Appendix Z

Reflectivity assessment

Sydney Metro West

Parramatta Over and Adjacent Station Development Reflectivity Assessment

Appendix Z

September 2022

NSW GOVERNMENT

sydney METRO

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Mott MacDonald Australia Pty Ltd

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Glossary

Term	Definition
2D	Two-dimensional
3D	Three-dimensional
ASD	Adjacent site development
CBD	Central business district
Concept and Stage 1 CSSI Application	Application SSI-10038, including all major civil construction works between Westmead and The Bays, including station excavation and tunnelling, associated with the Sydney Metro West line
Concept SSDA	A concept development application as defined in section 4.22 of the EP&A Act. It is a development application that sets out the concept for the development of a site, and for which detailed proposals for the site or for separate parts of the site are to be the subject of a subsequent development application or applications
CSSI	Critical state significant infrastructure
DPE	Department of Planning and Environment
Early morning	Between 6am and 8am (inclusive)
EIS	Environmental impact statement
EP&A Act	*Environmental Planning and Assessment Act 1979*
GFA	Gross floor area
Hassall's Method	The method outlined in David N. H. Hassall's (1991) 'Reflectivity: Dealing with rogue solar reflections' publication
Late afternoon	Between 4pm and 7pm (inclusive)
LV	Veiling luminance
Mid-afternoon	Between 1pm and 3pm (inclusive)
Mid-morning	Between 9am and 11am (inclusive)
OSD	Over station development
RL	Relative level
SEARs	Secretary's Environmental Assessment Requirements
SSD	State significant development
Stage 2 CSSI Application	Application SSI-19238057, including major civil construction works between The Bays and Hunter Street Station
Stage 3 CSSI Application	Application SSI-22765520, including rail infrastructure, stations, precincts and operation of the Sydney Metro West line
Sydney Metro West	Construction and operation of a metro rail line and associated stations between Westmead and the Sydney CBD as described in section 1.1
The site	The site which is the subject of the Concept SSDA

Executive summary

This Reflectivity Impact Assessment Report supports a Concept State Significant Development Application (Concept SSDA) submitted to the Department of Planning and Environment pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Concept SSDA is made under section 4.22 of the EP&A Act.

Sydney Metro is seeking to secure concept approval for an over station development (OSD) and adjacent station development (ASD) on the Parramatta metro station site (referred to as the 'proposed development'). The proposed development will comprise three new commercial office buildings (Buildings A, C, D), and one new residential building (Building B).

The Concept SSDA seeks consent for a building envelope and mixed-use purposes, maximum building height, a maximum gross floor area (GFA), pedestrian and vehicular access, circulation arrangements and associated car parking, and the strategies and design parameters for the future detailed design of the proposed development.

This Reflectivity Impact Assessment Report responds specifically to the Secretary's Environmental Assessment Requirements (SEARs) and for glare impacts that may affect the environmental amenity of the area. It will assess distinct locations and their susceptibility to veiling glare.

There are many different types of glare impacts which may range from causing mild discomfort to temporary blindness. For this project, the type of glare of concern is "veiling glare", also known as "disability glare", measured by the veiling luminance (LV). It is caused by multiple reflections and the scattering within the eye by direct light from a bright source. The method published by Hassall (1991) was used to determine the veiling glare at various assessment locations. LV was calculated at discrete points, representative of sensitive receptors (light rail operators, drivers, pedestrians) traversing routes within the vicinity of the development. A conservative approach has been considered by assuming entirely glazed facades without external shading elements on the façade and future development that might otherwise shield glare. For all assessments undertaken, a LV limit of 500cd/m^2 was adopted as the acceptable amount of reflected solar glare to which a driver should be exposed.

The following routes are expected to have LV impacts above the criteria:

- Route 1: Light rail operators travelling northwest along Macquarie Street
- Route 2: Light rail operators travelling southeast along Macquarie Street
- Route 4: Drivers travelling southeast along Macquarie Street
- Route 5: Drivers travelling northwest along George Street
- Route 6: Drivers travelling southeast along George Street.

In addition, six pedestrian locations were tested in the public domain for pedestrians looking in various directions. With standard glazing, pedestrians at three of the six locations were found to have the potential to experience disability glare (LV exceeding 500cd/m^2) due to the north-facing podium level glazing of the northern most building. However, the risk of glare impact on pedestrians is considered to be low as they can move or look away from the façade.

As part of this assessment, sensitivity studies were also undertaken to determine effectiveness of using a sun visor and combining a sun visor with lower reflective glazing. It was found that both measures will reduce the disability glare risks but may not be sufficient to eliminate them. Using sun visors, the maximum LV expected to be experienced along all routes did not decrease and remained at 12,640cd/m^2. Using a combination of a sun visor and a lower reflective glazing, the maximum LV expected to be experienced along all routes decreased from 12,640cd/m^2 to 5,620cd/m^2.

It is recommended that mitigative measures are applied to minimise the glare risk to sensitive receptors near the proposed Parramatta metro station development. The following are suggested as effective mitigative measures:

- using a less reflective glazing
- different material
- shielding the façade
- changing built form (e.g. more articulation, angles of the building to minimise sun reflections, etc.).

These mitigative measures will be considered and analysed in future Detailed SSDAs for the final building designs.

1 Introduction

1.1 Sydney Metro West

Sydney Metro West will double rail capacity between Greater Parramatta and the Sydney Central Business District (CBD), transforming Sydney for generations to come. The once in a century infrastructure investment will have a target travel time of about 20 minutes between Parramatta and the Sydney CBD, link new communities to rail services and support employment growth and housing supply.

Stations have been confirmed at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock, The Bays, Pyrmont and Hunter Street (Sydney CBD).

Sydney Metro West station locations are shown in Figure 1-1 Sydney Metro West.

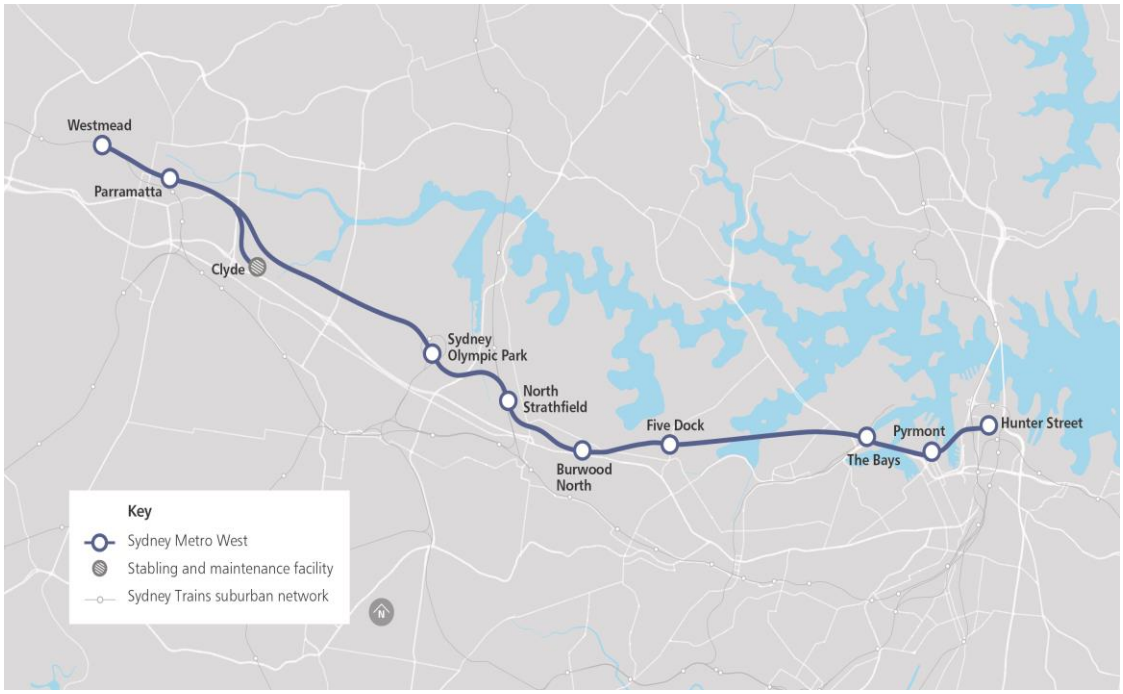


Figure 1-1 Sydney Metro West

1.2 Background and planning context

Sydney Metro is seeking to deliver Parramatta metro station under a two-part planning approval process. The station fit out infrastructure is to be delivered under a Critical State Significant Infrastructure (CSSI) application subject to provisions under division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), whereas the over and adjacent station developments are to be delivered under a State Significant Development (SSD) subject to the provisions of part 4 of the EP&A Act.

1.2.1 Critical State Significant Infrastructure

The State Significant Infrastructure (SSI) planning approval process for the Sydney Metro West metro line, including delivery of station infrastructure, has been broken down into a number of planning application stages, comprising the following:

- Concept and Stage 1 CSSI Approval (SSI-10038) – All major civil construction works between Westmead and The Bays including station excavation, tunnelling and demolition of existing buildings (approved 11 March 2021)
- Stage 2 CSSI Application (SSI-19238057) – All major civil construction works between The Bays and Hunter Street Station (approved 24 August 2022)
- Stage 3 CSSI Application (SSI-22765520) – Tunnel fit-out, construction of stations, ancillary facilities and station precincts between Westmead and Hunter Street Station, and operation and maintenance of the Sydney Metro West line (under assessment, lodged).

1.2.2 State Significant Development Application

The SSD will be undertaken as a staged development with the subject Concept State Significant Development Application (Concept SSDA) being consistent with the meaning under section 4.22 of the EP&A Act and seeking conceptual approval for a building envelope, land uses, maximum building heights, a maximum gross floor area, pedestrian and vehicle access, vertical circulation arrangements and associated car parking. A subsequent Detailed SSDA is to be prepared by a future development partner which will seek consent for detailed design and construction of the development.

1.3 Purpose and scope

This Reflectivity Impact Assessment Report supports a Concept SSDA submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the EP&A Act. The Concept SSDA is made under section 4.22 of the EP&A Act.

This report has been prepared to specifically respond to the Secretary's Environmental Assessment Requirements (SEARs) issued for the Concept SSDA on 22 February 2022 which states that the environmental impact statement is to address the following requirements shown in Table 1-1.

Table 1-1 SEARs and where this is addressed in this SSD report

Key issue	SEARs	Addressed in
4. Environmental Amenity:	Assess amenity impacts on the surrounding locality, including lighting impacts, reflectivity, solar access, visual privacy, visual amenity, view loss and view sharing, overshadowing and wind impacts. A high level of environmental amenity for any surrounding residential or other sensitive land uses must be demonstrated.	Throughout report

This Reflectivity Impact Assessment Report assesses the proposal for any glare resulting from sun light glancing off the façade and causes an impact on vehicles and pedestrians moving around the site and/or nearby roads.

2 The site and proposal

2.1 Site location and description

The subject application is in the Parramatta CBD, in the City of Parramatta Local Government Area (LGA). It is within the city block bounded by George Street, Church Street, Smith Street, and Macquarie Street.

The site presents a 164m long frontage to Macquarie Street, 125m frontage to George Street, 48m frontage to Church Street, and 15.5m frontage to Smith Street (in the form of Macquarie Lane). The site location is shown in Figure 2-1 and Table 2-1.

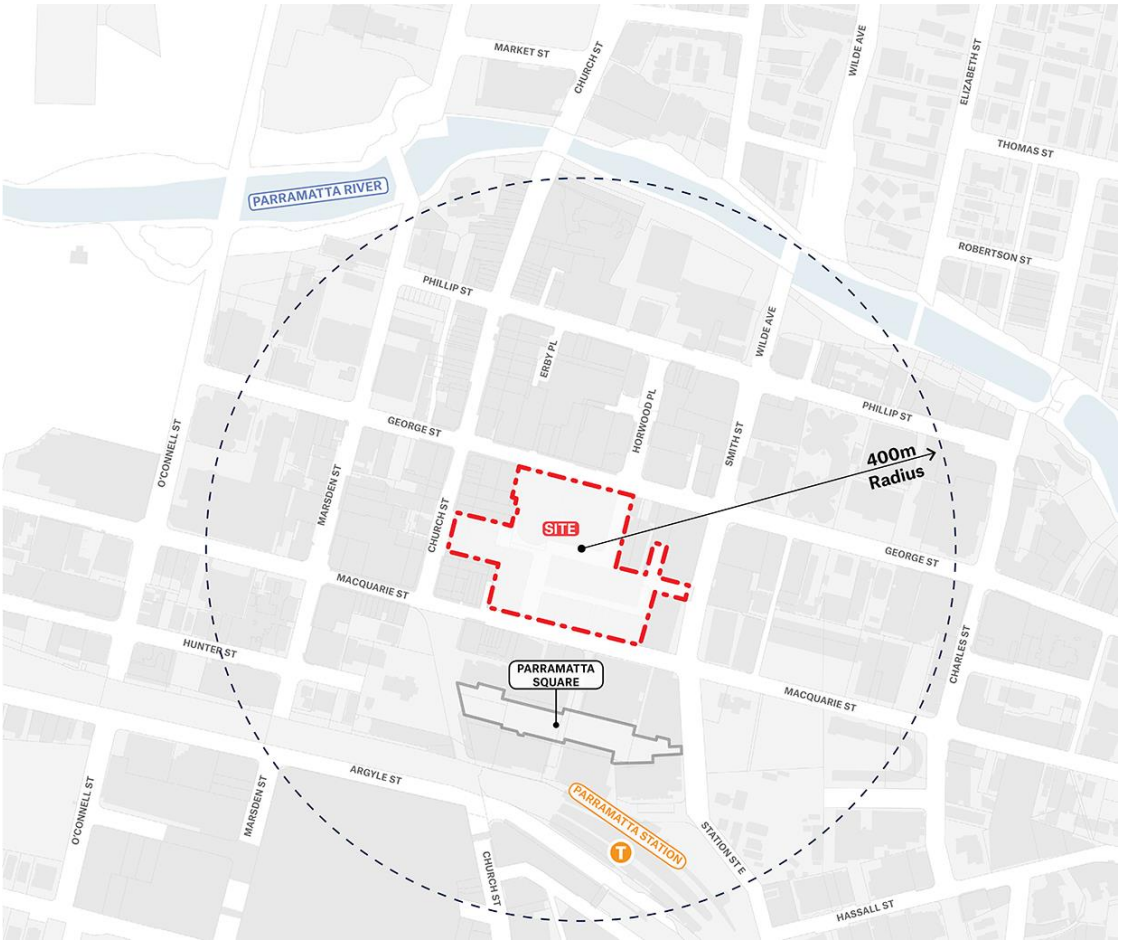


Figure 2-1 Parramatta metro station precinct location

As described in Table 2-1, the site comprises fourteen (14) different allotments of varying sizes. It is irregular in shape, with a total area of approximately 24,899m^2.

Table 2-1 Site legal description

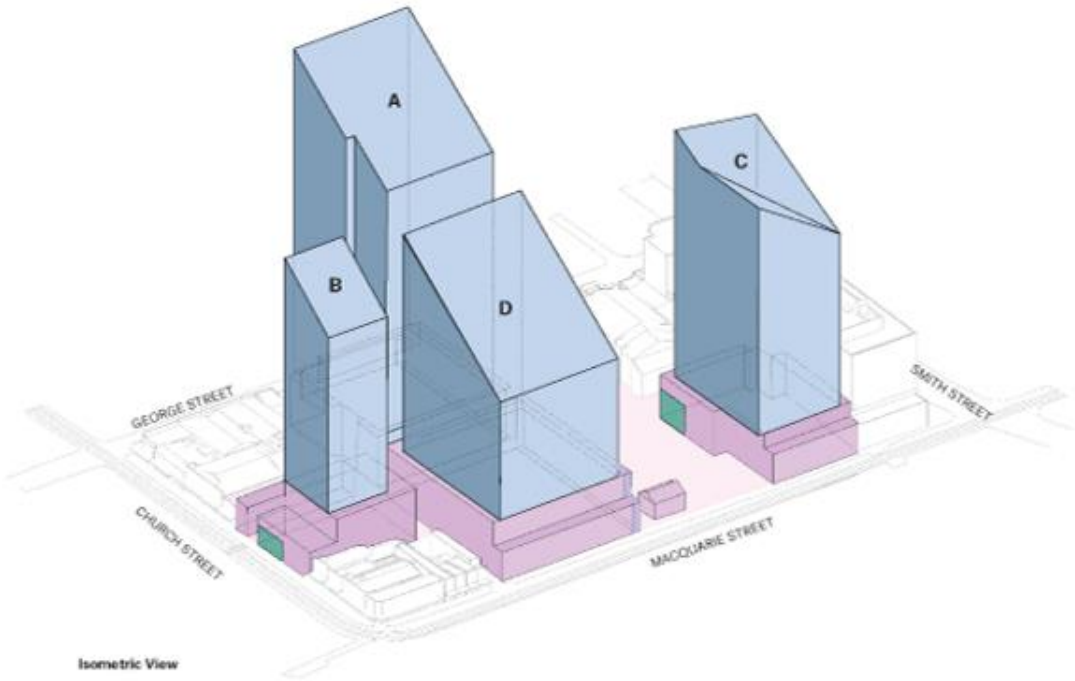
Street address	Legal description
41-59 George Street	Lot 10 in DP858392
45A George Street	Lot 2 in DP701456
61B George Street	Lot 1 in DP607181
71 George Street	Lot 100 in DP607789
220 Church Street	Lot 1 in DP1041242
222 Church Street	Lot 1 in DP702291
232 Church Street	Lot 1 in DP651992
236 Church Street	Lot 1 in DP128437
238 Church Street	Lot 2 in DP591454
48 Macquarie Street	Lot B in DP394050
58-60 Macquarie Street	Lot 1 in DP399104
62-64 Macquarie Street	Lot AY in DP400258
68 Macquarie Street	Lot 1 in DP711982
70 Macquarie Street	Lot E DP 402952
72 Macquarie Street	Lot 3 in DP218510
74 Macquarie Street	Lot H in DP405846

2.2 Overview of this proposal

The Concept SSDA will seek consent for four building envelopes as detailed in Table 2-2 and Figure 2-2.

Table 2-2 Parramatta metro station proposed development overview

Item	Description
Building use	**Building A:** Commercial and retail **Building B:** Residential and retail **Building C:** Commercial **Building D:** Commercial and retail
Building Height (Number of storeys)	**Building A:** 38 storeys **Building B:** 33 storeys **Building C:** 26 storeys **Building D:** 25 storeys
Gross Floor Area (m²)	**Building A:** 78,700 **Building B:** 20,000 **Building C:** 35,950 **Building D:** 55,350 **TOTAL: 190,000**
Car parking spaces	455



Legend

- Parramatta Station CSSI Approval - Includes structure and building infrastructure and space for lift cores, access, parking, retail and building services for future OSD & ASD
- OSD & ASD Concept SSD Building Envelope - Includes OSD & ASD Areas inside the CSSI 'shell' below ground and in the podium levels
- Metro Station Entry and Box (Indicative)
- 3m Podium Articulation Zone - refer to Design Guidelines.
- Heritage Interface Zone - refer to Design Guidelines.

Figure 2-2 Proposed Concept SSDA development and CSSI scope

3 Scope of assessment

The reflectivity assessment has been prepared generally in accordance with the method outlined by Hassall (1991) of the University of New South Wales, which has been widely used to assess reflections off building projects in Sydney.

The built form (mass/scale and orientation) and surrounding development is shown below in Figure 3-1 and Figure 3-2. This assessment only considers the potential reflectivity impacts from the development (shown in blue). The analysis assumes the facades are entirely glass without any obstructions by way of external elements to understand the risk of glare hazard on surrounding roads and pedestrians.

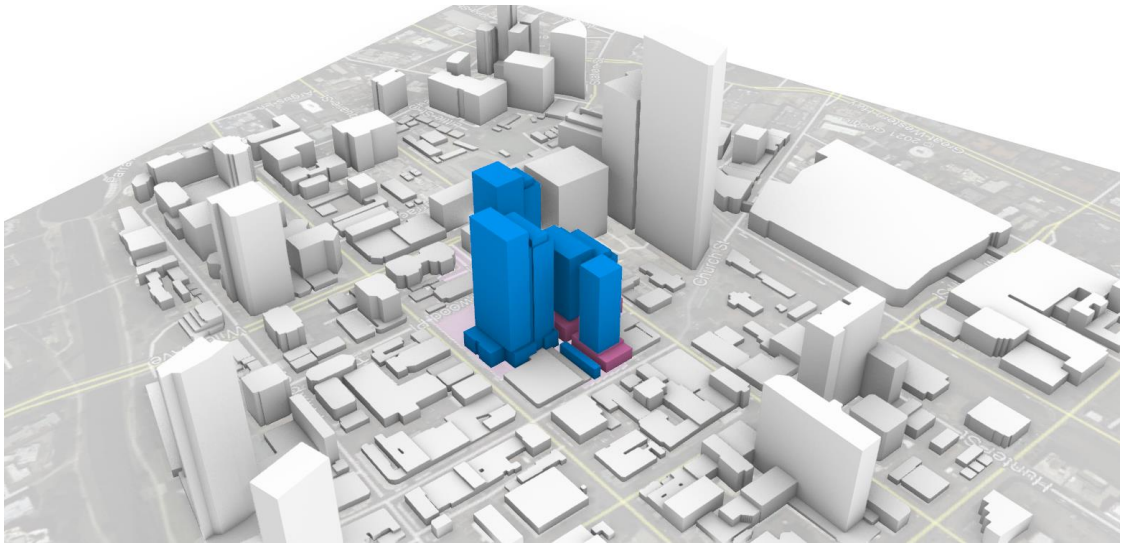


Figure 3-1 Site and surrounds model (viewed from the northwest)

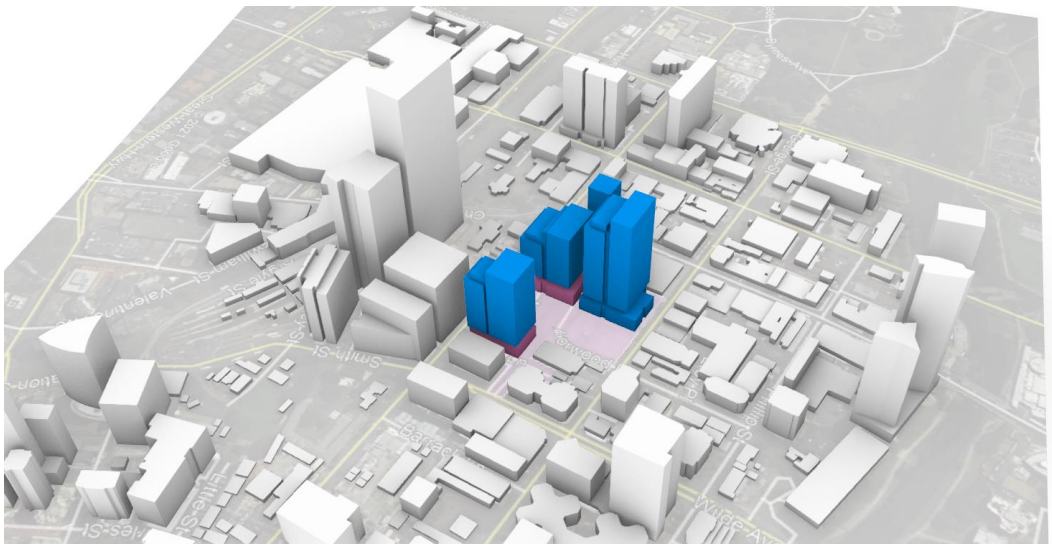


Figure 3-2 Site and surrounds model (viewed from the northeast)

3.1 Assessment criteria

The Parramatta metro station precinct is located within the City of Parramatta. The Parramatta Development Control Plan (DCP) 2011 Part 3 Development Principles Building Facades and Articulation outlines the following requirements with respect to reflected glare:

"Facade treatment and the design detail and construction contribute significantly to the way a building 'reads' from the street and to the character and continuity of the streetscape. The composition and detailing of the building facade also has an impact on the apparent bulk and scale of a building.

It is important when considering the design of new development that the predominant patterns, compositions and articulation of facades reinforces the character and continuity of the streetscape. This does not mean replicating the appearance of buildings. Contemporary design solutions based on sound design principles, which reinforce and make reference to the underlying elements that create the character of the area are encouraged.

New buildings and facades should not result in glare that causes discomfort or threatens safety of pedestrians or motorists. A Reflectivity Impact Assessment Report that analyses the effects of potential glare from the proposed new development on pedestrian and motorists may be required."

4 Assessment

4.1 Glare characteristics

The term “glare” describes adverse visual effects caused by large contrasts of luminance in the visual field. As such, glare is likely more significantly felt at times of low background luminance (e.g., during dawn and dusk hours) as compared to those of high background luminance (e.g., high noon), even if the amount of solar reflections from building surfaces remain the same (Figure 3-1).

There are many different types of glare, the impacts of which may range from causing mild discomfort to temporary blindness. For this project, the type of glare of concern is “veiling glare”, also known as “disability glare”. It is caused by multiple reflections and the scattering within the eye by direct light from a bright source. It produces a perception that a thin veil has been overlaid on the visual scene, which can reduce the luminance contrast, impair visual tasks, and at times cause temporary blindness.

It is critical that sensitive receptors’, and particularly that of drivers’, views are unaffected by disability glare, as this has the potential to cause road accidents. The Hassall methodology focuses on prediction of this glare by calculating veiling luminance (LV) (refer to section 4.2.1).

Figure 4-1 Illustration of potential disability glare (CBS58, 2020)

4.2 Methodology

The method for this study is based on David N. H. Hassall’s (1991) ‘Reflectivity: Dealing with rogue solar reflections’ (Hassall’s Method), which is widely used to assess reflections off building projects in Sydney, and included:

- Performed a high-level desktop assessment of at-risk drivers with the potential to experience disability glare form the proposed developed by assessing site aerial image.

