diver, R. B. (August 5, 2011). "Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation." ASME. J. Sol. Energy Eng. August 2011; 133(3): 031021.

[3] To assess glare to surrounding buildings, the comfort limit outlined by Ho et al. (2011) has been increased to consider glazing between the glare source and the building occupant, which will reduce the intensity of reflected glare. As the material properties of surrounding buildings are unknown, a glazing visible light transmittance (VLT) of 70% has been conservatively assumed.

3.0 Site and Context

3.1 Description of the Site

The Site is known as 8-10 Lee Street, Haymarket. It is an irregular shaped allotment. The allotment has a small street frontage to Lee Street, however this frontage is limited to the width of the access handle (Figure 1).

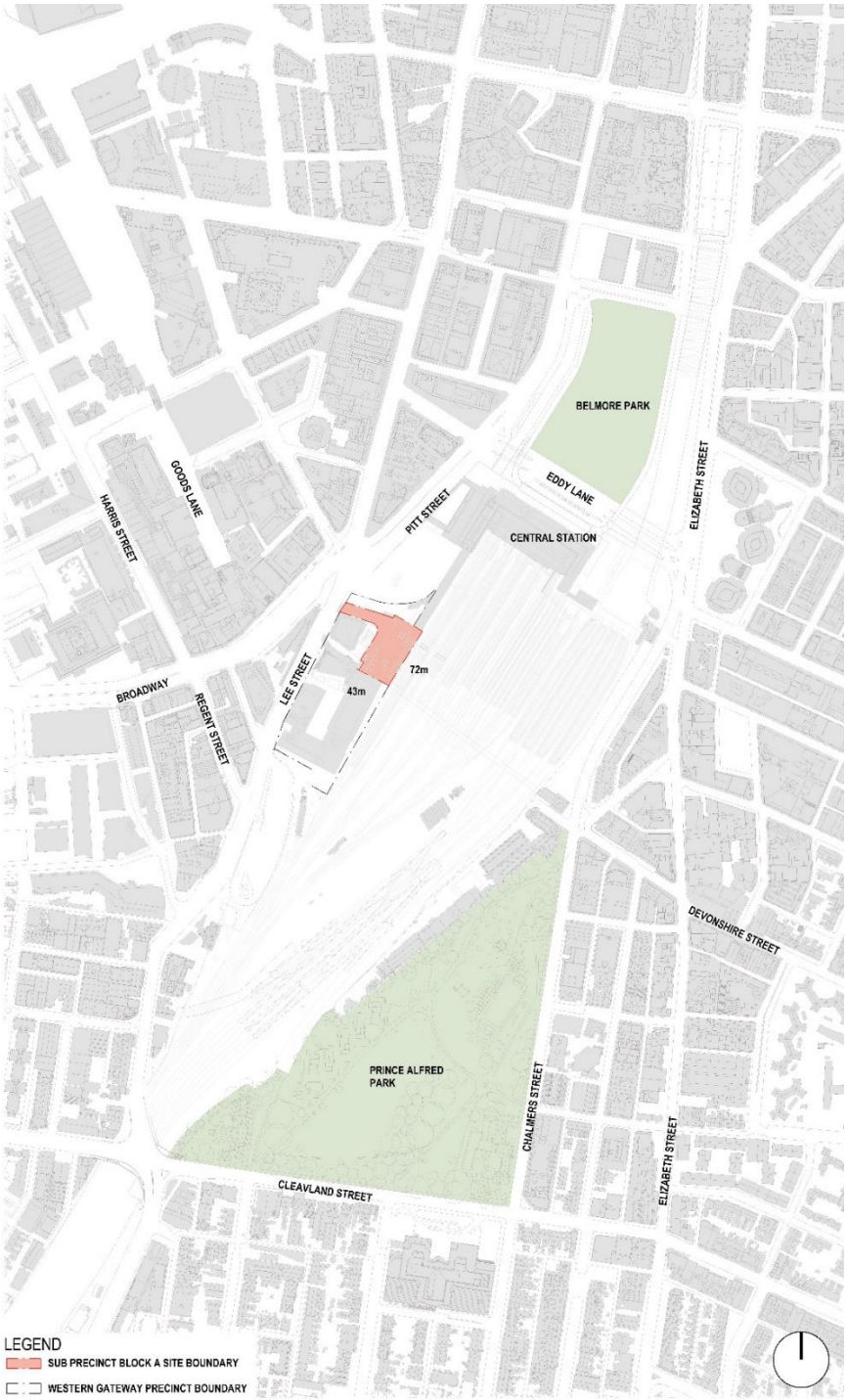


Figure 1: Site location and dimensions (image source: BVN and SHoP Architects).

The Site comprises multiple parcels of land which exist at various stratums. All the lots are in the freehold ownership of Transport for NSW, with different leasing arrangements:

- Lot 116 in DP 1078271: YHA is currently the long-term leaseholder of the Site.
- Lot 117 in DP 1078271: This is currently in the ownership of TfNSW and the applicant is seeking the transfer of the leasehold on this land to provide for an optimise basement and servicing outcome for the Site.
- Lot 118 in DP 1078271: This is currently in the ownership of TfNSW and the applicant is seeking the transfer of the leasehold for part of the air-rights above part of this allotment to allow for an optimised building envelope for the project. The proposal also uses a part of Lot 118 in DP 1078271 within Ambulance Avenue for Day 1 bike access, secondary pedestrian access and fire service vehicle access.
- Lot 13 in DP 1062447: This is currently in the ownership of TfNSW but TOGA (who hold the lease for the Adina Hotel) have a long-term lease of this space in the lower ground area.

The Site has an area of approximately 3,764m² which includes 277m² of air rights that apply from RL40.

3.2 Site and Surrounding Context

The Site is directly adjacent to the Western Wing Extension of the Central Station, and forms part of the 'Western Gateway Sub-precinct' of the Central Railway Station lands. It is situated between the existing CountryLink and Intercity railway platforms to the east and the Adina Hotel (former Parcel Post Office) to the west.

Existing vehicle access to the Site is via Lee Street, however the Lee Street frontage of the Site is only the width of the access handle.

Current improvements on the Site include the Parcels Shed, which operated in association with the former Parcels Post Office (now the Adina Hotel). The Site is currently used as the Railway Square YHA. The Site also includes the western entryway to the Devonshire Street Pedestrian, which runs east-west through Central Station under the existing railway lines.

The Site is situated in one of the most well-connected locations in Sydney. It is directly adjacent to Central Station Railway which provides rail connections across metropolitan Sydney, as well as regional and interstate connections and a direct rail link to Sydney Airport. The Site is also within close proximity to several educational institutes and is a city fringe location which provides access to key support services.

Central Railway Station is currently undergoing rapid transformation to allow for integration of rail, metro and light rail transport infrastructure. This will elevate the role of Central Station not only for transport but also enhance opportunities for urban renewal and revitalisation of the surrounding precinct. This is one of the key drivers for the identification of the Central SSP and the Western Gateway Sub-precinct to accommodate a new innovation and technology precinct.

The proximity of the Western Gateway Sub-precinct to the city, while still being located outside the core Sydney CBD, provides opportunity for it to evolve to attract technology and innovation companies. It has access to all required services while being sufficiently separate to the CBD to establish a distinct technology industry ecosystem. Its CBD fringe location will provide affordable commercial rents which will support start-ups and entrepreneurs which are a key component of an innovation precinct.

3.3 Project Description

The proposed SSDA will facilitate the development of a new mixed-use development comprising 'tourist and visitor accommodation' (in the form of a 'backpackers') and commercial office space within the tower form. Retail, lobby and food and drink premises will be located at the Lower Ground level and the Upper Ground level.

Atlassian Central at 8-10 Lee Street will be the new gateway development at Central Station which will anchor the new Technology Precinct proposed by the NSW Government. The new building will be purpose-built to accommodate the Atlassian Headquarters, a new TfNSW Pedestrian Link Zone, and the new Railway Square YHA backpacker's accommodation, in addition to commercial floorspace to support Tech Start-ups.

The new development is to be built over the existing heritage former Inwards Parcels Shed (the Parcels Shed) located on the western boundary of Central Station with the Adina hotel to the west. The works includes a 38-storey mixed-use tower with basement loading dock facilities and EOT facilities accessed off Lee Street, 2 storey lobby utilising the Parcels Shed building, lower ground and upper ground retail, YHA hostel and commercial tower with staff amenities to the mid-level and roof top areas and a pedestrian Link Zone works for TfNSW.

The building design has been conceived to support the delivery of a site plan designed to connect with future developments to both the south and east and integrate with a cohesive public realm for the broader Sydney community in accordance with NSW government strategic planning.

The tower design is a demonstration project for Atlassian, representing their commitment to environmental sustainability and contemporary workplace settings through tower form and construction systems along with a set of emblematic outdoor workplaces stacked in the tower form. The proposed envelope comprises of a double-skin façade, with the external enclosure comprising of staggered, glazing panels. The inner façade includes a mixture of fixed and operable glazing, providing occupants with a semi-enclosed space in between. The outer skin of the south and east elevations generally consists of fixed panels while the north and west elevations have a combination of fixed panels and operable glazed louvres.

Figure 2 shows the proposed façade design for the development.

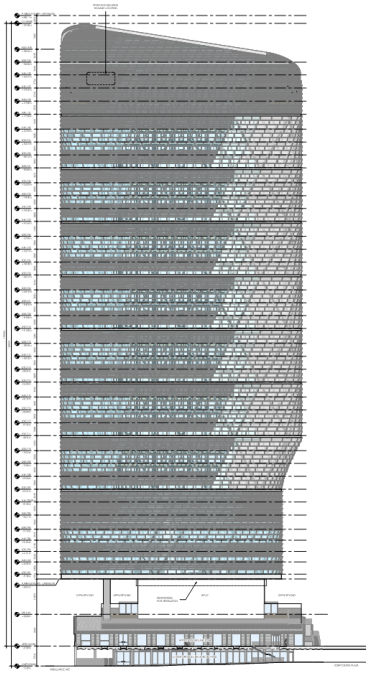


Figure 2: Proposed façade design (image source: BVN and SHoP Architects).

The existing Parcels Shed will be adaptively re-used in accordance with best practice heritage process and form the upper level of a 2-storey entry volume that connects visually with the 2 level Link Zone. Over the roof of the Parcels Shed, a new privately owned but publicly assessible landscaped area will be created as the first part of a new upper level public realm that may extend to connect to a future Central Station concourse or future Over Station Development.

Currently the Site is predominantly surrounded by low to medium rise developments to the north, west and south. Planning is underway for two new towers of similar height to the south of the Site (Dexus Fraser's site). The railway corridor forms the eastern boundary of the Site. The Site is adjacent to Pitt Street, George Street and Quay Street; all of which are arterial roads. While the development will receive significant solar shading from the proposed adjacent buildings to the south of the Site, shading from other surrounding buildings will be negligible due to their relatively low heights.

As the project is adjacent to a major railway corridor, this area is critical in this assessment and will ensure that all TfNSW external development standards are achieved. This ensures there is no impact to the operation or safety of these TfNSW assets. Other key areas considered in this study include the Central Station platforms, nearby roads, tram line on Devonshire Street facing the Site, the proposed towers at the Dexus Fraser's site to the south, as well as public open spaces such as the adjacent Western Forecourt to the north of the Site and Prince Alfred Park on the other side of the railway corridor.

Figure 3 shows the project site and neighbouring context.

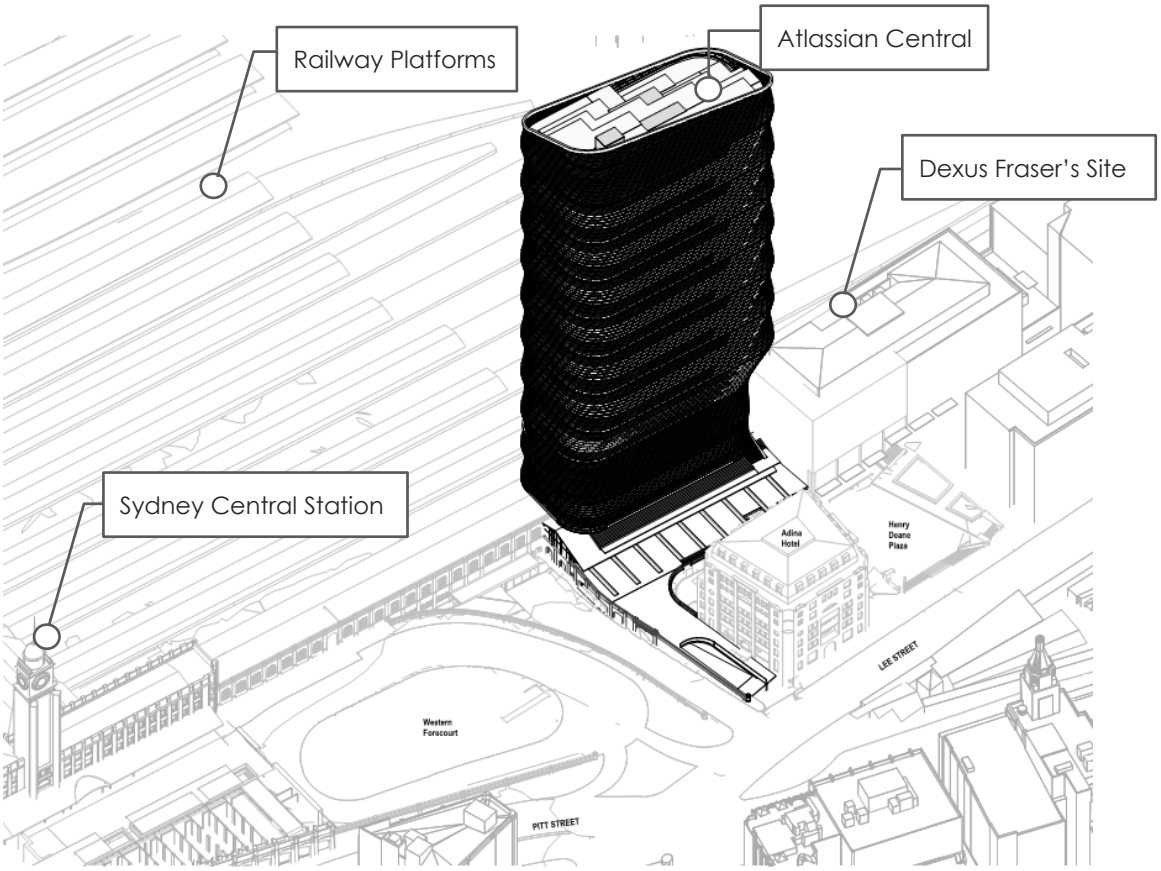


Figure 3: Site location and context (image source: BVN and SHoP Architects).

3.4 Critical Observer Locations

Based on the project scale and site location, critical transport infrastructure and surrounding buildings within 3km of the Site have been assessed for potential glare impact.

The critical observer locations and viewing directions considered in this assessment are:

- Northbound, southwest bound and northeast bound trains on the railway line east of the Site - Regions A, B and C respectively
- General public perspective of train users waiting along Platform 2 (closest to the Site) and Platform 22 (farthest from the Site) - Regions B1 and B2 respectively
- Motorists and pedestrians travelling along the following nearby roads:
    - George Street (eastbound and southbound) - Regions D and E respectively
    - Quay Street (southeast bound; pedestrians only) – Region F
    - Devonshire Street (northwest bound; tram line) – Region G
    - Railway Collonade (southwest bound) – Region H
    - Moore Park Road (northwest bound) – Region I
    - Western Forecourt (southwest bound) – Region J
- General public perspective along the following nearby public spaces:
    - Tennis courts at Prince Alfred Park – Region K
    - Swimming pool at Prince Alfred Park– Region L
- Occupants of the following neighbouring buildings:
    - Proposed towers at the Dexus Fraser's Site to the south of the Site – Regions M and N respectively
    - 28 Broadway (Central Park Sydney) and 26-60 Broadway to the west of the Site – Region O
    - 818-820 George Street to the west of the Site – Region P

Figure 4 illustrates the critical observer locations and viewing directions considered.

