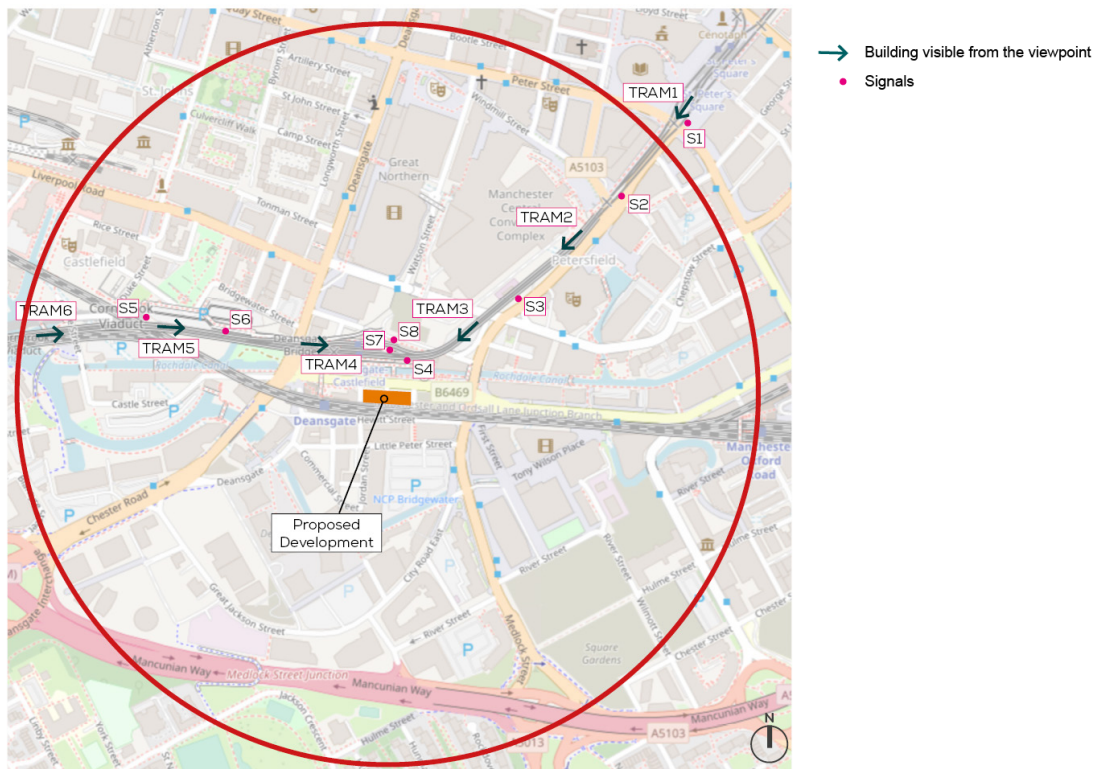


TECHNICAL NOTE: Response to Metrolink Queries in relation to Solar Glare from 2-4 Whitworth Street

Following consultation feedback provided by Transport for Greater Manchester on 13th January 2025, regarding potential solar glare impacts of the proposed development on drivers of Metrolink trams, GIA have prepared the following responses and provided additional information where necessary.

Query 1 - Selection of Viewpoint

GIA confirm that the selection of viewpoints has been informed by the location of signals within the relevant stretch of track. The below map identifies where GIA understand signals to be located and their relationship to the viewpoints assessed within the submitted ES Chapter. The only signal that's approach has not been assessed is Signal 2 however as there is no significant concern for Signals 1 and 3, it is expected that Signal 2 would have similar conditions. Regarding Signals 7 and 8, these are end of platform signals and the proposed development would no longer be visible so they do not require consideration. Therefore, it is not considered that any additional viewpoints require assessment to understand the impact on signal sighting.



For completeness, the relevant signals serving the eastbound trams have been added to the revised imagery provided in Appendix 1 and 2.

Query 2 - Viewpoint Height

It has been confirmed by TfGM that the viewpoint height is 2.2m not 2m as assessed has been noted. Whilst we do not consider this would alter the effects nor conclusions set out in the ES, for completeness, GIA has update the analysis and provided these results in Appendix 1 alongside those submitted for comparison purposes. The results provided in Appendix 1 confirm there is no noticeable difference between the results of the raised viewpoints at 2.2m compared to the 2m high viewpoints as submitted, therefore the effects and conclusions set out within Chapter 12 of the ES remain unchanged.

Query 3 - Mitigation Strategies

It has been stated that a professional statement in relation to proposed mitigation strategies is not sufficient and that it must be evidenced that Low VLR glazing would appropriately mitigate the potentially significant effects identified along the eastbound tram line.

It is not proportionate to this stage of the design to have sufficient information to accurately undertake this detailed testing as the glazing specification is not yet known. It is standard to have this covered by a condition that further testing will be run once the glazing is known to ensure the glare risk is satisfactorily mitigated.

To address TfGM concerns at this early stage, we have run a supplementary assessment with an indicative VLR of 16%, in the knowledge that standard low VLR residential glazing tends to be in the 13-15% range. The results for the eastbound tram viewpoints are included in Appendix 2. The results provided in Appendix 2 have demonstrated that, with a VLR of 16% or less, the reflections from the proposed development towards tram drivers travelling eastbound are below the threshold for glare and would not impact visibility of signals.

I trust this addresses the further information requested in relation to the 2-4 Whitworth Street proposal.

Yours sincerely

For and on behalf of GIA



Krystle Stewart
Director
krystle.stewart@gia.uk.com

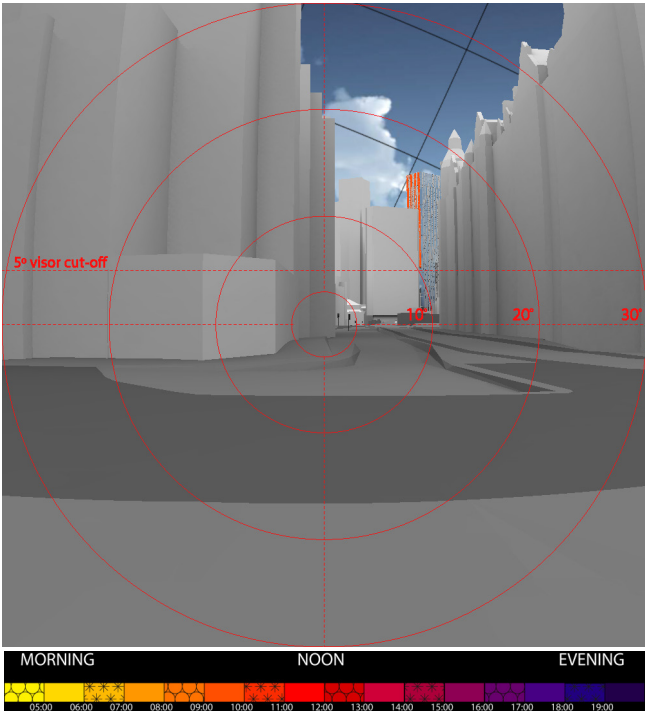
Encl. Appendix 01 – Assessment of Revised Viewpoint Heights
Appendix 02 – Glare Intensity Assessment

APPENDIX 1 - ASSESSMENT OF REVISED VIEWPOINT HEIGHTS

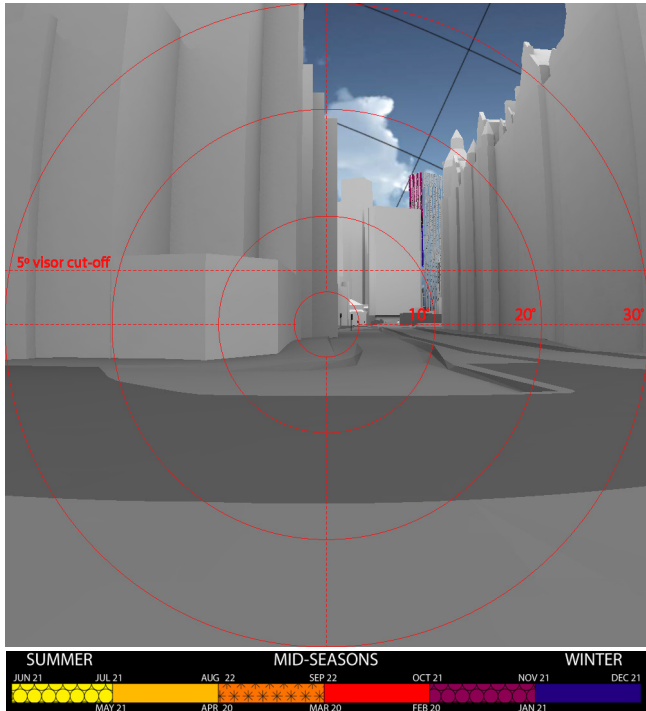
VIEWPOINT 1

Submitted Results (2.0m Viewpoint Height)

Time of Day (hours)

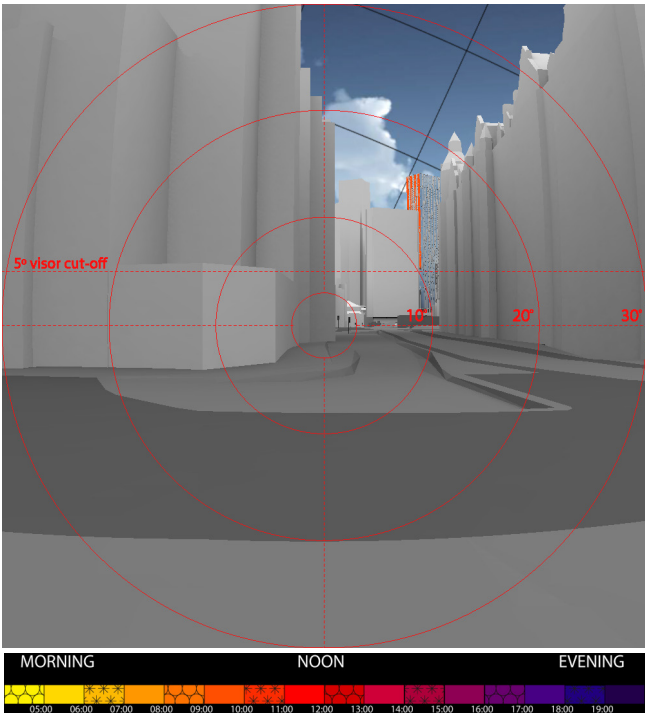


Time of Year (months)

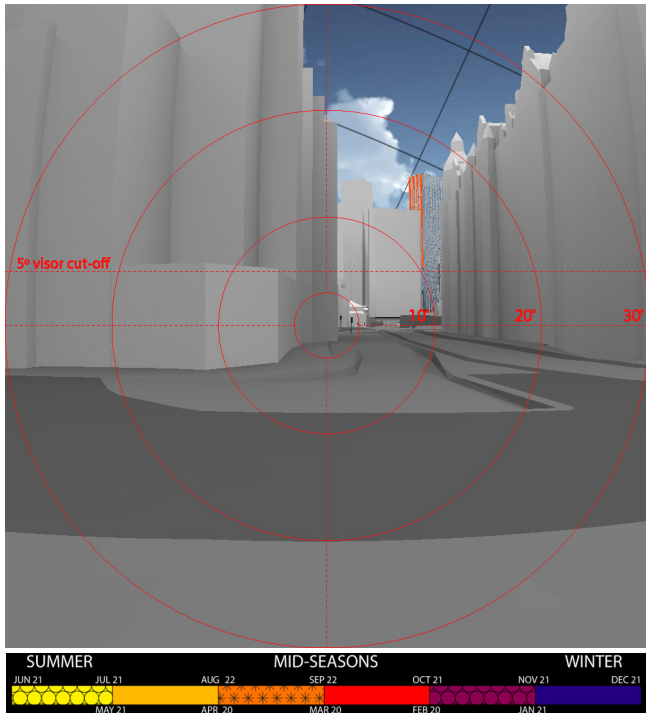


Updated Results (2.2m Viewpoint Height)