- Created a simplified three-dimensional (3D) model of the proposed building and surrounding context, including buildings, roads, topography and any other significant structure that may impact the reflectivity of the site (refer to Figure 3-2). The model excludes small scale details such as joints, any expressed framing profiles, downpipes, etc. as they subtend insufficient angles in the visual field to reflect a large enough portion of the sun disk to cause unacceptable glare.
- Selectively identified sensitive receptor (driver) locations based on possible routes of approach and retreat from the development.
- Undertook parametric modelling (refer to section 4.2.3) to assess reflectivity impacts of the proposed development on sensitive receptors.
- When the sun is reflected towards any observer, the equivalent LV in the eye of the observer is calculated and evaluated against the maximum allowed level of 500cd/m^2, as per Hassall's Method. This involves calculations of the strength of solar illumination, the position of the sun, the apparent position of the sun reflected in the façade, and the reflected solar illumination received by the observer.
- Undertook a series of sensitivity studies to assess effectiveness of various mitigative measures in reducing disability glare.

4.2.1 Calculating veiling luminance

LV is a parameter used to predict veiling glare (Van Derlofske, n.d.). Hassall (1991) proposed a workflow to estimate this by tracking solar geometry, estimating sun intensity, establishing actual façade reflectance, and numerically calculating a measure for the veiling effect. Veiling luminance is measured in cd/m^2 (candela per metre squared) and is a representation of apparent brightness to the human eye. The veiling luminance accounts for the angular distance of the glare source from the centre of focus.

4.2.2 Assumptions and limitations

The analysis and results presented in this report are only accurate and valid for the design assessed.

The following assumptions have been made:

- the built form (mass/scale and orientation) and surrounding development was developed from version 38 (V38) of the Parramatta metro station federated building information model (BIM)
- surface roughness and small details have a negligible impact
- all facades are glazed
- drivers are looking ahead in the direction of the road they are driving on
- assessment heights are based on the assumed eye level of the person:
    - light rail driver – 2.75m
    - vehicle driver – 2m
    - pedestrian – 1.5m.
- no reflections from other buildings within the vicinity
- no obstructions from the streetscape (e.g., vegetation, signage, etc.) within the vicinity
- reflections from construction methods (e.g., metal rivets, etc.) are not considered

- cloud coverage is not included to assess the worst-case scenarios
- only select routes are assessed
- disability glare for pedestrians can be managed by them moving and looking away from the source
- base case assumes sun visors are not used, determines the worst-case scenario
- for the base case, the Visible Light External Reflectance (VLR) is 20%, with an angular specular reflectivity specification that changes with the angle of incidence as shown in Table 4-1 (note, 'I' is the angle of incidence and S_R is the angle of specularity)

Table 4-1 Assumed reflectivity of glazed surfaces with angle of incidence

I (deg)	0	10	20	30	40	50	60	70	80
S_R	0.19	0.183	0.181	0.184	0.194	0.212	0.247	0.332	0.542

Source: Hassall, 1991

4.2.3 Parametric modelling

The method outlined by Hassall (1991) was implemented in a parametric modelling (Grasshopper and Ladybug (version 1.2.0) within Rhino 7) framework to consider the shielding effects of surrounding buildings, and hence provide a more realistic approach. Parametric modelling also enables the assessment of different days and times throughout the year to be automated. Thus, allowing the assessment at one hour intervals throughout the entire year.

Grasshopper is a visual programming language and environment that runs within the Rhinoceros 3D computer-aided design (CAD) application. Ladybug imports standard EnergyPlus Weather files (.EPW) into Grasshopper. It provides a variety of two-dimensional (2D) and three-dimensional interactive climate graphics that support the decision-making process during the early stages of design. Ladybug also supports the evaluation of initial design options through solar radiation studies, view analyses, sunlight-hours modelling, and more. Integration with visual programming environments allows instantaneous feedback on design modifications and a high degree of customization.

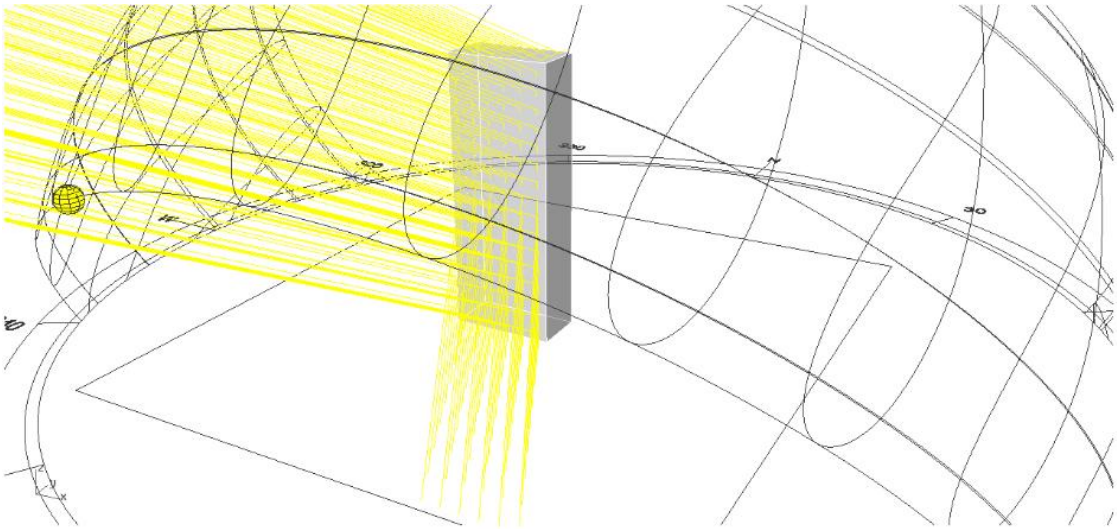


Figure 4-2 Ray tracing within Rhino using Grasshopper/Ladybug Tools

4.2.4 Assessment criteria

The impact of glare is subjective as it varies for different people, what may be considered as mildly annoying of one person could cause temporary blindness in another. As such, Hassall (1991) proposed a veiling luminance limit of 500 cd/m², based on the Holladay formula, would be a practical and acceptable amount of reflected solar glare to which a driver should be exposed. Where this is exceeded, solar reflections are considered as potentially causing disability glare. This approach has been adopted in the present assessment, as accepted as industry best practice.

4.3 Impact assessment

4.3.1 Rationale for route definition

There are many approach routes to Parramatta metro station (Figure 4-3), including personal vehicles, trains, buses, and the light rail. Assessment routes were selected based on these approach routes and their likelihood of being impacted by reflections from the proposed development on a solar diagram for the site. The selected routes (Figure 4-4) are:

1. Northwest along Macquarie Street – assessing the impacts on the light rail
2. Southeast along Macquarie Street – assessing the impact on the light rail
3. South along Church Street – assessing the impacts on the light rail
4. Southeast along Macquarie Street – assessing the impact on private vehicles
5. Northwest along George Street – assessing the impact on private vehicles
6. Southeast along George Street – assessing the impact on private vehicles
7. South along Wild Avenue/Smith Street – assessing the impact and private vehicles.

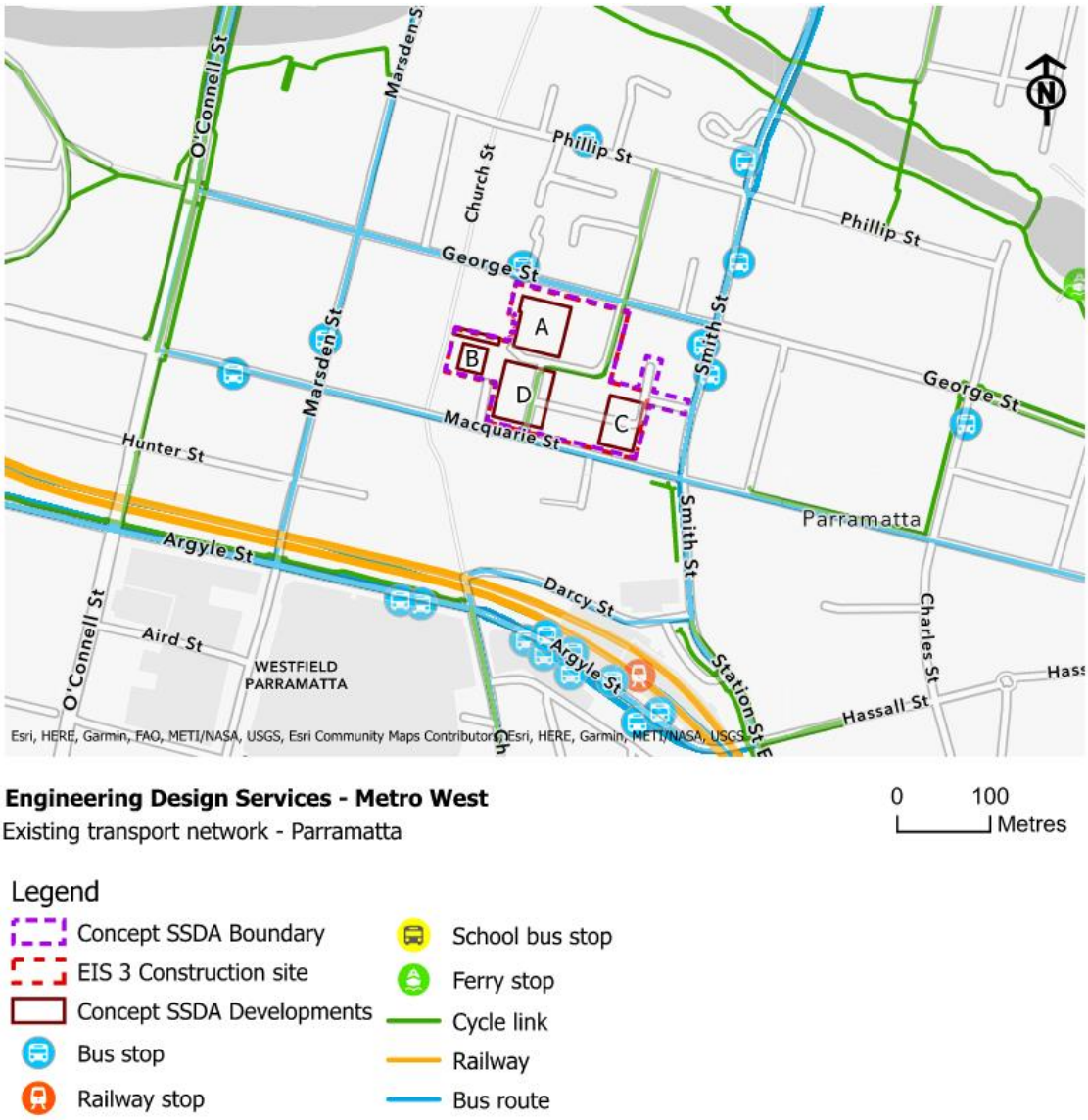


Figure 4-3 Road and public transport network around Parramatta metro station

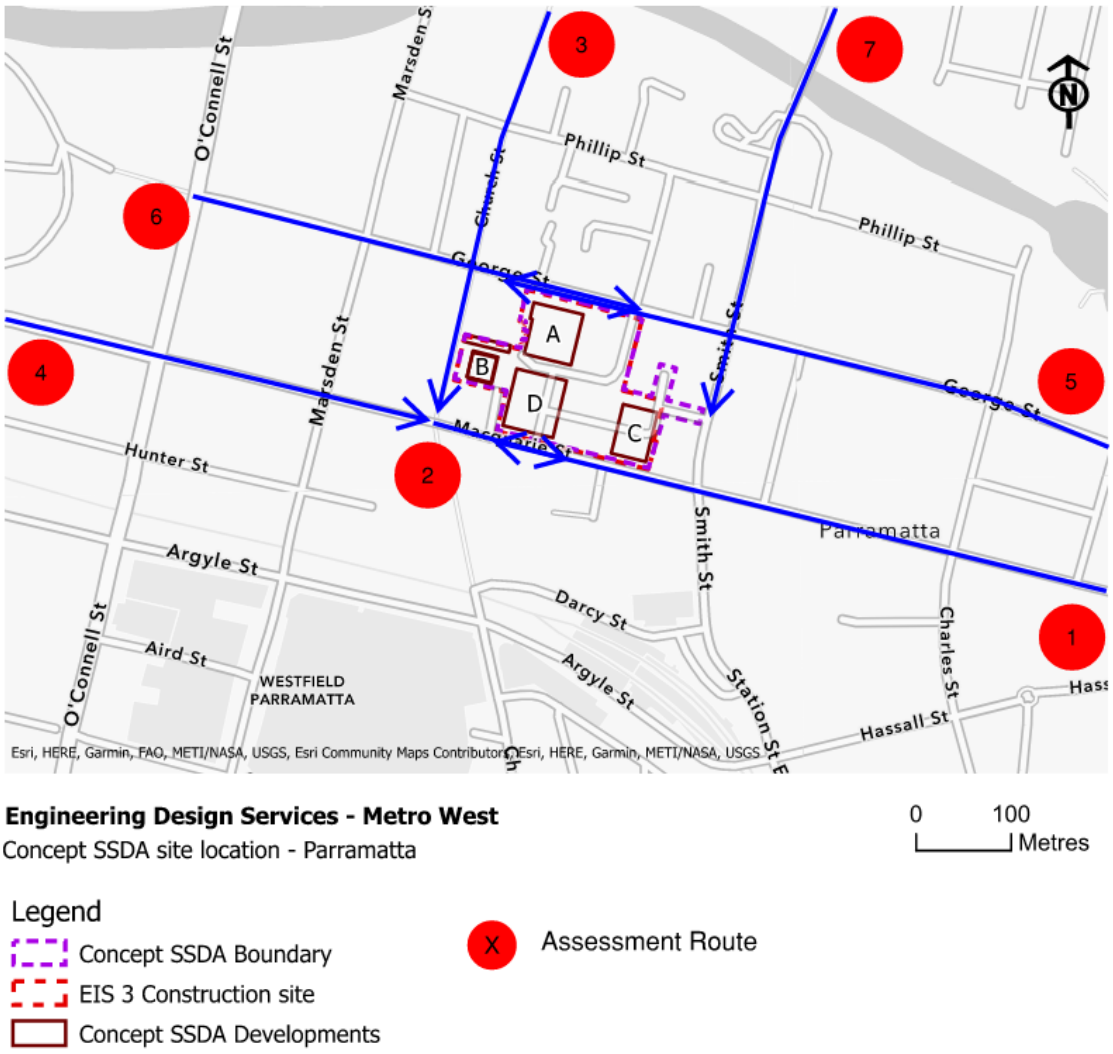


Figure 4-4 Assessment routes (routes are shown in blue)

For each assessment route, 11 locations were selected to be assessed. These assessment locations are shown in Figure 4-5 to Figure 4-11 and the locations are labelled 1 through to 11 (with 1 located the furthest from the development and 11 being the closest).

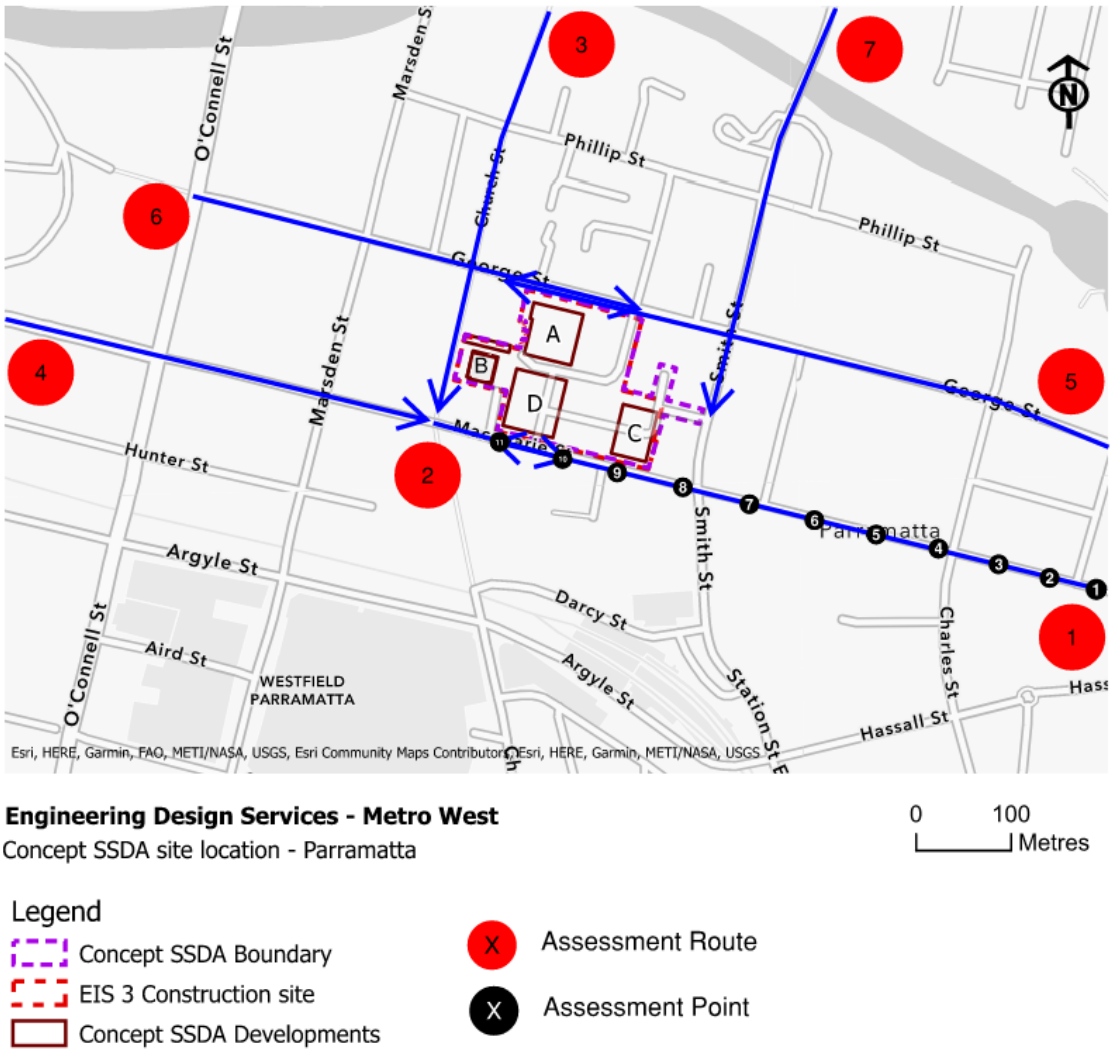


Figure 4-5 Assessment locations (shown in black) for light rail operators travelling northwest along Macquarie Street (route 1)

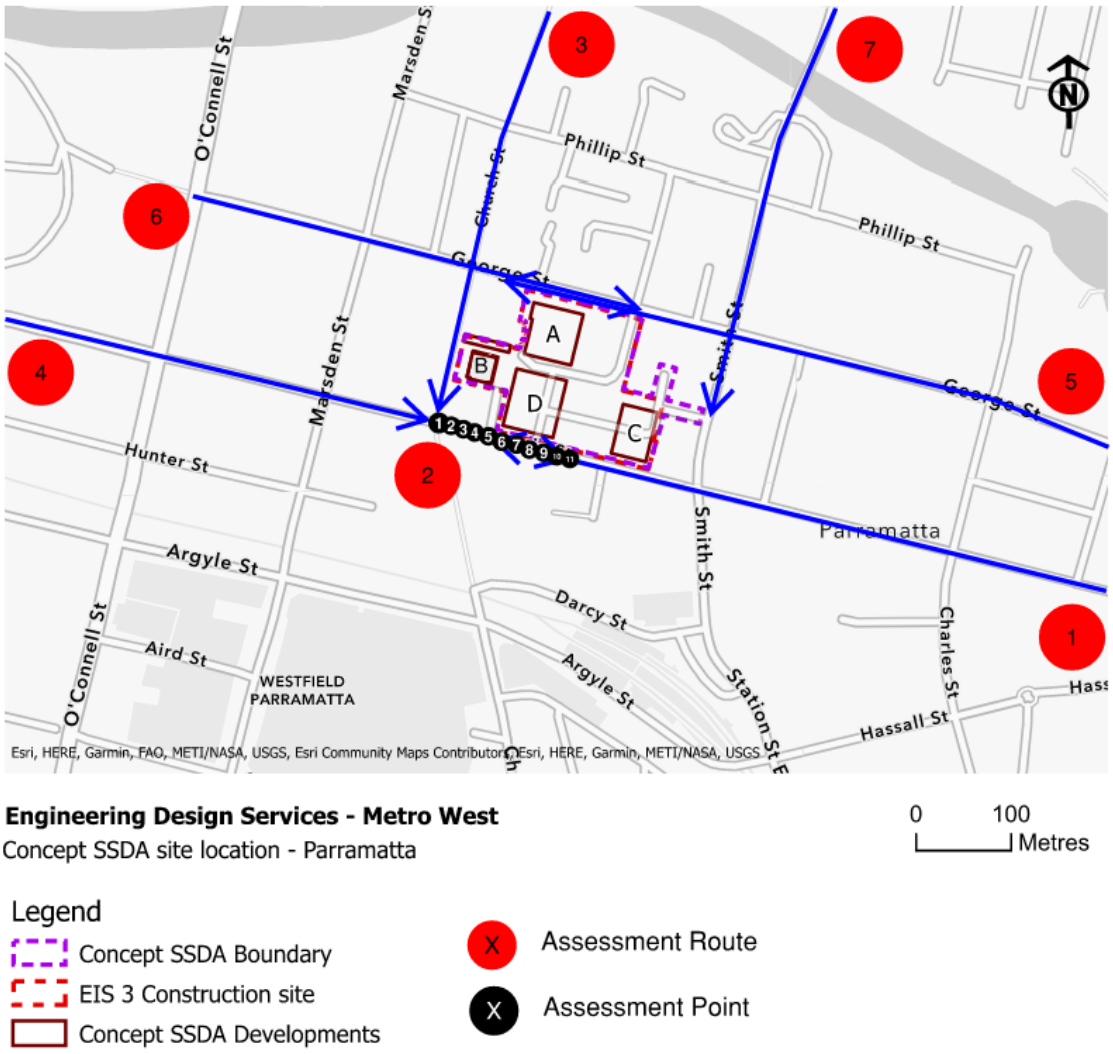


Figure 4-6 Assessment locations (shown in black) for light rail operators travelling southeast along Macquarie Street (route 2)

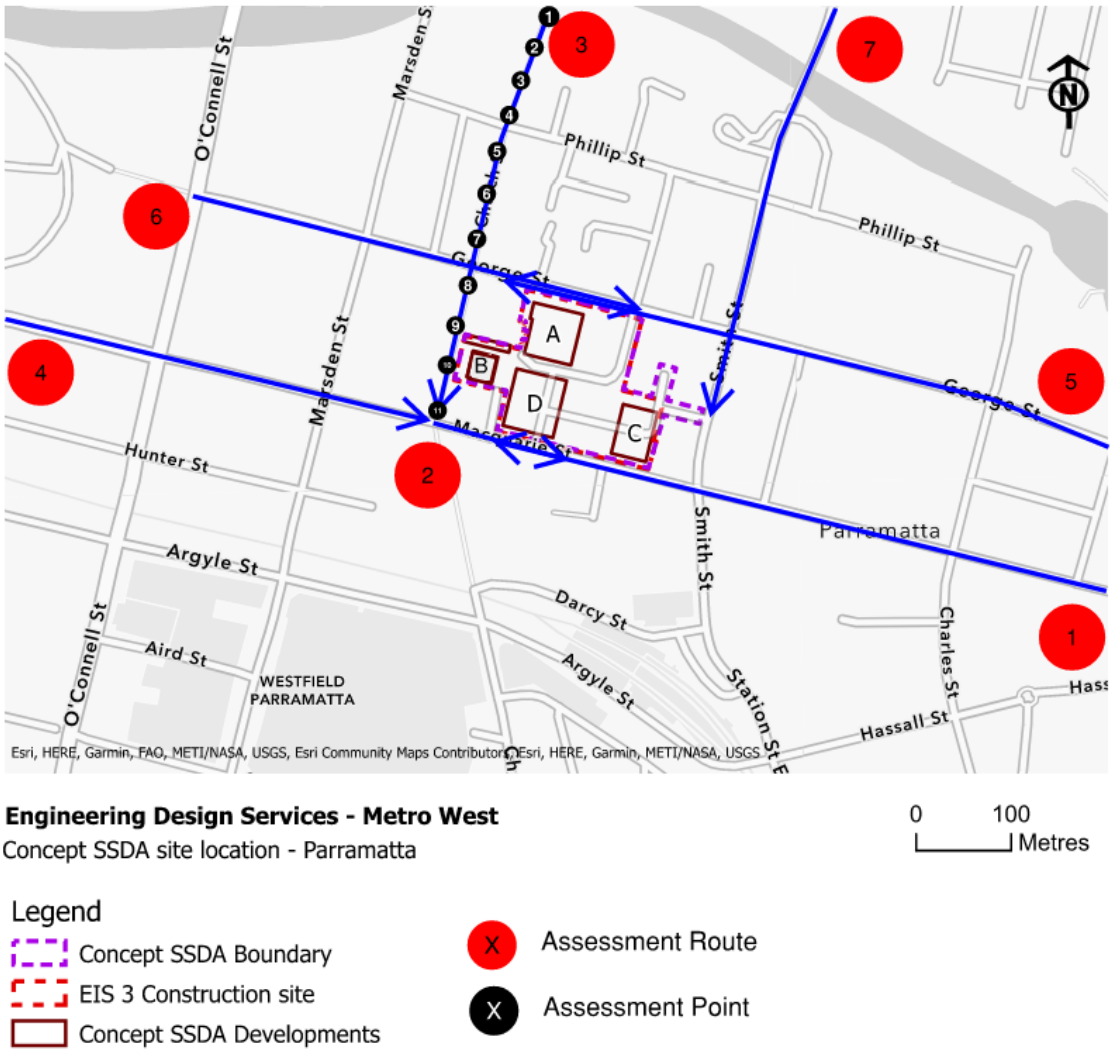


Figure 4-7 Assessment locations (shown in black) for light rail operators travelling south along Church Street (route 3)