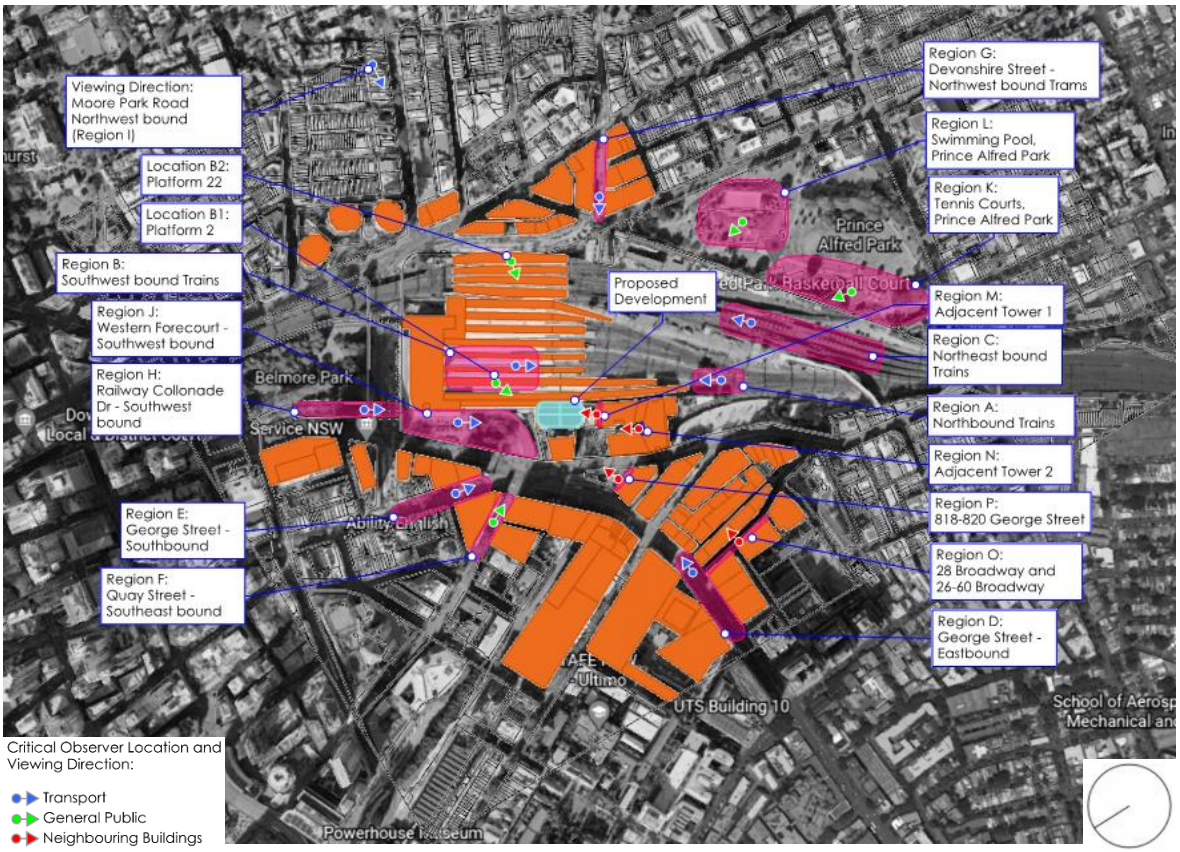


Figure 4: Regions (in magenta) identified for detailed study (Note- Region I- Moore Park Road approx. 2km away from the Site has been excluded in the image due to the large scale).

4.0 Methodology

4.1 Process

Figure 5 illustrates the modelling process adopted.

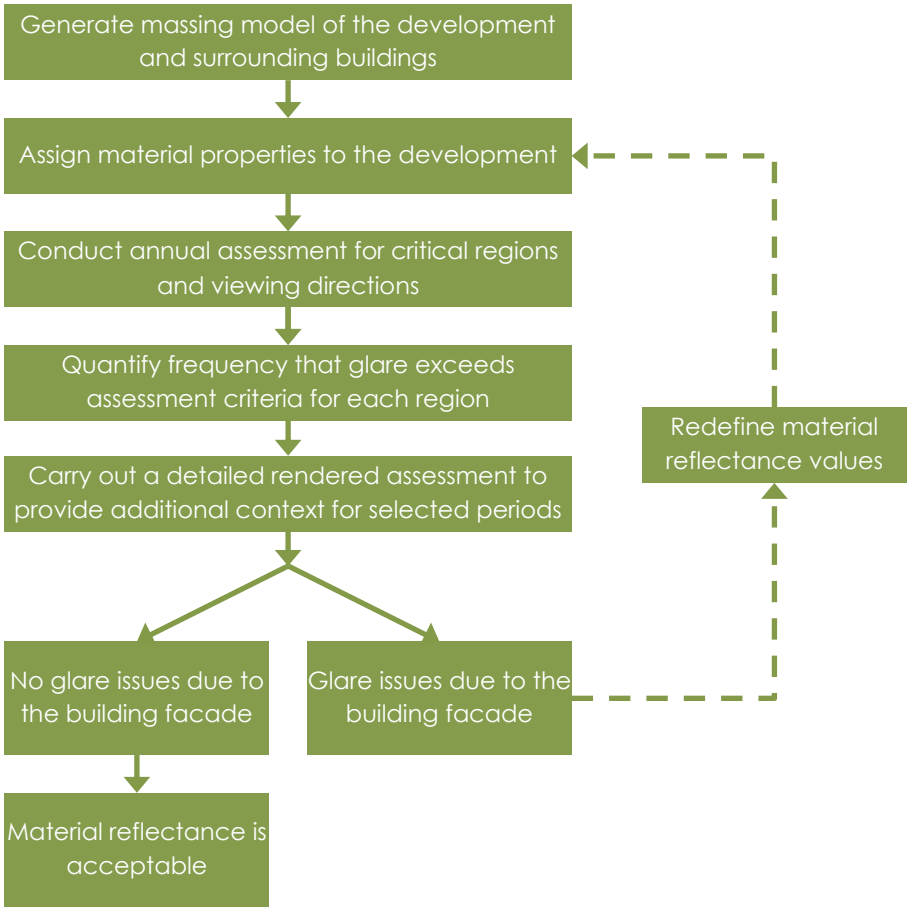


Figure 5: Flowchart showing the reflected glare assessment process.

4.2 Tools and Software

The proposed development and the surrounding buildings were modelled in a 3D modelling software, Rhinoceros 6. A simulation tool developed by Inhabit using Grasshopper, a plug-in of Rhinoceros, was then used to quantify the potential for reflected glare across the 3D environment.

Detailed image-based assessment was then undertaken using the Radiance[4] programme 'Evalglare'. The programme outputs an image highlighting glare sources and quantifies glare using the Daylight Glare Probability (DGP) scale (Wienold & Christoffersen, 2006).

[4] Radiance is a high-detail, open source, ray-tracing software. It was developed by Lawrence Berkeley National Laboratory (LBNL) with primary support from the U.S. Department of Energy and additional support from the Swiss Federal Government. Radiance is widely considered the industry standard tool for lighting simulation and glare calculations.

4.3 Veiling Luminance

For both road and rail driver safety, Hassall (1991) nominates a veiling luminance[5] of 500 candelas per square metre (Cd/m²) as an upper limit for safety. This limit has been derived using the Holladay (1927) formula to determine the risk of glare due to light reflections. For pedestrians, Ho et al. (2011) nominates a veiling luminance of 887 Cd/m² as the upper limit for visual comfort. For surrounding buildings, the Ho et. al (2011) criterion has been increased to 1267 Cd/m² to consider glazing (70% VLT) between the glare source and the building occupant.

4.4 Spectral and Diffuse Reflection

Reflected glare is defined by the McGraw-Hill Dictionary of Architecture and Construction (2003) as glare resulting from specular reflection of high brightness in polished or glossy surfaces in the field of view. Therefore, when considering the impact of reflected glare, the critical material properties are the combination of reflectance and specularity together.

Reflectance in the context of this assessment is a measure of visible light that is reflected from a surface when illuminated by a light source such as the sun.

Specularity can be described as how smooth a surface is on a microscopic level. The higher the surface specularity, the more mirror-like or shiny the surface is. Specular reflection reflects all light which arrives from a given direction at the corresponding opposite angle. Conversely, surfaces with low specularity results in a diffuse reflection caused by light being reflected in a broad range of directions.

It is important to note that a material with high reflectance and low specularity has less potential to result in reflected glare when compared to a high reflectance and high specularity. This is due to a lower specular reflection which predominantly drives glare impact.

In this assessment, glazed and non-matte metallic façade elements have been defined conservatively having high specularity.

4.5 Direct Glare and Reflected Glare

For periods when the unobstructed sun is within the observer's field of view, any glare identified as reflected off the façade is excluded from the results. The reason for this is that direct glare from the sun will always be the dominant source of glare when compared to any reflected component. In this assessment the observer's field of view is limited to 60° from the observer's visual axis or bearing in accordance with Hassall (1991).

[5] Veiling luminance is the threshold of contrast for an object, where any additional light superimposed on the retina will reduce the clarity of the object.

5.0 Modelling Inputs

5.1 Annual Sun Path

The assessment has used the sun's position in the sky (azimuth and altitudes) from the following coordinates:

- Latitude: -33.88° South
- Longitude: 151.20° East

5.2 Sky Conditions

Sunny clear sky conditions have been assumed and the luminous efficacy of 179 lm/W (equal energy white source) has been used in this analysis. This represents a conservative scenario for the risk of reflected glare. An overcast or polluted sky will reduce the intensity of solar reflections thereby reducing the risk of glare.

5.3 Time of Analysis

Hourly calculations have been performed for all daylight hours, on the 21st day of each month throughout the year. The 21st day of each month has been selected to account for the summer and winter solstices, covering representative solar positions throughout the year. This time resolution provides an appropriate representation of annual glare impact.

5.4 Model Geometry

The model geometry used in the glare assessment has been based on architectural plan drawings by BVN Architects and SHoP Architects. A façade enclosure Revit model by SHoP was used as reference to develop the façade geometry.

Massing geometry of neighbouring buildings (including the two proposed buildings at the Dexus Fraser's site) have been included to provide context and accuracy in solar obstructions. Trees and greenery have been excluded from the model as their permanence is uncertain, and coverage varies throughout the year. The 3D model geometry is shown in Figure 6 below.

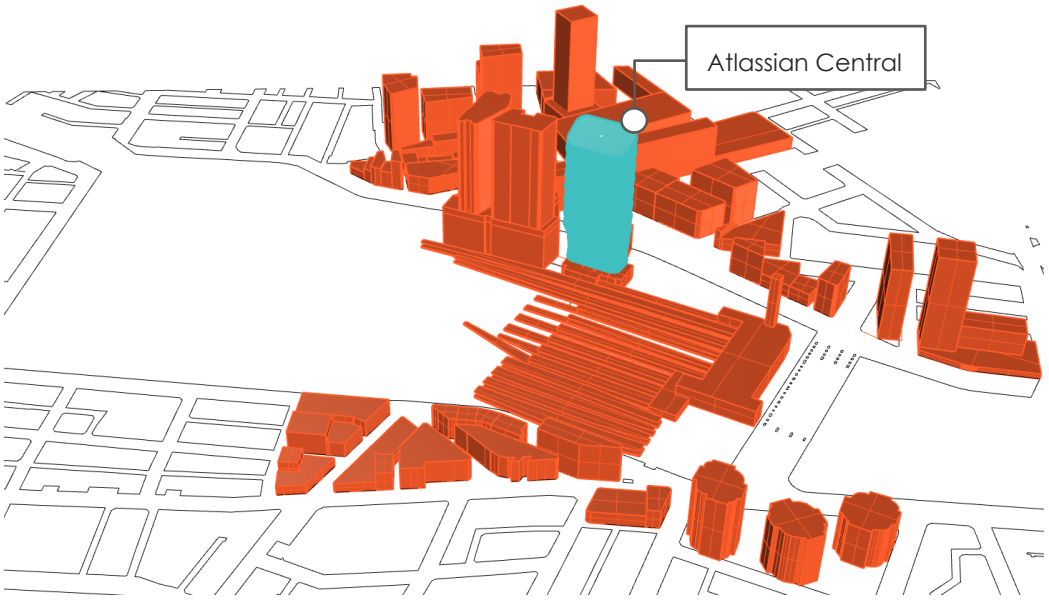
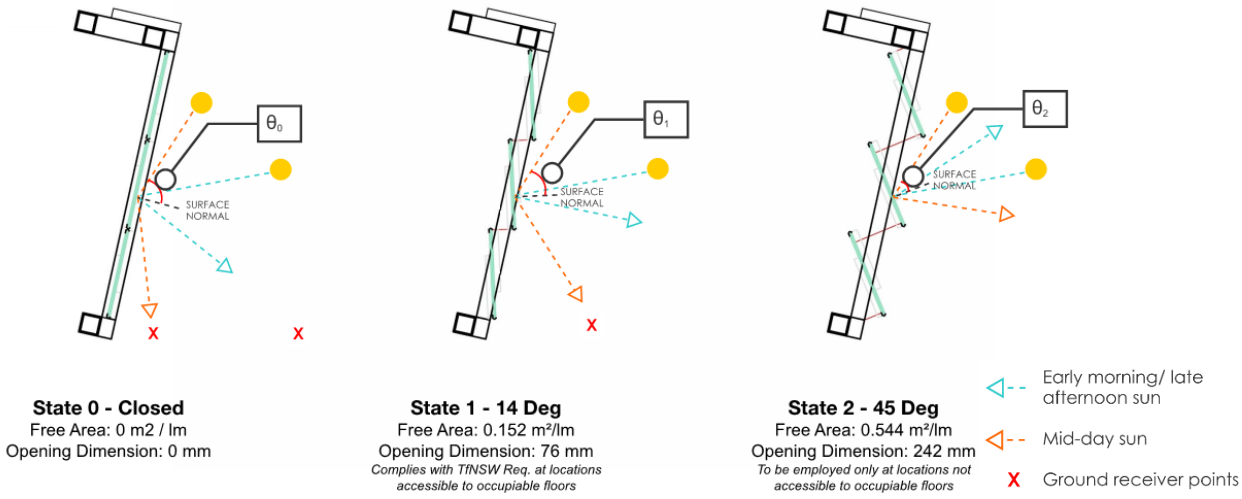


Figure 6: Southeast perspective view of model geometry.

5.5 Louvre Position

The louvres on the outer skin of the development were modelled in the closed position (conservative) in this assessment. As shown in Figure 7, when the louvres are open, fewer reflection receiving points are expected on the ground plane when compared to louvres in open position. Further, for any given time, the veiling luminance values for louvres in open position are expected to be lower than those for louvres in closed position. This is due to the smaller angle of incidence (angle between the incident solar ray and the normal of the reflective surface), and consequently a reduced reflectance value for louvres in open position when compared to those in closed position. Refer to Section B.3 for further details.



Angle of incidence, $\theta_0 > \theta_1 > \theta_2$

Therefore, reflectance value, $R_0 > R_1 > R_2$

Therefore, luminance, $L_{v0} > L_{v1} > L_{v2}$

(Subscripts 0, 1 and 2 refer to corresponding louvre position, i.e. State 0 – Closed, State 1 – 14 degrees, and State 2 – 45 degrees respectively)

Figure 7: Indicative reflected ray path for various louvre positions.