Time of Day (hours)



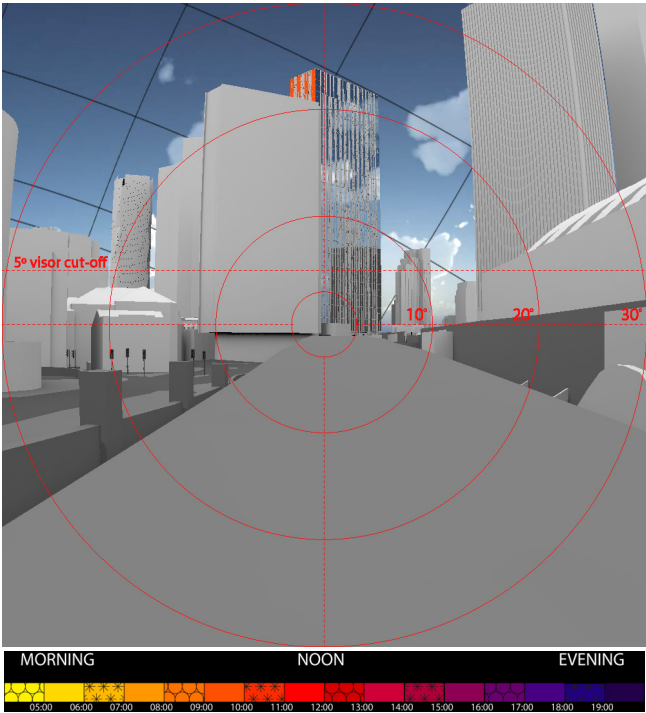
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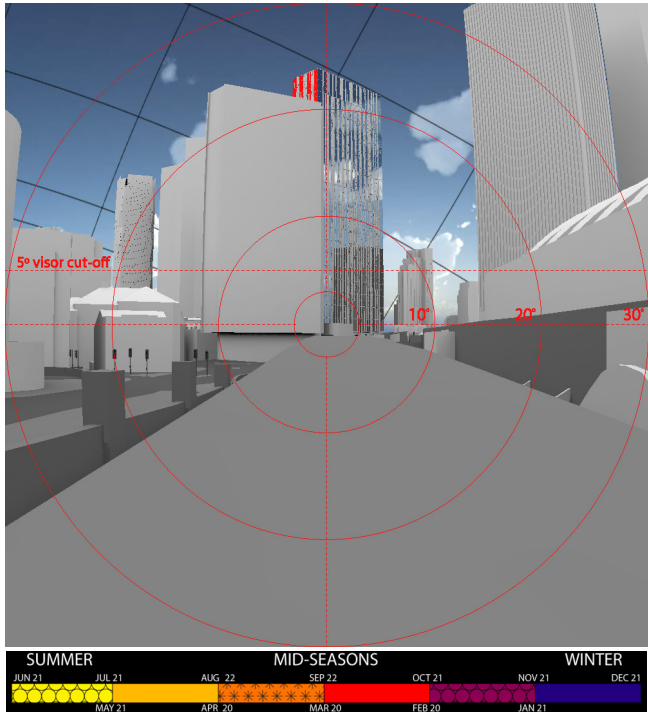
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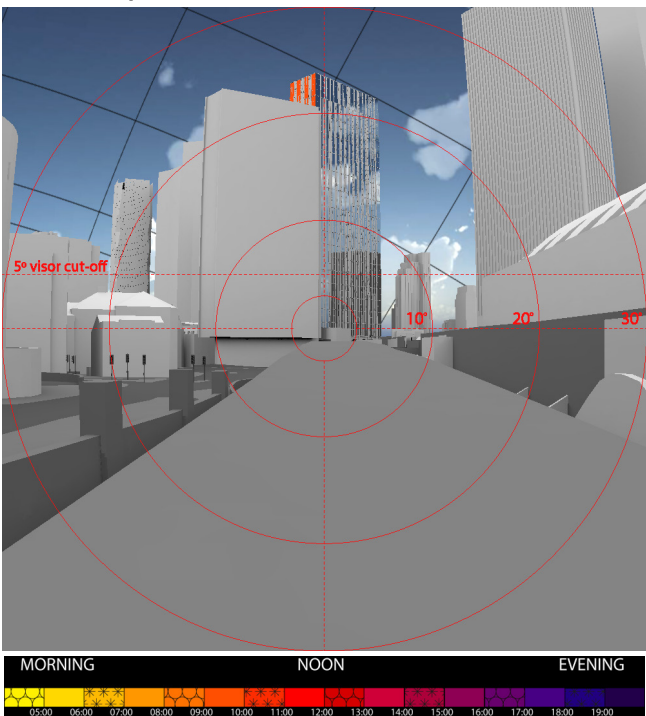


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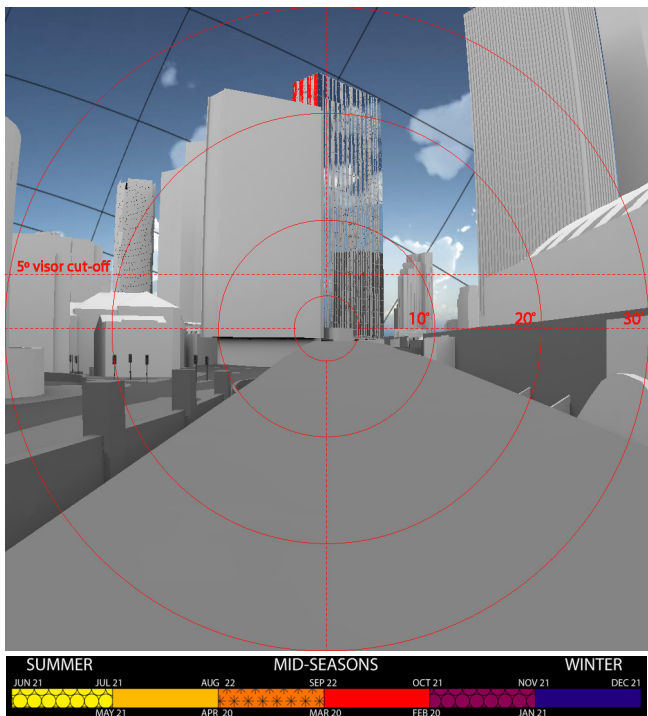


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Time of Day (hours)



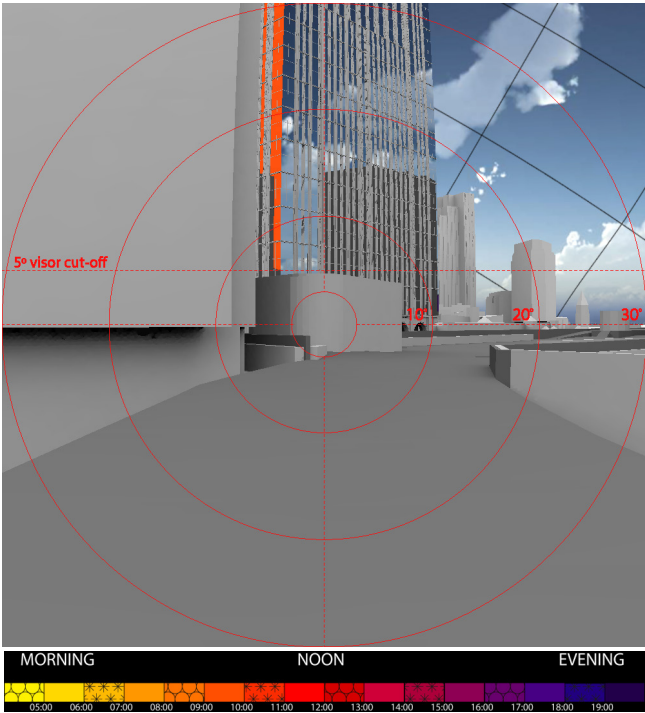
Time of Year (months)



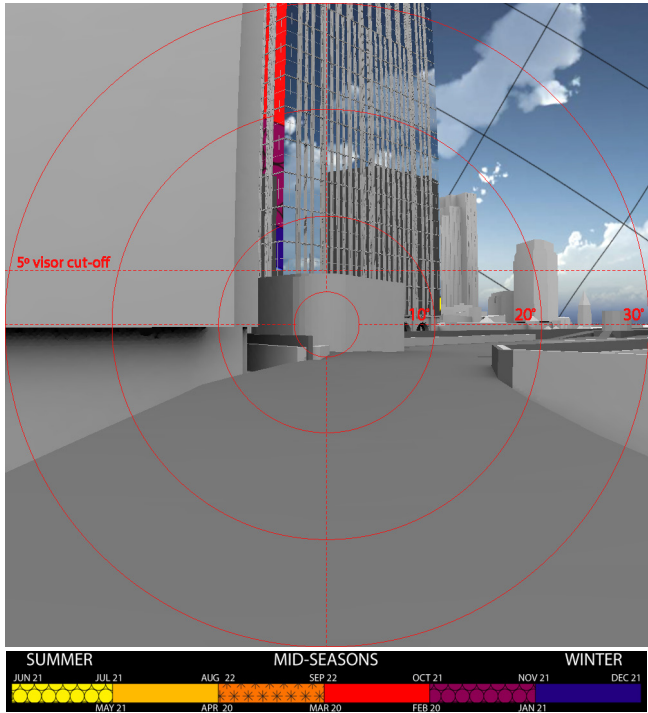
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Time of Day (hours)

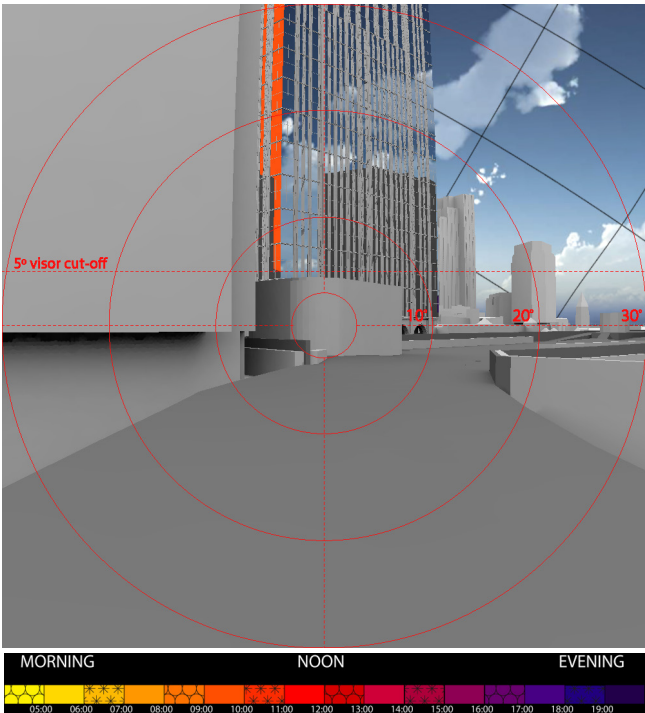


Time of Year (months)