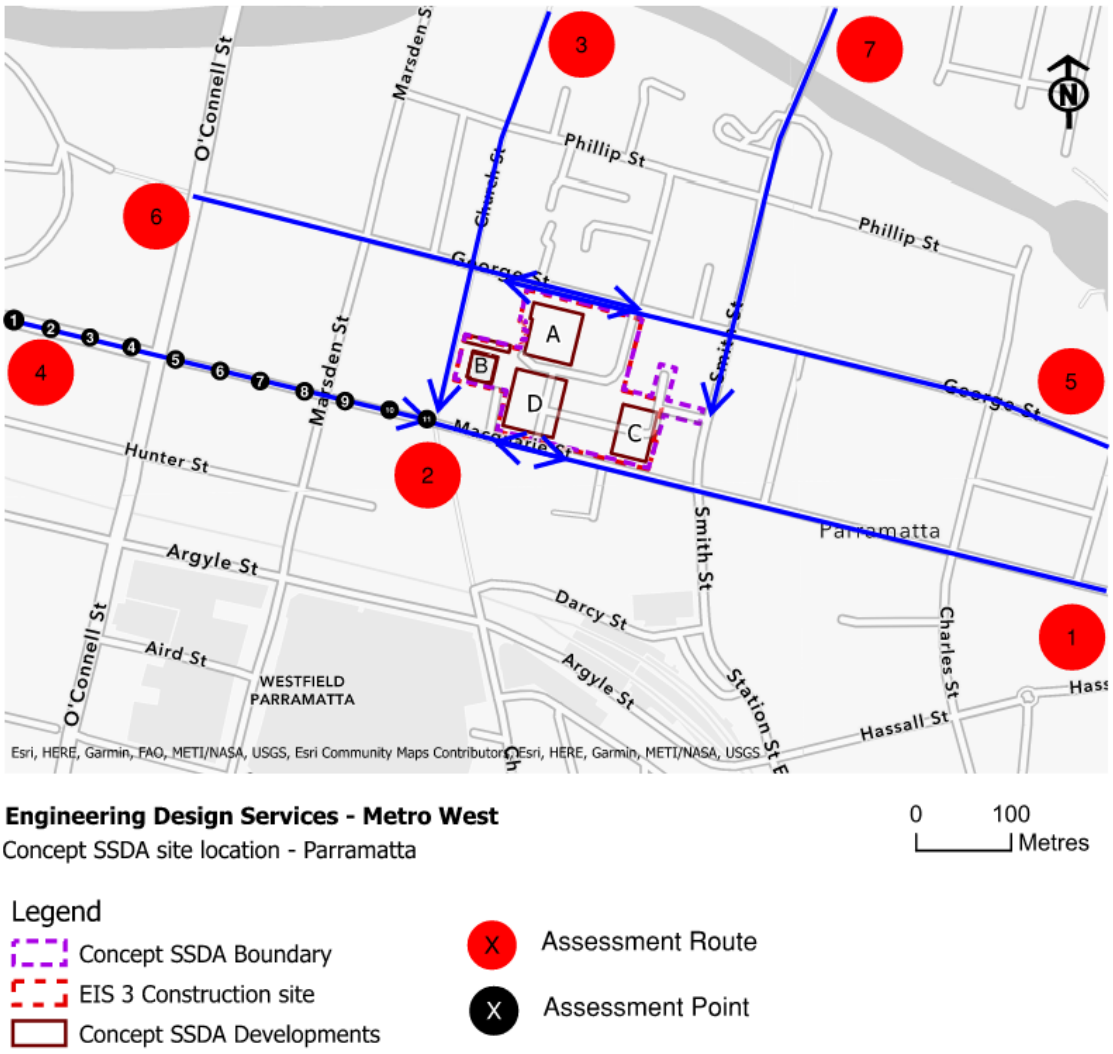


Figure 4-8 Assessment locations (shown in black) for vehicles travelling southeast along Macquarie Street (route 4)

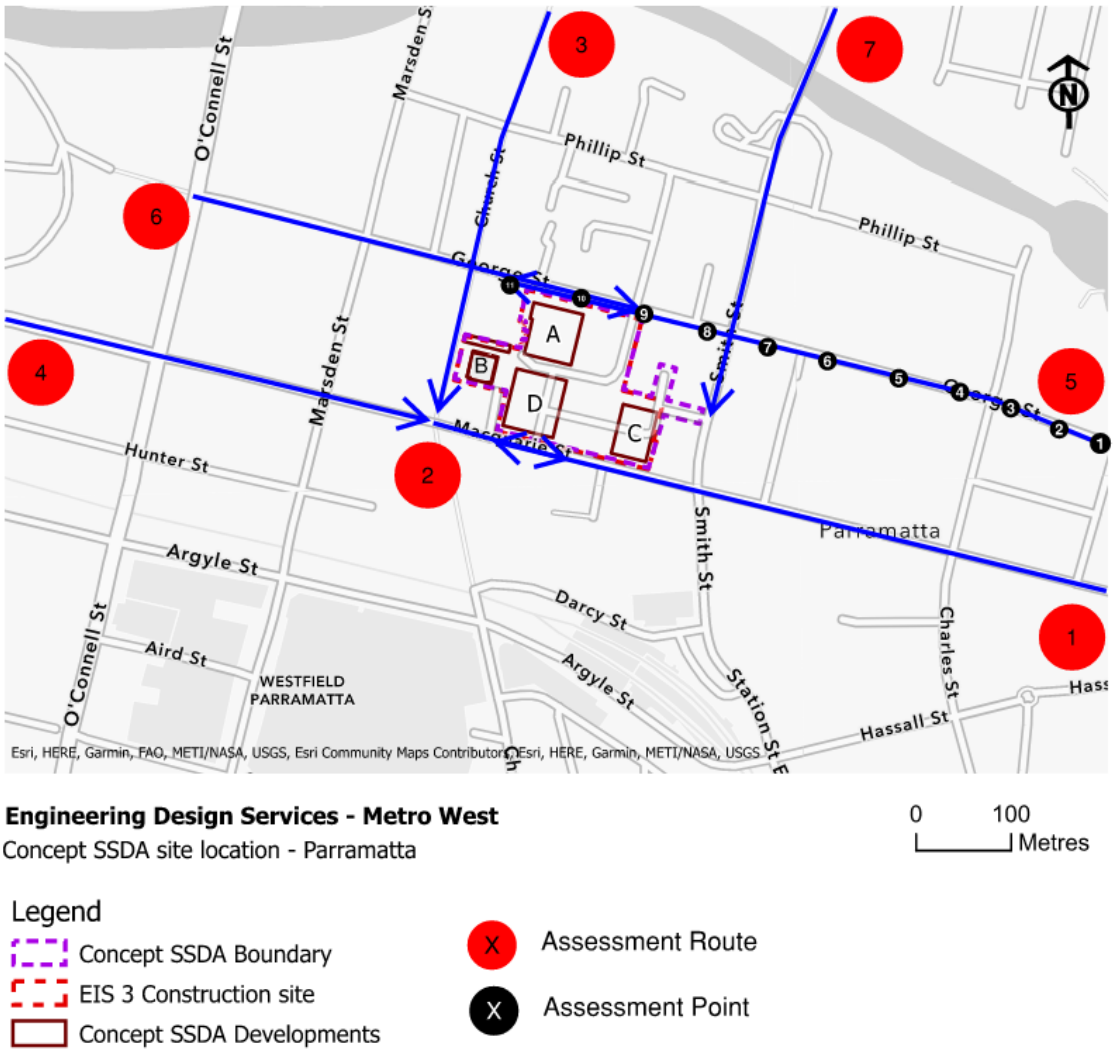


Figure 4-9 Assessment locations (shown in black) for vehicles travelling northwest along George Street (route 5)

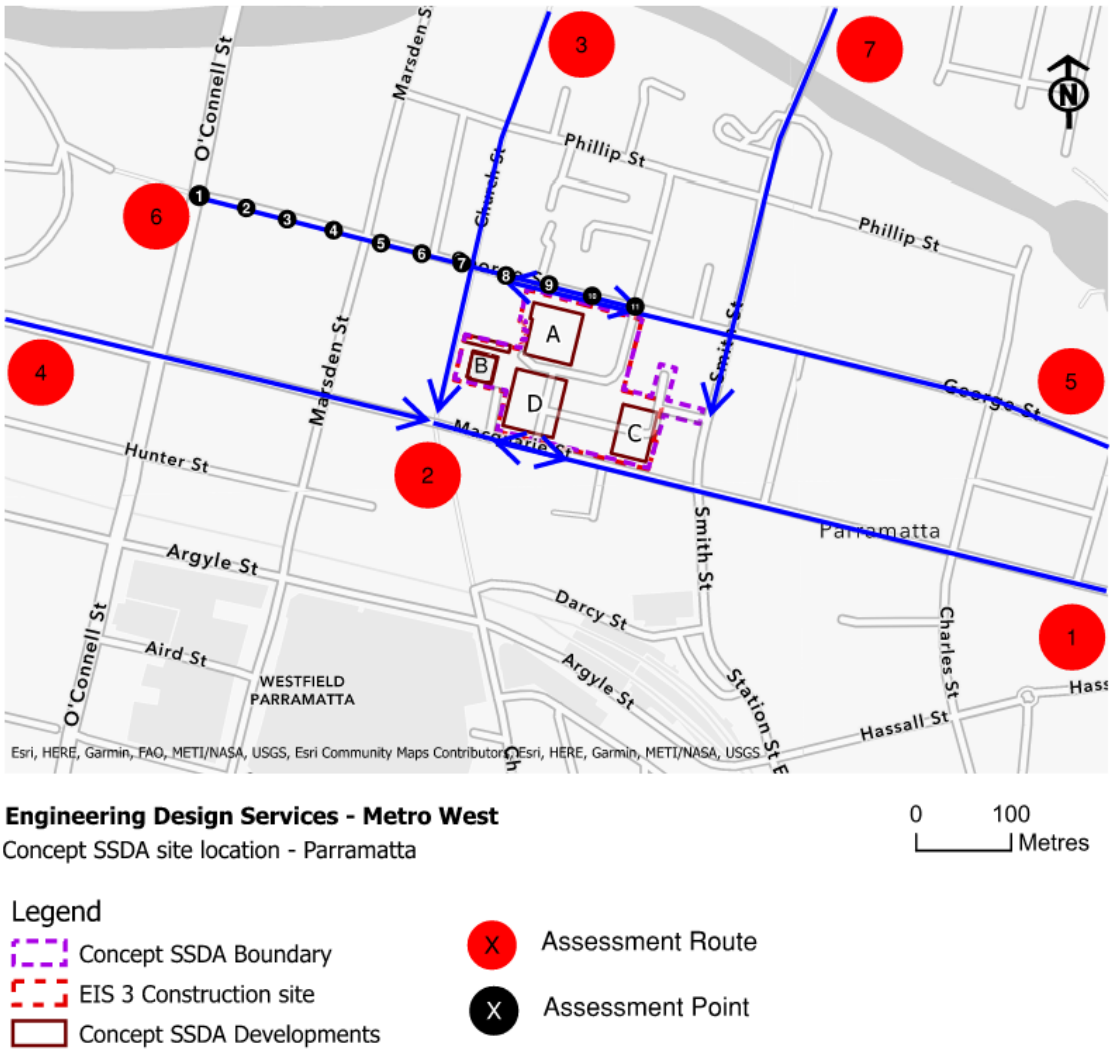


Figure 4-10 Assessment locations (shown in black) for vehicles travelling southeast along George Street (route 6)

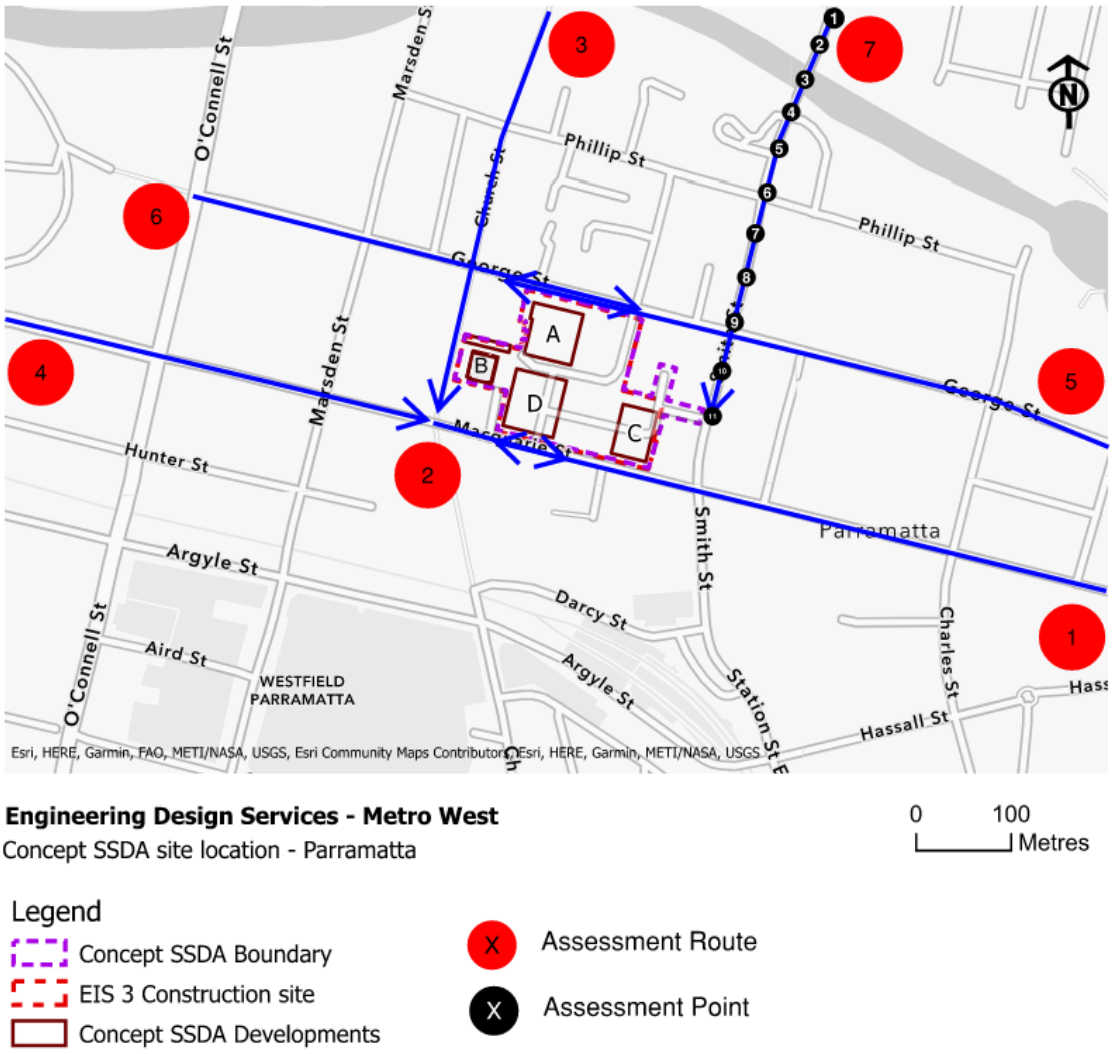


Figure 4-11 Assessment locations (shown in blacks) for vehicles travelling south along Wild Avenue/Smith Street (route 7)

4.3.2 Rationale for pedestrian locations

As part of the proposed precinct, there will be a large public domain to activate the development. Due to this large public domain, it is expected that pedestrians will be walking around the area looking in all directions and therefore may be impacted by glare from the building facades. Six locations were assessed with various views of the façade (refer to Figure 4-12 where view one is shown in black, view two is shown in red, view three is shown in blue, view four is shown in green, view five is shown in orange, and view six is shown in purple). These locations, and directions of view, were assessed to give an indication of the pedestrian experience. However, we expect the impact of disability glare to be low given their ability to look away from problematic glare.

Figure 4-12 Pedestrian locations and directions of view

4.4 Results

The base case assumes that standard glazing is used for all façades and the individual results of these assessments is provided in Appendix A. A summary of these results is provided in Table 4-2.

Table 4-2 Summary of reflectivity impacts for the base case

Route/ pedestrian location	Maximum veiling luminance [cd/m^2]	Maximum number of hours LV is at risk of exceeding 500 cd/m^2 in a day	Comment
Route 1	12,640	2	Some risk of disability glare in the early morning and late afternoon
Route 2	2,150	1	Some risk of disability glare in the early morning and late afternoon
Route 3	0	0	No disability glare risks found
Route 4	5,480	2	Some risk of disability glare in the early morning, mid-afternoon and late afternoon
Route 5	5,700	1	Some risk of disability glare in the early morning and late afternoon
Route 6	5,710	3	Some risk of disability glare in the early morning and late afternoon

Route/ pedestrian location	Maximum veiling luminance [cd/m^2]	Maximum number of hours LV is at risk of exceeding 500 cd/m^2 in a day	Comment
Route 7	0	0	No disability glare risks found
Pedestrian 1	25,420	1	Some risk of disability glare in the late afternoon
Pedestrian 2	430	0	No disability glare risks found
Pedestrian 3	370	0	No disability glare risks found
Pedestrian 4	320	0	No disability glare risks found
Pedestrian 5	570	1	Some risk of disability glare in the late afternoon
Pedestrian 6	870	1	Some risk of disability glare in the mid-morning

4.5 Mitigation measures

Section 4.4 highlighted expected reflectivity issues from the proposed development with a fully glazed façade. Therefore, mitigation strategies will be required to reduce the risk of disability glare on nearby sensitive receptors. Some common mitigation measures include:

- Using a less reflective glazing – reduces the amount of light that is reflected from the façade
- Different material – using a non-reflective material or materials with increased roughness, will help to control the impact of reflections
- Shielding the façade – introducing a non-reflective structure, design, or landscaping that shields the glazed façade will help to control the impact of reflections
- Changing built form – incorporating different built forms can help disperse light reflections (e.g. articulation of the facades, or reorientation of the facades, etc.). Note that concave built forms should be avoided as these will instead concentrate sunlight, exacerbating the glare risk.

The use of a sun visor can also be useful to mitigate the effects of reflections from the tall buildings as it blocks out the upper portion of the building. However, it cannot be used to assess compliance with any criteria as it cannot be expected that all vehicle drivers and train operators will use their sun visors (or have it in a position to block glare as soon as it occurs as there is a delay between the initial glare impact and someone deploying their sun visor). However, it is provided for reference to determine which areas of the facades provide the biggest impact if sun visors are used.

4.6 Sensitivity studies

This assessment included two sensitivity studies to assess the reflectivity impacts for different scenarios:

- Study One – using a sun visor
- Study Two – using a lower reflectivity glazing and a sun visor.

The sensitivity study results assume that drivers are using a sun visor and is assessed as per Hassall's (1991) alterations to account for a sun visor. Study two also assumes that the glazing is designed with a lower reflectivity and angular specularity, refer to Table 4-3 (note 'I' is the angle of incidence and S_R is the angular specularity)

Table 4-3 Assumed reflectivity of glazed surfaces with angle of incidence

I (deg)	0	10	20	30	40	50	60	70	80
S_R	0.084	0.084	0.085	0.087	0.093	0.111	0.158	0.276	0.542

Individual results for study one and study two are shown in Appendices B and C, respectively, with a comparison of the summary results shown in Table 4-4.

Table 4-4 Summary of the reflectivity impacts for the two sensitivity analyses

Route/ pedestrian location	Maximum veiling luminance [cd/m^2]			Maximum number of hours LV is at risk of exceeding 500 cd/m^2 in a day			Comment
	Base case	Study one	Study two	Base case	Study one	Study two	
Route 1	12,640	12,640	5,620	2	1	1	Some risk of disability glare in the early morning and late afternoon
Route 2	2,150	0	0	1	0	0	Some risk of disability glare in the early morning and late afternoon
Route 3	0	0	0	0	0	0	No disability glare risks found
Route 4	5,480	5,480	2,470	2	1	1	Some risk of disability glare in the early morning, mid-afternoon and late afternoon
Route 5	5,700	5,700	2,570	1	1	1	Some risk of disability glare in the early morning and late afternoon
Route 6	5,710	5,710	2,580	3	3	2	Some risk of disability glare in the early morning and late afternoon
Route 7	0	0	0	0	0	0	No disability glare risks found
Pedestrian 1	25,420	N/A	11,350	1	N/A	1	Some risk of disability glare in the late afternoon
Pedestrian 2	430	N/A	200	0	N/A	0	No disability glare risks found
Pedestrian 3	370	N/A	170	0	N/A	0	No disability glare risks found
Pedestrian 4	320	N/A	150	0	N/A	0	No disability glare risks found
Pedestrian 5	570	N/A	260	1	N/A	0	Some risk of disability glare in the late afternoon
Pedestrian 6	870	N/A	400	1	N/A	0	Some risk of disability glare in the mid-morning

5 Conclusion

A reflectivity analysis has been carried out assessing the potential for hazardous glare from the proposed development at Parramatta metro station.

The method published by Hassall (1991) was used, with local solar charts used to calculate veiling luminance as a measure of glare. Veiling luminance was calculated at discrete points, representative of sensitive receptors (light rail operators, drivers, pedestrians) traversing routes within the vicinity of the development. A conservative approach has been considered by assuming entirely glazed facades without external shading elements on the façade and future development that might otherwise shield glare. For all assessments undertaken, a veiling luminance limit of 500cd/m^2 was adopted as the acceptable amount of reflected solar glare to which a driver should be exposed.

It was found that five of the proposed routes had assessment locations that were expected to exceed the 500cd/m^2 limit at points along the route. The routes that are expected to pose a glare risk are:

- Route 1: Light rail operators travelling northwest along Macquarie Street
- Route 2: Light rail operators travelling southeast along Macquarie Street
- Route 4: Drivers travelling southeast along Macquarie Street
- Route 5: Drivers travelling northwest along George Street
- Route 6: Drivers travelling southeast along George Street.

In addition, six pedestrian locations were tested in the public domain for pedestrians looking in various directions. With standard glazing, pedestrians at 1, 5 and 6 were found to have the potential to experience disability glare (LV exceeding 500cd/m^2) due to the north-facing podium level glazing of the northern most building. However, the risk of glare impact on pedestrians is considered to be low as they can move or look away from the façade.

As part of this assessment, sensitivity studies were also undertaken to determine effectiveness of using a sun visor and combining a sun visor with lower reflective glazing. It was found that both measures will reduce the disability glare risks but may not be sufficient to eliminate them. Using sun visors, the expected number of exceedance hours for the worst-affected sensitive receptor on Route 6 reduced from 150 hours to 148. However, the maximum LV expected to be experienced along all routes did not decrease. Using a combination of a sun visor and a lower reflective glazing, the expected number of exceedance hours for the worst-affected sensitive receptor on Route 6 reduced from 150 hours to 87. In addition, the maximum veiling luminance expected to be experienced along all routes decreased from 12,640cd/m^2 to 5,620cd/m^2.

It is recommended that mitigative measures are applied to minimise the glare risk to sensitive receptors near the proposed development. The following are suggested as effective mitigative measures:

- using a less reflective glazing
- different material
- shielding the façade
- changing built form (e.g. more articulation, angles of the building to minimise sun reflections, etc.).

These mitigation measures will be considered and analysed in future Detailed SSDAs for the final building design.

6 References

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Appendix A Results standard glazing

Results presented in this appendix are for assessments assuming that all facades are glazed using standard glazing (section 4.4).

A.1 Route 1

This route was assessed for light rails travelling northwest along Macquarie Street.

Based on the assessment, numerous exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur along route 1 (refer to Table A-1). These were typically found to occur in the early morning summer and spring and late afternoon in autumn and spring.