5.6 Material Properties

Table 5 summarises the material properties adopted for this assessment.

Table 5: Material properties.

Element	Specular Light Reflectance (at normal incidence)	Comment
Glazing	20%	Maximum allowable Council requirement
Metal cladding	n/a – none proposed in façade design	Not applicable
Opaque Materials (e.g. walls, roof, ground)	n/a - no specular reflectance	No council requirement for non-glazed elements

6.0 Results

Table 6 summarises the regions and the frequency that reflected glare exceeds the nominated criterion. Detailed results are provided in Appendix A of this report.

Table 6: Summary of results.

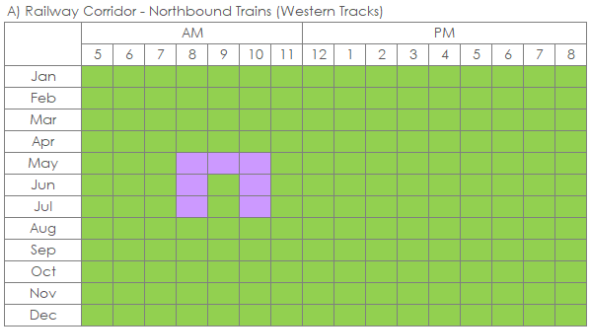
Region	Performance Criteria	Annual Frequency Criteria Exceeded[1]
A – Northbound Train Perspective (Western Tracks)	< 500 Cd/m²	0%
B – Southwest bound Train Perspective	< 500 Cd/m²	0%
B1 – Platform Perspective (Platform 2)	< 887 Cd/m²	0%
B2 – Platform Perspective (Platform 22)	< 887 Cd/m²	0%
C – Northeast bound Train Perspective (Eastern Tracks)	< 500 Cd/m²	0%
D – Eastbound Motorist Perspective (George Street)	< 500 Cd/m²	0%
E – Southbound Motorist Perspective (George Street)	< 500 Cd/m²	0%
F – Southeast bound Pedestrian Perspective (Quay Street)	< 887 Cd/m²	0%
G – Northwest bound Tram Perspective (Devonshire Street)	< 500 Cd/m²	0%
H – Southwest bound Motorist Perspective (Railway Collonade)	< 500 Cd/m²	0%
I – Northwest bound Motorist Perspective (Moore Park Road)	< 500 Cd/m²	0%
J – Southwest bound Motorist Perspective (Western Forecourt)	< 500 Cd/m²	0%
K – General Public Perspective - Tennis Courts, Prince Alfred Park[2]	< 887 Cd/m²	0%
L – General Public Perspective - Swimming Pool, Prince Alfred Park[2]	< 887 Cd/m²	0%
M – Occupant Perspective - Tower 1, Dexus Fraser's Site (to the south)	< 1267 Cd/m²	0%
N – Occupant Perspective - Tower 2, Dexus Fraser's Site (to the south)	< 1267 Cd/m²	0%
O – Occupant Perspective – Neighbouring Buildings (to far west)	< 1267 Cd/m²	0%
P – Occupant Perspective - Neighbouring Building (to the west)	< 1267 Cd/m²	0%

[1] Perspectives with direct solar glare in the field of view are considered acceptable because direct glare will always dominate any reflected glare due to the luminance of the sun and the size of the sun as a glare source.

[2] Result conservatively assumes the observer is facing directly towards the source of glare.

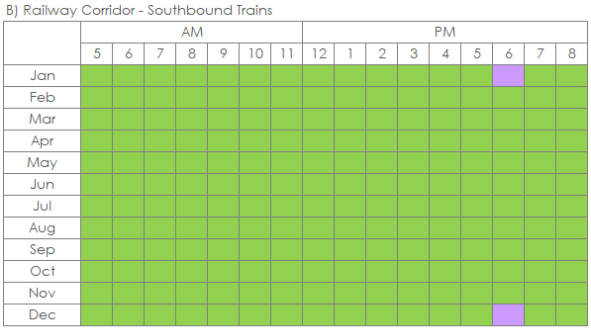
The following charts indicate the times of year when potential reflected glare from the proposed façade exceeds the performance criteria in each region. Orange indicates when the performance criterion has been exceeded, and purple indicates when the performance criteria is exceeded however the sun is within 60° of the observer's visual axis. When the observer experiences both direct and reflected glare, the direct glare will always dominate due to the luminance of the sun and the size of the sun as a glare source. In these instances, reflected glare from the building façade can be considered acceptable because the direct glare from the sun will already be present.

Region A - Railway Corridor – North bound Trains (Western Tracks)



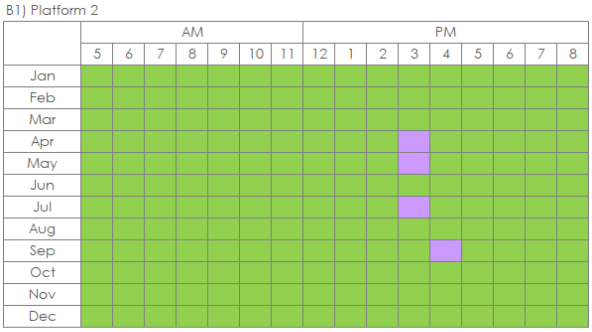
168	Nominal Daylight Hours
95.8%	Acceptable - Within performance criteria
4.2%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region B - Railway Corridor – South bound Trains



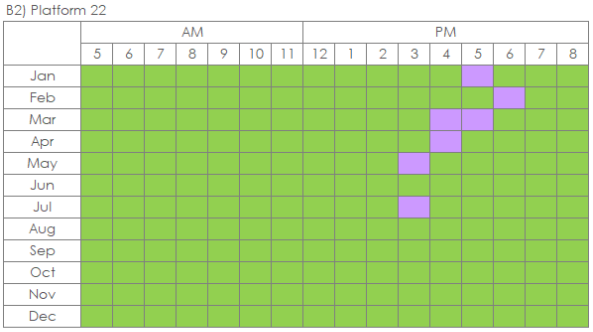
168	Nominal Daylight Hours
98.8%	Acceptable - Within performance criteria
1.2%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region B1: Platform 2 - General Public Perspective



168	Nominal Daylight Hours
97.6%	Acceptable - Within performance criteria
2.4%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

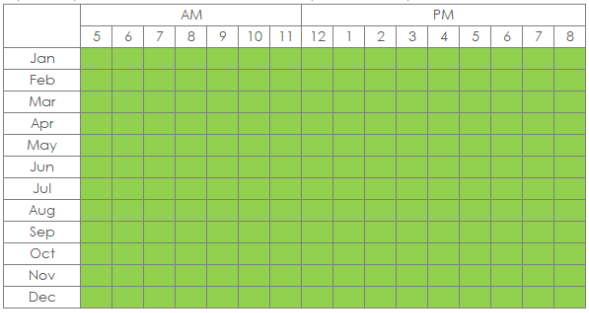
Region B1: Platform 22 - General Public Perspective



168	Nominal Daylight Hours
95.8%	Acceptable - Within performance criteria
4.2%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region C: Railway Corridor – Northeast bound Trains (Eastern Tracks)

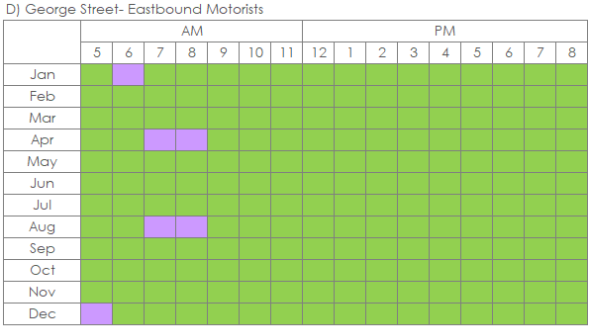
C) Railway Corridor - Northeast bound Trains (Eastern Tracks)



168	Nominal Daylight Hours
100.0%	Acceptable - Within performance criteria
0.0%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region D: George Street - Eastbound Motorists

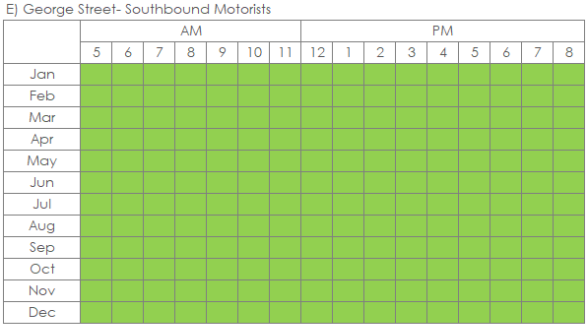
D) George Street- Eastbound Motorists



168	Nominal Daylight Hours
96.4%	Acceptable - Within performance criteria
3.6%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region E: George Street - Southbound Motorists

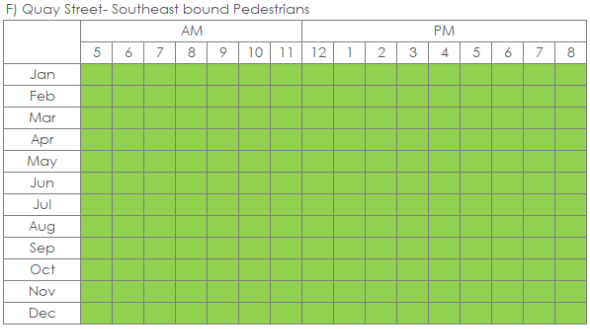
E) George Street- Southbound Motorists



168	Nominal Daylight Hours
100.0%	Acceptable - Within performance criteria
0.0%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region F: Quay Street – Southeast bound Pedestrians

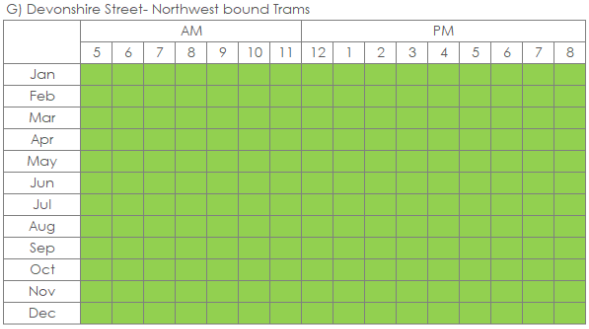
F) Quay Street- Southeast bound Pedestrians



168	Nominal Daylight Hours
100.0%	Acceptable - Within performance criteria
0.0%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region G: Devonshire Street - Northwest bound Trams

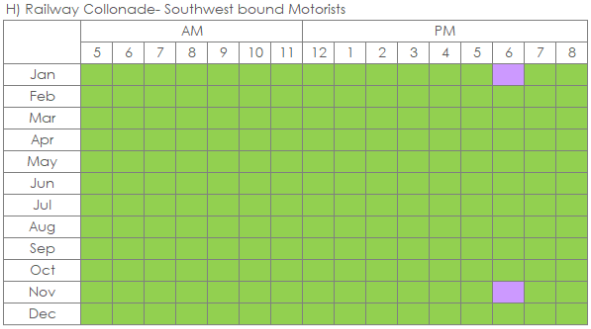
G) Devonshire Street- Northwest bound Trams



168	Nominal Daylight Hours
100.0%	Acceptable - Within performance criteria
0.0%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region H: Railway Collonade – Southwest bound Motorists

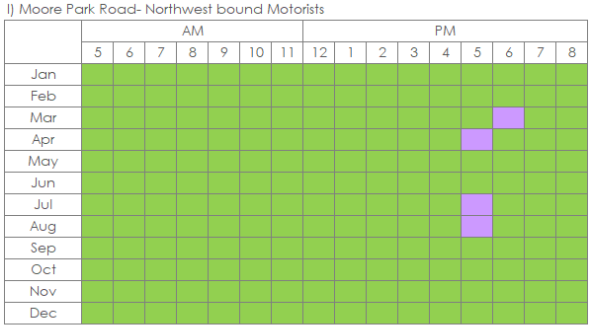
H) Railway Collonade- Southwest bound Motorists



168	Nominal Daylight Hours
98.8%	Acceptable - Within performance criteria
1.2%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region I: Moore Park Road - Northwest bound Motorists

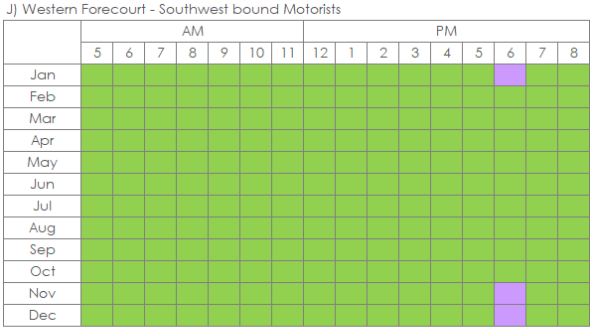
I) Moore Park Road- Northwest bound Motorists



168	Nominal Daylight Hours
97.6%	Acceptable - Within performance criteria
2.4%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region J: Western Forecourt – Southwest bound Motorists

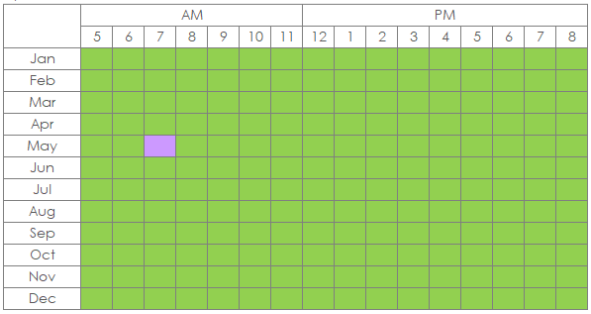
J) Western Forecourt - Southwest bound Motorists



168	Nominal Daylight Hours
98.2%	Acceptable - Within performance criteria
1.8%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region K: Tennis Courts, Prince Alfred Park - General Public Perspective

K) Tennis Courts, Prince Alfred Park



168	Nominal Daylight Hours
99.4%	Acceptable - Within performance criteria
0.6%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

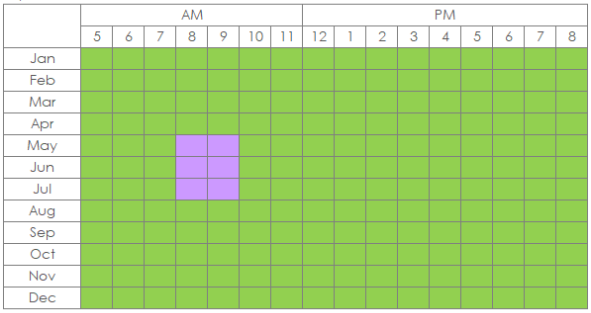
Region L: Swimming Pool, Prince Alfred Park - General Public Perspective

L) Swimming Pool, Prince Alfred Park

168	Nominal Daylight Hours
100.0%	Acceptable - Within performance criteria
0.0%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region M: Tower 1, Dexus Fraser's Site to the South– Occupant Perspective

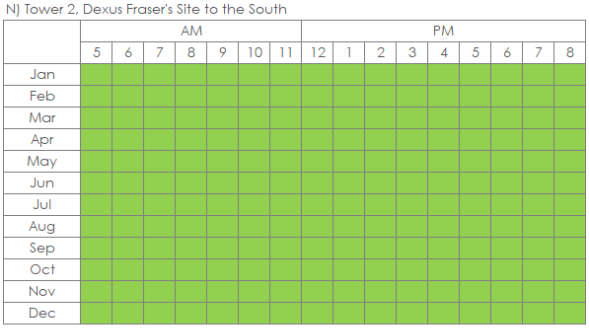
M) Tower 1, Dexus Fraser's Site to the South