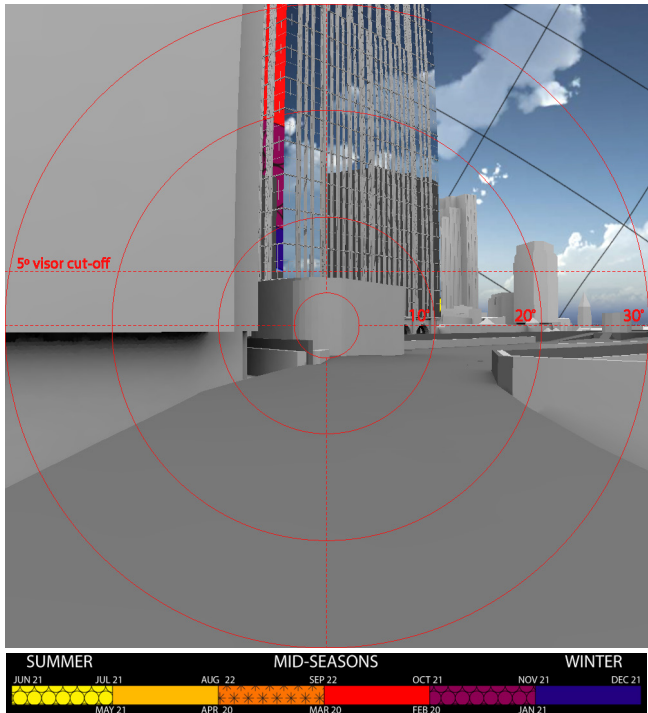


Updated Results (2.2m Viewpoint Height)

Time of Day (hours)



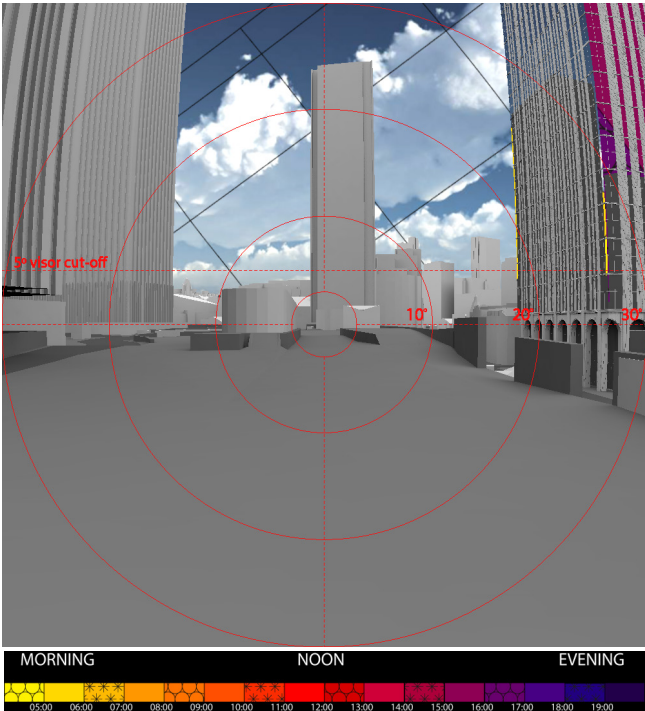
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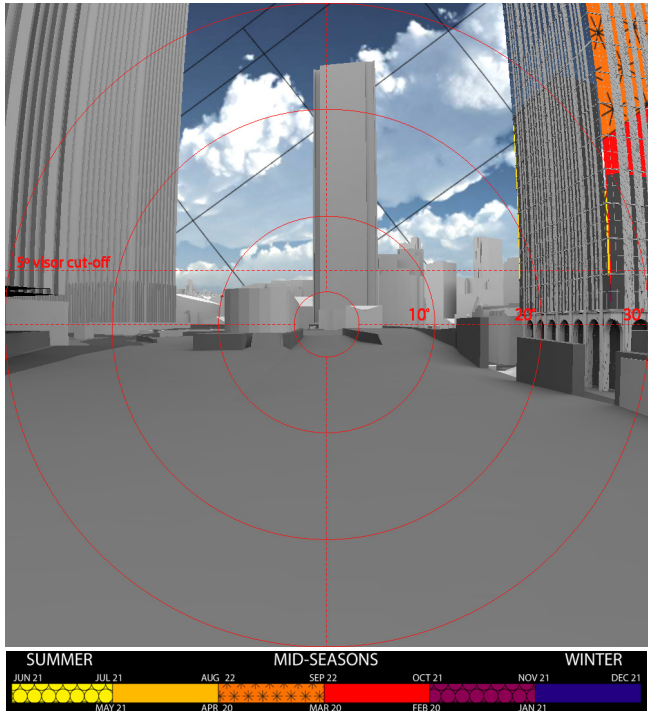
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Time of Day (hours)

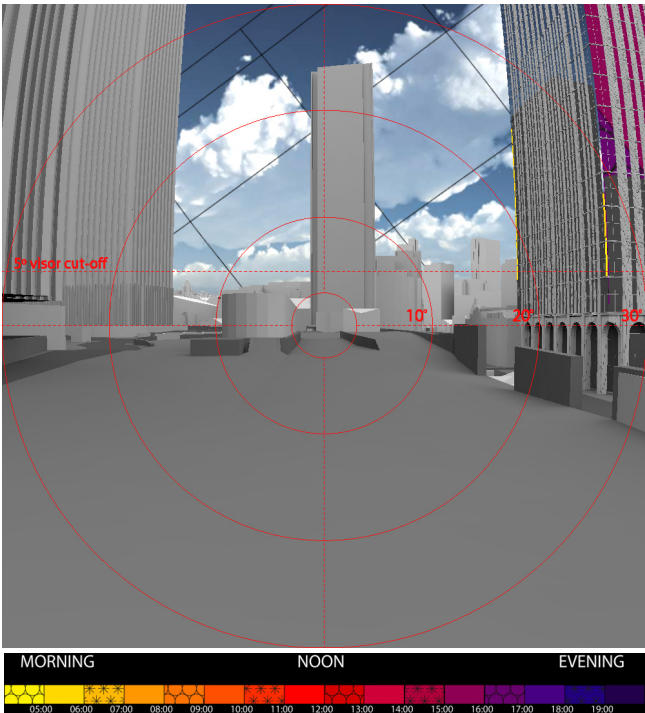


Time of Year (months)

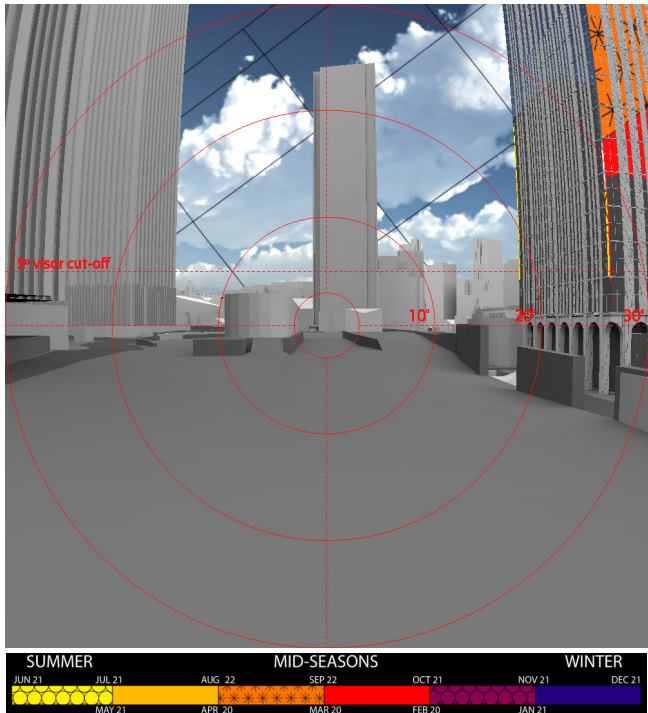


Updated Results (2.2m Viewpoint Height)

Time of Day (hours)



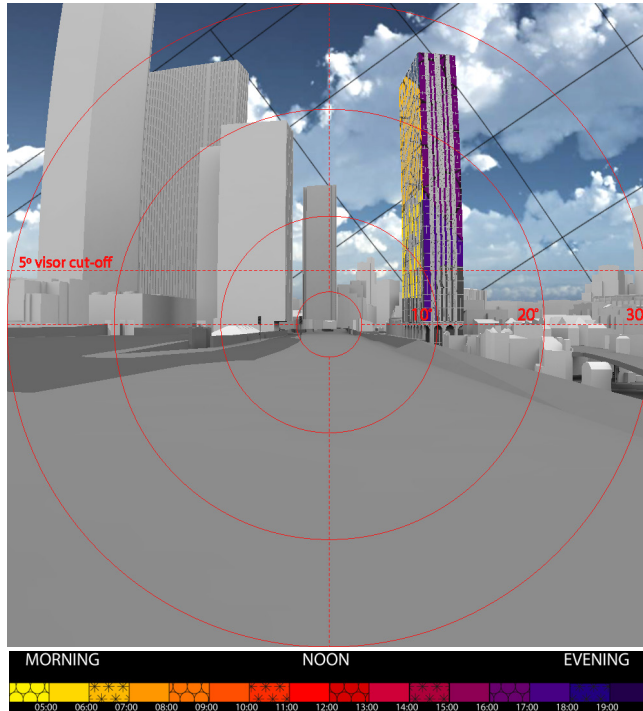
Time of Year (months)



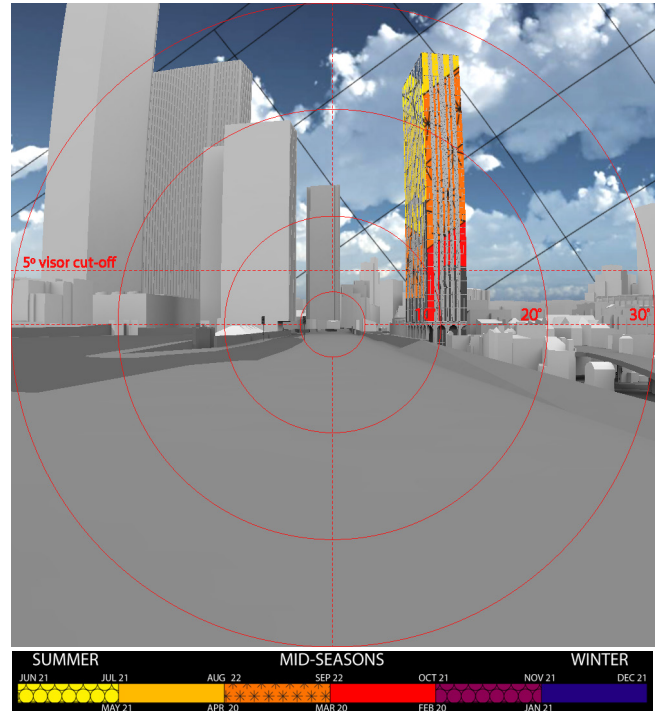
VIEWPOINT 5

Submitted Results (2.0m Viewpoint Height)

Time of Day (hours)