View of the assessed facades and their veiling luminance are shown in Figure A-1 to Figure A-9 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-1 Reflectivity impacts on light rail operators travelling northwest along Macquarie Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	12	• Early morning in October • Late afternoon in March and September	2,310
2	11	• Early morning in February and November • Late afternoon in March and September	2,630
3	22	• Early morning in October and November • Late afternoon in March and September	12,640
4	51	• Early morning in February, October, and November • Late afternoon in March and September	9,730
5	42	• Early morning in January, February, and October • Late afternoon in March and September	7,160
6	17	• Late afternoon in March, September, and October	4,990
7	50	• Early morning in February, October, and November • Late afternoon in March, September, and October	3,170
8	4	• Late afternoon in March and October	660
9	0	• Not applicable	450
10	0	• Not applicable	0
11	0	• Not applicable	0

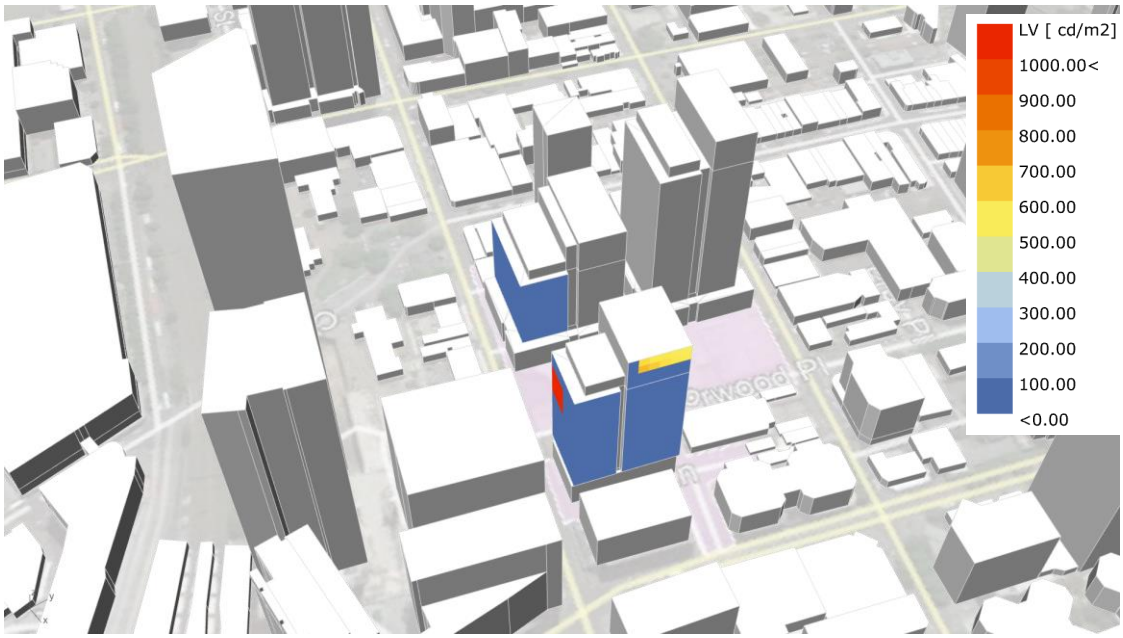

Figure A-1 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

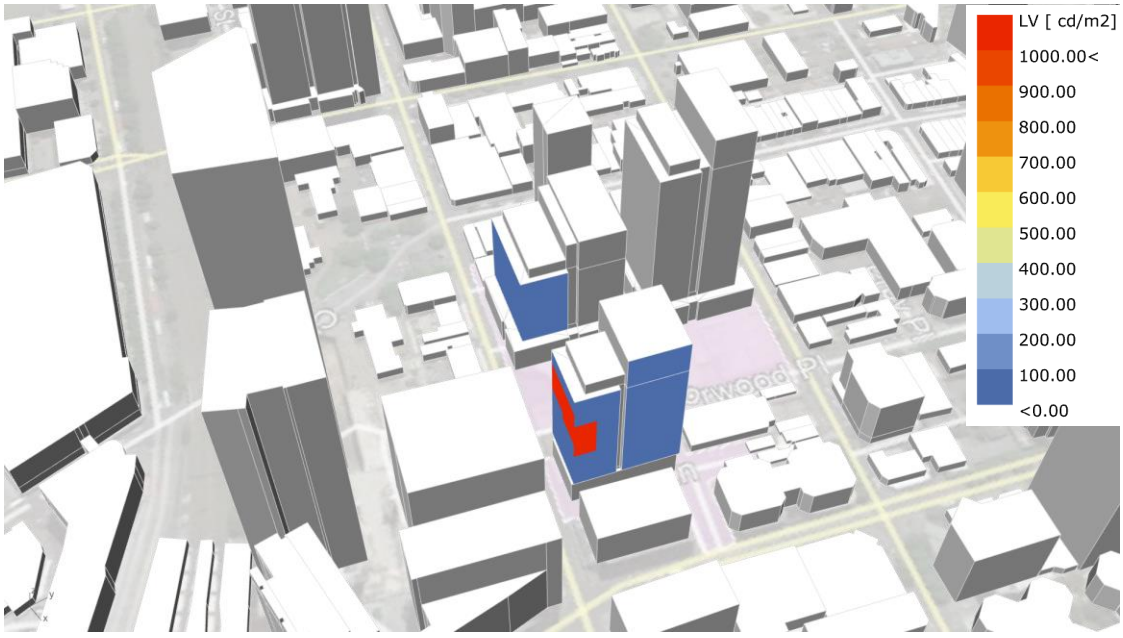

Figure A-2 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

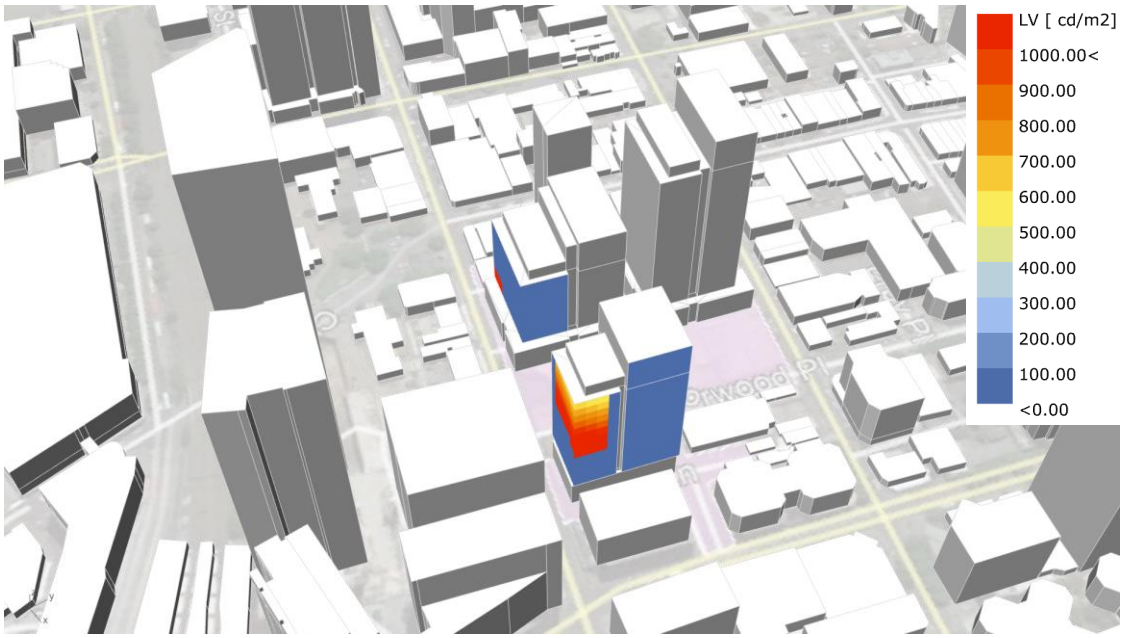

Figure A-3 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

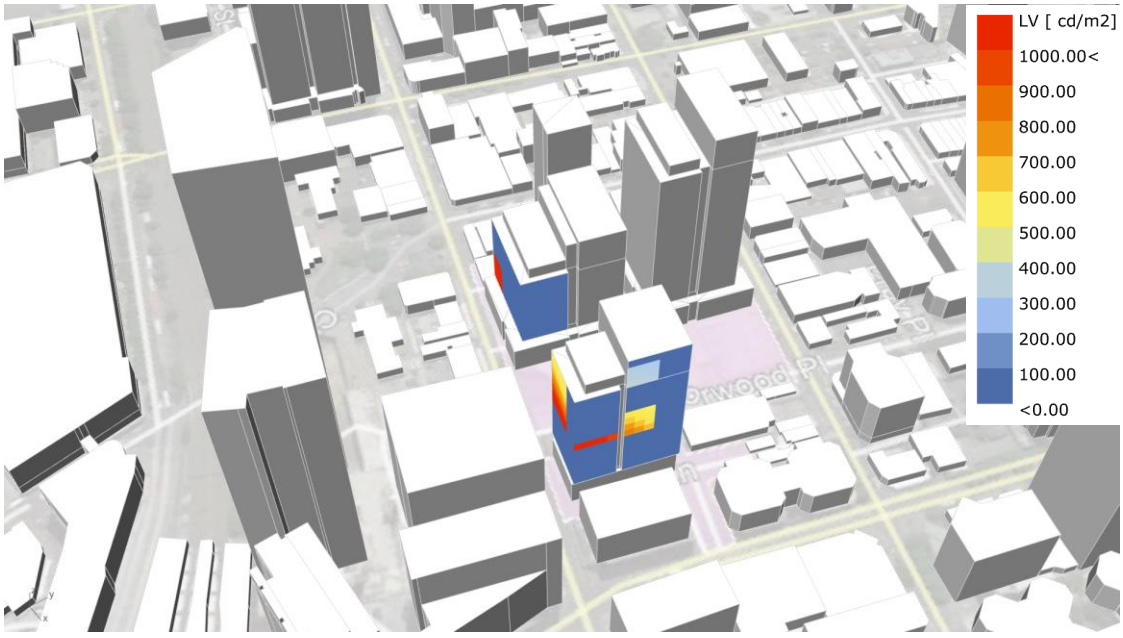

Figure A-4 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

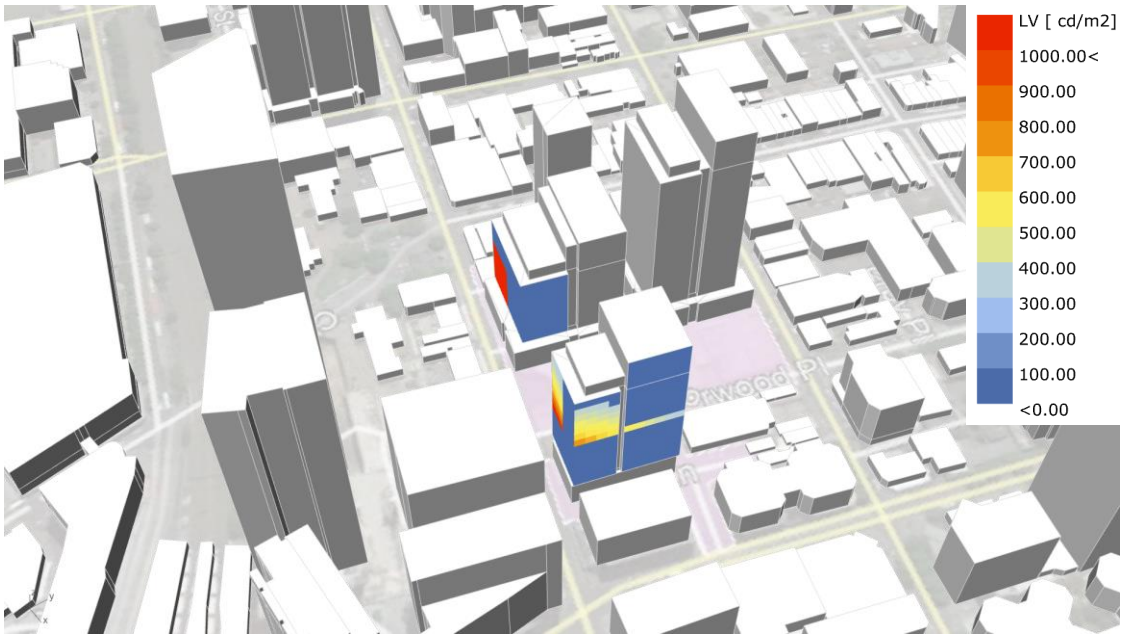

Figure A-5 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

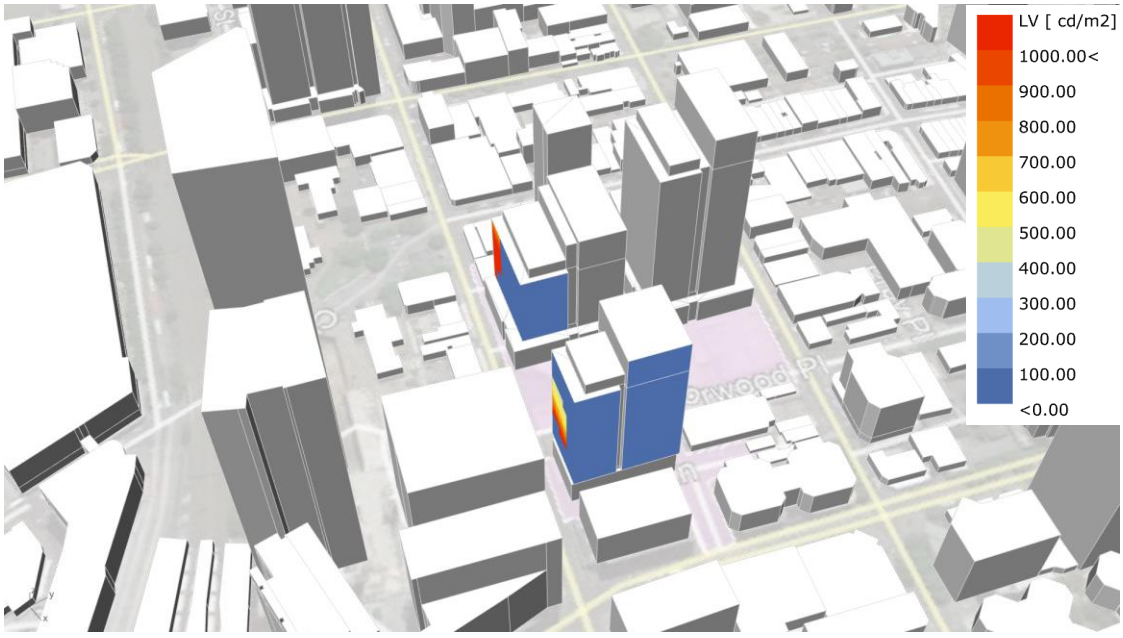

Figure A-6 Development façades at risk of posing disability glare Location 6, and their reflectivity impacts

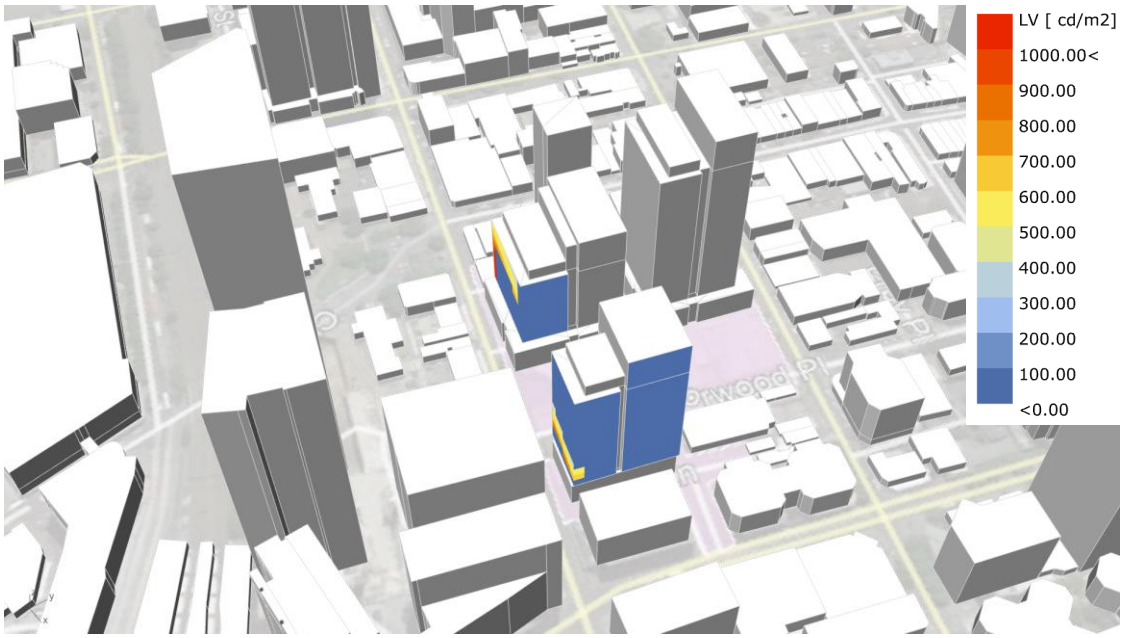

Figure A-7 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

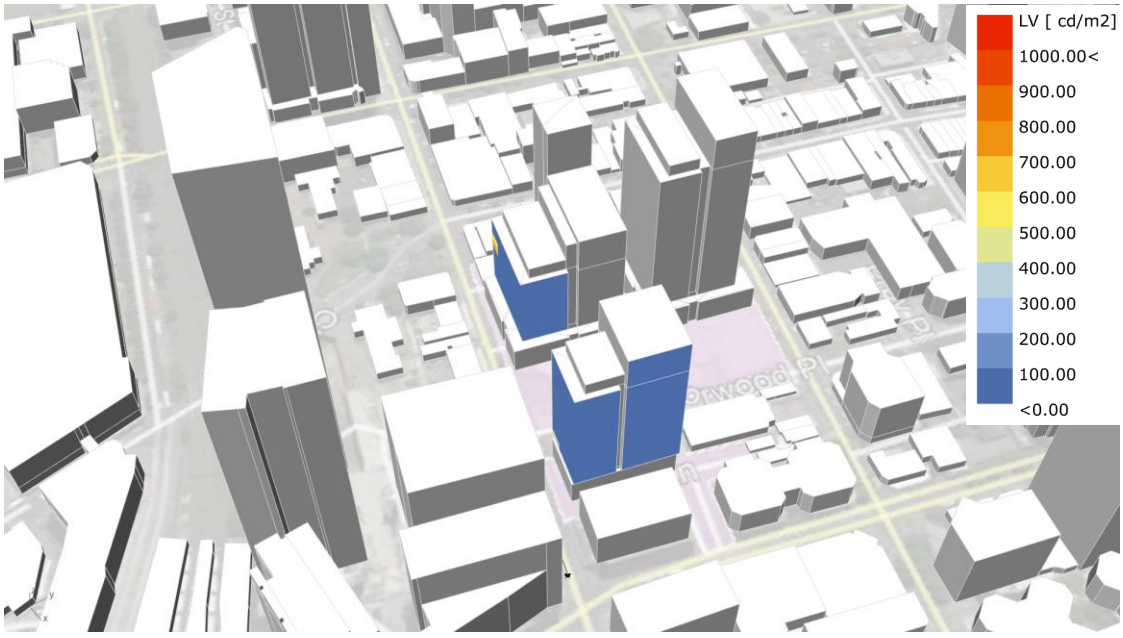

Figure A-8 Development façades at risk of posing disability glare at Location 8, and their reflectivity impacts

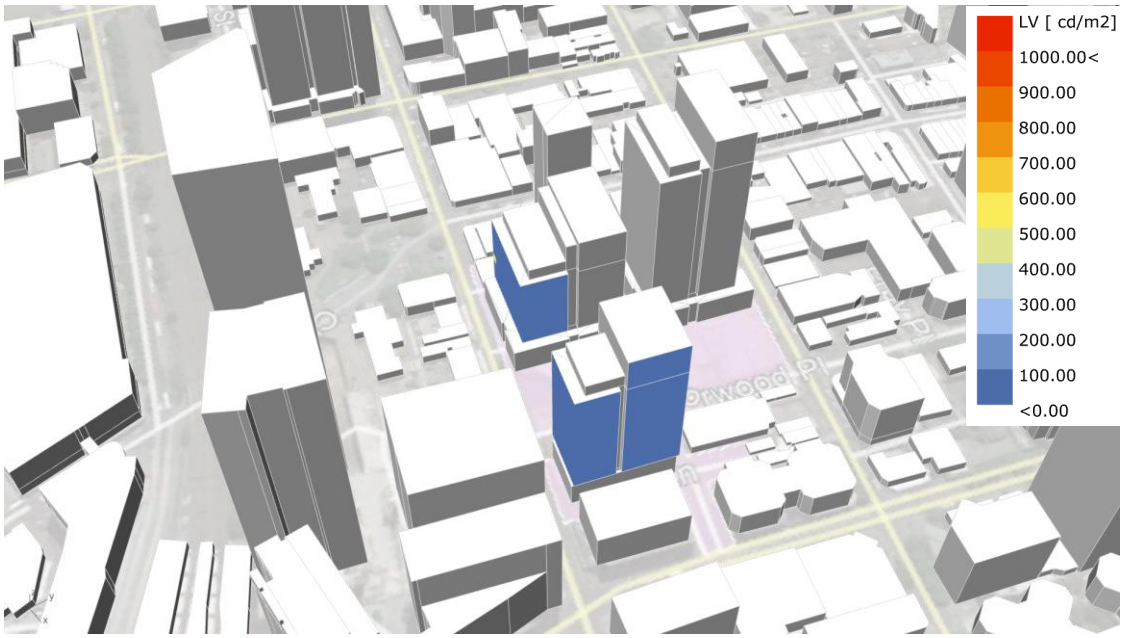

Figure A-9 Development façades at risk of posing disability glare at Location 9, and their reflectivity impacts

A.2 Route 2

This route was assessed for light rails travelling southwest along Macquarie Street.

Based on the assessment, numerous exceedances of the 500 cd/m^2 veiling luminance criteria are expected to occur along route 2 (refer to Table A-2). These were typically found to occur in the early morning summer and spring and late afternoon in autumn and spring.

View of the assessed facades and their veiling luminance are shown in Figure A-10 to Figure A-15 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-2 Reflectivity impacts on light rail operators travelling southwest along Macquarie Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	29	• Early morning in January, November, and December • Late afternoon in March and September	2,150
2	8	• Early morning in January, November, and December • Late afternoon in March and September	1,860
3	11	• Early morning in January and December • Late afternoon in March, April, and September	1,510
4	17	• Early morning in January and December	1,300

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
5	41	• Early morning in January and December	1,020
6	21	• Early morning in January and December	760
7	0	• Not applicable	0
8	0	• Not applicable	0
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

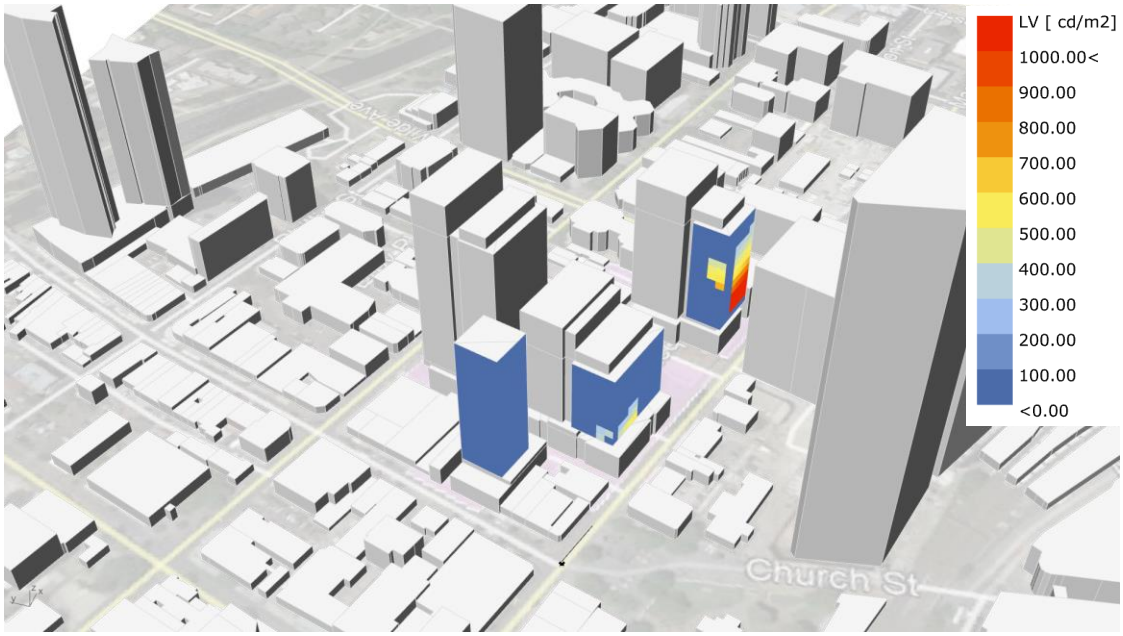

Figure A-10 Development façades at risk of posing disability glare Location 1, and their reflectivity impacts