168	Nominal Daylight Hours
96.4%	Acceptable - Within performance criteria
3.6%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

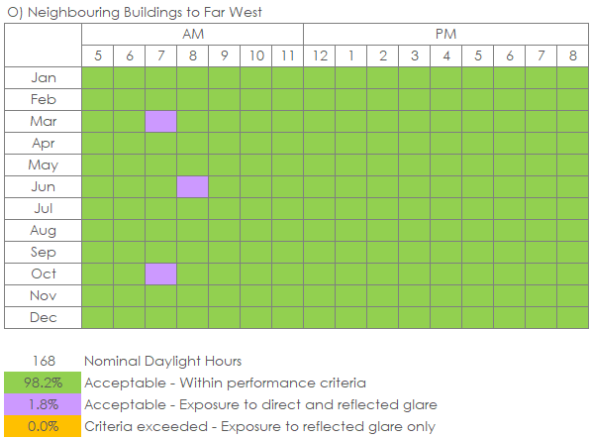
Region N: Tower 2, Dexus Fraser's Site to the South– Occupant Perspective

N) Tower 2, Dexus Fraser's Site to the South

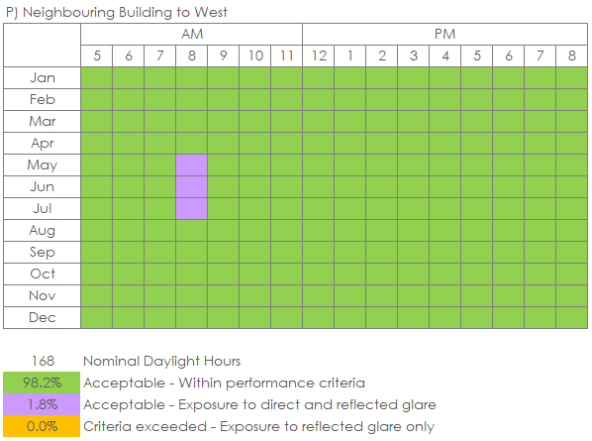


168	Nominal Daylight Hours
100.0%	Acceptable - Within performance criteria
0.0%	Acceptable - Exposure to direct and reflected glare
0.0%	Criteria exceeded - Exposure to reflected glare only

Region O: Neighbouring Buildings to Far West (28 Broadway, 26-60 Broadway) – Occupant Perspective



Region P: Neighbouring Building to West (818-820 George Street) – Occupant Perspective



6.1 Environmental Risk Assessment

The SEARs require an environmental risk analysis be included to identify potential environmental impacts associated with the proposed development.

Risk can be quantified based on the likelihood of an event occurring and the consequences of that event. For this external reflected glare assessment, the following descriptors were adopted for 'likelihood' and 'consequence' (Table 7).

Table 7: Risk Descriptors

Likelihood	Description	Consequence	Description
A	Almost Certain	1	Railway incident resulting in significant property damage, personal injury and/ or death.
B	Likely	2	Road incident resulting in property damage, personal injury and/ or death.
C	Possible	3	Visual disability of pedestrians indirectly resulting in non-permanent personal injury.
D	Unlikely	4	Visual disability of general public in open spaces or building occupants resulting in temporary visual impairment and inability to carry out non-critical tasks.
E	Rare	5	Visual discomfort of general public in open spaces or building occupants resulting in annoyance however does not prevent task from being carried out.

The risk levels for likely and potential impacts were derived using the risk matrix shown in Figure 8 below.

Consequence	Likelihood A	Likelihood B	Likelihood C	Likelihood D	Likelihood E
1	High	High	Medium	Low	Very Low
2	High	High	Medium	Low	Very Low
3	Medium	Medium	Medium	Low	Very Low
4	Low	Low	Low	Low	Very Low
5	Very Low	Very Low	Very Low	Very Low	Very Low

Figure 8: Risk Matrix

For each of the regions studied in this assessment, the risk level has been identified based on the definitions above. The likelihood and consequence have been classified depending on receiver type, glare intensity and annual frequency. We note that the presence of glare does not guarantee that an event will occur, however it does increase its likelihood occurring. As this relationship is difficult to quantify, our assumptions are considered conservative for the purposes of this assessment. As can be seen in Table 8 below, risk levels for the regions vary between 'Low' to 'Very Low'.

Table 8: Summary of risk levels for assessed regions.

Region	Receiver Type	Risk	Risk Level
A – Northbound Train Perspective (Western Tracks)	Railway Driver	D1	Low
B – Southwest bound Train Perspective	Railway Driver	D1	Low
B1 – Platform Perspective (Platform 2)	Pedestrian	D3	Low
B2 – Platform Perspective (Platform 22)	Pedestrian	D3	Low
C – Northeast bound Train Perspective (Eastern Tracks)	Railway Driver	E1	Very Low
D – Eastbound Motorist Perspective (George Street)	Motorist	D2	Low
E – Southbound Motorist Perspective (George Street)	Motorist	E2	Very Low
F – Southeast bound Pedestrian Perspective (Quay Street)	Pedestrian	E3	Very Low
G – Northwest bound Tram Perspective (Devonshire Street)	Motorist	E2	Very Low
H – Southwest bound Motorist Perspective (Railway Collonade)	Motorist	D2	Low
I – Northwest bound Motorist Perspective (Moore Park Road)	Motorist	D2	Low
J – Southwest bound Motorist Perspective (Western Forecourt)	Motorist	D2	Low
K – General Public Perspective - Tennis Courts, Prince Alfred Park	General Public	D4	Low
L – General Public Perspective - Swimming Pool, Prince Alfred Park	General Public	E5	Very Low
M – Occupant Perspective - Tower 1, Dexus Fraser's Site (to the south)	Building Occupant	D4	Low
N – Occupant Perspective - Tower 2, Dexus Fraser's Site (to the south)	Building Occupant	E5	Very Low
O – Occupant Perspective – Neighbouring Buildings (to far west)	Building Occupant	D4	Low
P – Occupant Perspective - Neighbouring Building (to the west)	Building Occupant	D4	Low

7.0 Discussion

Based on this study, it has been determined that while glare does exceed the performance criteria at various times throughout the year, direct glare is the dominant source of glare in each of the scenarios assessed. Therefore, the reflected glare from the façade does not result in glare that would not already be experienced by the observer due to direct glare.

This is further verified using detailed image-based assessment, wherein high-quality wide-angle images have been rendered for specific viewpoints and times using Radiance. The viewpoints for each region were determined based on the distribution of the glare receiver points identified by the annual assessment. The 180° view angle enables the glare calculation to sample areas representing a conservative field of view. The Radiance programme 'Evalglare' has been used to automatically identify glare sources in the image at each location and time. The Evalglare programme outputs an image highlighting glare sources and quantifies glare using the Daylight Glare Probability (DGP) scale (Wienold & Christoffersen, 2006). The images (included in Appendix A) along with the DGP value allows us to understand the source and intensity of glare in the field of view.

Table 9 summarises the findings of the image-based assessment. The times at which each observer perspective was assessed is based on the veiling luminance values calculated in the previous section. Radiance parameters used in the glare analysis are detailed in Appendix C. These values are at the "Accurate" level that Radiance recommends for rendering.

The image-based assessment has been undertaken for the louvres in closed position. As discussed in Section 5.5 of this report, the closed louvre position is considered more conservative.

Table 9: Verification of results by image-based assessment.

Region	Time Assessed	Performance Criteria	Modelled Result (DGP)	Comments[1]
A – Northbound Train Perspective (Western Tracks)	21st Jun 10am	< Discomfort Glare (0.40 DGP)	1.00	Acceptable – Glare due to direct glare, not reflected glare
B – Southwest bound Train Perspective	21st Dec 6pm	< Discomfort Glare (0.40 DGP)	0.20	Acceptable (Imperceptible Glare)
B1 – Platform Perspective (Platform 2)	21st Apr 3pm	< Disability Glare (0.45 DGP)	1.00	Acceptable – Glare due to direct glare, not reflected glare
B2 – Platform Perspective (Platform 22)	21st Mar 5pm	< Disability Glare (0.45 DGP)	0.36	Acceptable (Imperceptible Glare)
C – Northeast bound Train Perspective (Eastern Tracks)	21st May 8am	< Discomfort Glare (0.40 DGP)	0.45	Acceptable – Glare due to direct glare, not reflected glare
D – Eastbound Motorist Perspective (George Street)	21st Aug 7am	< Discomfort Glare (0.40 DGP)	0.25	Acceptable (Imperceptible Glare)
E – Southbound Motorist Perspective (George Street)	21st Apr 8am	< Discomfort Glare (0.40 DGP)	0.39	Acceptable (Imperceptible Glare)

Region	Time Assessed	Performance Criteria	Modelled Result (DGP)	Comments[1]
F – Southeast bound Pedestrian Perspective (Quay Street)	21st Feb 7am	< Disability Glare (0.45 DGP)	0.29	Acceptable (Imperceptible Glare)
G – Northwest bound Tram Perspective (Devonshire Street)	21st Feb 6pm	< Discomfort Glare (0.40 DGP)	0.22	Acceptable (Imperceptible Glare)
H – Southwest bound Motorist Perspective (Railway Collonade)	21st Nov 6pm	< Discomfort Glare (0.40 DGP)	0.39	Acceptable (Perceptible Glare)
I – Northwest bound Motorist Perspective (Moore Park Road)	21st Mar 6pm	< Discomfort Glare (0.40 DGP)	0.81	Acceptable – Glare due to direct glare, not reflected glare
J – Southwest bound Motorist Perspective (Western Forecourt)	21st Dec 6pm	< Discomfort Glare (0.40 DGP)	0.22	Acceptable (Imperceptible Glare)
K – General Public Perspective - Tennis Courts, Prince Alfred Park[2]	21st May 7am	< Disability Glare (0.45 DGP)	0.18	Acceptable (Imperceptible Glare)
L – General Public Perspective - Swimming Pool, Prince Alfred Park[2]	21st Jun 4pm	< Disability Glare (0.45 DGP)	0.57	Acceptable – Glare due to direct glare, not reflected glare
M – Occupant Perspective - Tower 1, Dexus Fraser's Site (to the south)	21st Jun 8am	< Disability Glare (0.45 DGP)	0.41	Acceptable (Disturbing Glare)
N – Occupant Perspective - Tower 2, Dexus Fraser's Site (to the south)	21st Aug 10am	< Disability Glare (0.45 DGP)	1.00	Acceptable – Glare due to direct glare, not reflected glare
O – Occupant Perspective – Neighbouring Buildings (to far west)	21st Mar 7am	< Disability Glare (0.45 DGP)	0.73	Acceptable – Glare due to direct glare, not reflected glare
P – Occupant Perspective - Neighbouring Building (to the west)	21st Jul 8am	< Disability Glare (0.45 DGP)	1.00	Acceptable – Glare due to direct glare, not reflected glare

[1] Refer Appendix B Table 10 for further detail on the DGP scale.

8.0 Conclusion

An external reflected glare study has been conducted on the proposed development at 8-10 Lee Street, Haymarket, Sydney. The study has been carried out in accordance with the SEARs requirements that identifies potential adverse glare conditions. The proposed building façade with a 20% visible reflectance does not result in unacceptable reflected glare. Any change in the building facade geometry or material specular light reflectance will require reassessment.

9.0 References

1. Bellia, L., Cesarano, A., Iuliano, G.F., & Spada, G. (2008). Daylight glare: a review of discomfort indexes.
2. Jr, Diver & Ghanbari, Cheryl & Ho, Clifford. (2011). Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation. Journal of Solar Energy Engineering. 133. 10.1115/ES2010-90053.
3. Hassall, David N. H. (1991). Reflectivity: Dealing with rogue solar reflections / written and illustrated by David N. H. Hassall, Newport, N.S.W.
4. Holladay, L. L. (1927). Action of a Light Source in the Field of View in Lowering Visibility. Journal of the Optical Society of America. Vol. 14, no. 1, p. 1.
5. Ho, C. K., Ghanbari, C. M., and Diver, R. B. (August 5, 2011). "Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation." ASME. J. Sol. Energy Eng. August 2011; 133(3): 031021.
6. Hopkinson, R.G. (1957). Evaluation of glare, Illuminating Engineering, XII, pp. 305-316.
7. Wienold, Jan & Christoffersen, Jens. (2006). Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras. Energy and Buildings. 38. 743-757. 10.1016/j.enbuild.2006.03.017.

A Appendix – Detailed Results

The following charts present the maximum veiling luminance in each region throughout the year. Further, representative observer's perspective along with the DGP outputs at the nominated time is also provided for each observer location. The purpose of the DGPs is to provide visual context and to verify that the sun is in the observer's field of view.

A.1.1 Region A: Railway Corridor - Northbound Trains (Western Tracks)

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	153	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	145	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	249	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	299	323	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	282	615	593	752	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	1221	0	1328	0	0	0	0	0	0	0	0	0	0
Jul	0	0	131	522	0	996	0	0	0	0	0	0	0	0	0	0
Aug	0	0	444	299	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	83	278	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	195	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	164	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	133	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
95.8%	Within performance criteria - Results < 500 Cd/m²
4.2%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

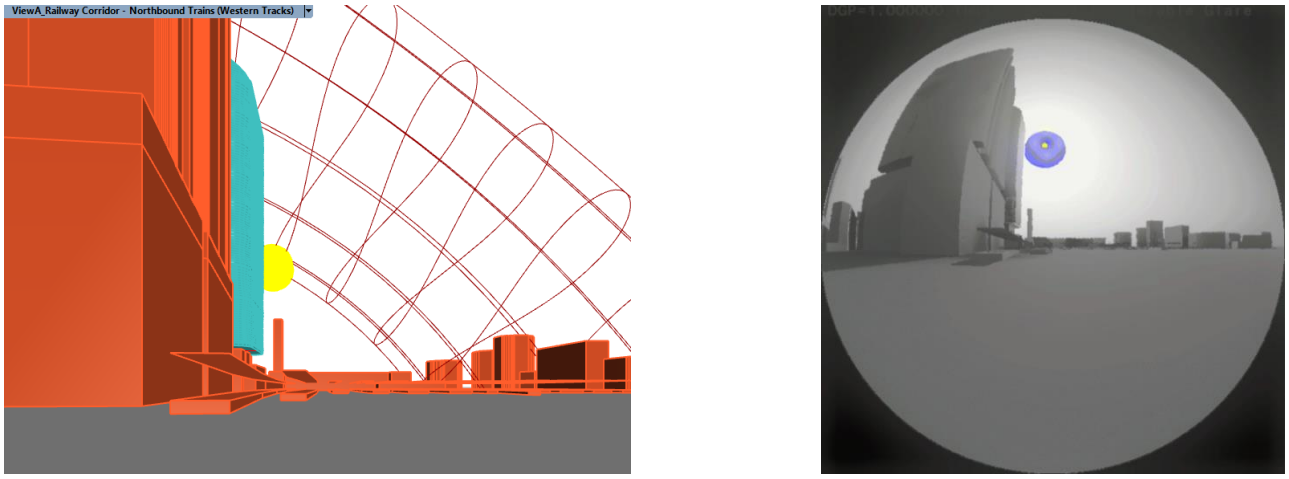


Figure 9: Representative driver perspective in Region A (left) and DGP output for observer location (right) at 10am in June.