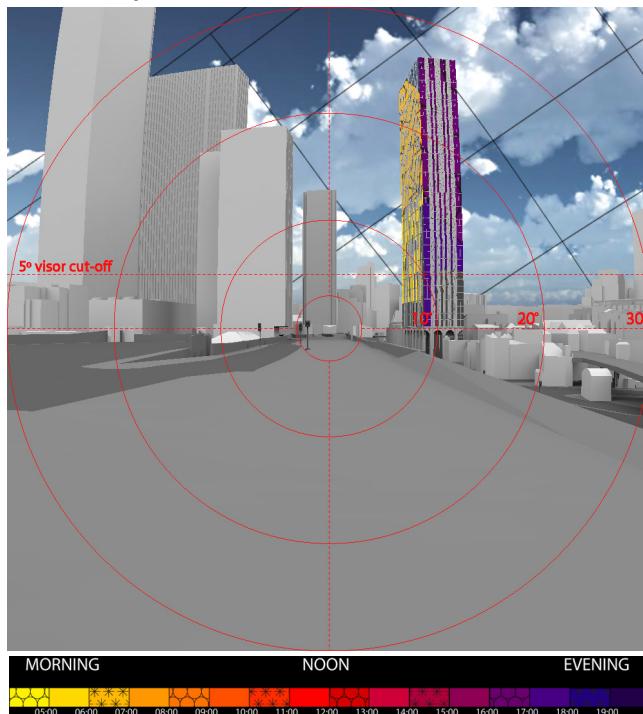


Time of Year (months)

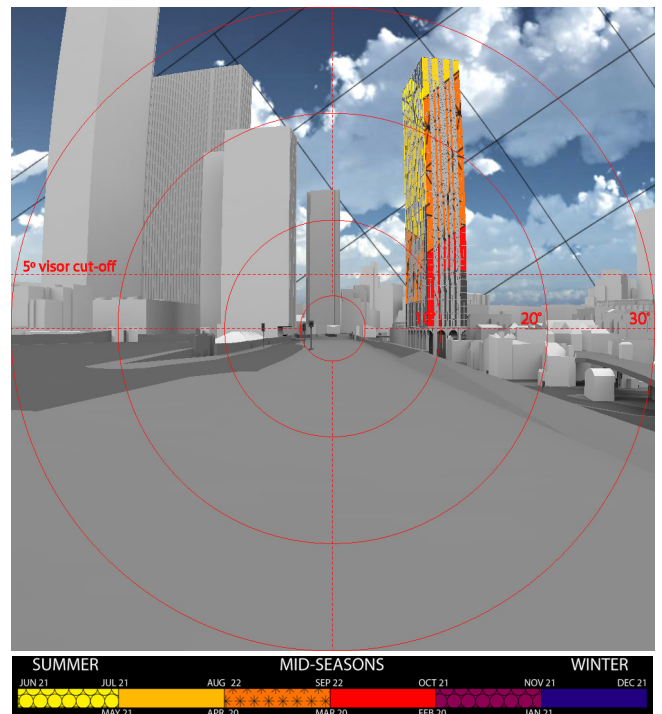


Updated Results (2.2m Viewpoint Height)

Time of Day (hours)



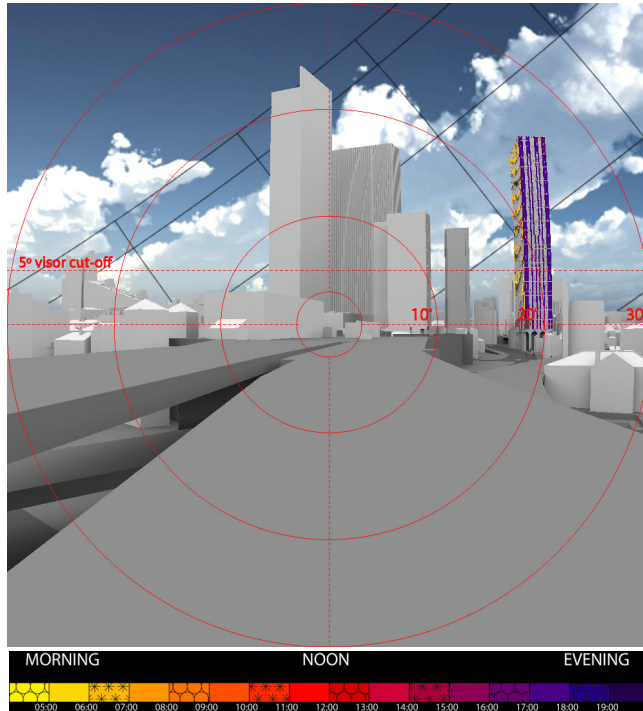
Time of Year (months)



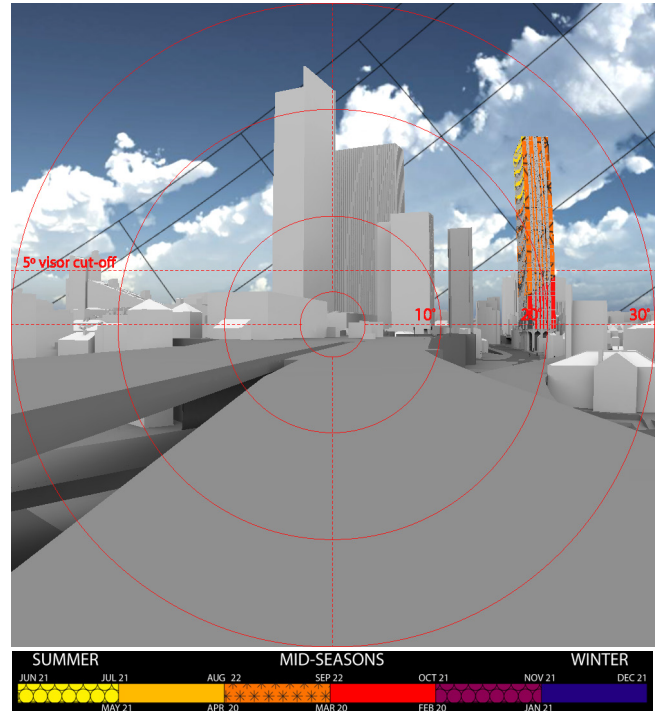
VIEWPOINT 6

Submitted Results (2.0m Viewpoint Height)

Time of Day (hours)

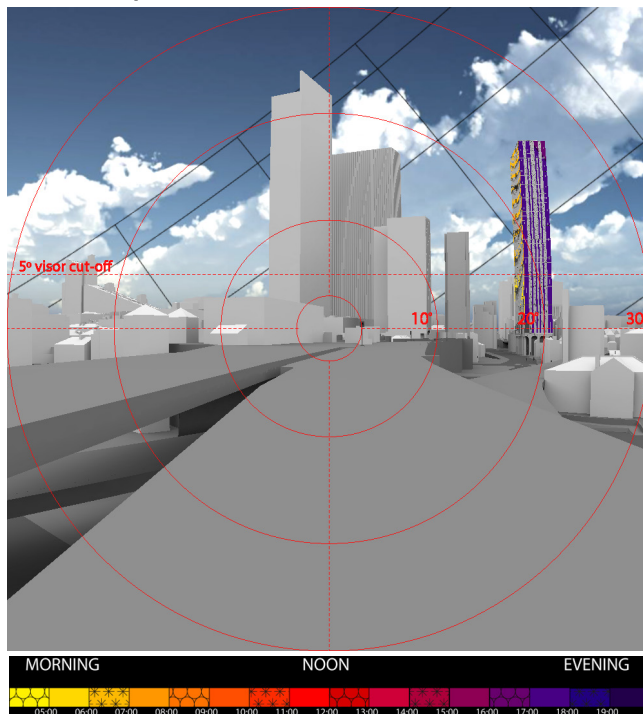


Time of Year (months)

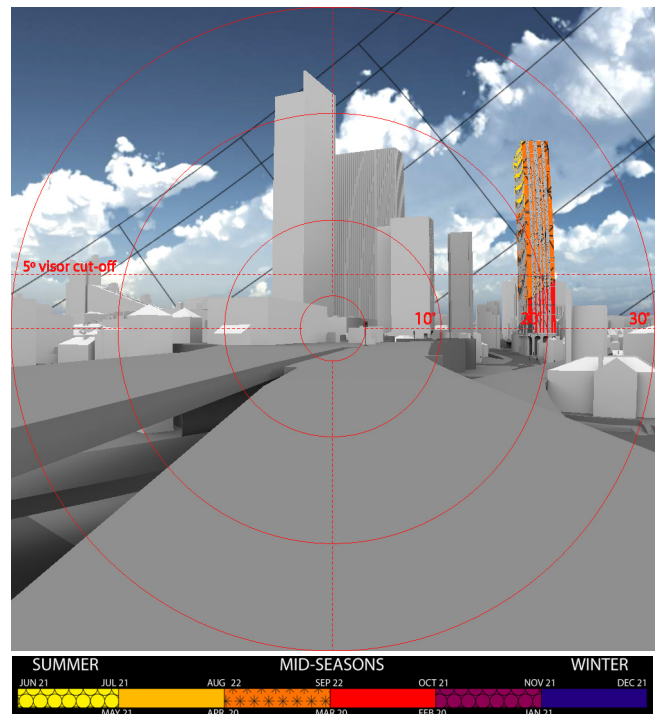


Updated Results (2.2m Viewpoint Height)

Time of Day (hours)



Time of Year (months)



APPENDIX 2 - GLARE INTENSITY ASSESSMENT

1 INTRODUCTION

GIA have assessed the proposed scheme in order to ascertain whether solar reflections given off the proposed building's facade will be visible from sensitive viewpoints which may affect road users and train drivers.

1.1 GLARE

Glare is a phenomenon occurring in the eye that is caused by the presence of bright light sources within the visual field. It can lead to visual discomfort and, if the glare source is very bright compared to its surrounding, even be disabling in the sense that objects become hard or impossible to see (Fig. 01 and Fig. 02). This is because they are cloaked by the high intensity glare source, whose light gets scattered within the eye.

The CIE 146:2002 Collection on Glare expresses the latter type of glare more formally as:

"Disability glare is glare that impairs vision (CIE, 1987). It is caused by scattering of light inside the eye [...]. The veiling luminance of scattered light will have a significant effect on visibility when intense light sources are present in the peripheral visual field and the contrast of objects to be seen is low. "

"Disability glare is most often of importance at night when contrast sensitivity is low and there may well be one or more bright light sources near to the line of sight, such as car headlights, streetlights or floodlights. But even in daylight conditions disability glare may be of practical significance: think of traffic lights when the sun is close to them, or the difficulty viewing paintings hanging next to windows."

Glare is of particular concern if it affects drivers of motor vehicles or trains, since it might impair the visibility of signals and traffic signs, potentially putting the driver, passengers or other parties at risk.

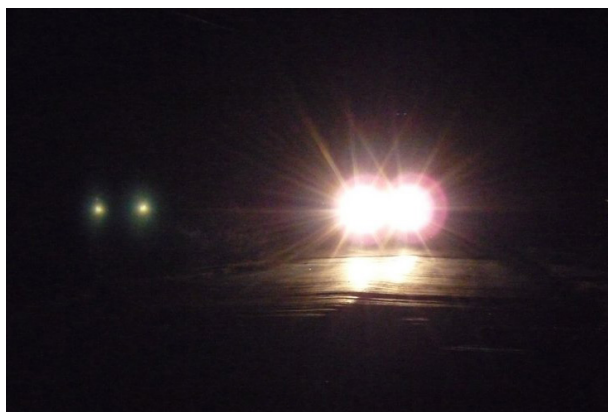


Fig. 01: Headlights at night

1.2 GLARE FROM REFLECTED SUNLIGHT

Whether or not a sun reflection will cause an instance of glare depends upon a number of factors, these are summarised below:

- The location of the observer and his view direction;
- The sun's position in the sky, which changes not only with the hour of the day, but with the seasons too;
- The location and orientation of the reflective surface, e.g. a glazed facade, in relation to the observer's view direction;
- The specific quality of the reflective surface, e.g. sheen, specularity, etc.;
- The observer's physiology, e.g. age and eye pigmentation; and
- The background brightness defining the state of adaptation in the observer's eye;

This final point is an important one as the same brightness which could cause glare against a dark background may be perfectly acceptable when looked against a light one. A typical example of adaptation is illustrated in Fig. 01-02 where the same headlights cause glare at night whereas they do not during daytime hours.