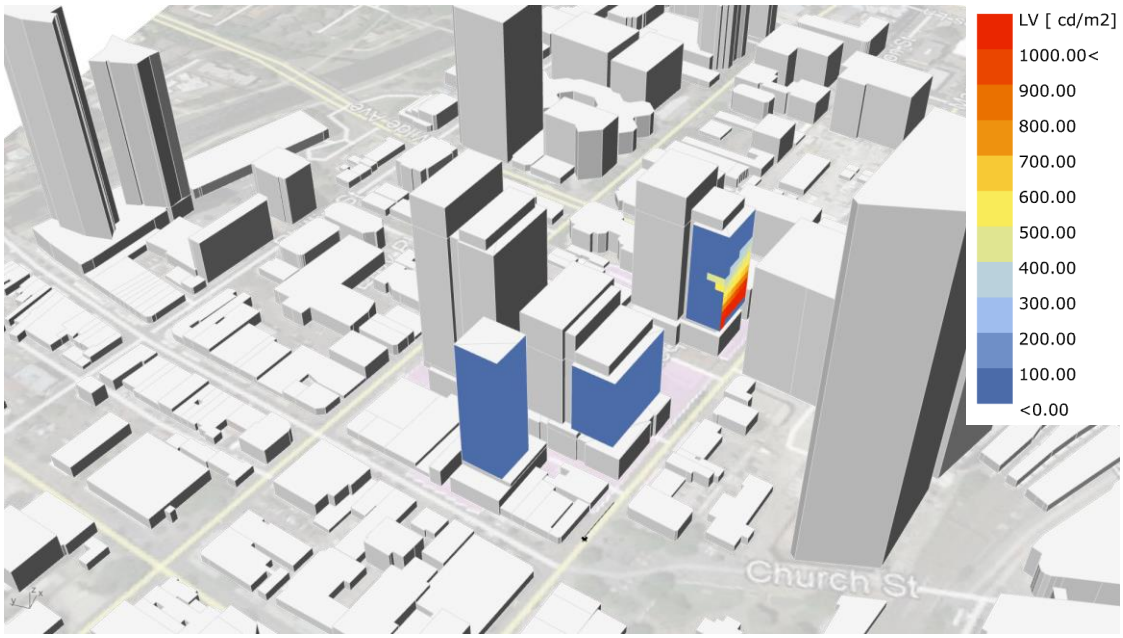

Figure A-11 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

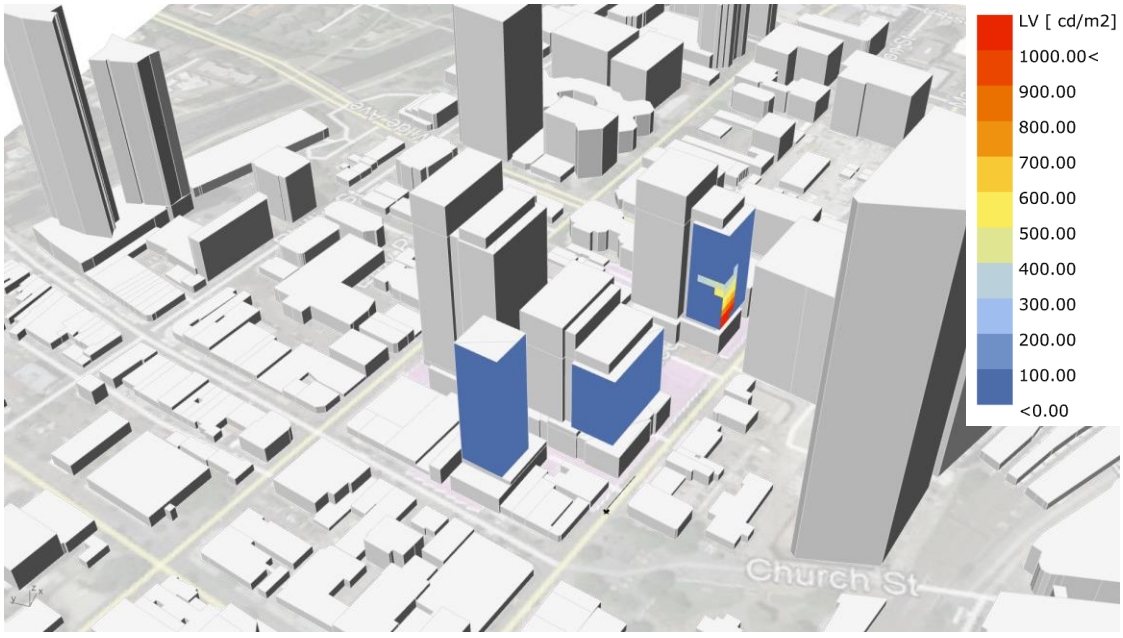

Figure A-12 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

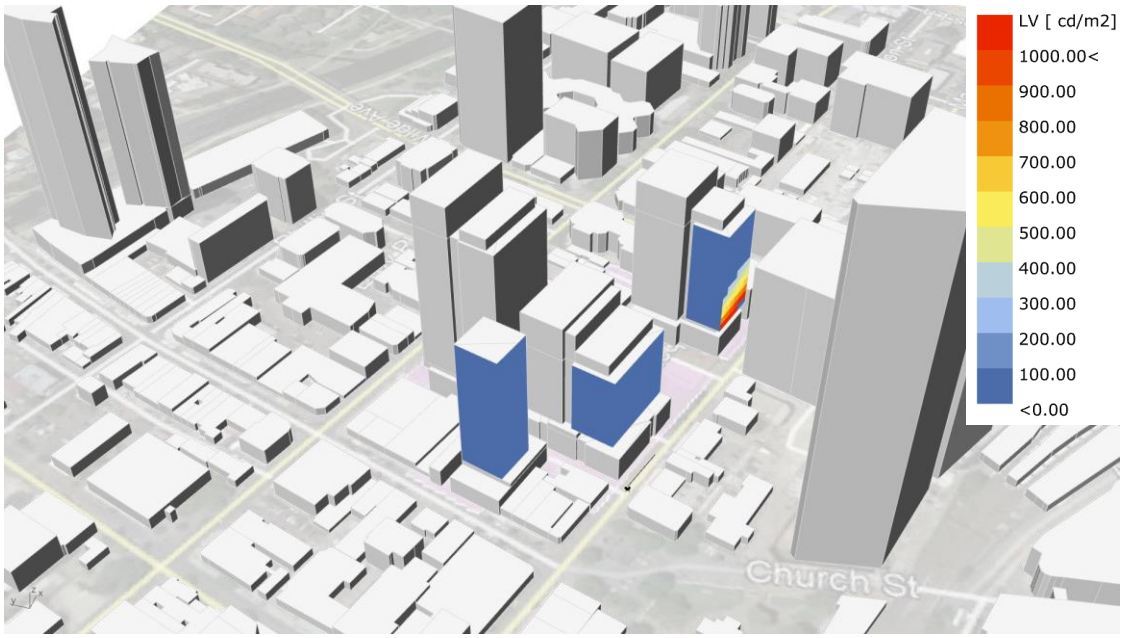

Figure A-13 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

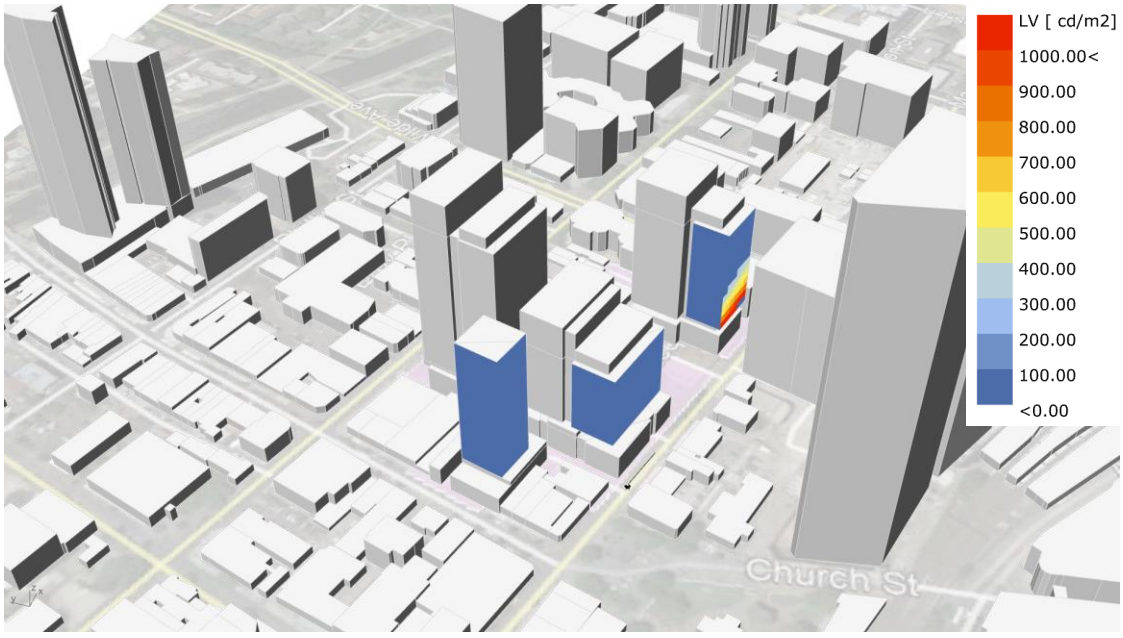

Figure A-14 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

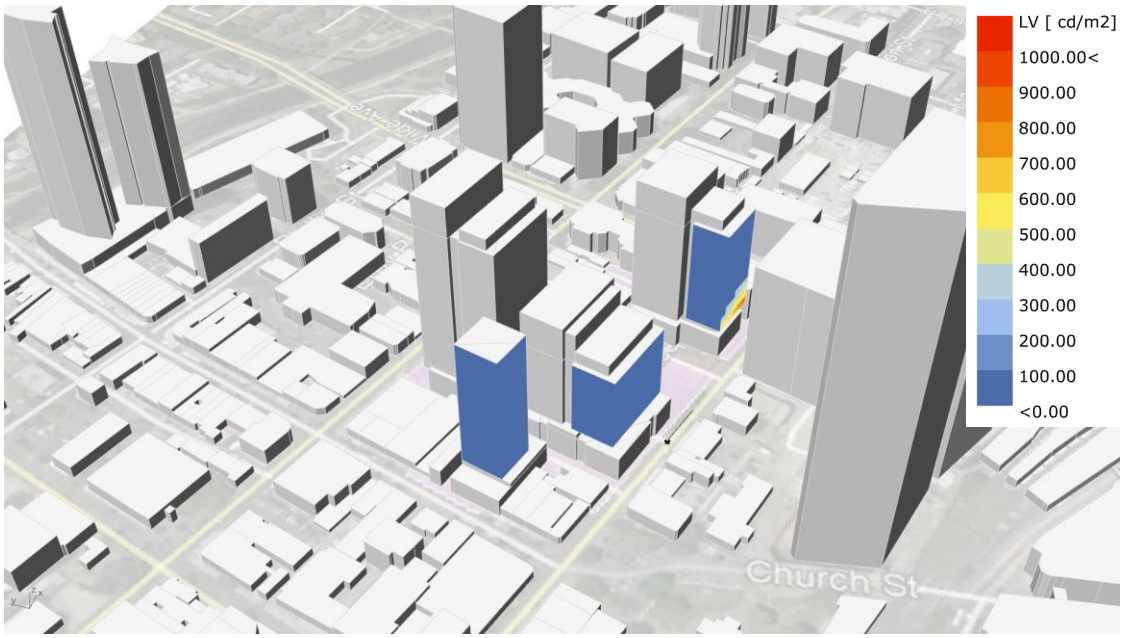

Figure A-15 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

A.3 Route 4

This route was assessed for vehicles travelling southeast along Macquarie Street.

Based on the assessment, numerous exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur along route 4 (refer to Table A-3). These were typically found to occur in the early morning summer and spring and late afternoon in autumn, winter, and spring.

View of the assessed facades and their veiling luminance are shown in Figure A-16 to Figure A-26 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-3 Reflectivity impacts on vehicles travelling southeast along Macquarie Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	48	• Late afternoon in April, August, and September	5,430
2	39	• Late afternoon in April, August, and September	4,540
3	56	• Late afternoon in April, August, and September	2,680
4	81	• Late afternoon in April, August, and September	2,070
5	80	• Late afternoon in April, August, and September	1,230
6	12	• Late afternoon in April, August, and September	2,730
7	11	• Late afternoon in April and August	5,480

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
8	8	• Late afternoon in September	5,260
9	83	• Late afternoon in March, April, August, and September	4,230
10	107	• Early morning in January and December • Late afternoon in March, April, May, August, and September	3,320
11	33	• Early morning in January and December • Mid-afternoon in April, August, and September	2,300

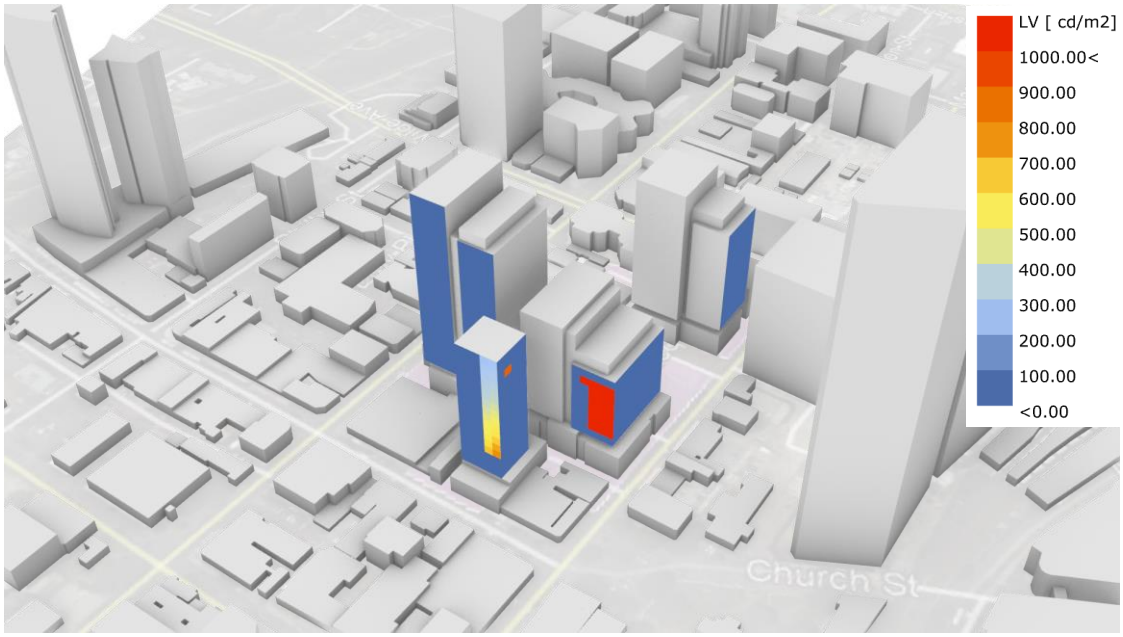

Figure A-16 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

Figure A-17 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

Figure A-18 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

Figure A-19 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

Figure A-20 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

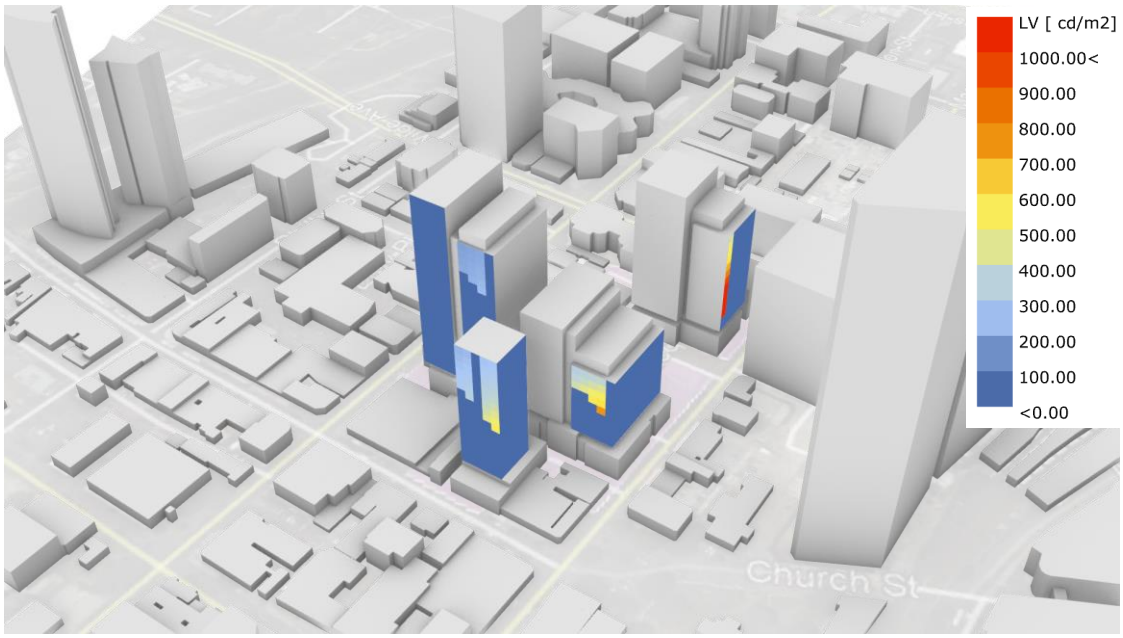

Figure A-21 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

Figure A-22 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

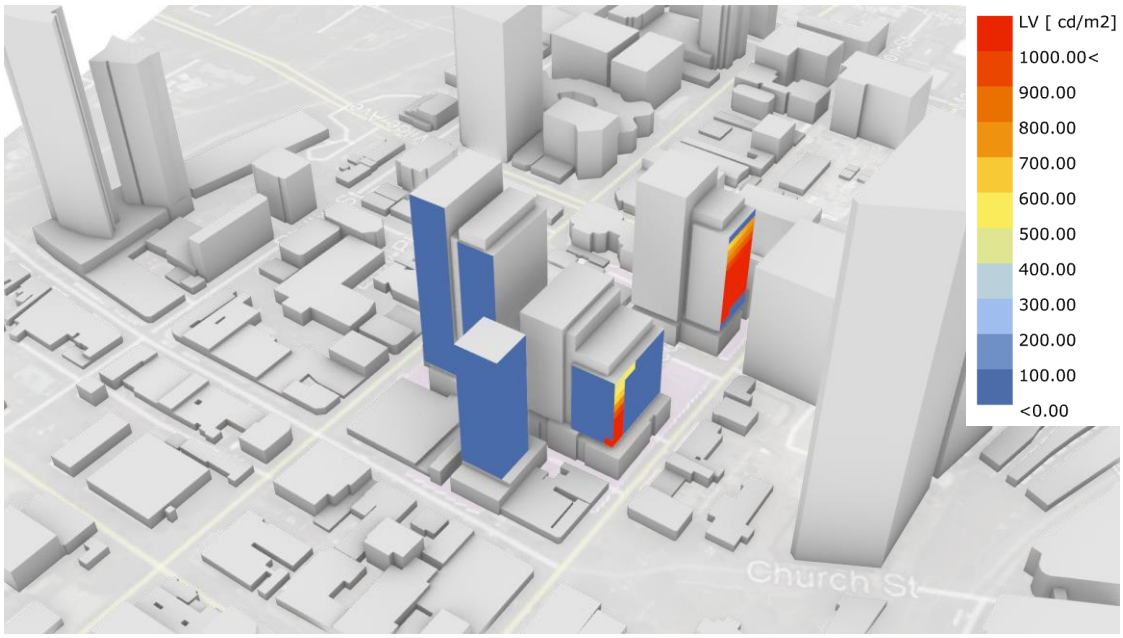

Figure A-23 Development façades at risk of posing disability glare at Location 8, and their reflectivity impacts

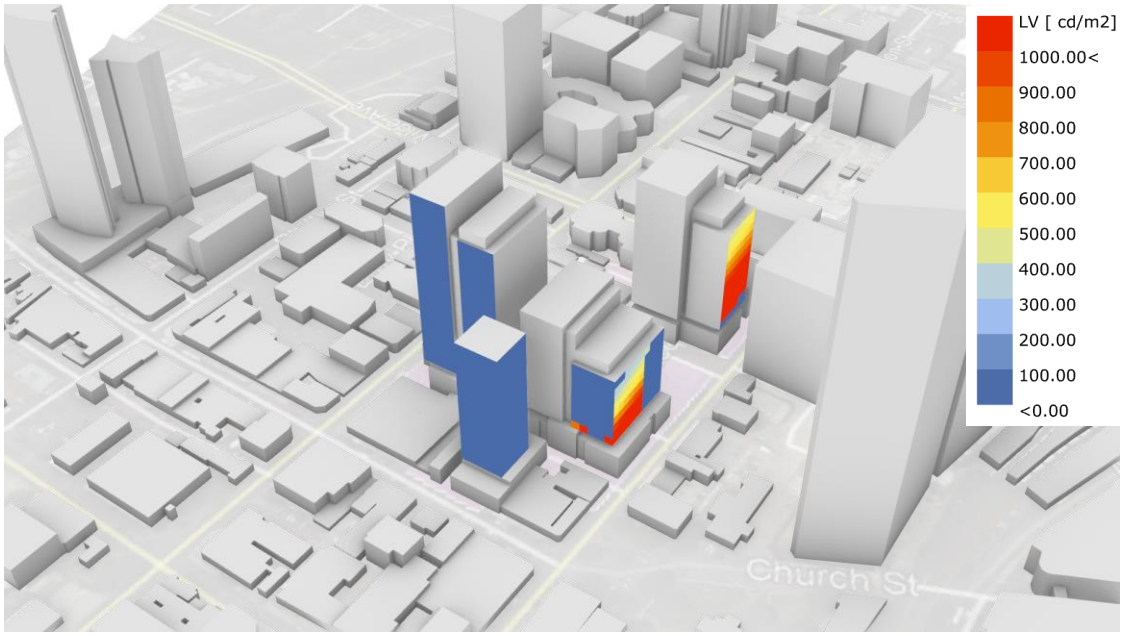

Figure A-24 Development façades at risk of posing disability glare at Location 9, and their reflectivity impacts

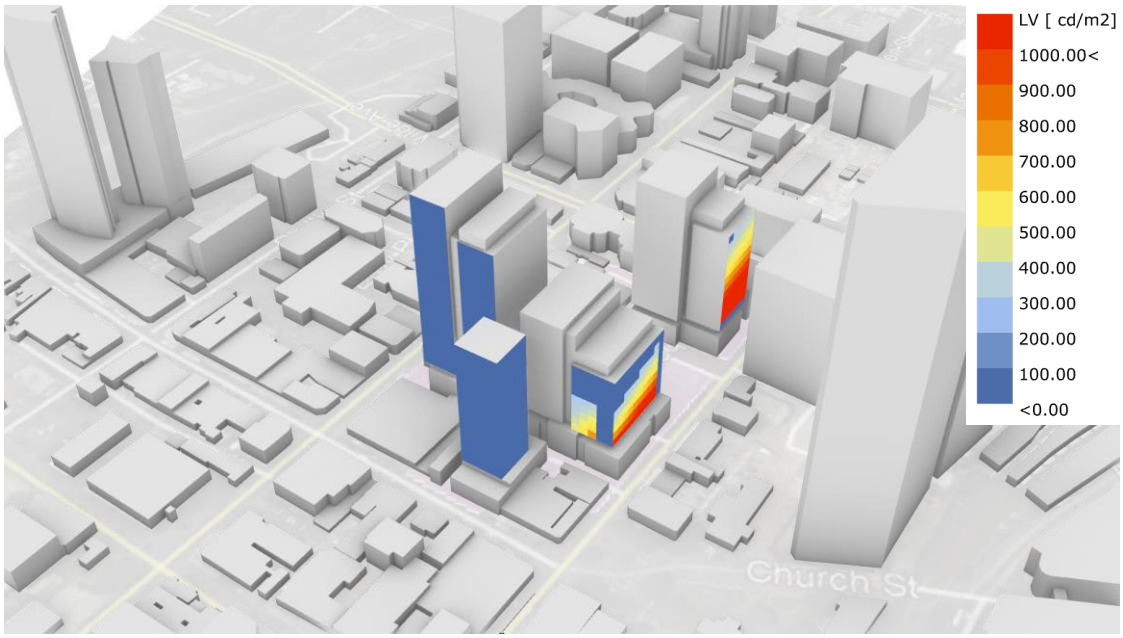

Figure A-25 Development façades at risk of posing disability glare at Location 10, and their reflectivity impacts

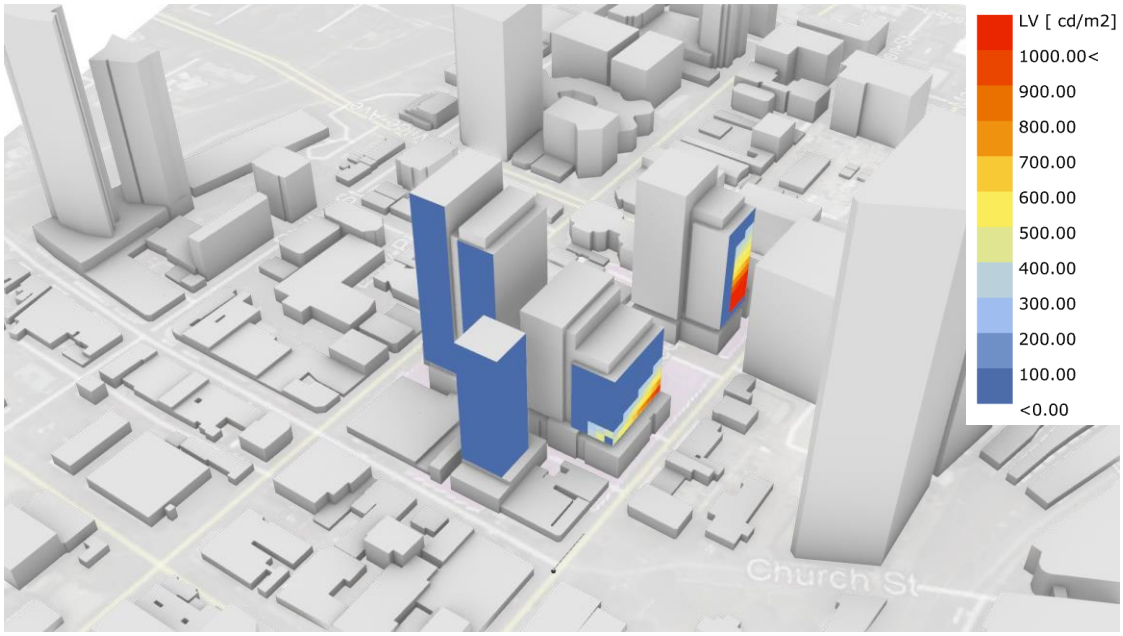

Figure A-26 Development façades at risk of posing disability glare at Location 11, and their reflectivity impacts

A.4 Route 5

This route was assessed for vehicles travelling northwest along George Street.

Based on the assessment, numerous exceedances of the 500 cd/m^2 veiling luminance criteria are expected to occur along route 5 (refer to Table A-4). These were typically found to occur in the early morning summer and spring and late afternoon in autumn, winter, and spring.