A.1.2 Region B: Railway Corridor – Southwest bound Trains

	AM										PM					
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	34	22	7	0	0	0	0	0	0	105	187	326	512	0	0
Feb	0	43	47	26	9	0	0	0	0	0	80	140	202	208	0	0
Mar	0	0	30	16	22	7	0	0	12	29	79	131	195	0	0	0
Apr	0	0	49	45	30	18	15	15	28	46	62	139	114	0	0	0
May	0	0	21	52	37	26	23	25	59	54	70	95	0	0	0	0
Jun	0	0	0	54	41	30	27	28	41	57	72	89	0	0	0	0
Jul	0	0	6	57	40	29	24	25	36	52	68	93	0	0	0	0
Aug	0	0	46	47	31	19	15	15	54	43	61	134	132	0	0	0
Sep	0	13	27	13	18	0	0	0	15	33	90	145	205	0	0	0
Oct	0	60	35	17	0	0	0	0	0	54	107	170	226	0	0	0
Nov	17	29	17	0	0	0	0	0	0	0	135	235	414	472	0	0
Dec	20	37	23	8	0	0	0	0	0	0	137	235	396	558	0	0

Legend	
168	Nominal daylight hours
98.8%	Within performance criteria - Results < 500 Cd/m²
1.2%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

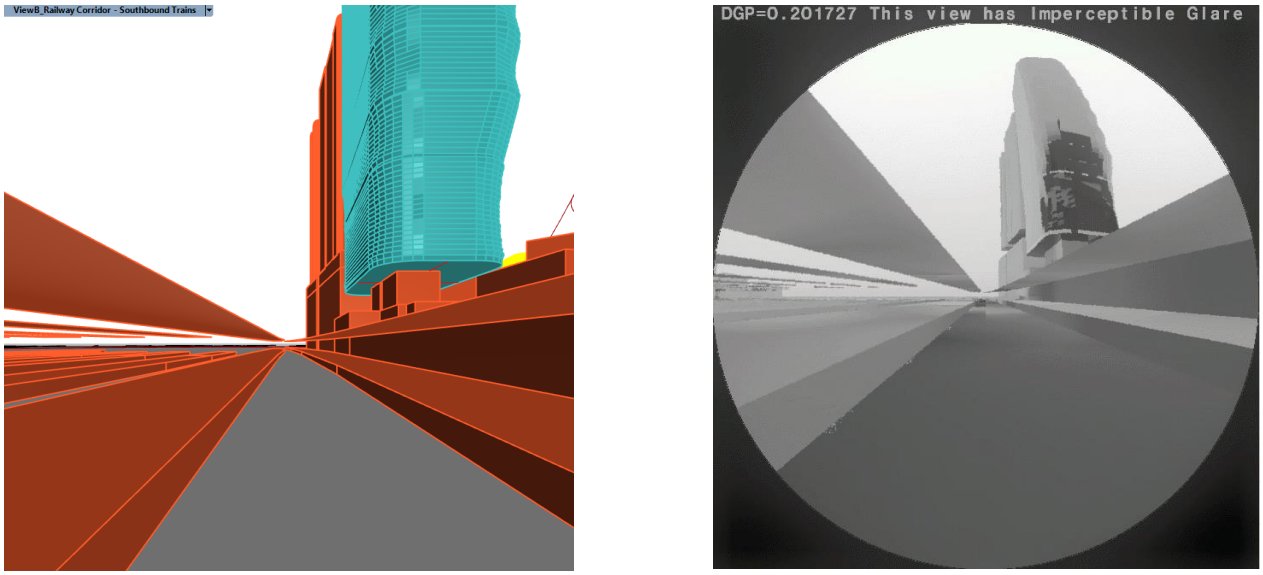


Figure 10: Representative driver perspective in Region B (left) and DGP output for observer location (right) at 6pm in December.

A.1.3 Region B1: Platform 2 - General Public Perspective

	AM										PM					
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	28	0	0	0	0	0	0	237	517	0	0	0
Feb	0	52	78	84	64	0	0	0	0	0	0	0	374	0	0	0
Mar	0	0	130	108	102	53	66	0	0	0	0	0	0	0	0	0
Apr	0	0	187	138	228	278	286	110	0	0	1599	0	0	0	0	0
May	0	0	0	261	370	326	350	417	164	647	1103	0	0	0	0	0
Jun	0	0	0	421	420	343	136	376	465	525	859	0	0	0	0	0
Jul	0	0	0	247	330	279	290	341	140	532	1324	0	0	0	0	0
Aug	0	0	166	134	215	255	259	142	234	0	0	0	0	0	0	0
Sep	0	41	134	94	119	68	0	0	0	486	0	997	0	0	0	0
Oct	0	83	80	66	45	0	0	0	0	0	0	491	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
97.6%	Within performance criteria - Results < 887 Cd/m²
2.4%	Within performance criteria - Results ≥ 887 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 887 Cd/m² (exposure to reflected glare only)

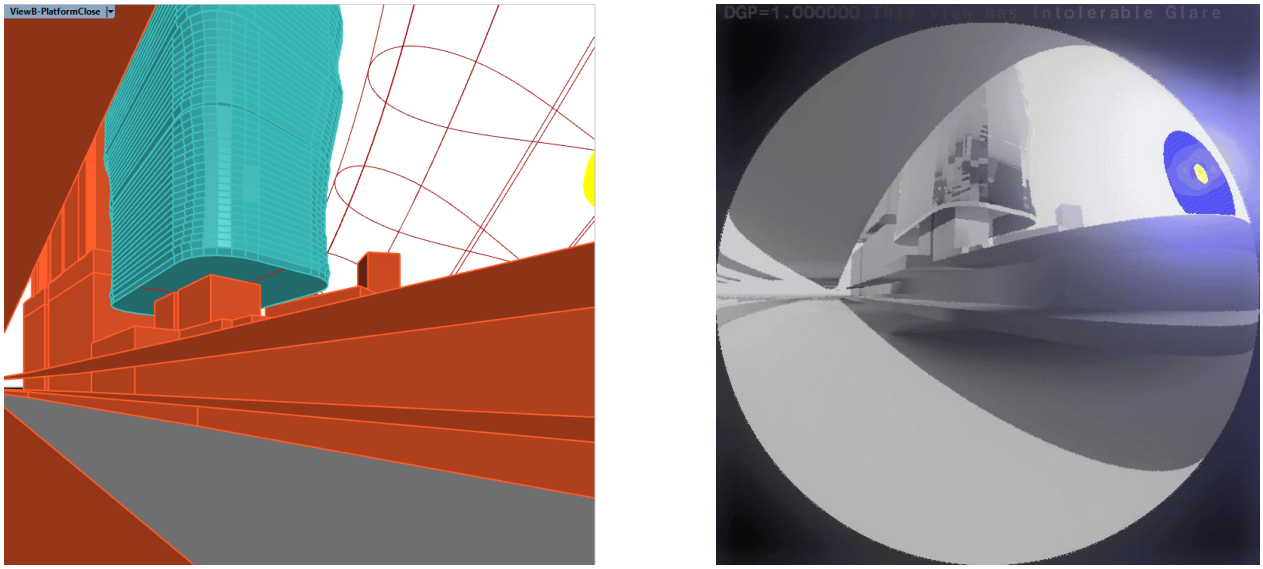


Figure 11: Representative pedestrian perspective in Region B1 (left) and DGP output for observer location (right) at 3pm in April.

A.1.4 Region B2: Platform 22 - General Public Perspective

	AM									PM						
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	1166	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	3463	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	1145	3898	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	2713	0	0	0	0
May	0	0	0	0	0	0	0	0	0	466	1673	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	383	562	0	0	0	0	0
Jul	0	0	10	0	0	0	0	0	0	0	1211	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
95.8%	Within performance criteria - Results < 887 Cd/m²
4.2%	Within performance criteria - Results ≥ 887 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 887 Cd/m² (exposure to reflected glare only)

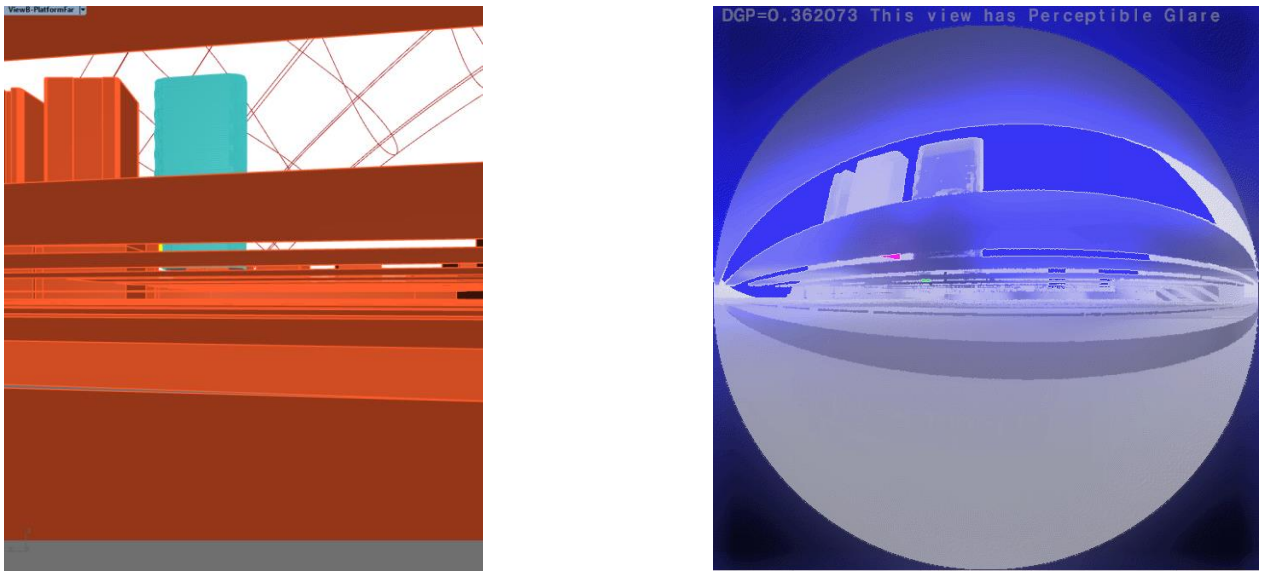


Figure 12: Representative pedestrian perspective in Region B2 (left) and DGP output for observer location (right) at 5pm in March.

A.1.5 Region C: Railway Corridor – Northeast bound Trains (Eastern Tracks)

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	196	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	59	215	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	209	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	13	169	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	159	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
100%	Within performance criteria - Results < 500 Cd/m²
0.0%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

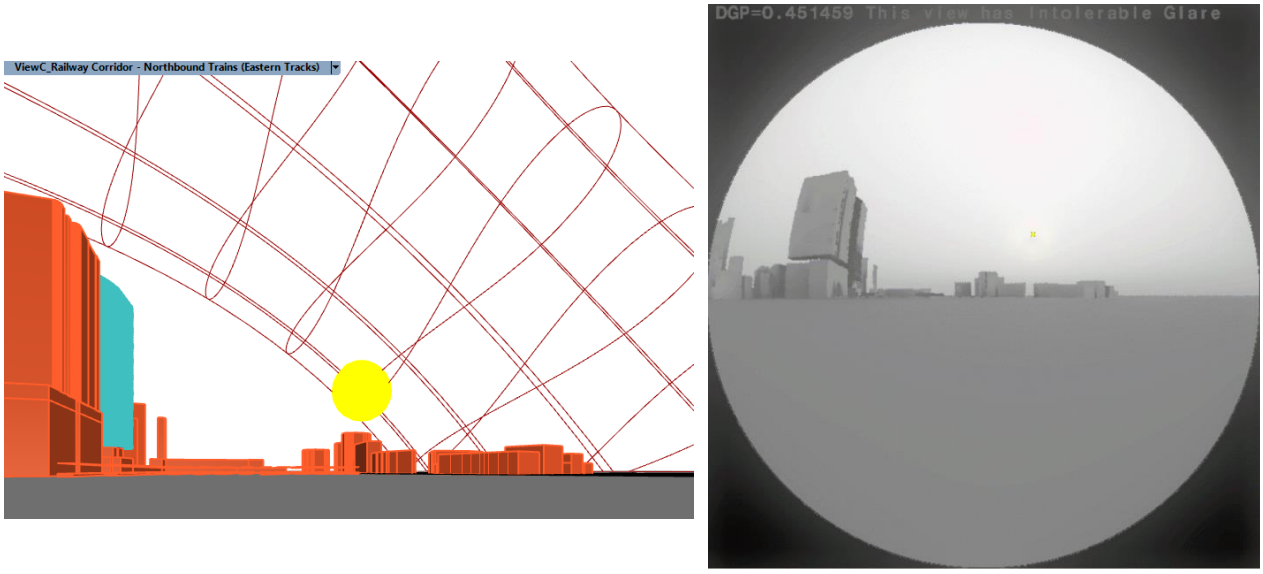


Figure 13: Representative driver perspective in Region C (left) and DGP output for observer location (right) at 8am in May.

A.1.6 Region D: George Street - Eastbound Motorists

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	2030	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	2843	977	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	2862	1070	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	698	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
96.4%	Within performance criteria - Results < 500 Cd/m²
3.6%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

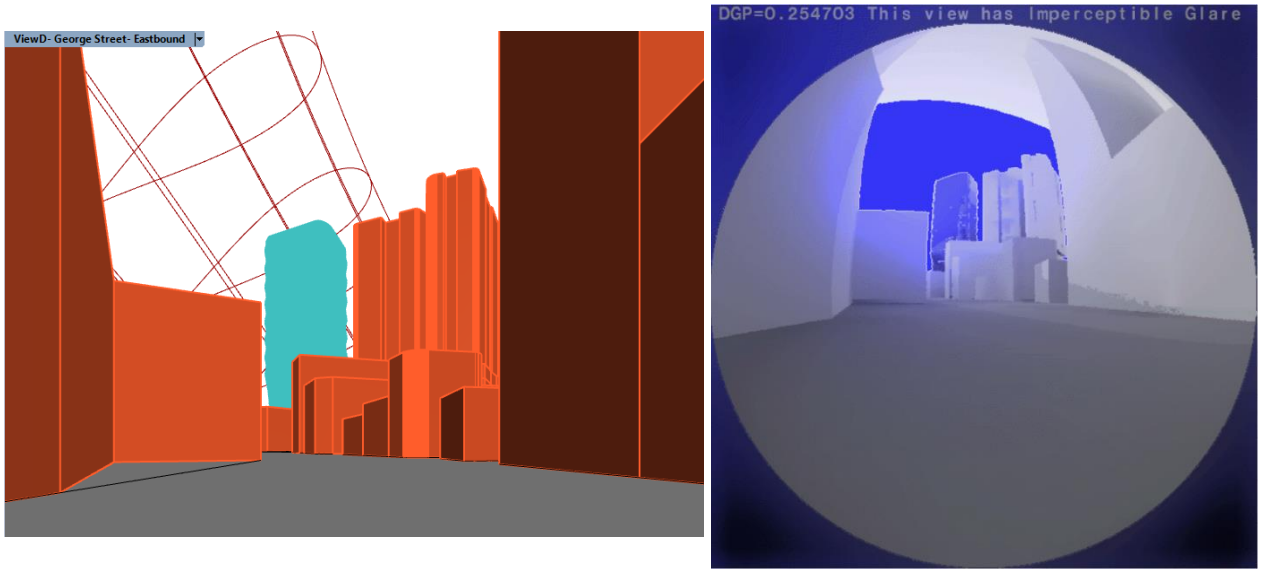


Figure 14: Representative driver perspective in Region D (left) and DGP output for observer location (right) at 7am in August.