Understanding whether solar glare is likely to occur is based on the observer's position and view direction. Given the transitory nature of the phenomenon, due to the sun's constant movement, any glare assessment should be carried out for a number of representative locations and view directions.

Such studies are often carried out with the help of sun path protractors or with the aid of a full three-dimensional computer simulation.



Fig. 02: Headlights during day

2 GUIDANCE

In the UK, guidance that is relevant to glare assessments is limited to a short section in the BRE's guidance "Site Layout Planning for Daylight and Sunlight: a guide to good practice" (BR209 - 2022 edition). It suggests that:

"If it is likely that a building may cause solar dazzle the exact scale of the problem should be evaluated. This is done by identifying key locations such as road junctions and windows of nearby buildings, and working out the number of hours of the year that sunlight can be reflected to these points. BRE Information Paper IP 3/87 gives details."

BR IP3/87 provides more detailed instructions on why and how solar dazzle can be calculated:

"Glare or dazzle can occur when sunlight is reflected from a glazed facade. For vertical façades this problem usually occurs only when the sun is low in the sky; but some types of modern design incorporate sloping glazed façades which can, under certain circumstances, reflect unwanted high altitude sunlight into the eyes of motorists, pedestrians and people in nearby buildings."

Both BR 209 and BR IP3/87 only deal with geometrical considerations of glare by identifying when and where reflections occur. However, neither pieces of guidance suggest any threshold values above which reflected sunlight may give rise to an instance of glare. That such a threshold exists in theory becomes clear from the guidance in BR 209:

"... Substituting clear or absorbing glass for reflective glass can also help although sometimes even clear glass may cause reflected glare if, eg. a motorist has the reflected sun close to the centre of their line of sight."

The City of London (CoL) published their own guidance in the form of a Planning Advice Note in July 2017. The aim was to establish "Guidelines and best practice for assessing solar glare in the City of London".

The CoL Guidelines distinguish between discomfort glare and disability glare.

"There are two types of reflected glare problem that can occur. Discomfort glare causes visual discomfort without necessarily affecting the ability to see. Disability glare happens when a bright source of light (such as the reflected sun) impairs the vision of other objects."

"Outdoors, disability glare is easily the more serious problem, as it can affect motorists' ability to drive safely. It is especially important at locations where a driver has to make a key decision, for example approaching a road junction, traffic signal or pedestrian crossing. It can also affect train drivers, particularly if they are looking at illuminated signals."

"Discomfort glare is a less dangerous problem because it does not impair the ability to see. It can be important where work involves continuous viewing of the outdoor space from a fixed vantage point, for example in security surveillance."

Because discomfort glare a) does not impair the ability to see; and b) it only needs to be looked at where work involves continuous viewing of the outdoor space from a fixed vantage point – which is clearly the case for a train driver – GIA's solar glare assessments do not assess disability glare.

The CoL Guidelines also explains with regard to disability glare that:

"If the reflected sun would be visible close to the driver's line of sight, then either a more detailed calculation of solar glare is required, or measures should be taken to reduce the glare."

However, it does not elaborate how such a more detailed calculation should be carried out. For this, one needs to look elsewhere.

One of the very few paper that addresses intensity levels of solar glare and acceptable thresholds was published by Hassall in 1996. The title of this paper is 'Dealing with Rogue Solar Reflections'. Although published in Australia, the theory, methodology and recommendations it introduced are equally applicable in other countries such as the UK.

The severity of glare can be calculated as the equivalent veiling luminance which is caused by the excess light being scattered in the eye thereby creating a 'veil' through which objects are seen. If the brightness of the veil is sufficiently high compared to that of the actual object, the latter becomes less visible. In very severe cases of disability glare, the object cannot be seen at all.

The veiling luminance can be calculated with a simple empirical formula first proposed by Holladay:

$$L_{seq} [cd/m^2] = K * E_{gl} / \theta^n < \text{threshold}$$

The Holladay glare formula depends on four variables, namely:

- **K**, which is a factor accounting for the observer's sensitivity to glare (eg. age);
- **E_{gl}**, which is the illuminance from the glare source, measured at the eye of the observer;
- **θ**, the angle between the line of sight and the glare source;
- **n**, indicating the power with which **θ** affects the outcome;

An individual's sensitivity to glare is affected primarily by age. We used a K factor of 17.5 in our calculations, which represents a 65-year old driver.

According to CIE 146:2002, the n power in Holladay's equation has three angular domains:

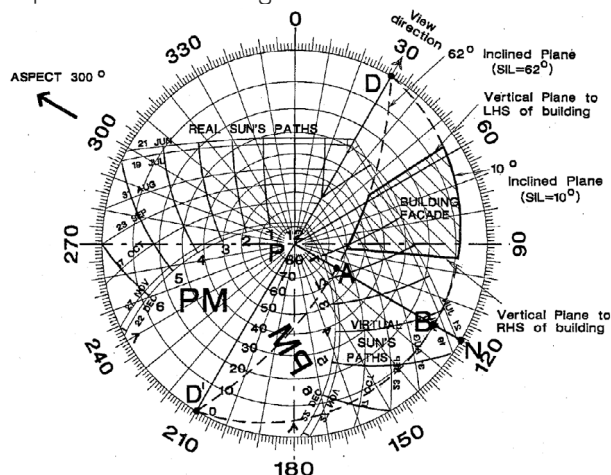


Fig. 03: Hassall's Protractor

- θ^3 for angles between 0.1° and 1° ;
- θ^2 for angles between 1° and 30° ; and
- θ for angles beyond 30° ;

This angular dependency means that a glare source close to the object being looked at has a much more severe impact upon the visibility of that object than a glare source at the periphery of the observer's visual field.

As stated in CIE 146:2002, occurrences at angles beyond 30° would be of little significance in most situations, but may be relevant in exceptional circumstances. When seated in a driving seat of a typical car, for example, the limits of the windscreen would generally obstruct the driver's view at angles beyond 30° from the line of sight. We have therefore adopted the 1° to 30° domain as a reference for our calculations.

Hassall in his paper proposes a threshold value of 500 cd/m^2 , which we have adopted as a threshold in our assessments.

Whilst Hassall's approach is based on protractor (Fig. 03) onto which the outline of the proposed building is meant to be drawn by hand, whilst working at GIA, Gil in 2016 picked up on Hassall's methodology and showed how this solar glare assessment could be done with computer software (V L-R Gil: *Evaluation of solar glare from reflective façades: A general method*; Lighting Research & Technology, Vol48, 2016), Fig. 04

GIA have adopted Gil's approach for their Stage 2 solar glare intensity assessments.

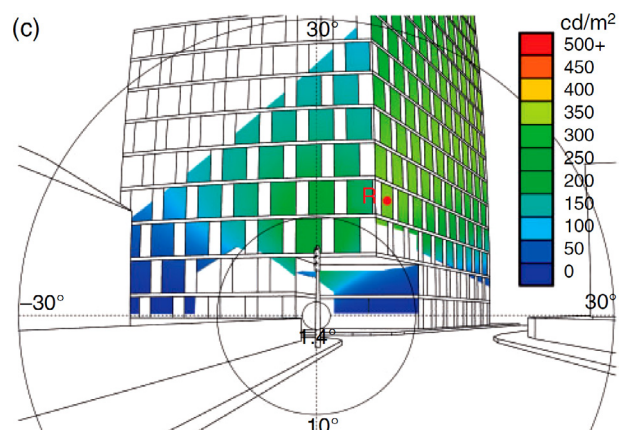


Fig. 04: Gil's (2015) Computerised version to Hassall's Protractor

3 GIA'S APPROACH AND METHODOLOGY

Following the guidance documents referenced above, GIA have developed specialised computer software to undertake reflected glare assessments, which are carried out following a three-stage approach.

The preparation of reflected solar glare assessments is based upon the steps described below:

- The construction of a 3d-computer model that includes the proposed building and its relevant setting (Paragraph 3.1);
- The physically accurate description of the reflective surface properties (Paragraph 3.2);
- Rendering of stills of the solar reflections (Paragraph 3.3);
- Masking the images to represent the Human Field of View (Paragraph 3.4); and
- Image analysis for:
 - » Stage 1 - Static assessment (Paragraph 3.5)
 - » Stage 2 - Potential Intensity of reflections (Paragraph 3.6)
- The limitations of this approach and methodology are set out in Paragraph 3.7.

3.1 3D-COMPUTER MODEL

The detailed geometry of the proposed building, and specifically of its facade and glazing configuration, is provided by the project architects either in 2d format (i.e. plans, sections and elevation drawings) or 3d format as a computer model. The received information is processed by GIA and prepared for assessment with our proprietary software. GIA also prepares the context 3d-model from photogrammetry and high resolution stereoscopic aerial photographs, including details relevant for assessment such as rail tracks, sleepers, gantries and signals as well as road junctions and traffic lights. An example of the details included in the solar glare context 3d-model is provided in Fig. 05, Fig. 06, Fig. 07 and Fig. 08.

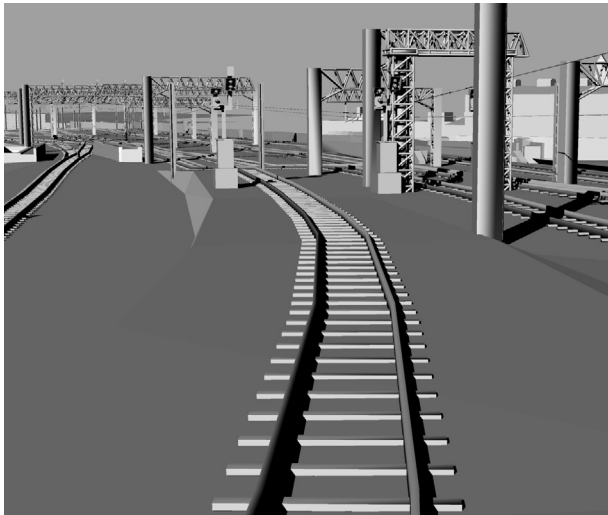


Fig. 05: Computer model of train tracks & signals from photogrammetry



Fig. 06: High-resolution aerial photograph

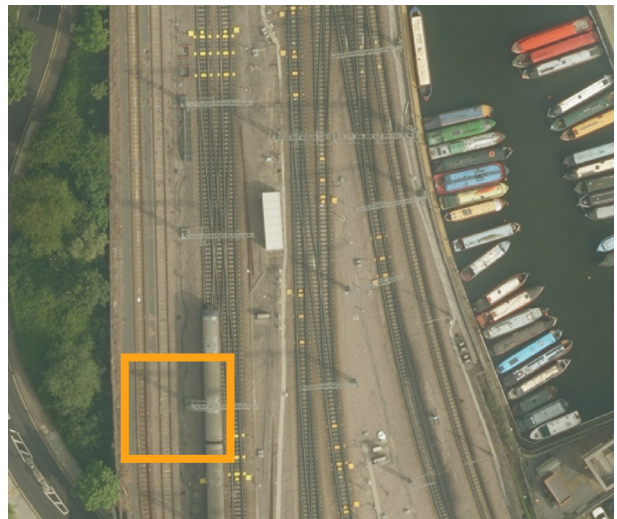


Fig. 07: High-resolution aerial photograph (close-up)



Fig. 08: High-resolution aerial photograph (close-up)

3.2 REFLECTIVE SURFACE PROPERTIES

In order to undertake the glare studies it is necessary to acquire physically accurate computer representations of all materials adopted in the Proposed Development that have the potential of specularly reflecting sunlight, thereby becoming sources of glare. Such materials would include all vertical or sloped glazing, but also certain facade materials such as metal cladding or glazed building tiles.