View of the assessed facades and their veiling luminance are shown in Figure A-27 to Figure A-34 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-4 Reflectivity impacts on vehicles travelling northwest along George Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	490
2	0	• Not applicable	0
3	70	• Early morning in January, November, and December	1,140
4	86	• Early morning in January and February • Late afternoon in April, August, September, November, and December	5,700
5	81	• Early morning in January • Late afternoon in March, April, August, September, November, and December	3,840
6	68	• Early morning in January • Late afternoon in March, April, August, September, and December	3,600
7	16	• Late afternoon in March, April, and September	2,120
8	41	• Late afternoon in March, April, August, and September	940
9	0	• Not applicable	340
10	0	• Not applicable	0
11	0	• Not applicable	0

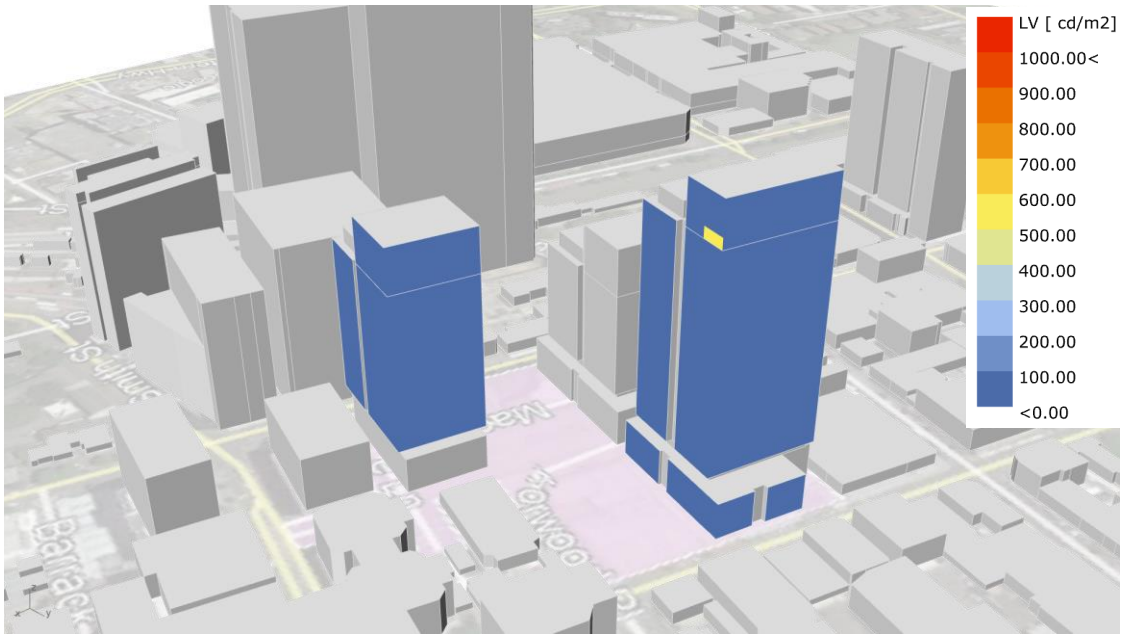

Figure A-27 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

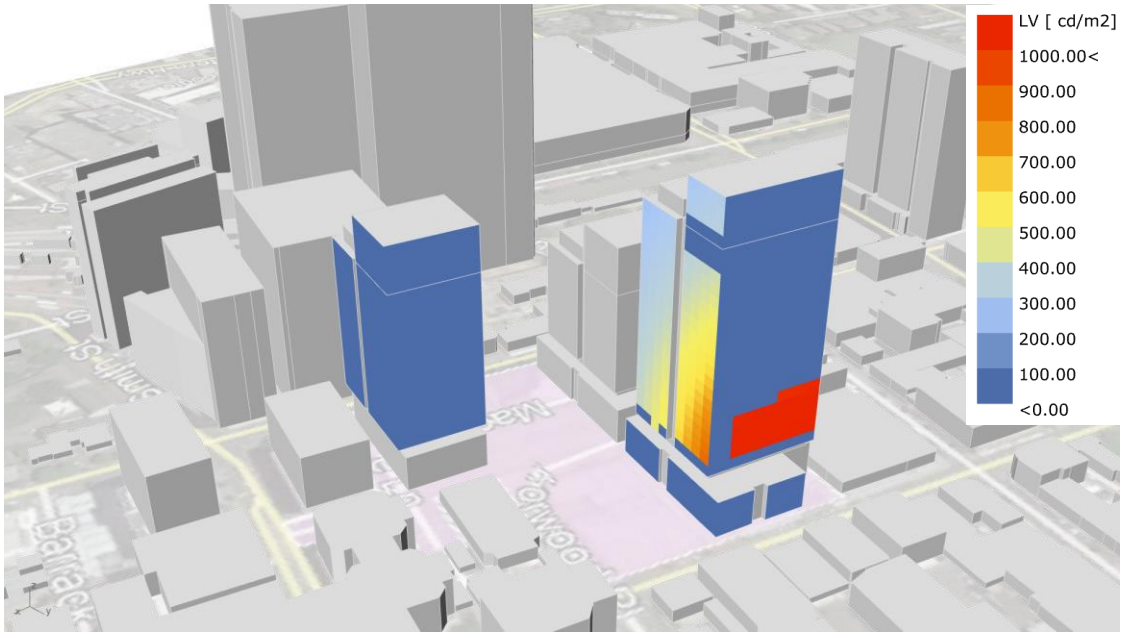

Figure A-28 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

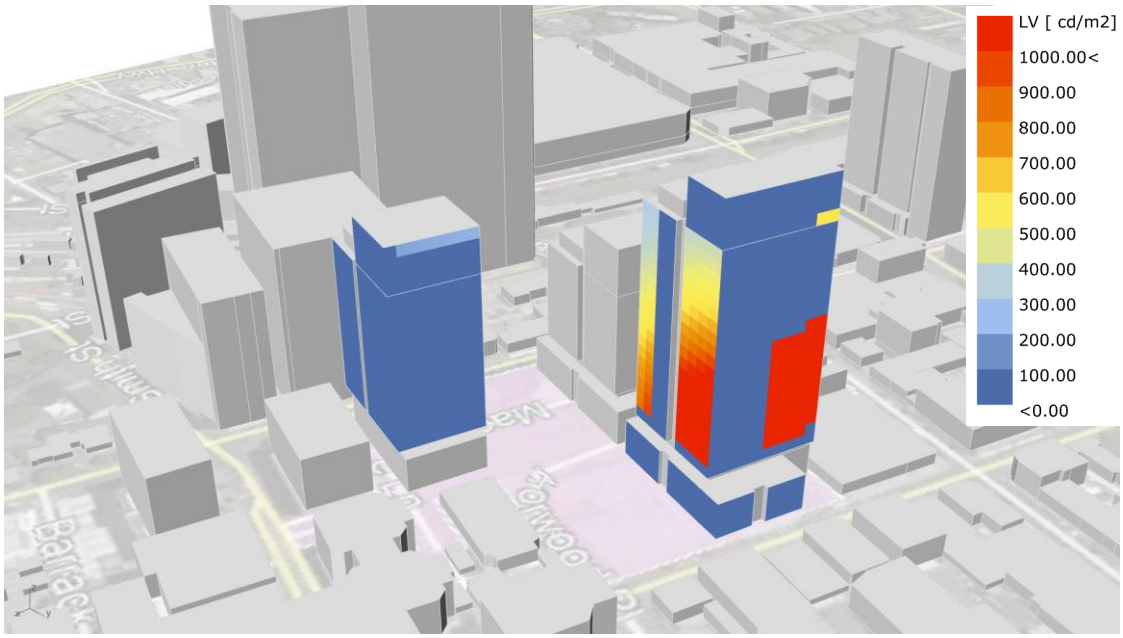

Figure A-29 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

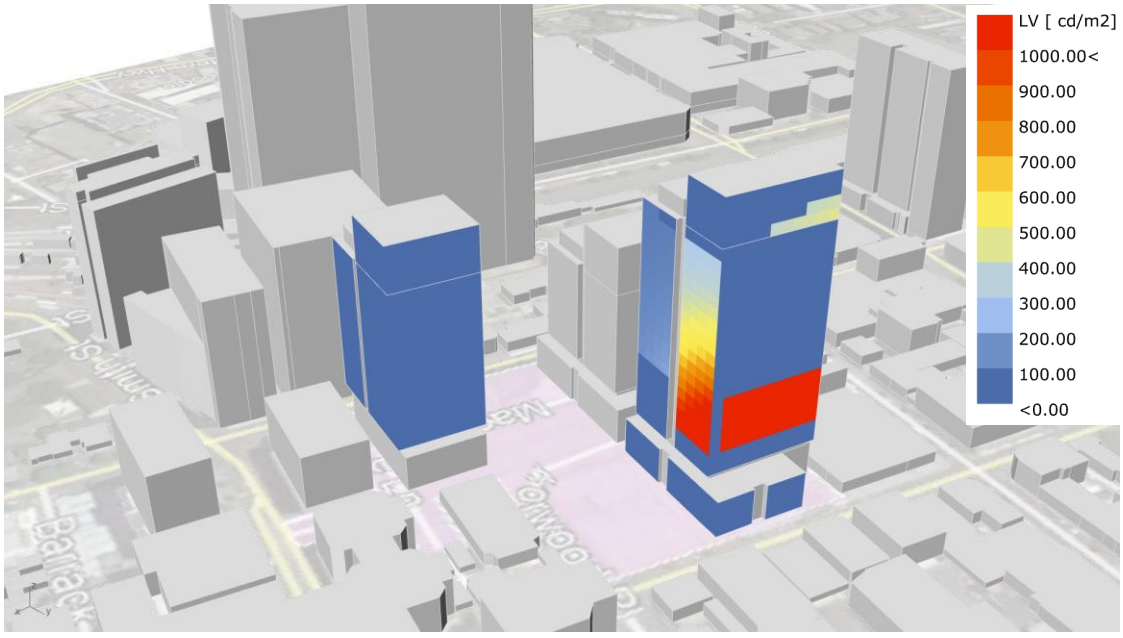

Figure A-30 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

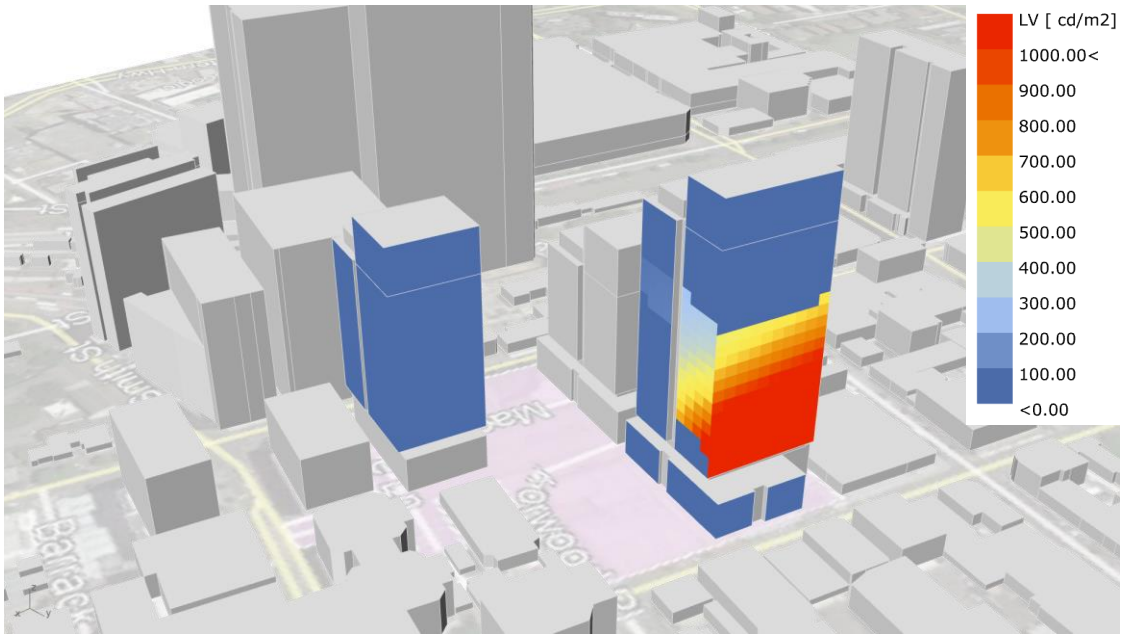

Figure A-31 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

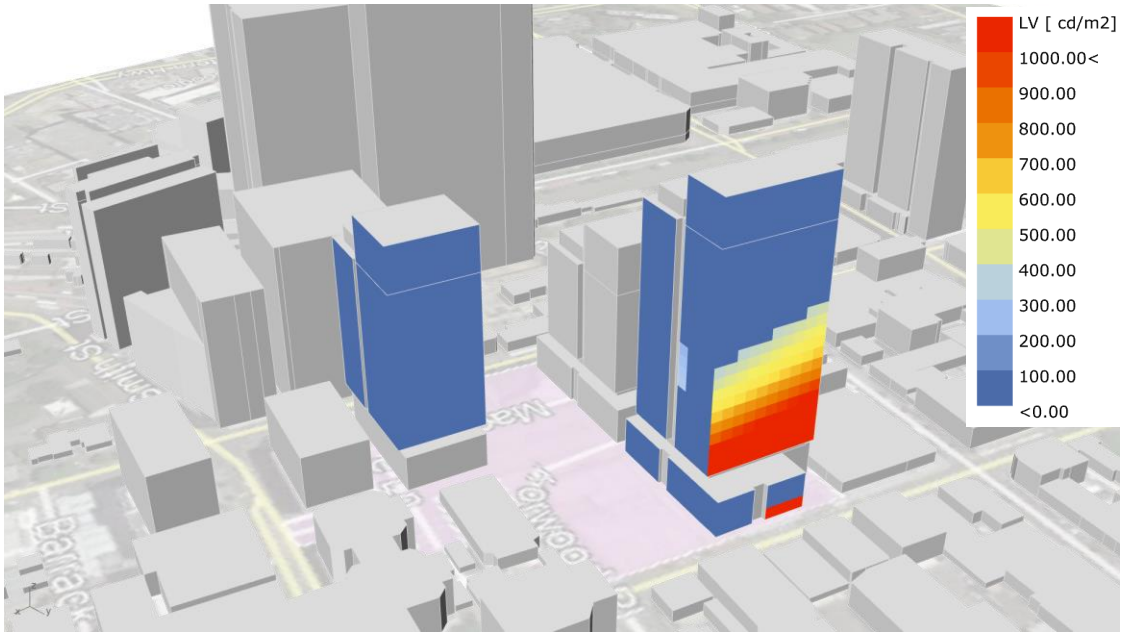

Figure A-32 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

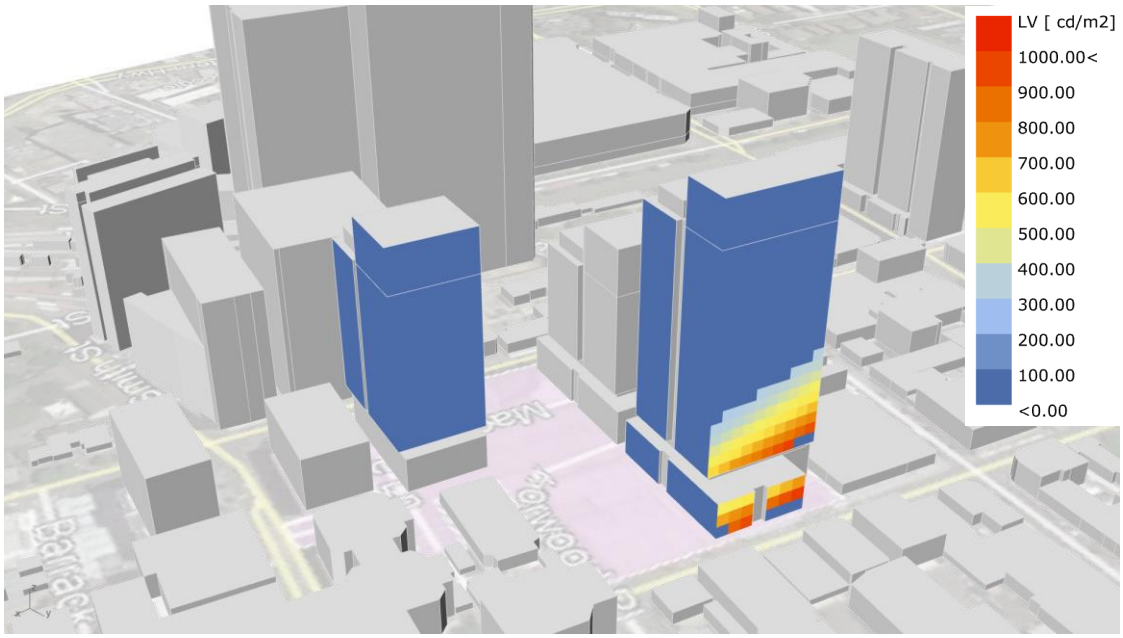

Figure A-33 Development façades at risk of posing disability glare at Location 8, and their reflectivity impacts

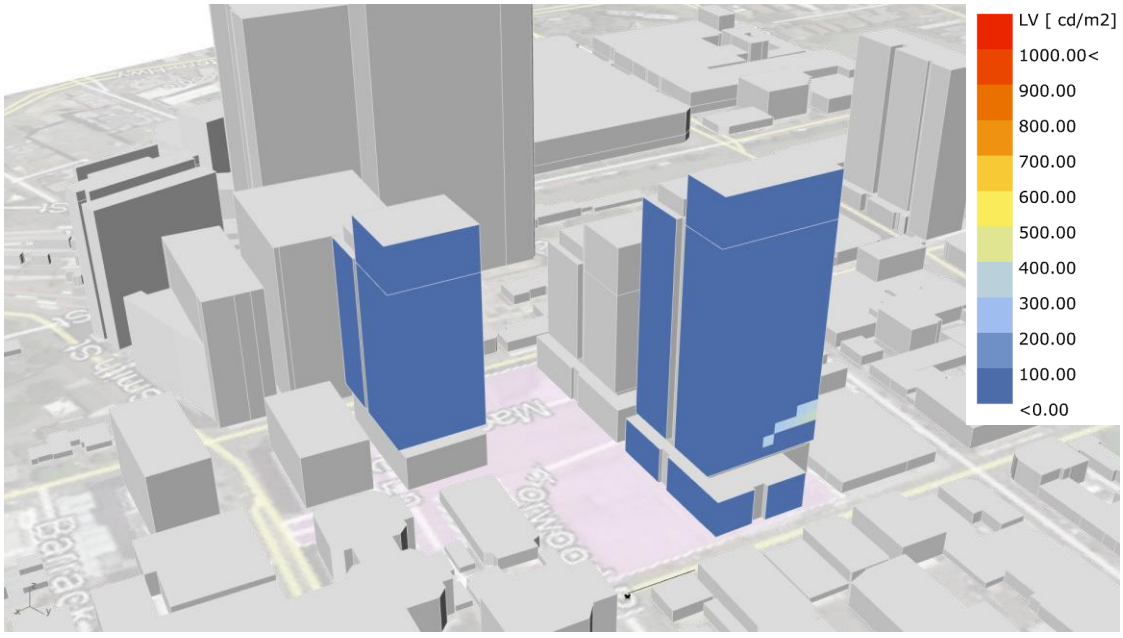

Figure A-34 Development façades at risk of posing disability glare at Location 9, and their reflectivity impacts

A.5 Route 6

This route was assessed for vehicles travelling southeast along George Street.

Based on the assessment, numerous exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur along route 5 (refer to Table A-5). These were typically found to occur in the early morning summer and spring and late afternoon in autumn, and spring.

View of the assessed facades and their veiling luminance are shown in Figure A-35 to Figure A-41 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-5 Reflectivity impacts on vehicles travelling southeast along George Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	101	• Early morning in January, February, October, and November • Late afternoon in February, March, September, and October	5,710
2	102	• Early morning in January, February, October, and November • Late afternoon in February, March, September, and October	4,730
3	143	• Early morning in January, February, October, and November • Late afternoon in January, February, March, September, October, and November	4,090
4	150	• Early morning in February, October, and November • Later afternoon in January, February, March, September, October, and November	2,960
5	126	• Early morning in February, October, and November • Late afternoon in February, October, and November	2,370
6	51	• Early morning in January, February, October, and November • Late afternoon in November	1,580
7	55	• Early morning in January, February, March, and October	700
8	0	• Not applicable	0
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