A.1.7 Region E: George Street - Southbound Motorists

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	135	84	0	0	0	0	0	0	0	0	0	96	159	41	0
Feb	0	70	66	0	0	0	0	0	0	0	0	0	59	79	0	0
Mar	0	0	50	176	0	0	0	0	0	0	0	0	71	9	0	0
Apr	0	0	48	363	0	0	0	0	0	0	0	40	49	0	0	0
May	0	0	23	46	41	0	0	0	0	0	34	60	0	0	0	0
Jun	0	0	0	50	39	0	0	0	0	0	41	66	0	0	0	0
Jul	0	0	6	46	42	0	0	0	0	0	39	56	15	0	0	0
Aug	0	0	43	54	0	0	0	0	0	0	0	39	58	0	0	0
Sep	0	36	49	177	0	0	0	0	0	0	0	48	80	0	0	0
Oct	0	109	59	126	0	0	0	0	0	0	0	0	72	32	0	0
Nov	46	116	73	0	0	0	0	0	0	0	0	0	117	164	0	0
Dec	75	137	78	0	0	0	0	0	0	0	0	0	0	219	26	0

Legend	
168	Nominal daylight hours
100%	Within performance criteria - Results < 500 Cd/m²
0.0%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

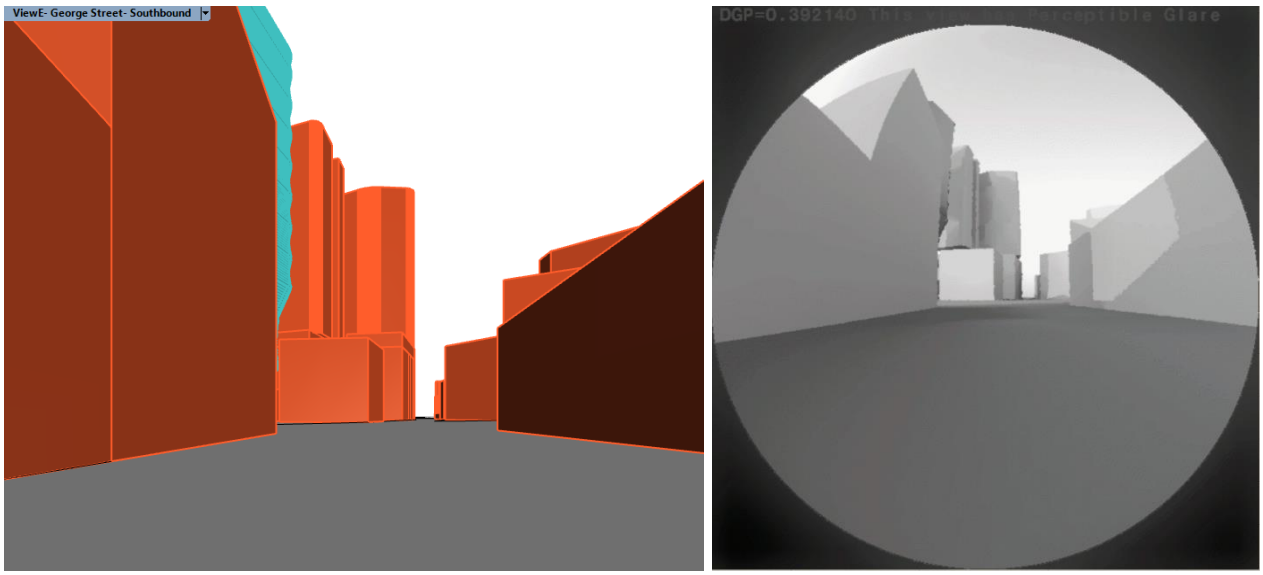


Figure 15: Representative driver perspective in Region E (left) and DGP output for observer location (right) at 8am in April.

A.1.8 Region F: Quay Street - Southeast bound Pedestrians

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	640	282	324	0	0	0	0	0	0	0	0	0	106	22	0
Feb	0	355	853	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	72	9	0	0
Apr	0	0	148	115	0	0	0	0	0	0	0	57	0	0	0	0
May	0	0	59	118	69	0	0	0	0	0	46	65	0	0	0	0
Jun	0	0	0	122	80	0	0	0	0	0	47	59	0	0	0	0
Jul	0	0	18	118	76	0	0	0	0	0	0	61	14	0	0	0
Aug	0	0	141	108	0	0	0	0	0	0	0	55	0	0	0	0
Sep	0	134	0	0	0	0	0	0	0	0	0	48	80	0	0	0
Oct	0	410	505	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	433	215	0	0	0	0	0	0	0	0	0	81	104	0	0
Dec	617	575	280	0	0	0	0	0	0	0	0	0	0	116	19	0

Legend	
168	Nominal daylight hours
100%	Within performance criteria - Results < 887 Cd/m²
0.0%	Within performance criteria - Results ≥ 887 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 887 Cd/m² (exposure to reflected glare only)

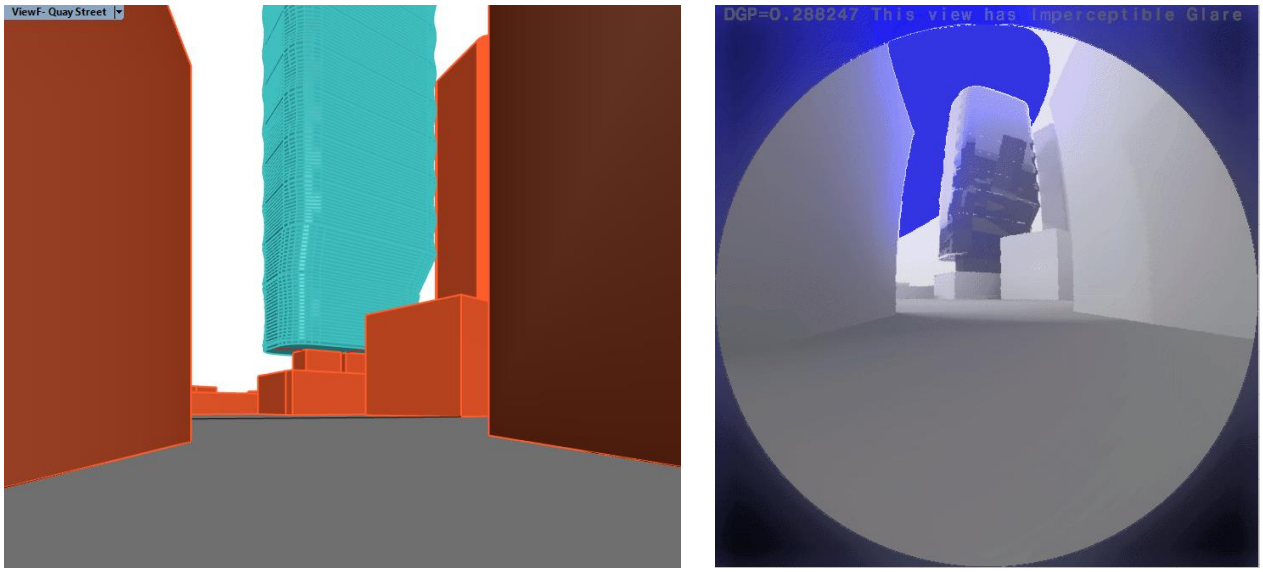


Figure 16: Representative pedestrian perspective in Region F (left) and DGP output for observer location (right) at 7am in February.

A.1.9 Region G: Devonshire Street - Northwest bound Trams

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	485	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	454	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	279	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	287	0	0

Legend	
168	Nominal daylight hours
100%	Within performance criteria - Results < 500 Cd/m²
0.0%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

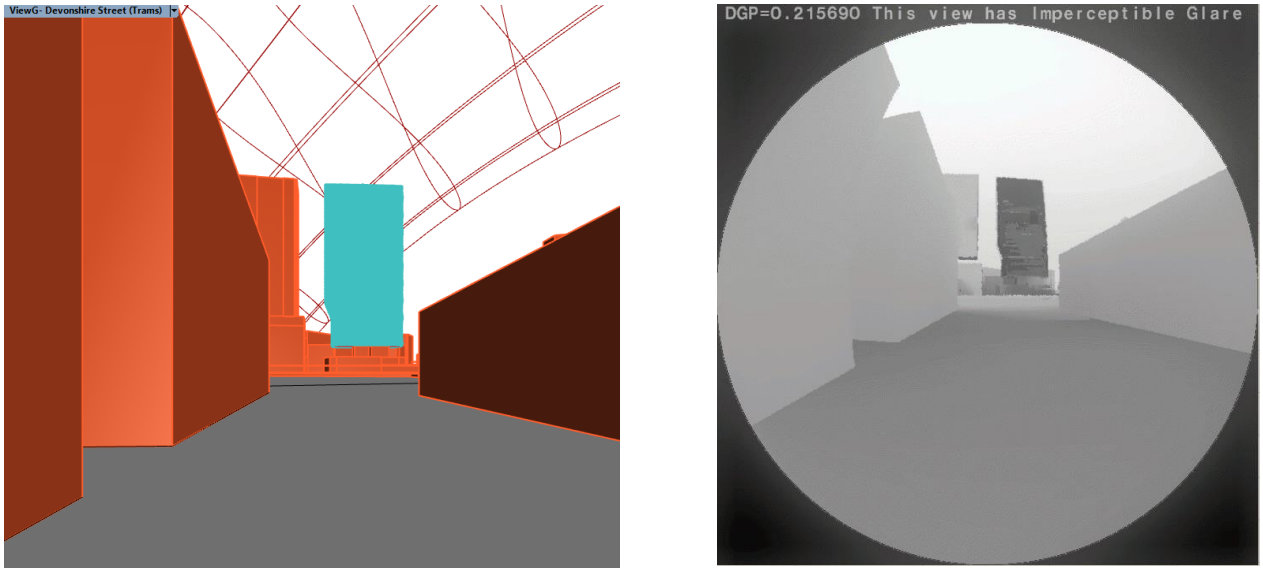


Figure 17: Representative driver perspective in Region G (left) and DGP output for observer location (right) at 6pm in February.

A.1.10 Region H: Railway Collonade – Southwest bound Motorists

	AM											PM				
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	577	277	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	222	438	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	123	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	316	260	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	354	723	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	285	0	269	0

Legend	
168	Nominal daylight hours
98.8%	Within performance criteria - Results < 500 Cd/m²
1.2%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

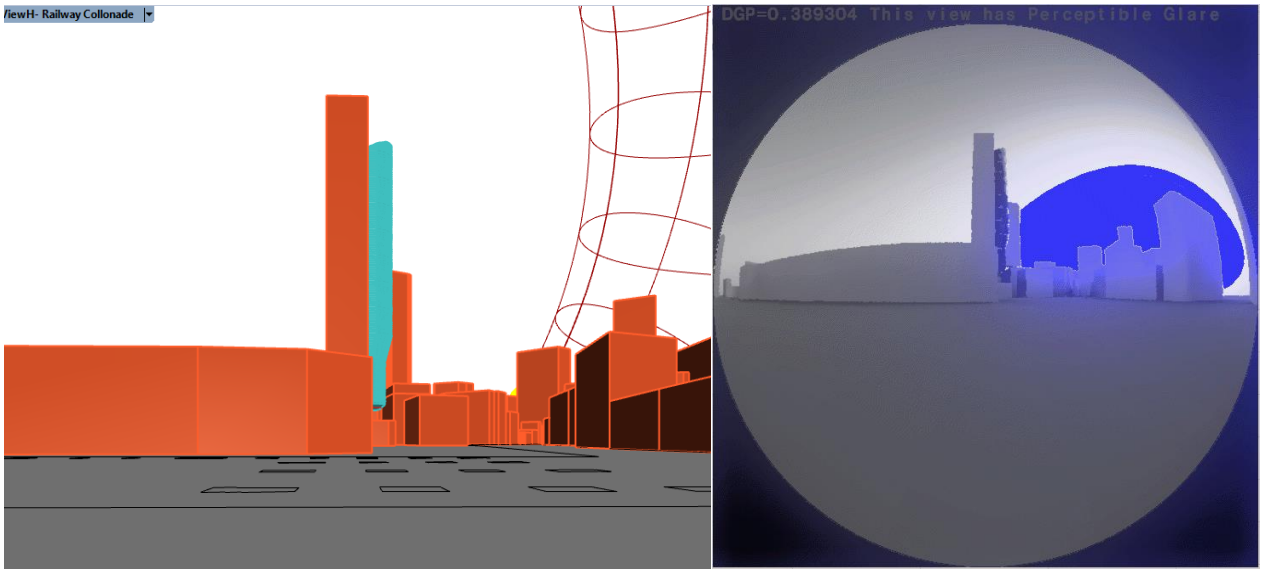


Figure 18: Representative driver perspective in Region H (left) and DGP output for observer location (right) at 6pm in November.

A.1.11 Region I: Moore Park Road - Northwest bound Motorists

	AM											PM				
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	5288	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	5448	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0	1291	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	5288	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
97.6%	Within performance criteria - Results < 500 Cd/m²
2.4%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

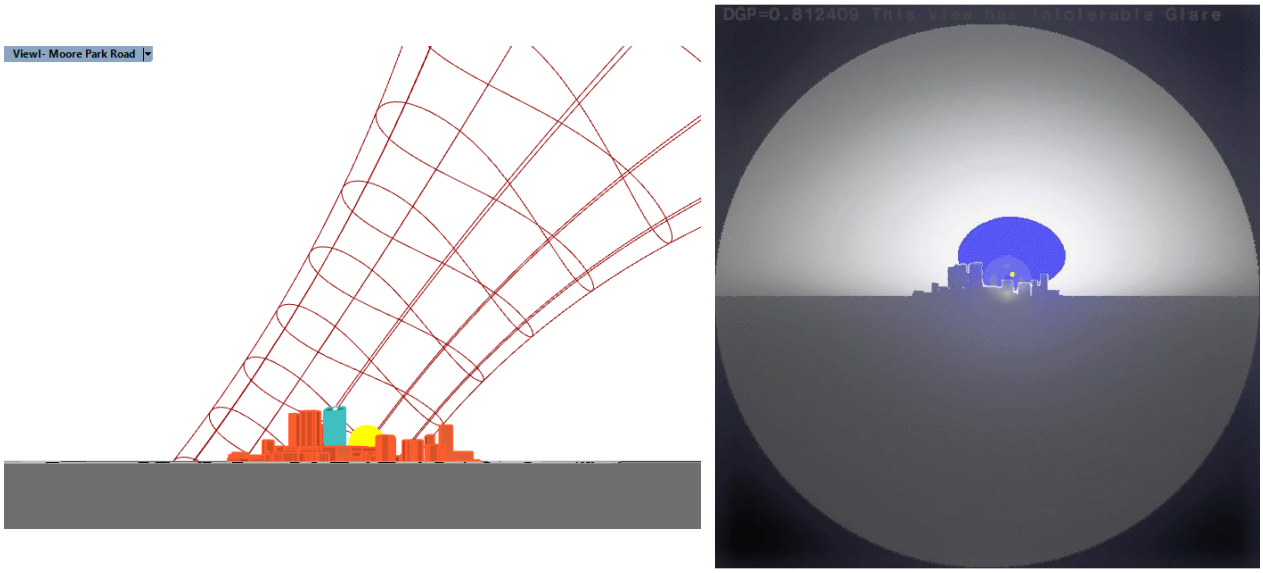


Figure 19: Representative driver perspective in Region I (left) and DGP output for observer location (right) at 5pm in April (Note- Region I is approx.. 2km away from project site. Model only includes neighbouring buildings to the Site. In reality, much of the view of the proposed development from Region I is expected to be covered by buildings between Region I and the Site).