Diffuse surface reflectance values and object colours can be measured relatively easily however, the same cannot be said of their specular characteristics. These parameters are very hard to estimate yet critical for the study of glare. It is therefore best practice to have samples of the glazing or cladding materials studied in specialised optical laboratories. An example of such a data set is given in Fig. 09. It shows the angular dependency of the reflective properties of a glazed cladding tile.

The City of London guidance states that “the severity of glare depends on the type of glazing or cladding. The glare caused depends on the specular reflectance of the glazing. This is the mirror-like direct reflection of sunlight. For glasses, the reflection is nearly all specular. Metals often combine specular reflection with diffuse reflection (where the reflected light is scattered in all directions). Surfaces like brick or matt cladding give mainly diffuse reflection, which is unlikely to cause disability glare.”

GIA's approach is based on three stages which vary in level of detail:

- *Stage 1 - Static assessment* assumes all potential reflective portions of the Proposed Development as “mirrors”, therefore portraying an absolute worst-case scenario which is however aimed at identifying whether a reflection can occur or not.
- *Stage 2 - Potential Intensity of reflections assessment*, however, is more advanced and considers the bespoke material specifications of the Proposed Development which are necessary to identify the potential intensity of reflections.

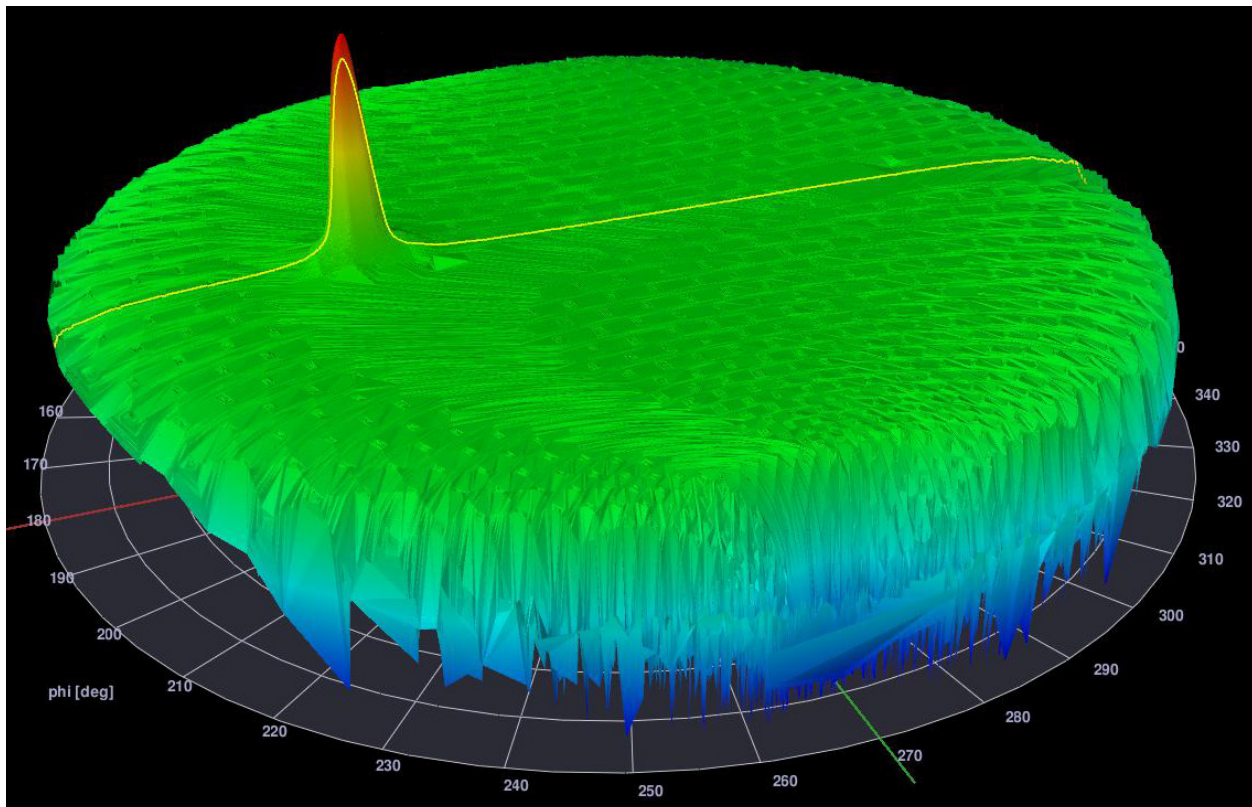


Fig. 09: Reflective properties measurement of a glazed tile

3.3 VIEWPOINTS

Potentially sensitive viewpoints around the site are selected. These viewpoints representing locations where reflected solar glare may cause adverse impacts to those travelling towards the development, such as road users or train drivers. The viewpoints are generally located at the minimum stopping distance and at the driver's eye height. The focal point is a relevant traffic element, such as signals or incoming traffic.

The stopping distance for cars is calculated as the combination of thinking and breaking distances $D_{\text{total}} = D_{\text{thinking}} + D_{\text{breaking}} = V \cdot T + V^2 / (2\mu \cdot g)$, where each component is:

- V = Relevant vehicle speed, typically the road speed limit.
- T = Thinking time (0.67 sec)
- μ = Breaking effort (considered 0.65 for cars, 0.5 for buses and 0.031 for trains)
- g = Gravity acceleration.

The height of the viewpoint is considered to be 1.5 m for cars, 2.0 m for buses and 2.75 m for trains.

I.e. A viewpoint for car driving at 30 mph would be placed at 23 m (see Figure 08) from a traffic light and at 1.5 m above the ground.

Typical Stopping Distances

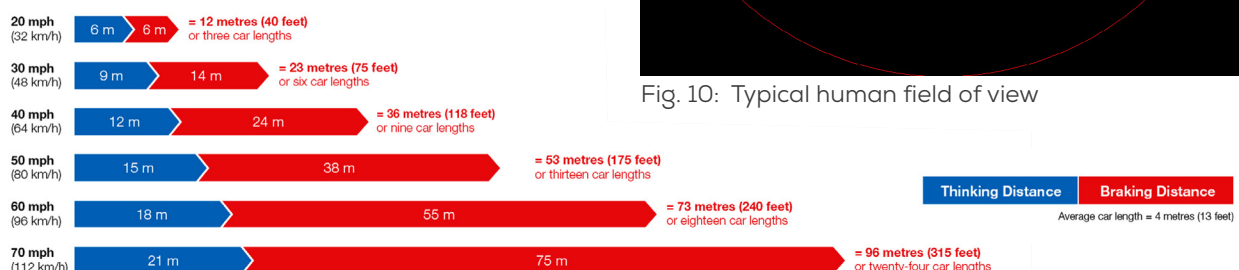


Fig. 11: Typical car stopping distances for various speed limits

3.4 HUMAN FIELD OF VIEW

The field of view is the angular extent within which objects can be observed by one or both eyes. Owing to the arrangement of the human eyes, the stereoscopic visual field extends to approximately 60° either side on the vertical and 90° either side on the horizontal.

In the United Kingdom, the minimum field requirement for driving is 60° either side of the vertical meridian, and 20° above and below horizontal.

The fovea centralis is the central area of the retina. It extends about 3° in all directions. The fovea is responsible for sharp vision that is used for reading, driving, and any other activity where visual detail is important. Fig. 11 shows our typical field of view overlay.

The CIE 146:2002 suggests that occurrences at angles beyond 30° would be of little significance in most situations, but may be relevant in exceptional circumstances. Any reflection within 30° is looked at in greater detail in terms of its duration, size of the reflective surface and where appropriate, predicted intensity.

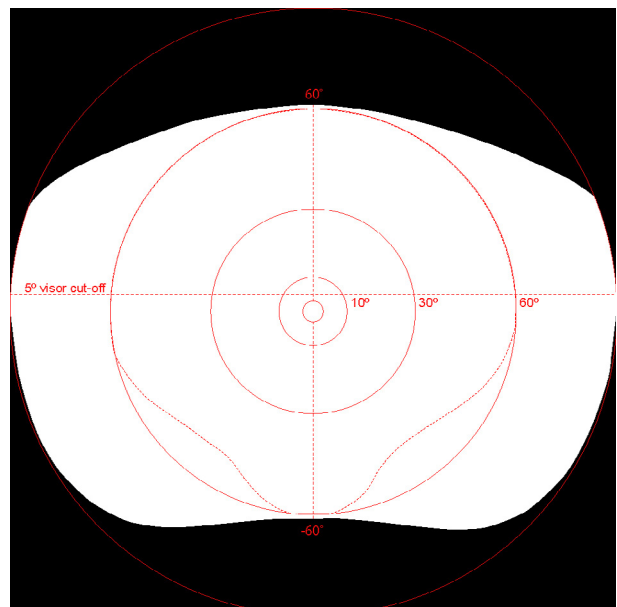


Fig. 10: Typical human field of view

3.5 **STAGE 1: STATIC ASSESSMENT**

The methodology described below is aimed at addressing the occurrence and duration throughout the year and the location of this occurrence in respect of a driver's line of sight. This will inform the necessity of implementing mitigations at either early or detailed design stage.

For this purpose the glazed facade of the Proposed Development is assumed to have the same properties of a mirror, i.e. it is fully reflective and all of its reflected component is specular. This therefore portrays a worst-case scenario.

The potential for reflected solar glare or dazzle from the glazed or reflective façades of the development are assessed using specialist lighting software.

In Stage 1, stills or a computer animation are generated with which the potential for the occurrence of reflected sunlight is evaluated with regards to the times of the year and hours of the day when this may happen, as well as its relative location to the observer's line of sight.

In order to achieve this, the yearly sun path is mapped onto the sky and colour-coded so that the hours of the day and the period of the year can be distinguished. This sun path is picked up by the reflective elements of the proposed buildings in our rendered stills.

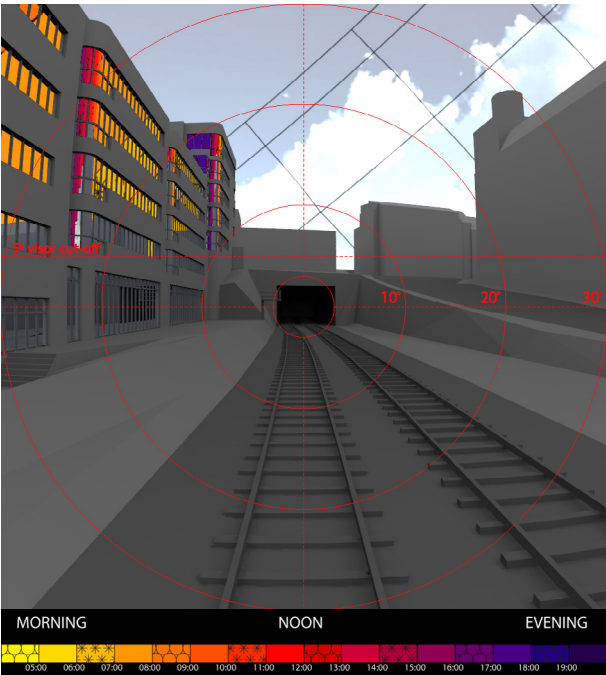


Fig. 13: Stage 1 Example - Hours

Fig. 12 shows the colour coded sunpaths projected onto the sky dome to visualise the time of day and season during which solar reflections occur.