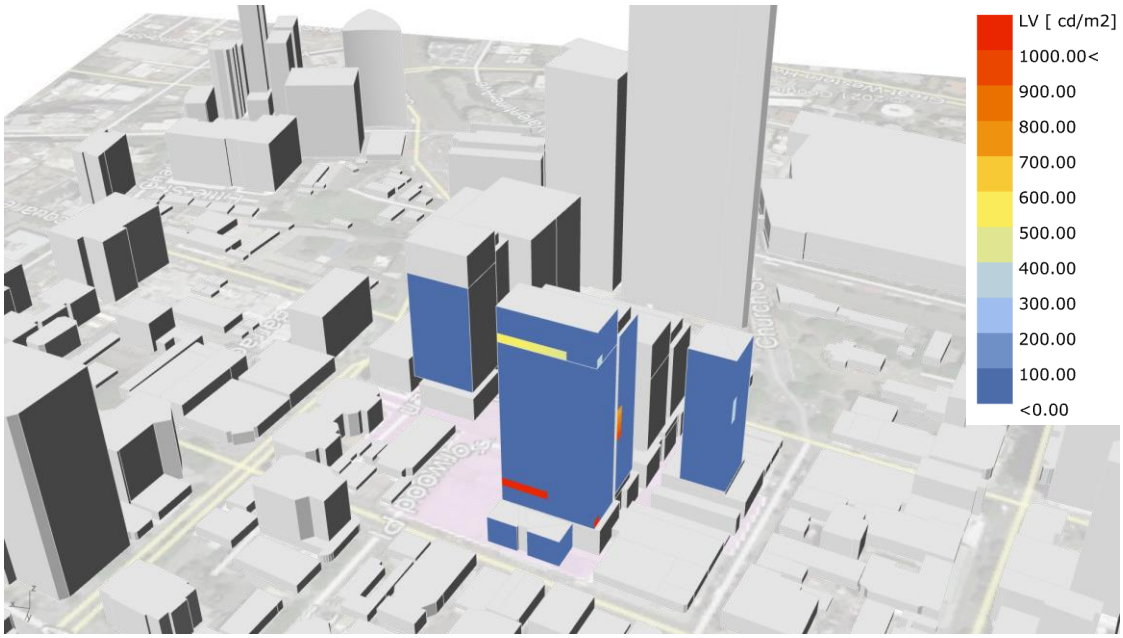

Figure A-35 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

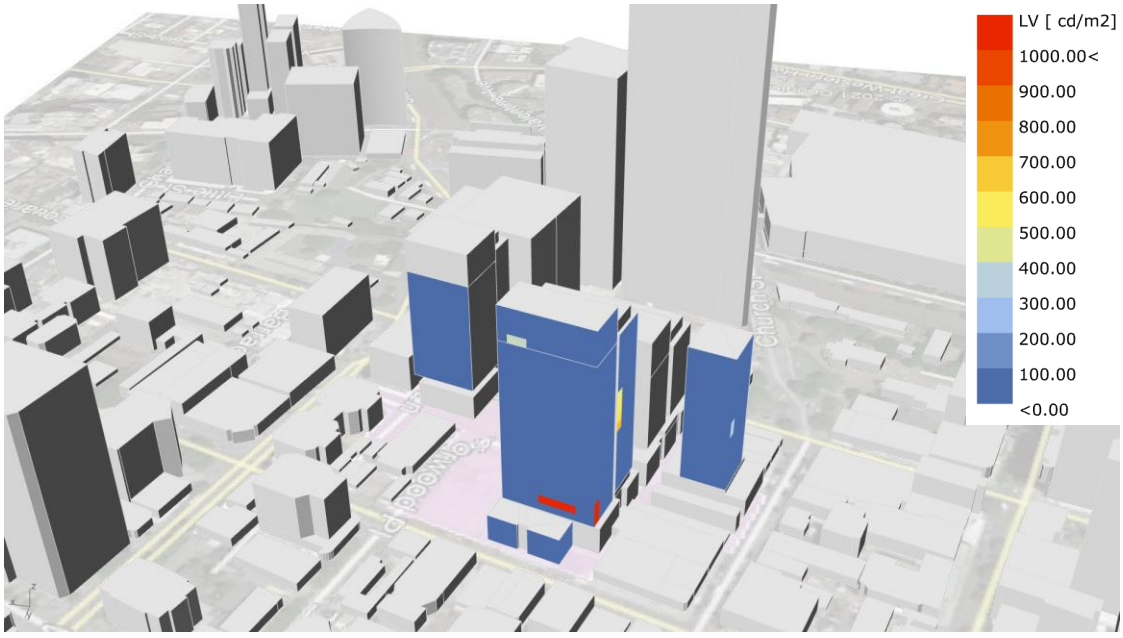

Figure A-36 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

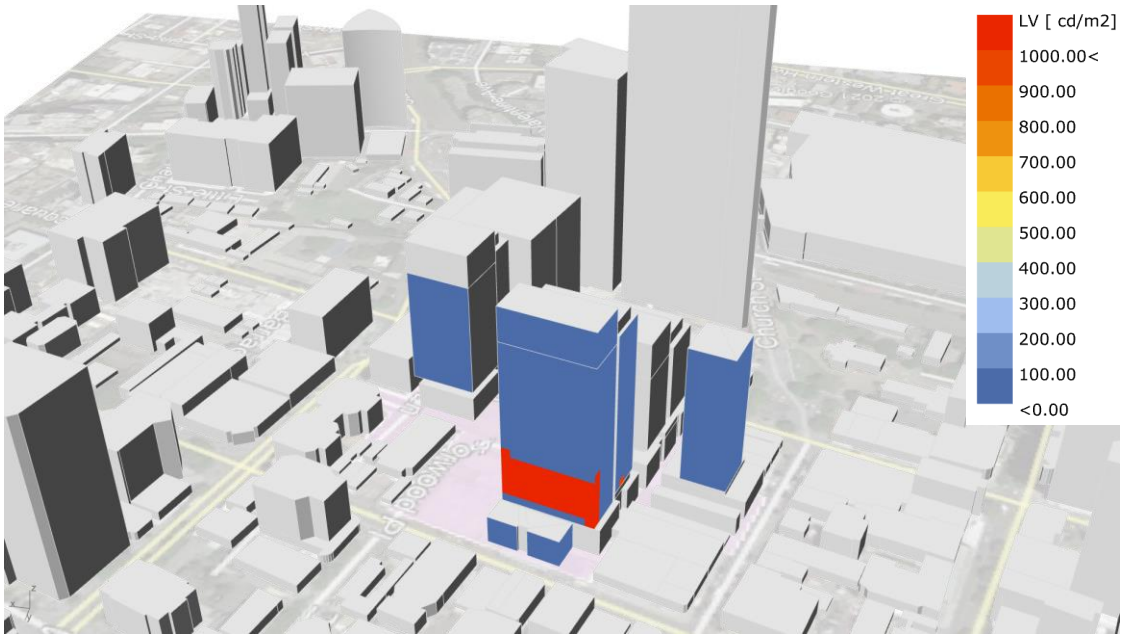

Figure A-37 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

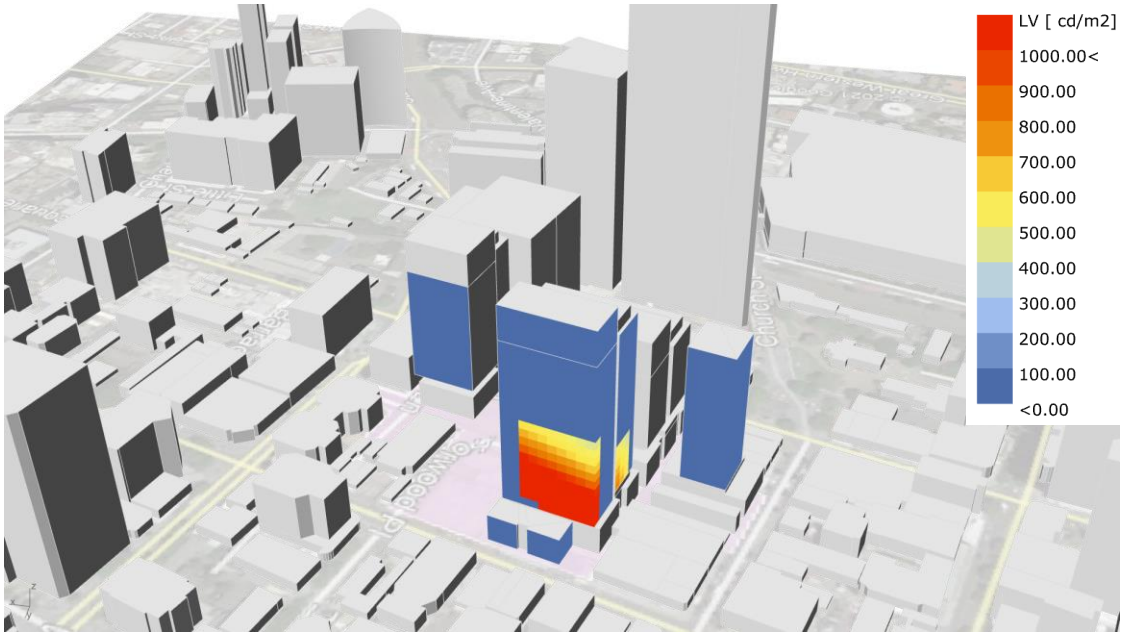

Figure A-38 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

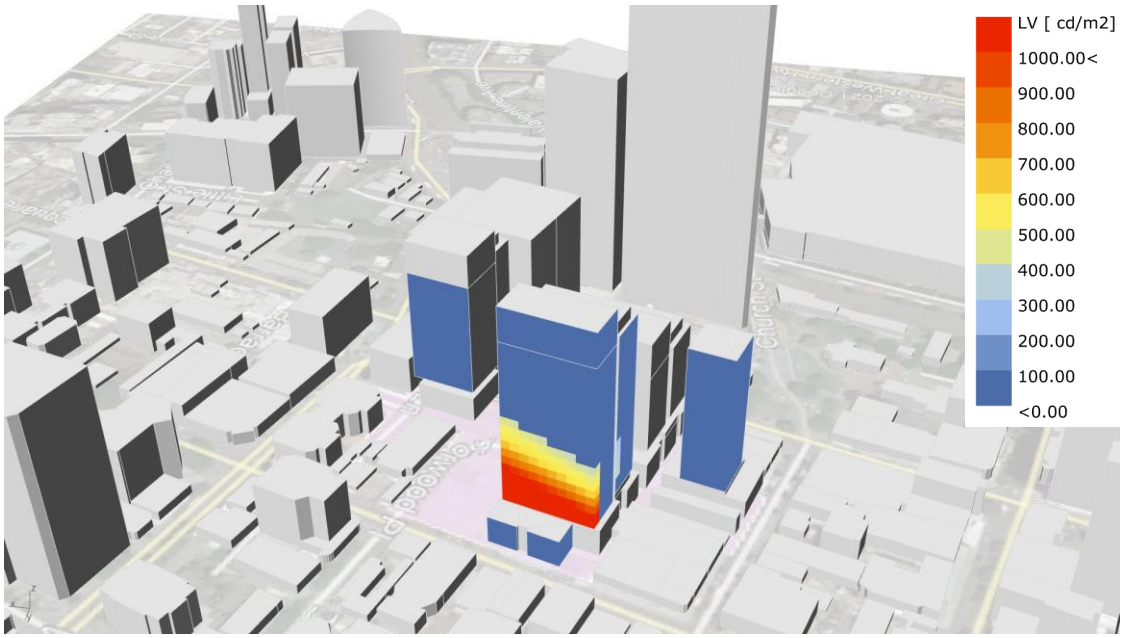

Figure A-39 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

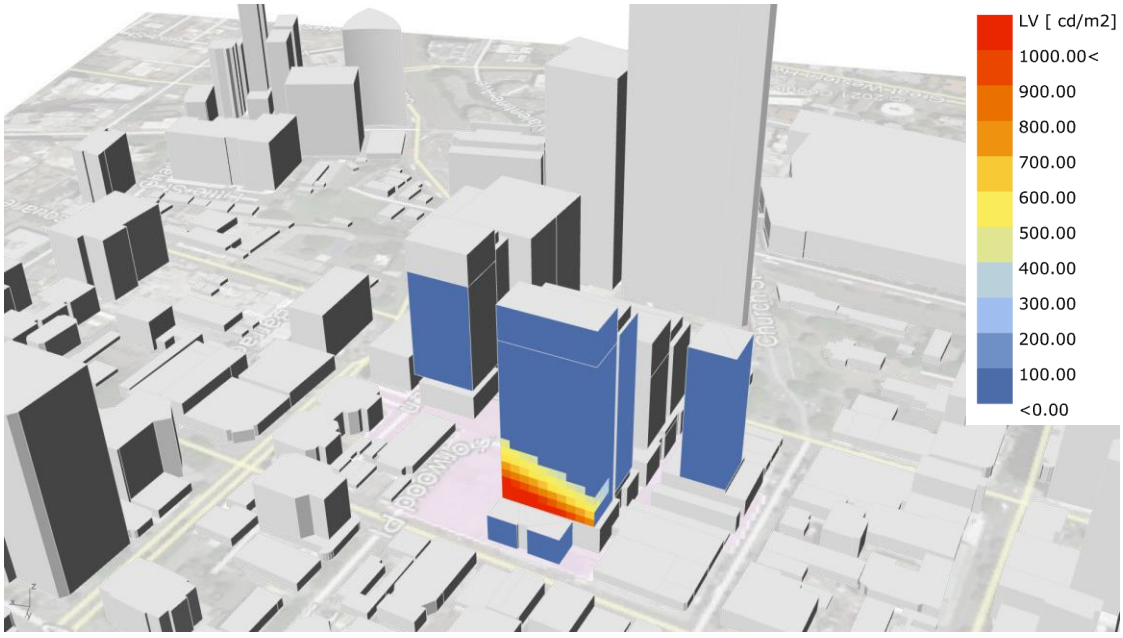

Figure A-40 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

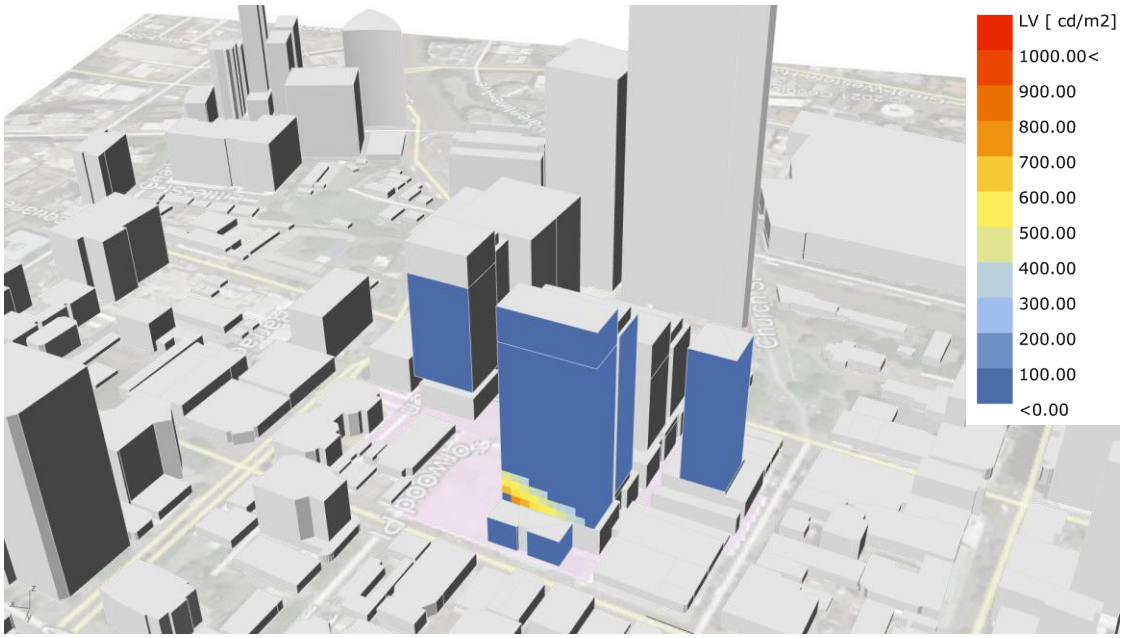

Figure A-41 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

A.6 Pedestrian 1

This provides the first assessment for a pedestrian located in the public domain.

Based on the assessment, some exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur at pedestrian location 1 (refer to Table A-6). These were typically found to occur in the late afternoon during autumn and spring.

View of the assessed facades and their veiling luminance are shown in Figure A-42 for the worst-case hour for each assessment direction for directions where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-6 Reflectivity impacts on a pedestrian at Location 1 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	26	• Late afternoon in March, April, August, and September	25,420

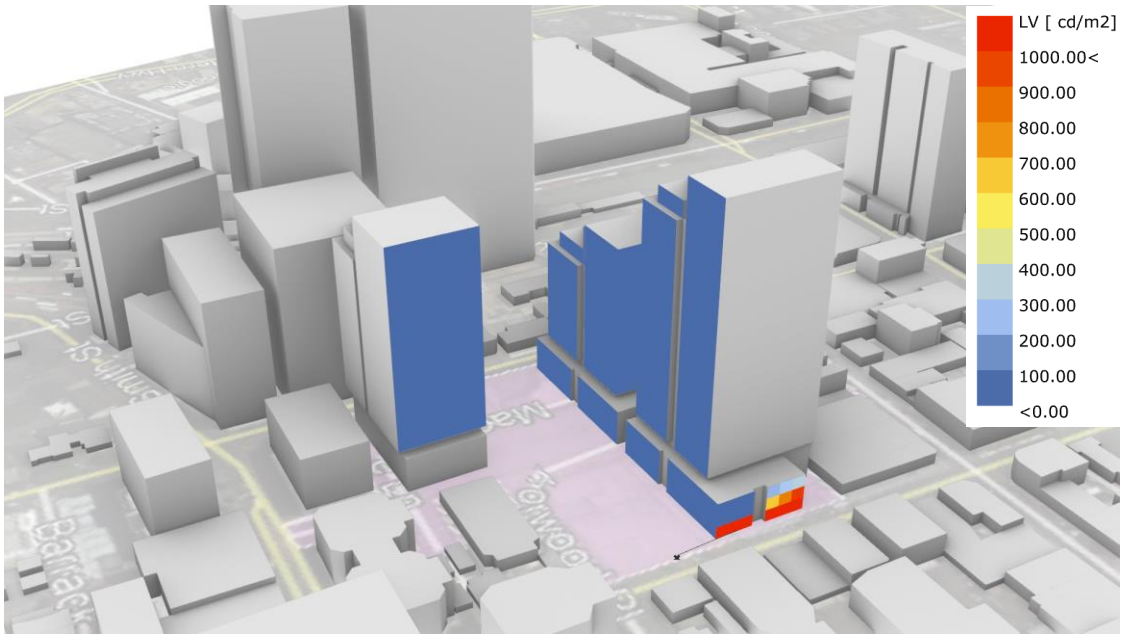

Figure A-42 Development façades at risk of posing disability glare for Direction 1, and their reflectivity impacts

A.7 Pedestrian 2

This provides the second assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 2 has no expected exceedances (refer to Table A-7) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure A-43 and Figure A-44 for the worst-case hour for each assessment direction for directions where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-7 Reflectivity impacts on a pedestrian at Location 2 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	390
3	0	• Not applicable	430
4	0	• Not applicable	0

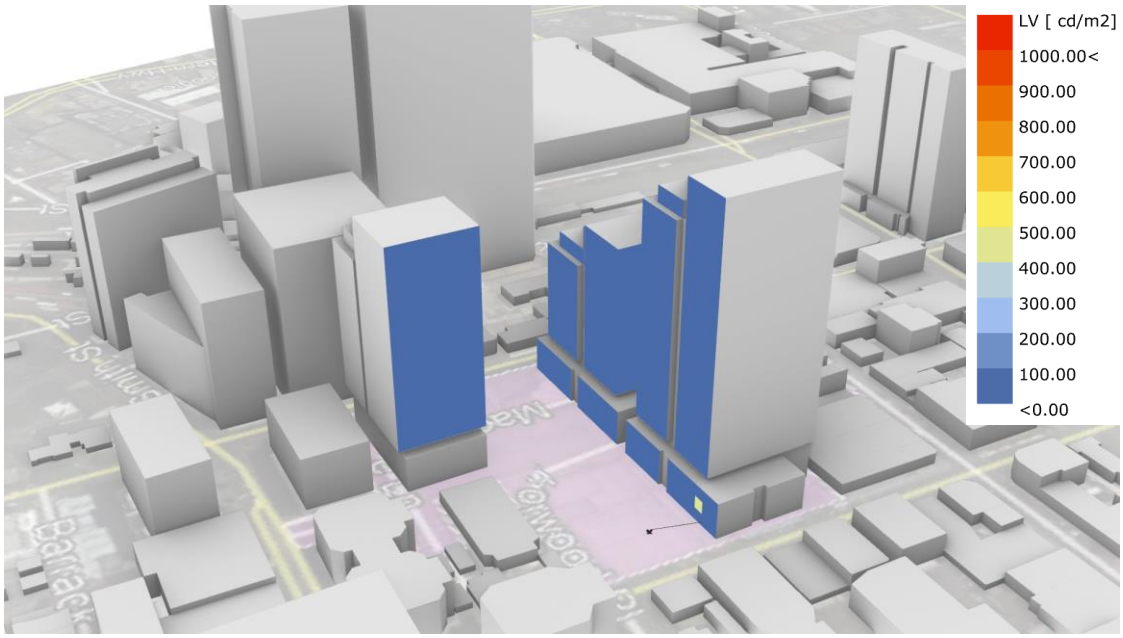

Figure A-43 Development façades at risk of posing disability glare for Direction 2, and their reflectivity impacts

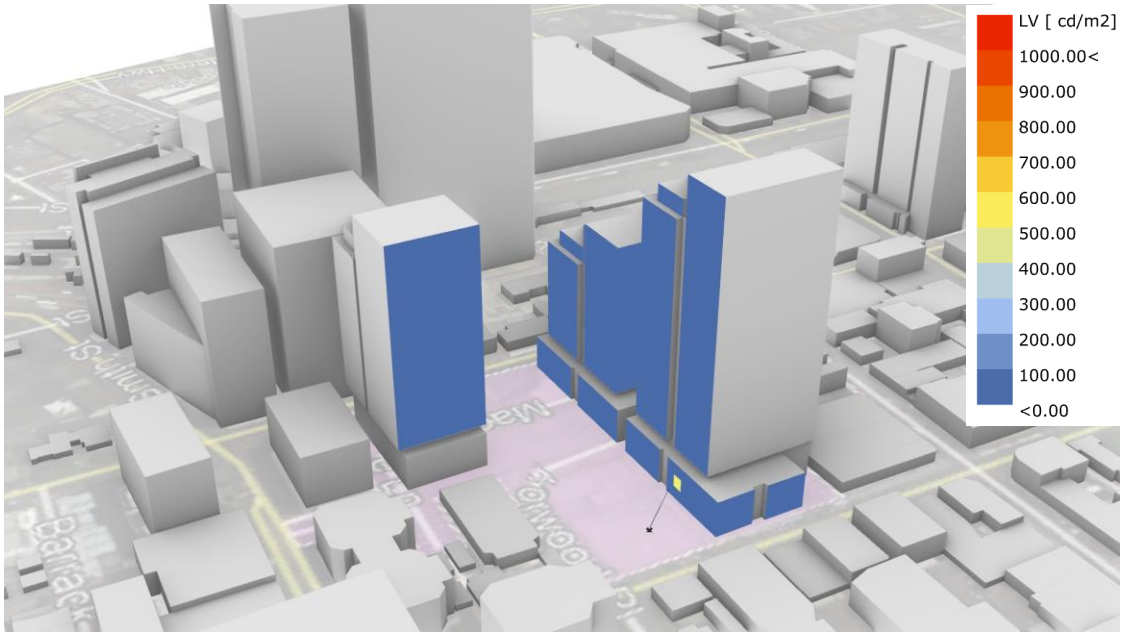

Figure A-44 Development façades at risk of posing disability glare for Direction 3, and their reflectivity impacts

A.8 Pedestrian 3

This provides the third assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 3 has no expected exceedances (refer to Table A-8) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure A-45 for the worst-case hour for each assessment direction for directions where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-8 Reflectivity impacts on a pedestrian at Location 3 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m² in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m²]
1	0	• Not applicable	0
2	0	• Not applicable	370
3	0	• Not applicable	0
4	0	• Not applicable	0

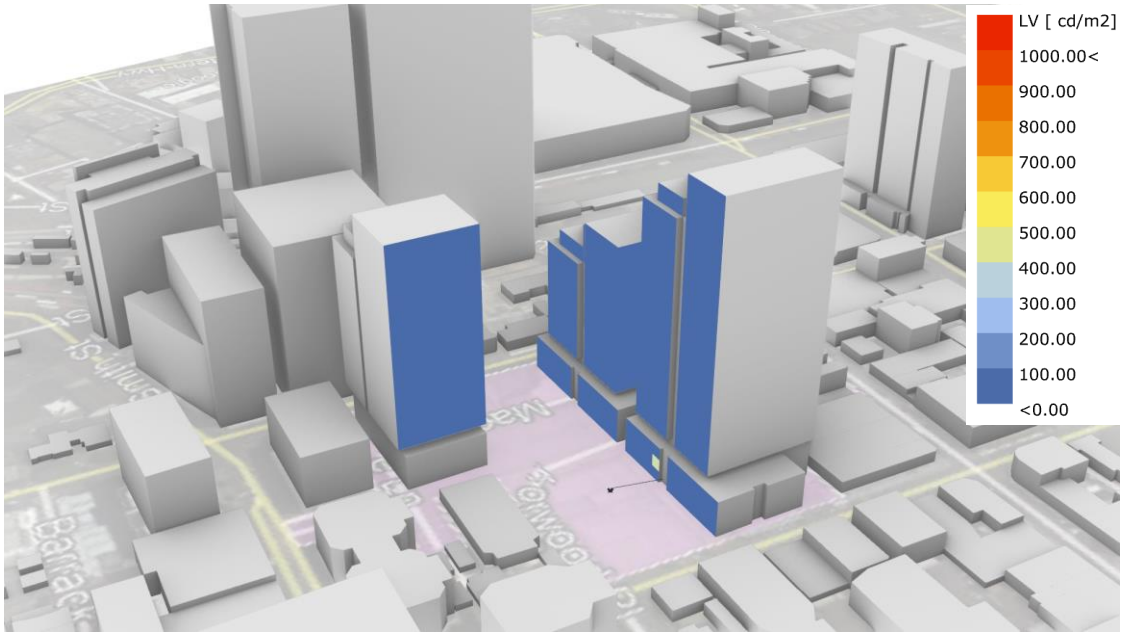

Figure A-45 Development façades at risk of posing disability glare Direction 2, and their reflectivity impacts

A.9 Pedestrian 4

This provides the fourth assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 4 has no expected exceedances (refer to Table A-9) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure A-46 and Figure A-47 for the worst-case hour for each assessment direction for directions where there is veiling luminance is expected (i.e., > 0 cd/m²).

Table A-9 Reflectivity impacts on a pedestrian at Location 4 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m² in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m²]
1	0	• Not applicable	0
2	0	• Not applicable	320
3	0	• Not applicable	0

Direction	Number of hours LV is expected to exceed 500 cd/m² in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m²]
4	0	• Not applicable	40

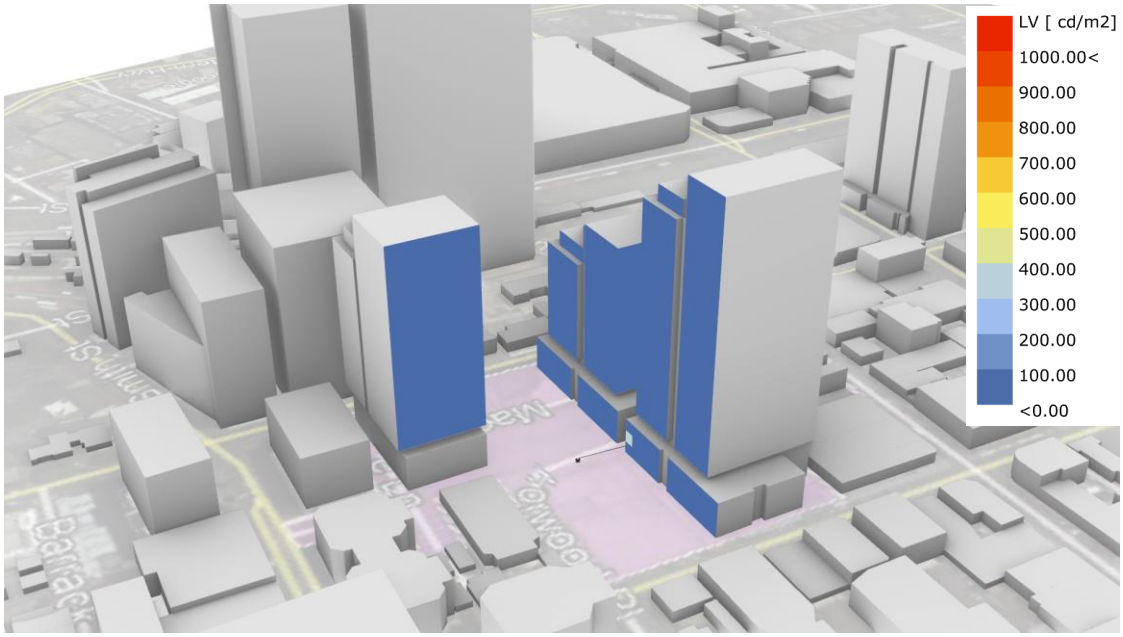

Figure A-46 Development façades at risk of posing disability glare for Direction 2, and their reflectivity impacts

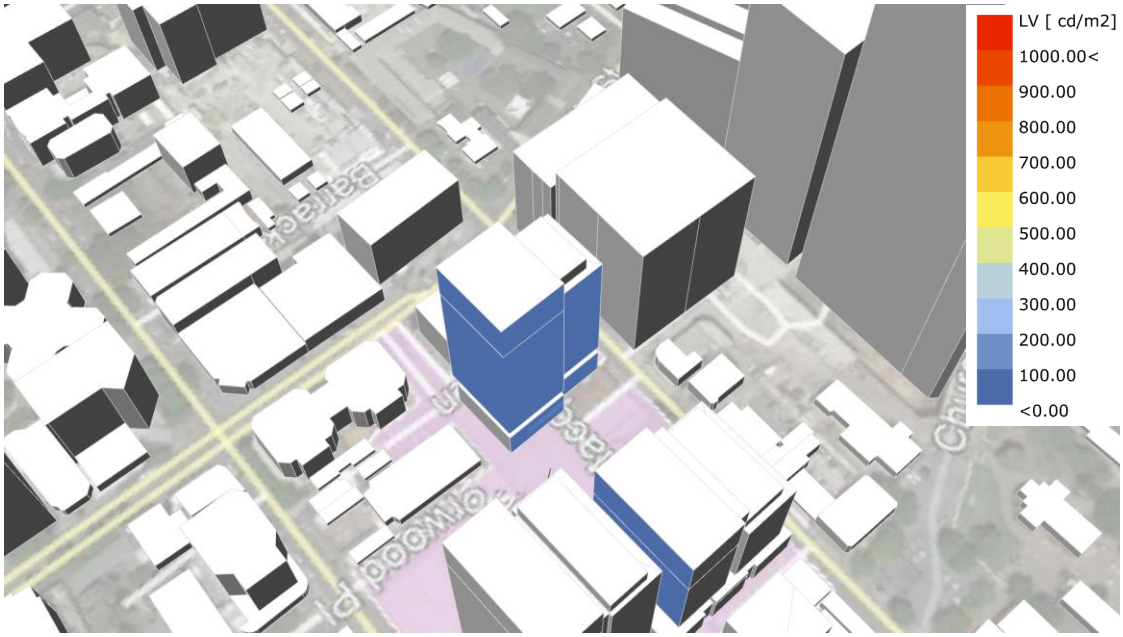

Figure A-47 Development façades at risk of posing disability glare for Direction 4, and their reflectivity impacts

A.10 Pedestrian 5

This provides the fifth assessment for a pedestrian located in the public domain.

Based on the assessment, some exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur at pedestrian location 5 (refer to Table A-10). These were typically found to occur in the late afternoon in summer, autumn, and spring.