A.1.12 Region J: Western Forecourt – Southwest bound Motorists

	AM										PM					
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	98	69	42	0	0	0	0	0	0	87	151	270	638	176	0
Feb	0	62	72	45	24	0	0	0	0	0	72	145	264	448	0	0
Mar	0	0	73	47	28	0	0	0	0	0	53	114	227	44	0	0
Apr	0	0	57	52	34	23	76	0	19	45	82	139	90	0	0	0
May	0	0	24	58	41	212	102	29	39	46	83	143	0	0	0	0
Jun	0	0	0	62	46	250	115	32	41	58	79	125	0	0	0	0
Jul	0	0	7	62	43	224	27	28	36	54	76	132	17	0	0	0
Aug	0	0	53	53	35	23	74	0	0	43	79	134	105	0	0	0
Sep	0	32	66	42	24	0	0	0	0	27	63	134	271	0	0	0
Oct	0	92	58	34	0	0	0	0	0	0	98	192	358	262	0	0
Nov	45	86	57	34	0	0	0	0	0	0	110	189	404	751	0	0
Dec	40	89	62	37	0	0	0	0	0	0	101	197	356	783	0	0

Legend	
168	Nominal daylight hours
98.2%	Within performance criteria - Results < 500 Cd/m²
1.8%	Within performance criteria - Results ≥ 500 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 500 Cd/m² (exposure to reflected glare only)

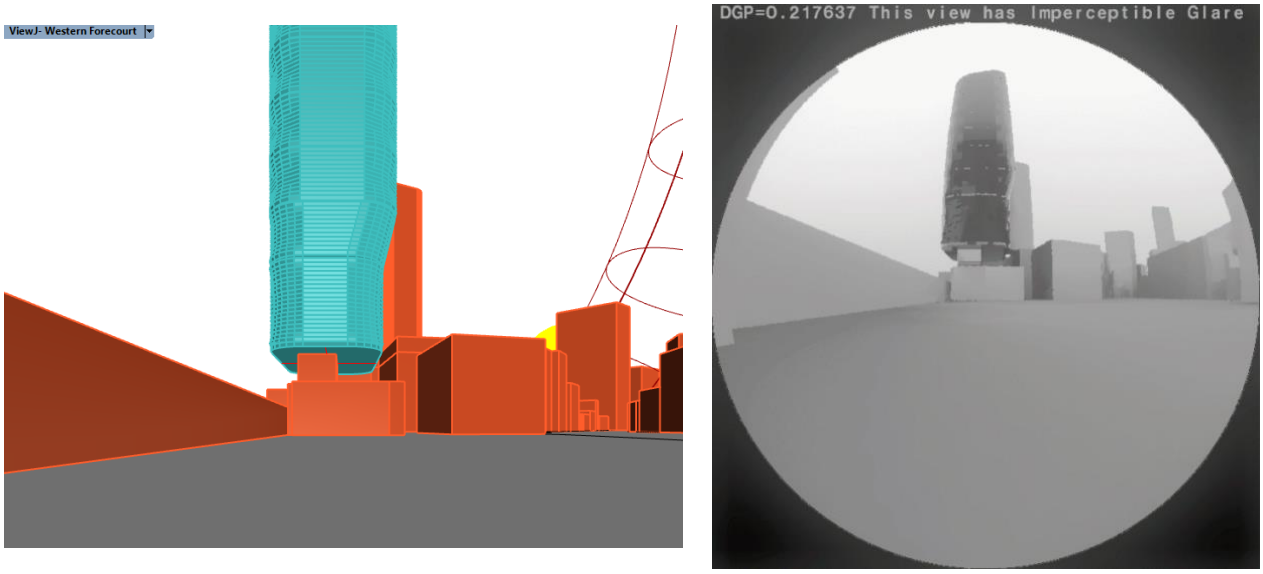


Figure 20: Representative driver perspective in Region J (left) and DGP output for observer location (right) at 6pm in December.

A.1.13 Region K: Tennis Courts, Prince Alfred Park - General Public Perspective

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	1629	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
99.4%	Within performance criteria - Results < 887 Cd/m²
0.6%	Within performance criteria - Results ≥ 887 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 887 Cd/m² (exposure to reflected glare only)

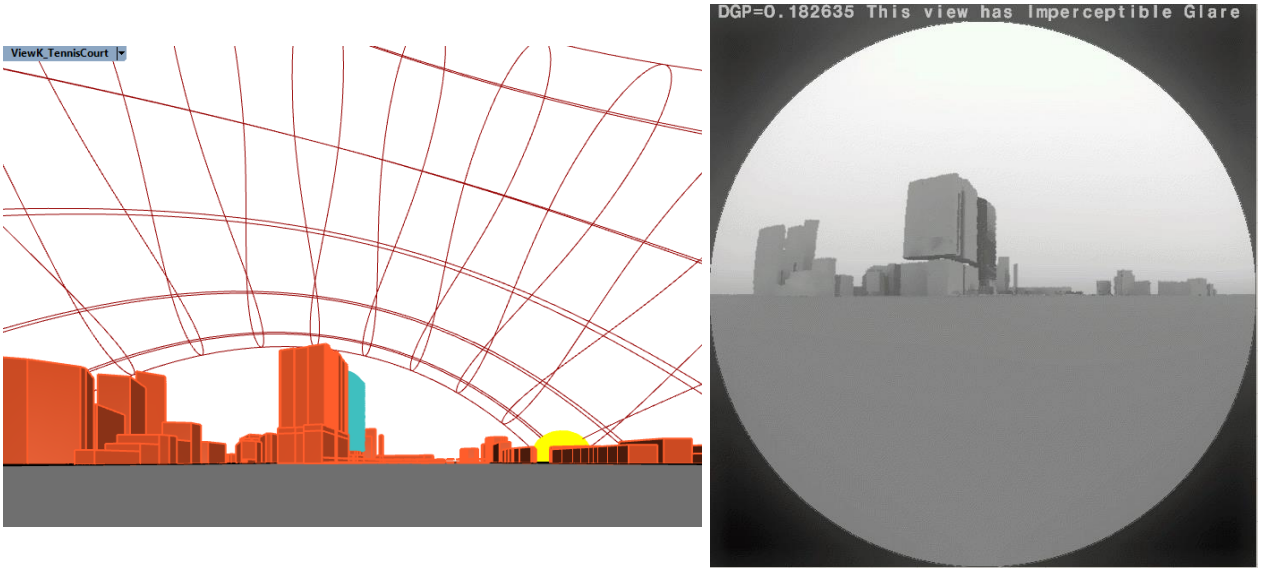


Figure 21: Representative pedestrian perspective in Region K (left) and DGP output for observer location (right) at 7am in May.

A.1.14 Region L: Swimming Pool, Prince Alfred Park - General Public Perspective

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	189	0	0	0
May	0	0	74	0	0	0	0	0	0	0	0	510	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	566	0	0	0	0
Jul	0	0	25	0	0	0	0	0	0	0	0	503	90	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	220	0	0	0
Sep	0	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
100%	Within performance criteria - Results < 887 Cd/m²
0.0%	Within performance criteria - Results ≥ 887 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 887 Cd/m² (exposure to reflected glare only)

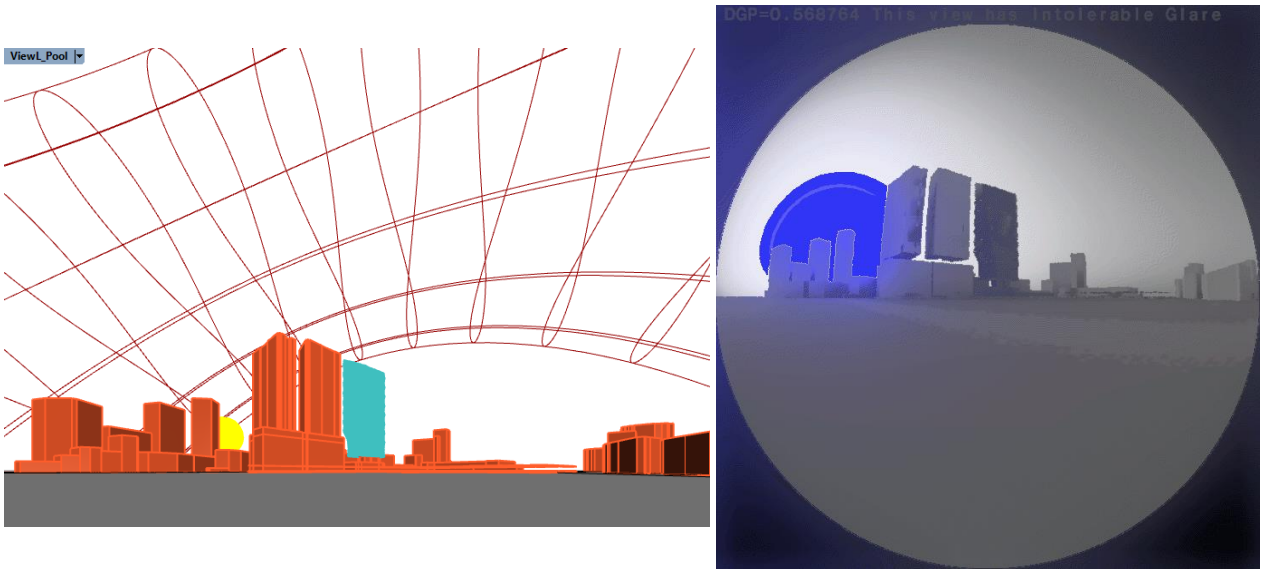


Figure 22: Representative pedestrian perspective in Region L (left) and DGP output for observer location (right) at 4pm in June.

A.1.15 Region M: Tower 1, Dexus Fraser's Site to the South– Occupant Perspective

	AM										PM					
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	210	184	182	208	0	0	0	0	0	0	35	49	66	11	0
Feb	0	148	284	288	309	0	0	0	0	0	39	43	59	69	0	0
Mar	0	0	578	530	600	0	0	0	95	70	67	68	75	8	0	0
Apr	0	0	852	1041	0	0	0	300	178	115	99	105	43	0	0	0
May	0	0	817	1946	1923	394	655	402	228	157	126	139	0	0	0	0
Jun	0	0	0	2606	2455	518	0	458	261	183	136	138	0	0	0	0
Jul	0	0	159	1995	1750	439	787	434	247	166	125	136	16	0	0	0
Aug	0	0	791	1030	0	247	0	321	184	117	98	103	51	0	0	0
Sep	0	206	555	539	590	0	0	0	86	66	66	59	80	0	0	0
Oct	0	245	299	318	307	0	0	0	0	0	41	51	69	26	0	0
Nov	101	196	182	194	163	0	0	0	0	0	25	41	55	59	0	0
Dec	84	184	166	157	136	0	0	0	0	0	0	34	48	64	8	0

Legend	
168	Nominal daylight hours
96.4%	Within performance criteria - Results < 1267 Cd/m²
3.6%	Within performance criteria - Results ≥ 1267 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 1267 Cd/m² (exposure to reflected glare only)

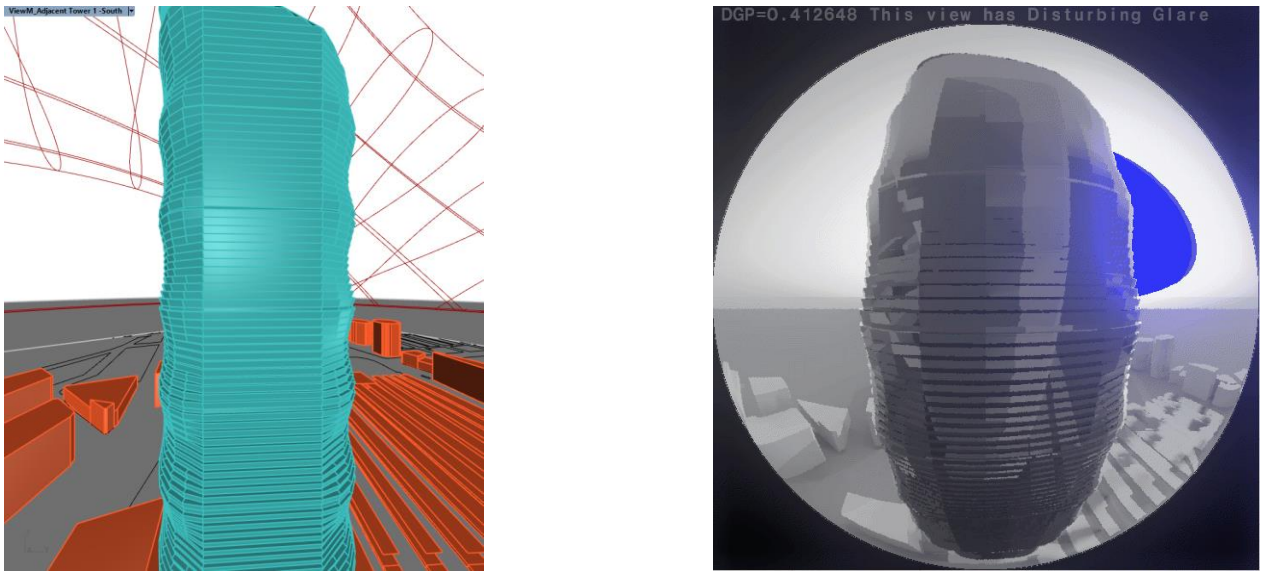


Figure 23: Representative perspective of an occupant in Region M (left) and DGP output for observer location (right) at 8am in June.

A.1.16 Region N: Tower 1, Dexus Fraser's Site to the South– Occupant Perspective

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	231	0	0	0	0	67	0	51	0	0	0
May	0	0	0	0	0	0	0	211	133	101	103	0	0	0	0	0
Jun	0	0	0	0	0	0	0	231	153	120	123	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	114	112	0	0	0	0	0
Aug	0	0	0	0	0	233	0	0	0	0	75	0	62	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	49	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	54	0	0

Legend	
168	Nominal daylight hours
100%	Within performance criteria - Results < 1267 Cd/m²
0.0%	Within performance criteria - Results ≥ 1267 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 1267 Cd/m² (exposure to reflected glare only)

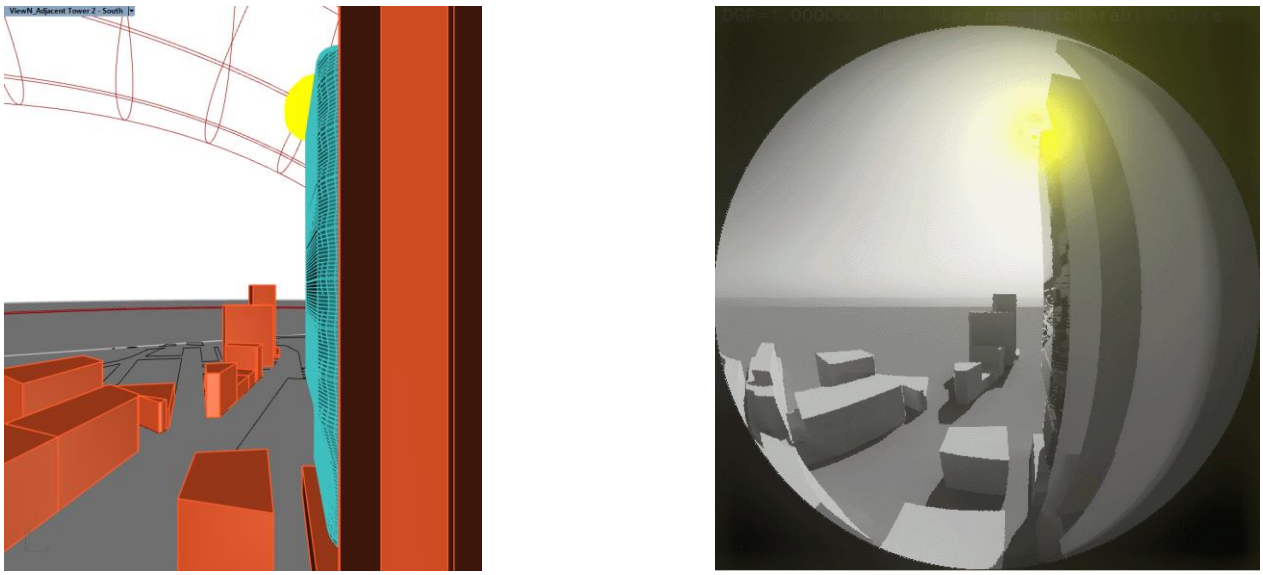


Figure 24: Representative perspective of an occupant in Region N (left) and DGP output for observer location (right) at 10am in August.