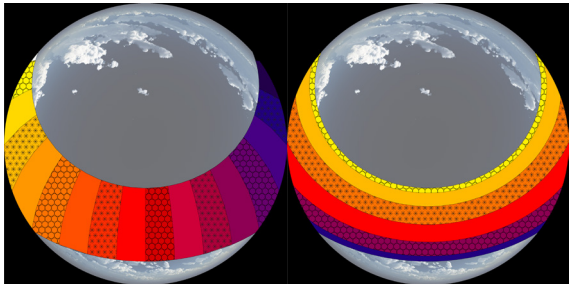


Fig. 12: Stage 1 - Colour coded sunpath for time of day and seasons

Two identical viewpoints are rendered as shown in Fig. 13 and Fig. 14: one focusing on the times of the day when the reflection would be visible, and the second looking at the months throughout the year.

The following guidance is used to determine whether an intensity study is necessary:

- Solar reflections are visible within 30° to 10° of the driver's line of sight for a long period of time (large reflective surface) or between 10° to 5° for a short period of time;
- Solar reflections are visible within 10° and 5° of the driver's line of sight occurring for a long period of time;
- Solar reflections are visible within 5° of a driver's line of sight;

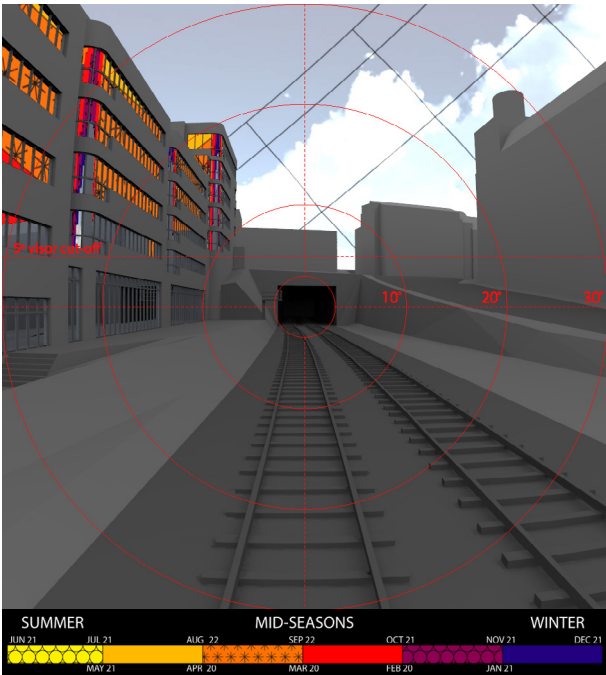


Fig. 14: Stage 1 Example - Months

3.6 STAGE 2: POTENTIAL INTENSITY OF REFLECTIONS

Stage 2 predicts the intensity of the reflected sunlight, using the Holladay formula. An example is provided in Fig. 15.

Any value exceeding 500 cd/m² is further looked into and discussed within the conclusions of our report.

A limitation of this Stage 2 methodology is that it can flag false positives when the reflector, i.e. a window, is too small to actually reflect the full extent of the solar disc. As a result of this, even a single bright pixel in the computer image is capable of producing a peak veiling luminance equivalent to that of the full solar disc.

Our solar glare animations are rendered with a resolution of 1,000x1000 pixels, and cover a field of view of $\pm 30^\circ$. With the diameter of the sun being 0.5° , this means that the size of the full solar disc is 8 pixels across, and covers about 52 pixels in area.

To calculate the corrected peak intensity for instances where the reflection is from an area less than the full solar disc, the number of pixels are calculated as a proportion of the full solar disc (i.e. number of pixels/52) and then applied to the equivalent peak veiling luminance reported in the rendered image.

An example of this is provided in Fig. 16 whereby the peak veiling illuminance of 1,140cd/m² occurs from an area of 3 pixels. Therefore the corrected peak veiling luminance is $1,140 \text{ cd/m}^2 \times 3/52 = 112 \text{ cd/m}^2$ 66cd/m².

3.7 LIMITATIONS

Great care is taken in identifying typical viewpoints around a new development. However, this does not guarantee that all sensitive locations where reflected solar glare could present a particular risk are covered, especially where these are farther away from the site.

IMPORTANT: The hours shown in the diagrams and described in the text reflect solar time and therefore do not take British Summer Time into account.

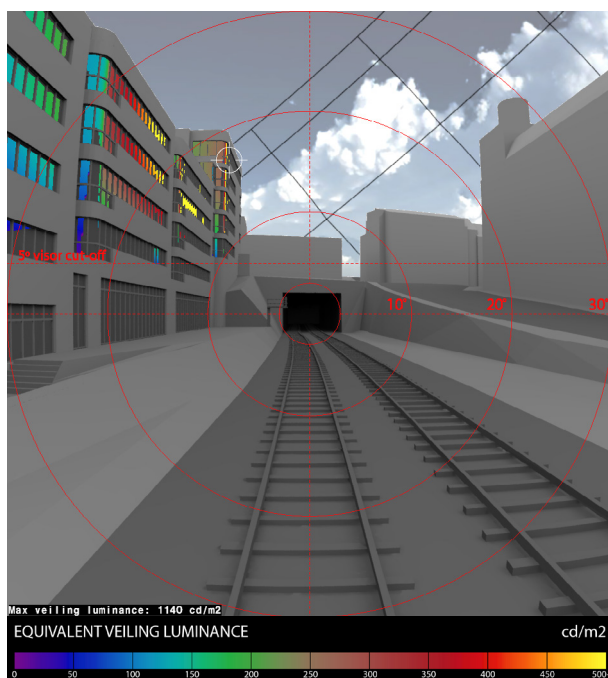


Fig. 16: Stage 2 Example - Veiling Glare Luminance

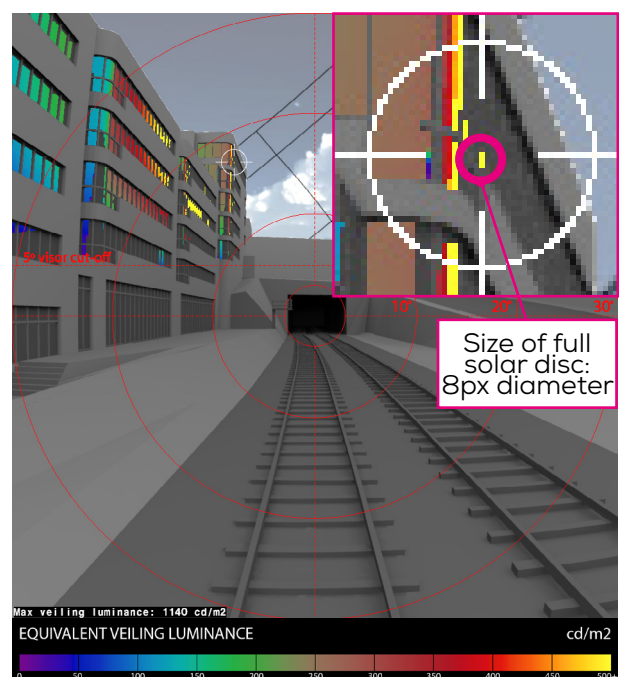


Fig. 15: Stage 2 Example - Solar Disc Diagram

4 ASSESSMENT RESULTS & SUMMARY

Three viewpoints have been assessed along the eastbound tramline with reflections occurring within 10° of a driver's direct line of sight on this track at one of the three viewpoints.

This assessment is based on the an assumed VLR threshold of 16%.

Figure 17 shows the peak intensity for viewpoint Tram 4 is 405 cd/m² which is below the threshold for glare of 500cd/m².

Figure 18 shows a peak intensity of reflections from the proposed development at viewpoint Tram 5. At this location, the reflections which generate the peak veiling luminance within viewpoint Tram 5 are significantly less than the full solar disc. The extent of the reflection is limited to 16 pixels which are very broken up by the non-reflective facade elements, so only approximately 16/50th of the full solar disc is visible in the reflection. The corrected peak intensity is therefore $1,100 \text{ cd/m}^2 * 16/50 = 352 \text{ cd/m}^2$ which is below the threshold for glare of 500cd/m².

Figure 19 shows the peak intensity of reflections from the proposed development at viewpoint Tram 6. At this location, the reflections which generate the peak veiling luminance within viewpoint Tram 6 are significantly less than the full solar disc. The extent of the reflection is limited to 16 pixels which are very broken up by the non-reflective facade elements, so only approximately 16/50th of the full solar disc is visible in the reflection. The corrected peak intensity is therefore $722 \text{ cd/m}^2 * 16/50 = 231 \text{ cd/m}^2$ which is below the threshold for glare of 500cd/m².

As noted, all reflections visible are below the threshold for glare and not considered a concern in terms of glare. Therefore, as tram drivers travel along this track, their vision would not be significantly affected by reflections from the proposed development nor would the reflections impact accurate sighting of the signals.

For the above reasons, it is not considered that reflections from the Proposed Development would significantly impact the ability of drivers to safely travel along this set of tram tracks and respond in a safe manner, as necessary, to the signalling. No further mitigation is considered necessary at this location provided the VLR threshold is adhered to.