A.1.17 Region O: Neighbouring Buildings to Far West (28 Broadway, 26-60 Broadway) – Occupant Perspective

	AM								PM							
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	5762	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	1266	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	1355	658	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	710	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	1509	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	681	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Legend	
168	Nominal daylight hours
98.2%	Within performance criteria - Results < 1267 Cd/m²
1.8%	Within performance criteria - Results ≥ 1267 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 1267 Cd/m² (exposure to reflected glare only)

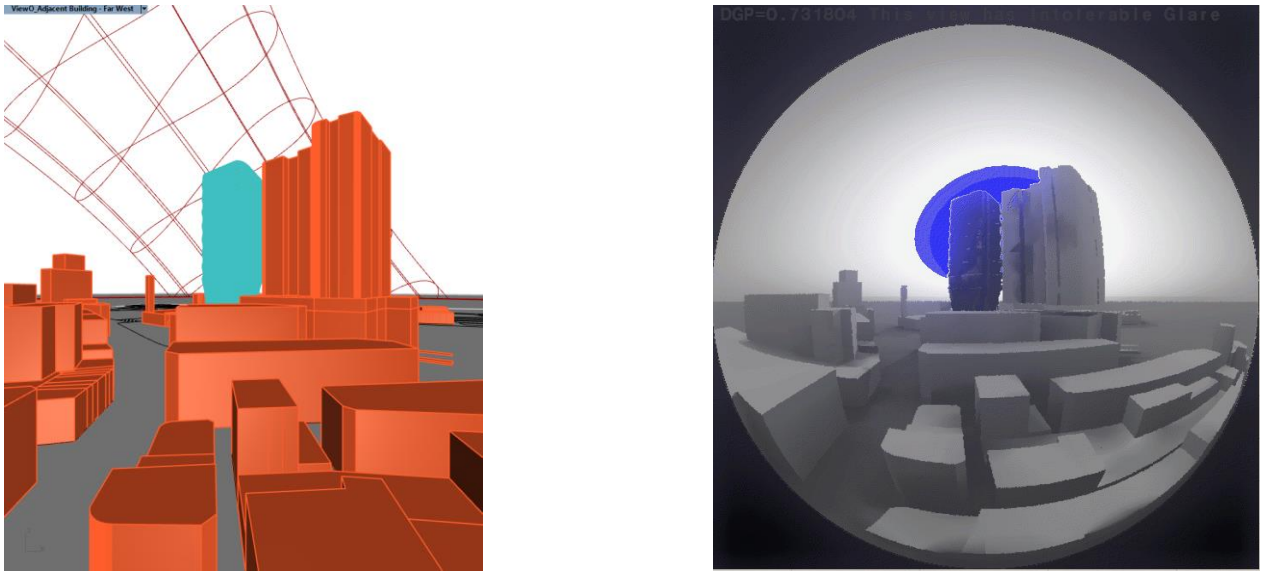


Figure 25: Representative perspective of an occupant in Region O (left) and DGP output for observer location (right) at 7am in March.

A.1.18 Region P: Neighbouring Building to West (818-820 George Street) – Occupant Perspective

	AM									PM						
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Jan	0	762	728	664	0	0	0	0	0	0	0	0	0	53	8	0
Feb	0	743	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	799	0	0	0	0	0	0	51	58	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	46	60	45	0	0	0
May	0	0	0	2499	838	310	0	0	0	49	64	70	0	0	0	0
Jun	0	0	0	2856	882	384	192	0	0	57	62	72	0	0	0	0
Jul	0	0	0	3112	973	363	171	0	0	53	56	70	15	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	59	54	0	0	0
Sep	0	0	0	0	620	0	0	0	0	0	0	53	57	0	0	0
Oct	0	1114	0	0	0	0	0	0	0	0	0	0	0	21	0	0
Nov	240	782	0	0	0	0	0	0	0	0	0	0	45	46	0	0
Dec	251	638	0	547	0	0	0	0	0	0	0	0	39	51	0	0

Legend	
168	Nominal daylight hours
98.2%	Within performance criteria - Results < 1267 Cd/m²
1.8%	Within performance criteria - Results ≥ 1267 Cd/m² (exposure to direct and reflected glare)
0.0%	Not within performance criteria - Results ≥ 1267 Cd/m² (exposure to reflected glare only)

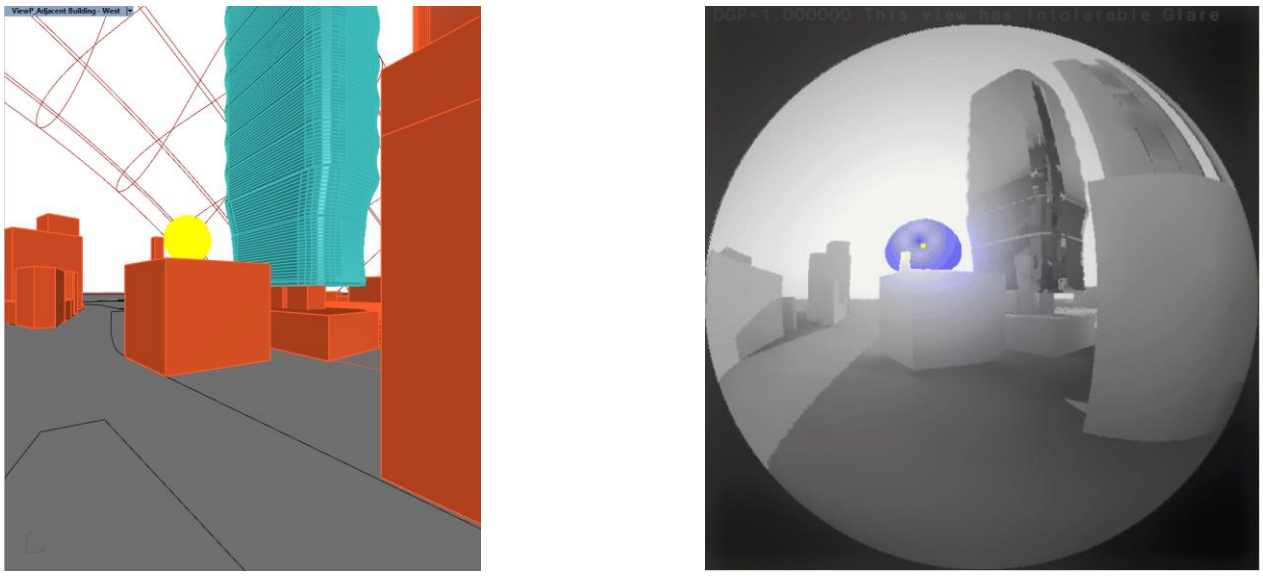


Figure 26: Representative perspective of an occupant in Region P (left) and DGP output for observer location (right) at 8am in July.

B Appendix – Detailed Methodology

B.1 Glare

Glare can be categorised in two kinds: discomfort glare and disability glare. Discomfort glare prompts an affected individual user to look away from the problem light source, where disability glare weakens vision without necessarily causing discomfort (International Commission on Illumination, Standard of Lighting Vocabulary, CIE S 017/E:2011, 2011). 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; and
- General field luminance controlling the adaptation level of the observer's eye.

B.2 Glare Classifications

Disability (Intolerable) 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.

Discomfort (Disturbing) 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.

B.3 Angular Dependent Reflectance

Reflectance of specularly reflective elements is a function of the angle of incidence (angle made by the solar incident ray with the surface normal of the façade).

- For solar incidence angles less than 40°, the reflectance is generally similar to the reflectance value measured at an incidence angle normal to the glazing element.
- For incidence angles greater than 40°, the reflectance values increase drastically with the angle of incidence.
- For a 90° incident angle (i.e. incident solar rays striking near parallel to the façade plane), the reflectance is equal to 100%.

This is depicted in Figure 27 below.

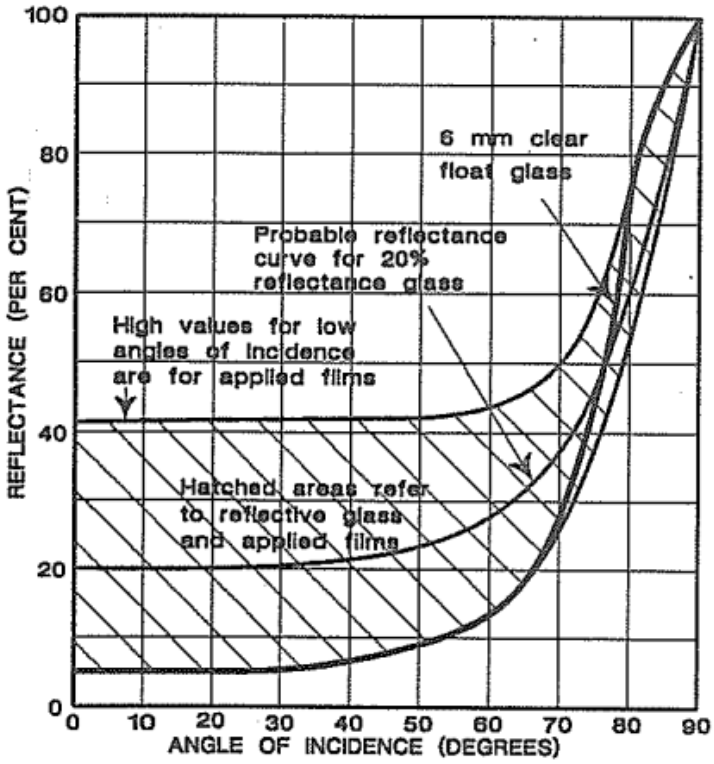


Figure 27: Reflectance versus angle of incidence (image extracted from the publication 'Reflectivity- Dealing with Rogue Solar Reflections' written by David N. H. Hassall).

B.4 Calculation of Veiling Luminance

This glare assessment has been calculated using the Holladay formula that determines a veiling luminance of 500 Cd/m² is a practical limit to the amount of reflected solar glare to which a driver should be exposed. While this criterion is an appropriate limit for vehicle drivers for safety, the limit for pedestrians and the general public is higher given the nature of their activity.

The following provides some approximate luminance levels for different light sources. Note that the maximum tolerable luminance by direct observation is 7,500 Cd/m².

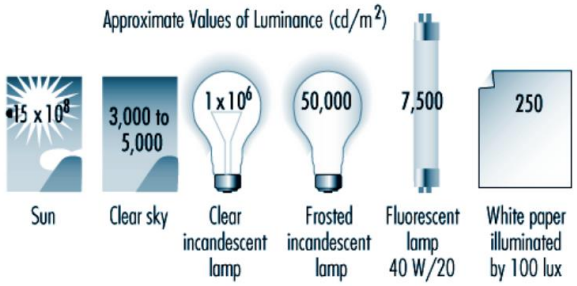


Figure 28: Approximate values of luminance for several light sources (Source: http://www.ilocis.org/documents/chpt46e.htm#JD_Figure46.11)

The Holladay formula calculates the equivalent veiling luminance or glare. It assesses the acceptability of solar reflections that fall within a driver's field of view.

The equivalent veiling luminance for the façade is calculated using the following formula.

$$L_v\left(\frac{Cd}{m^2}\right) = \frac{10 \cdot EG}{\theta^2} \qquad \textbf{Equation 1}$$

- Lv is the equivalent veiling luminance or glare.
- θ is the angle between the centre of the glare source and the line of sight. It is valid from 1.5˚ to 60˚.
- EG is the illumination on the observer's eye produced by the glare source in the plane perpendicular to the line of sight in lux. It is calculated using the following formula.

$$EG = E.R.\cos\theta \qquad \textbf{Equation 2}$$

- E is the solar illumination (lux) on the surface, calculated as a product of solar power (W/m^2) and luminous efficacy (lumens/W). Solar power is calculated as a function of the altitude (ALT) of the sun and is as per the following formula.

Solar Power (W/m^2) = ALT*50 (for ALT ≤ 10°)

Solar Power (W/m^2) = 500 + (ALT – 10)*15 (ALT ≥ 10°) **Equation 3**

- A luminous efficacy of 150 lumens/W corresponding to clear sky conditions has been used.
- R is the angular dependent reflectance of the surface.

The issue of solar glare and its effect on human vision is very complex and one for which science has not so far provided a definitive answer. One of the main problems is the great variation in individual human response to a given amount of glare. One person's slight inconvenience is another's blinding light.

The equivalent veiling luminance method models the sun path in relation to the proposed building development. Reflection conditions are modelled for all daylight hours throughout the year. This method is more accurate as it depends on the power of the solar radiation (W/m^2) for various altitudes, luminance efficacy (lumens/watt), sun position (azimuth and altitude) for various times of the day, observer's viewing direction (bearing), aspect of reflecting surface, reflectivity and specularity of surface.

This assessment assumes specular reflective façade surfaces, where the reflected ray angle is equal to the incident solar ray angle. It assumes that the equivalent veiling luminance is only calculation for periods of the day when the sun' azimuth is no greater than 90° of the various aspects of the proposed development.

B.5 Daylight Glare Probability

For the detailed image-based assessment, the glare sources and field are analysed using the Daylight Glare Probability (DGP) (Wienold & Christoffersen, 2006) over a field of view 90° in each direction on the horizontal plane. The DGP is a glare measurement which improves upon Daylight Glare Index (Hopkinson, 1957) 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 (Bellia et al., 2008). The degree of perceived glare using the DGP is shown in Table 10 below.

Table 10: The degree of perceived glare using the DGP scale.

Glare Response	Daylight Glare Probability
Imperceptible Glare	< 0.35
Perceptible Glare	0.35 – 0.40
Disturbing Glare (i.e. Discomfort Glare)	0.40 – 0.45
Intolerable Glare (i.e. Disability Glare)	≥ 0.45

C Appendix – Radiance Parameters

Parameter	Parameter Description	Value
-pt	sampling threshold	0.15
-pj	anti-aliasing jitter	0.6
-dj	source jitter	0.0
-ds	source sub-structuring	0. 5
-dt	direct thresholding	0.5
-dc	direct certainty	0.25
-dr	direct relays	0
-dp	direct pre-test density	64
-ab	ambient bounces	2
-aa	ambient accuracy	0.25
-ar	ambient resolution	16
-ad	ambient divisions	512
-as	ambient super-samples	128
-lr	limit reflection	4
-lw	limit weight	0.05

D Appendix – Glossary of Terms

Altitude: The angle between the horizontal plane and the sun.

Azimuth: The direction of the sun in plan, measure in degrees for north or from south depending on the hemisphere you are in.

Contrast: Defined as the ration of the difference between and object and its background and the luminance of a background.

Daylight Glare Probability (DGP): 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.

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.

Disability Glare: Impairs the vision of objects without necessarily causing discomfort.

Discomfort Glare: Results in an instinctive desire to look away from a bright light source or difficulty in seeing a task.

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.

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 (Cd/m²).

Luminous Efficacy: refers to the numbers of lumens per watt in sunlight which varies with solar altitude.

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

Solar Radiation: Energy from the sunn arriving at the surface as a direct, diffuse and effected component measured in watts per square metre (W/m²).

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.

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.

Veiling Luminance: Threshold of contrast for an object, where any additional light superimposed on the retina will reduce the clarity of the object.

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

E Appendix – 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 for the purposes of this assessment 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 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 also 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 scenarios analysed in this report contain 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 on a clear day. 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 reflected 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 Probability 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.