PEAK INTENSITY ASSESSMENT
VIEWPOINT TRAM 4 - EASTBOUND TO DEANSGATE-CASTLEFIELD

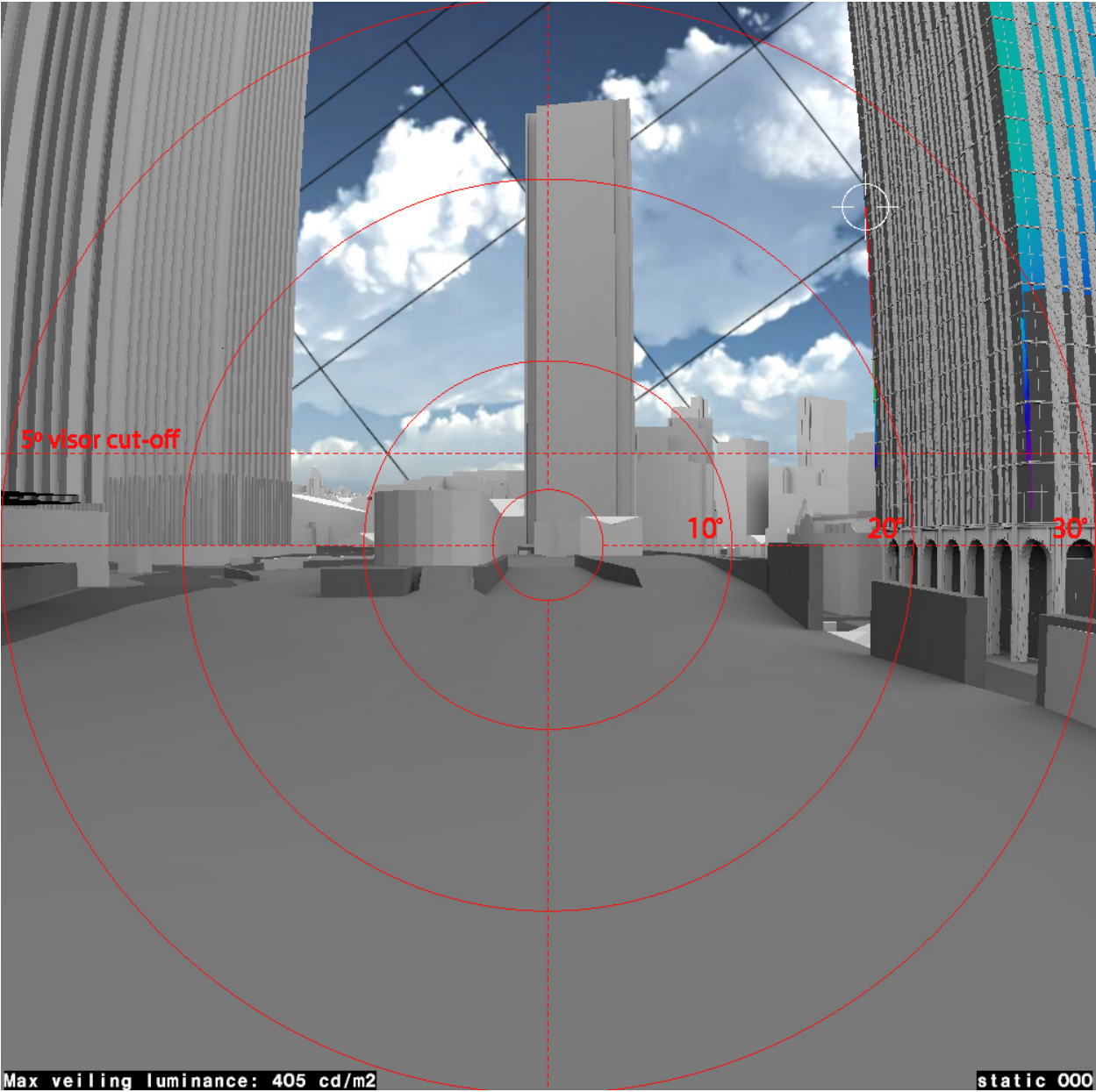
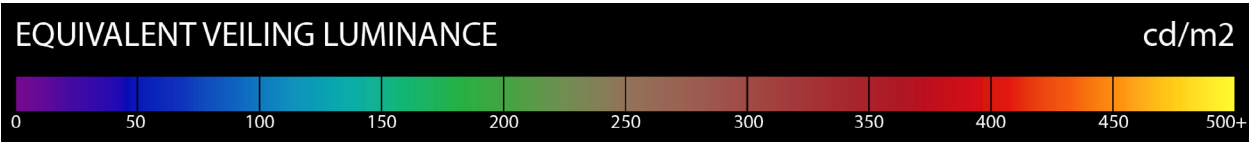


Fig. 17: Peak intensity



PEAK INTENSITY ASSESSMENT
VIEWPOINT TRAM 5 - EASTBOUND TO DEANSGATE-CASTLEFIELD

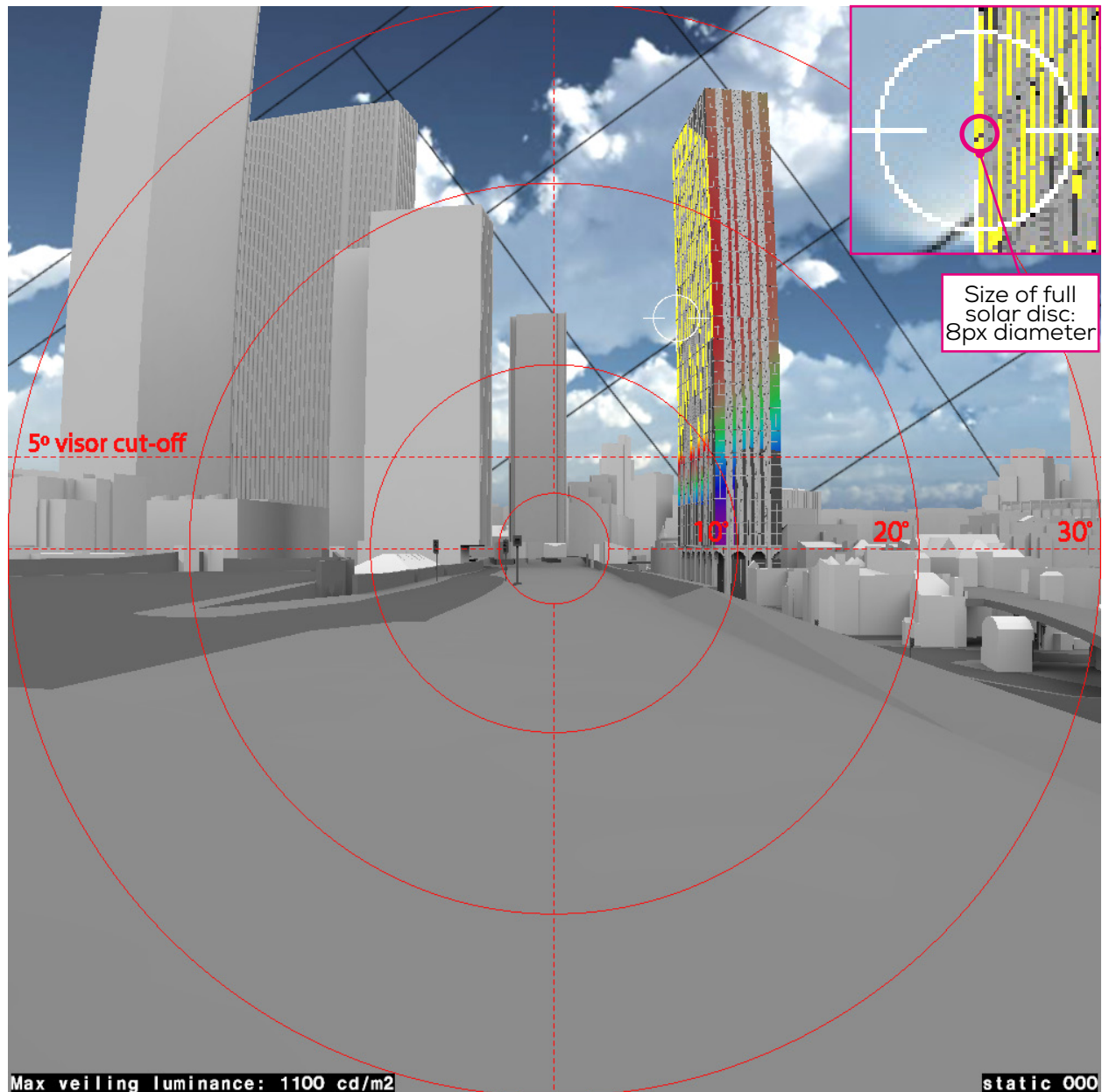
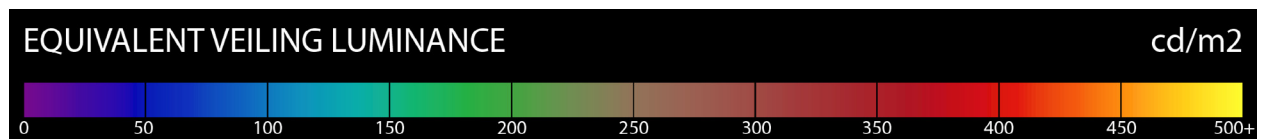


Fig. 18: Peak intensity



PEAK INTENSITY ASSESSMENT
VIEWPOINT TRAM 6 - EASTBOUND TO DEANSGATE-CASTLEFIELD

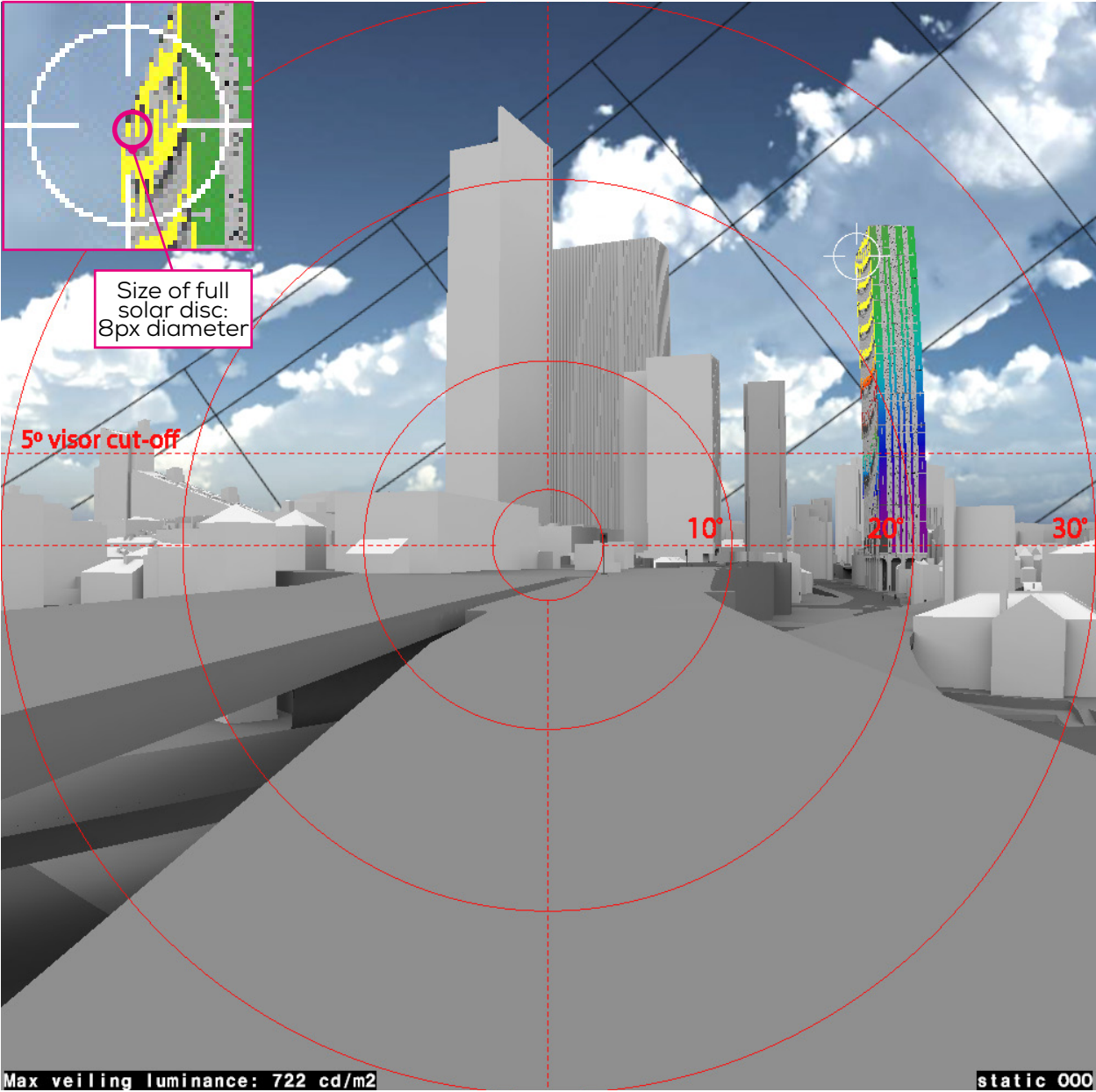


Fig. 19: Peak intensity