View of the assessed facades and their veiling luminance are shown in Figure A-48 and Figure A-49 for the worst-case hour for each assessment direction for directions where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-10 Reflectivity impacts on a pedestrian at Location 5 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	0
3	0	• Not applicable	0
4	0	• Not applicable	340
5	63	• Late afternoon in January, February, March, April, August, September, October, and November	570

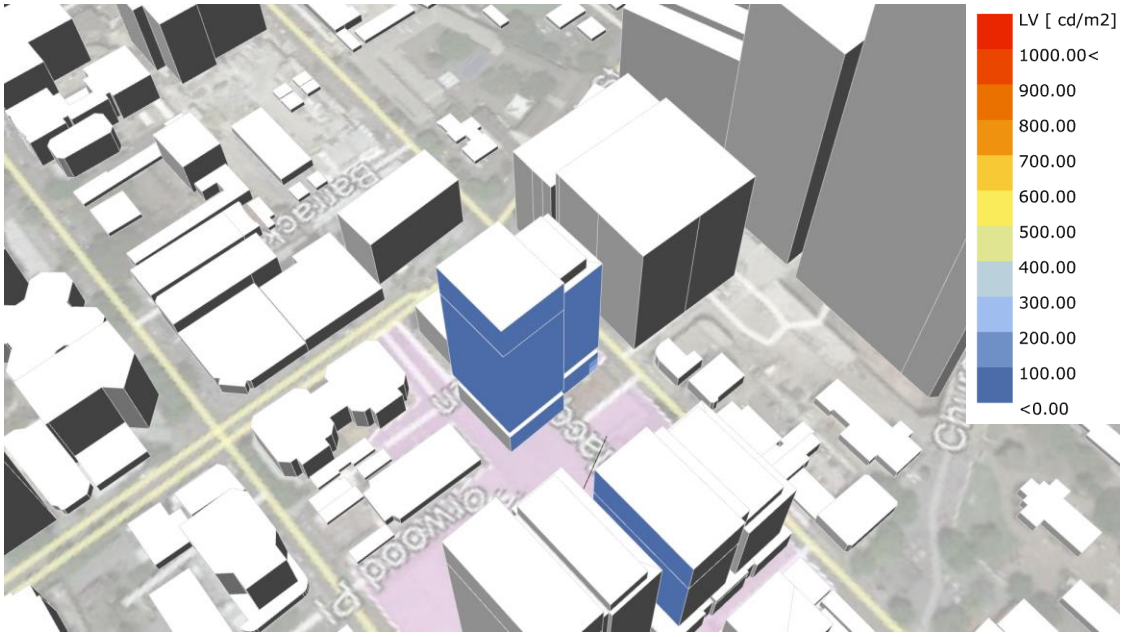

Figure A-48 Development façades at risk of posing disability glare for Direction 4, and their reflectivity impacts

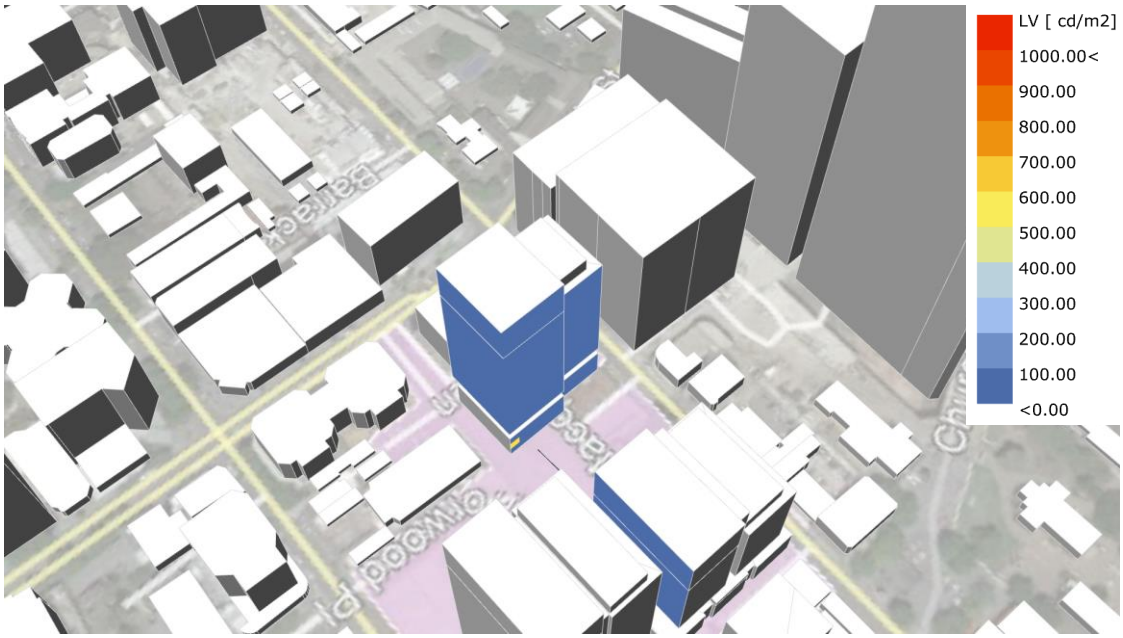

Figure A-49 Development façades at risk of posing disability glare for Direction 5, and their reflectivity impacts

A.11 Pedestrian 6

This provides the sixth assessment for a pedestrian located in the public domain.

Based on this assessment, some exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur at pedestrian location 5 (refer to Table A-11). These were typically found to occur during winter.

View of the assessed facades and their veiling luminance are shown in Figure A-50 and Figure A-51 for the worst-case hour for each assessment direction for directions where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table A-11 Reflectivity impacts on a pedestrian at Location 6 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	18	• Mid-morning during June and July	870
2	0	• Not applicable	0
3	0	• Not applicable	0
4	0	• Not applicable	0
5	0	• Not applicable	450
6	0	• Not applicable	0

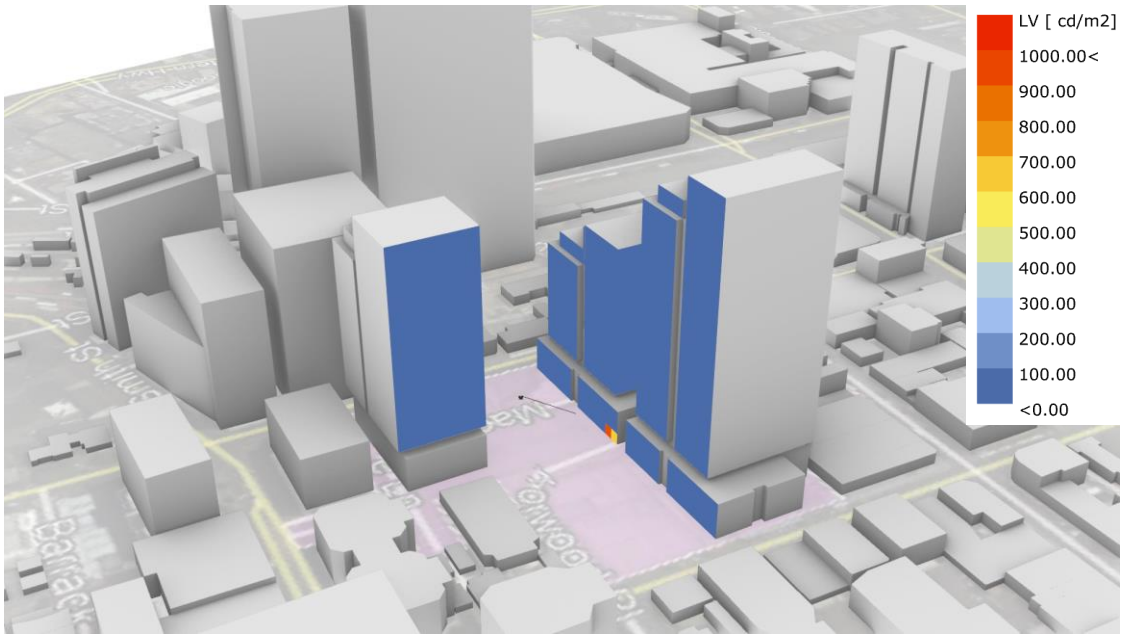

Figure A-50 Development façades at risk of posing disability glare for Direction 1, and their reflectivity impacts

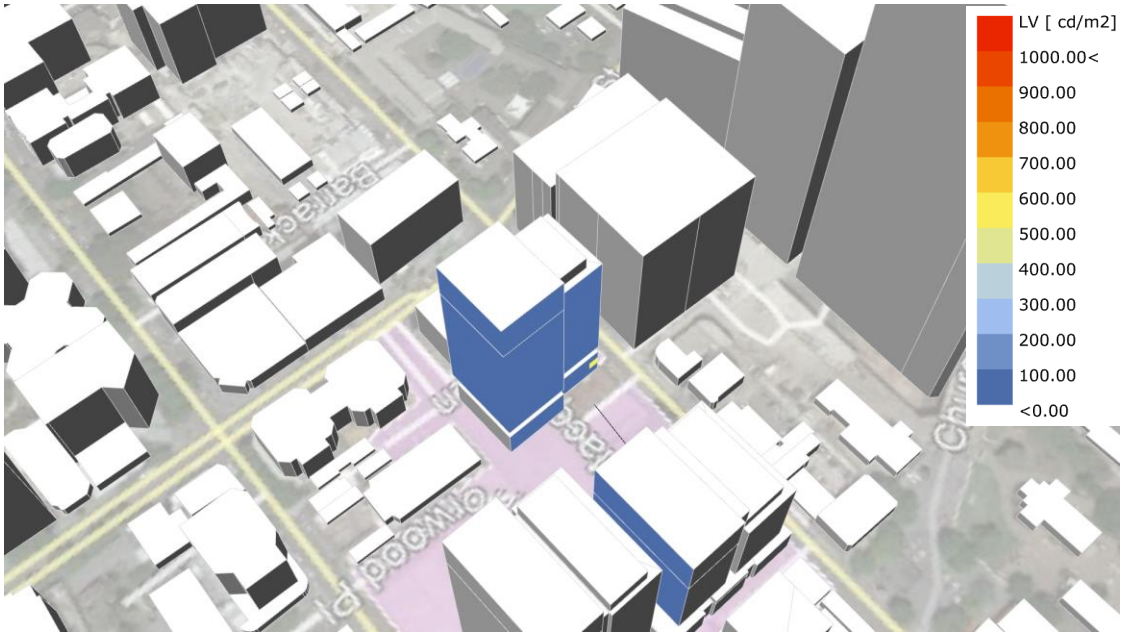

Figure A-51 Development façades at risk of posing disability glare for Direction 5, and their reflectivity impacts

Appendix B Results standard glazing sun visor

Results presented in this appendix are for assessments assuming that all facades are glazed using standard glazing and vehicles are using their sun visor (Section 4.5). Note: only results that have veiling luminance (i.e. > 0 cd/m^2) are presented in this appendix.

B.1 Route 1

This route was assessed for light rails travelling northwest along Macquarie Street.

Based on the assessment, minimal exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur along route 1 (refer to Table B-1). These were typically found to occur in the late afternoon in autumn and spring.

View of the assessed facades and their veiling luminance are shown in Figure B-1 to Figure B-5 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table B-1 Reflectivity impacts on light rail operators travelling northwest along Macquarie Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	0
3	3	• Late afternoon in March and September	12,640
4	6	• Late afternoon in March and September	9,730
5	7	• Late afternoon in March and September	7,160
6	8	• Late afternoon in March and September	4,990
7	6	• Late afternoon in March and September	3,170
8	0	• Not applicable	0
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

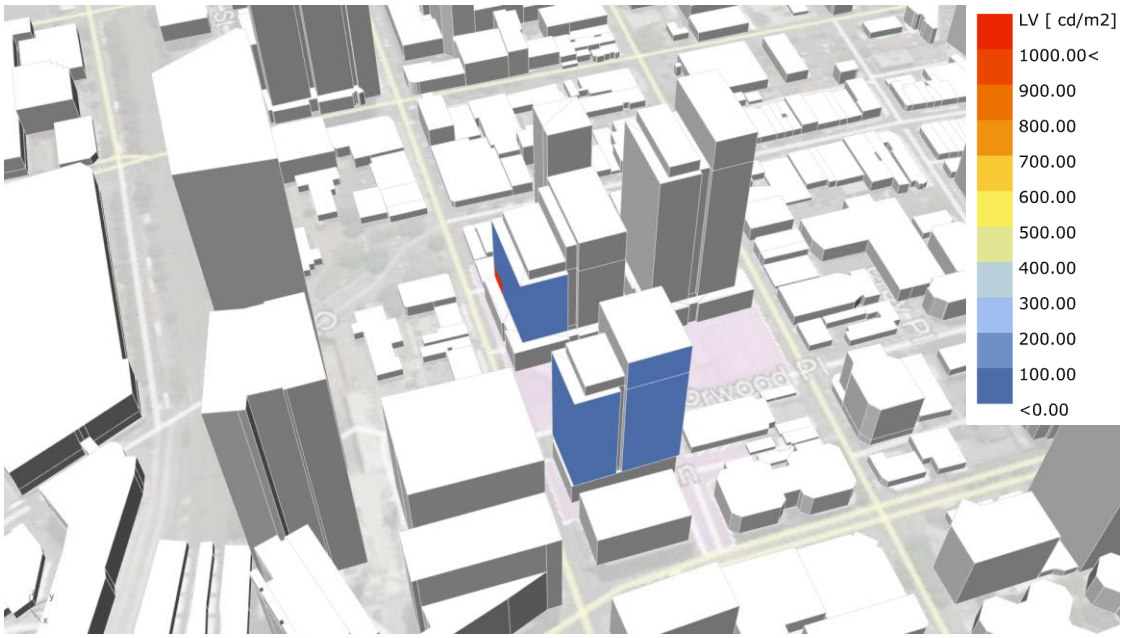

Figure B-1 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

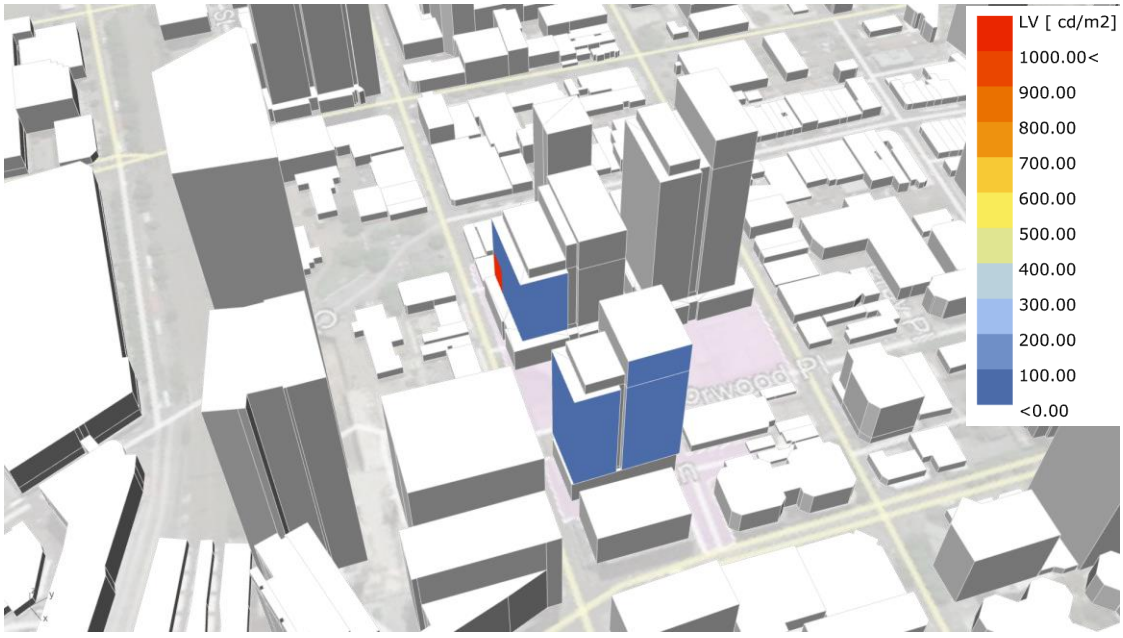

Figure B-2 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

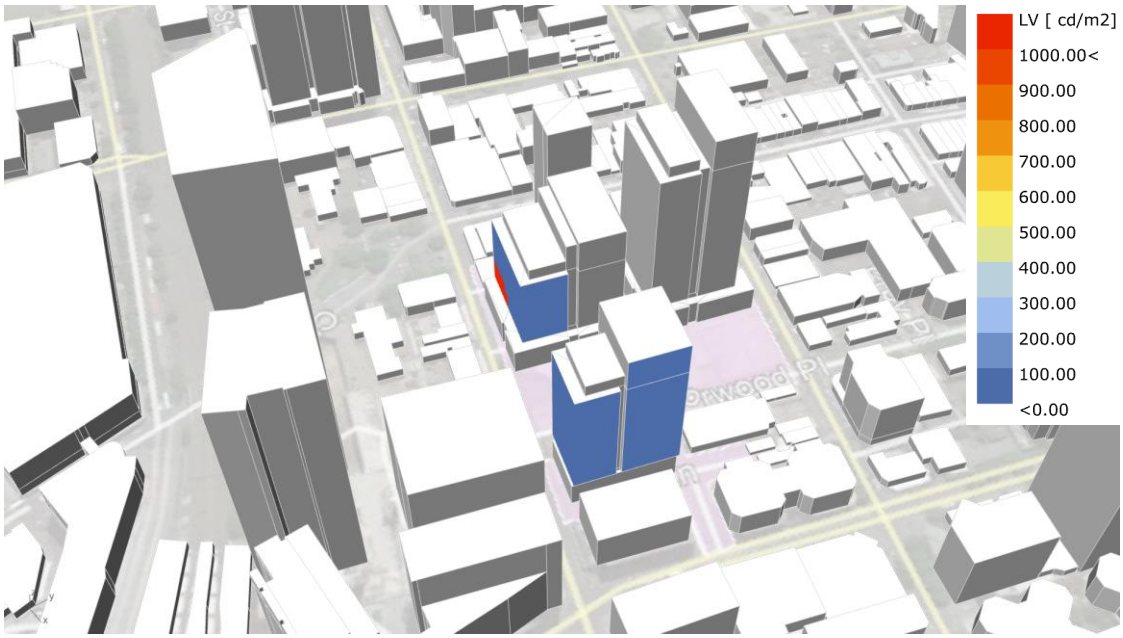

Figure B-3 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

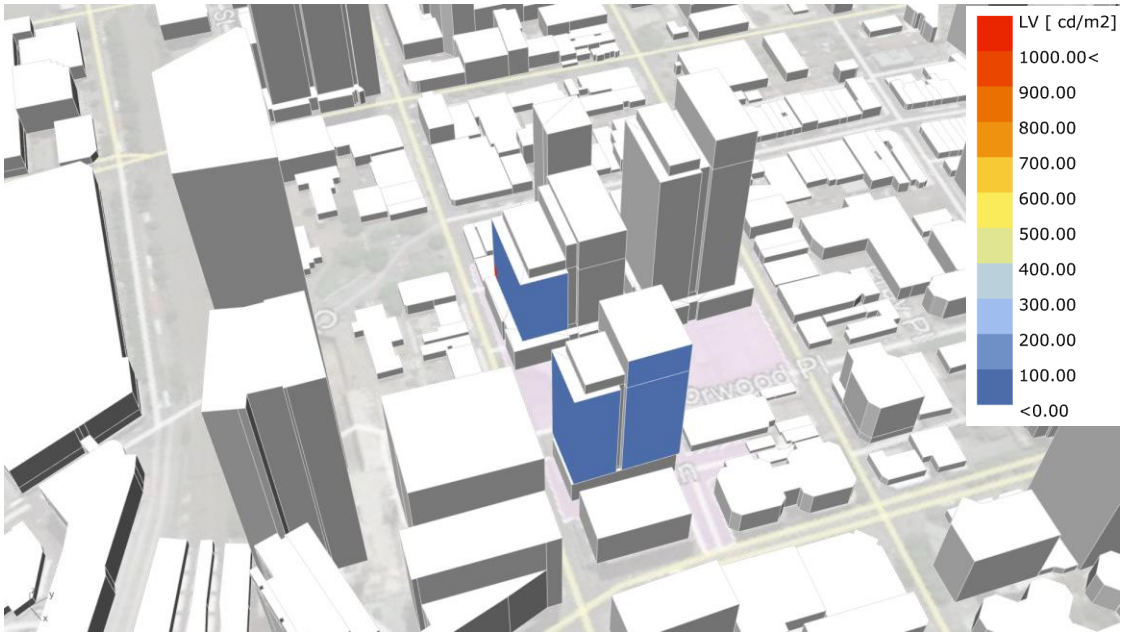

Figure B-4 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

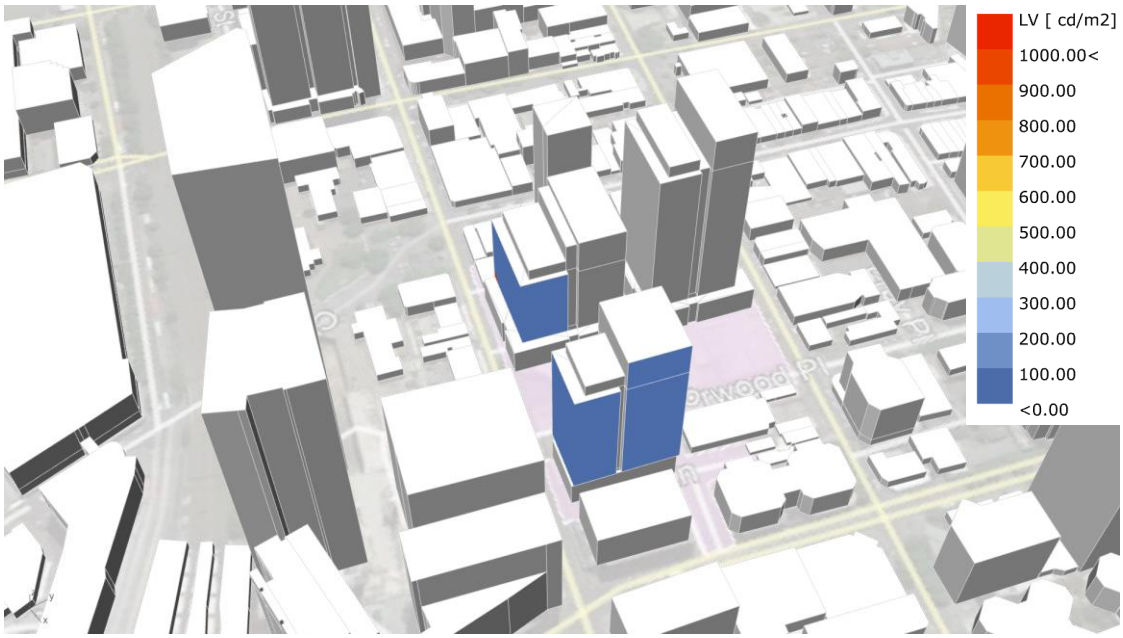

Figure B-5 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

B.2 Route 4

This route was assessed for vehicles travelling southeast along Macquarie Street.

Based on the assessment, some exceedances of the 500 cd/m^2 veiling luminance are expected to occur along route 4 (refer to Table B-2). These were typically found to occur in the late afternoon in autumn, and spring.

View of the assessed facades and their veiling luminance are shown in Figure B-6 to Figure B-12Figure B-12 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table B-2 Reflectivity impacts on vehicles travelling southeast along Macquarie Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	40	• Late afternoon in April, August, and September	5,430
2	31	• Late afternoon in April, August, and September	4,540
3	31	• Late afternoon in April, August, and September	2,680
4	27	• Late afternoon in April, August, and September	2,070
5	0	• Not applicable	0
6	1	• Early morning in February	2,730
7	1	• Early morning in November	5,480
8	1	• Early morning in November	5,260
9	0	• Not applicable	0

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
10	0	• Not applicable	0
11	0	• Not applicable	0

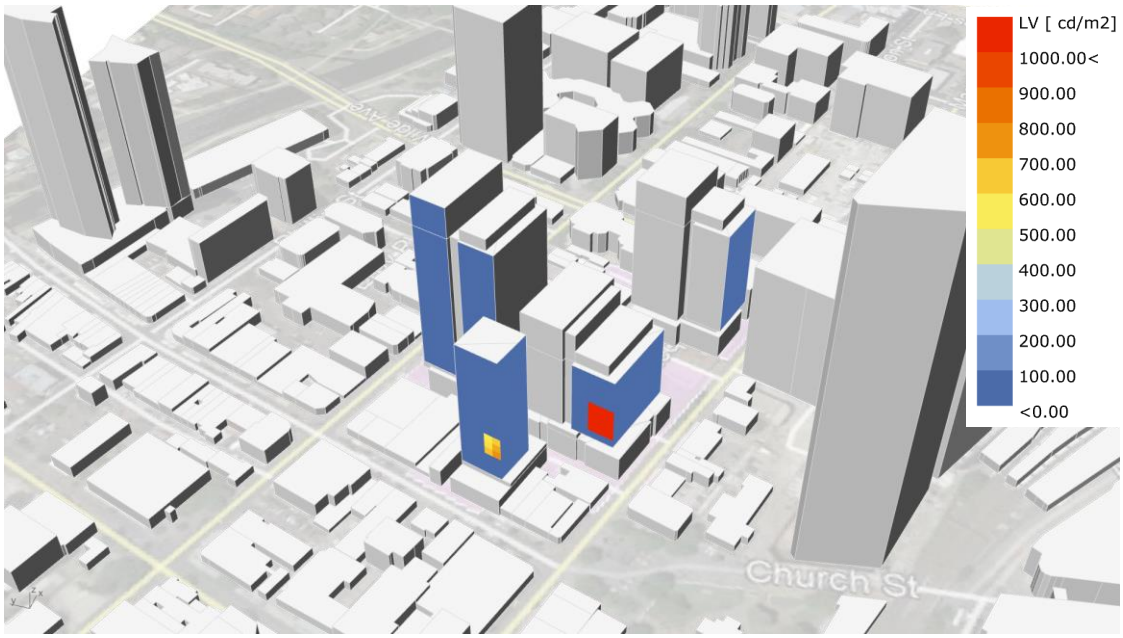

Figure B-6 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

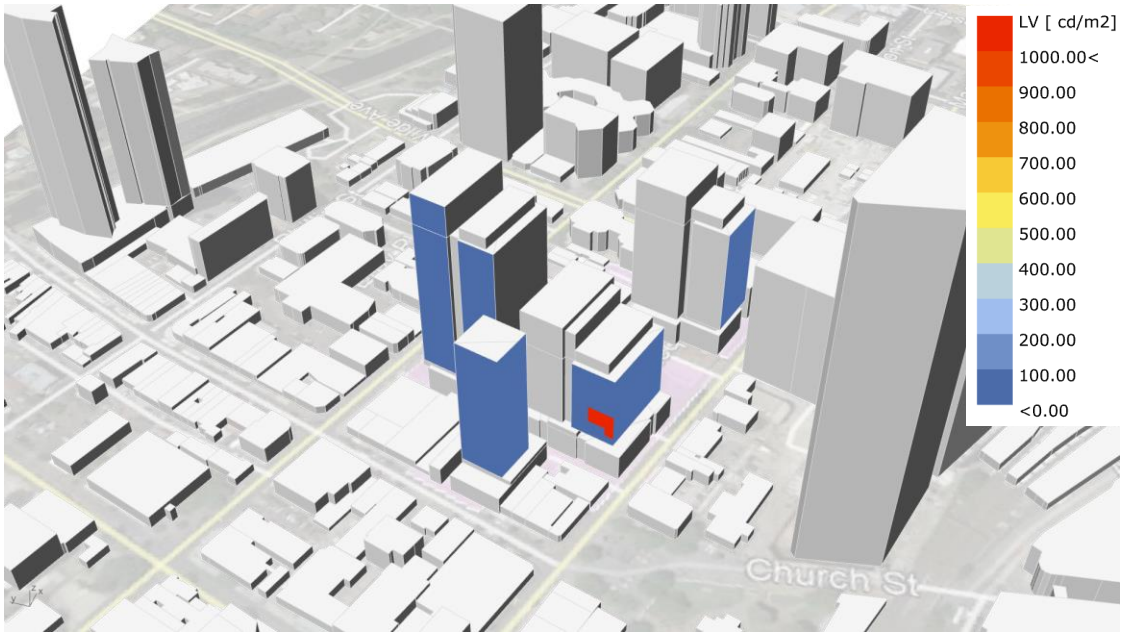

Figure B-7 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

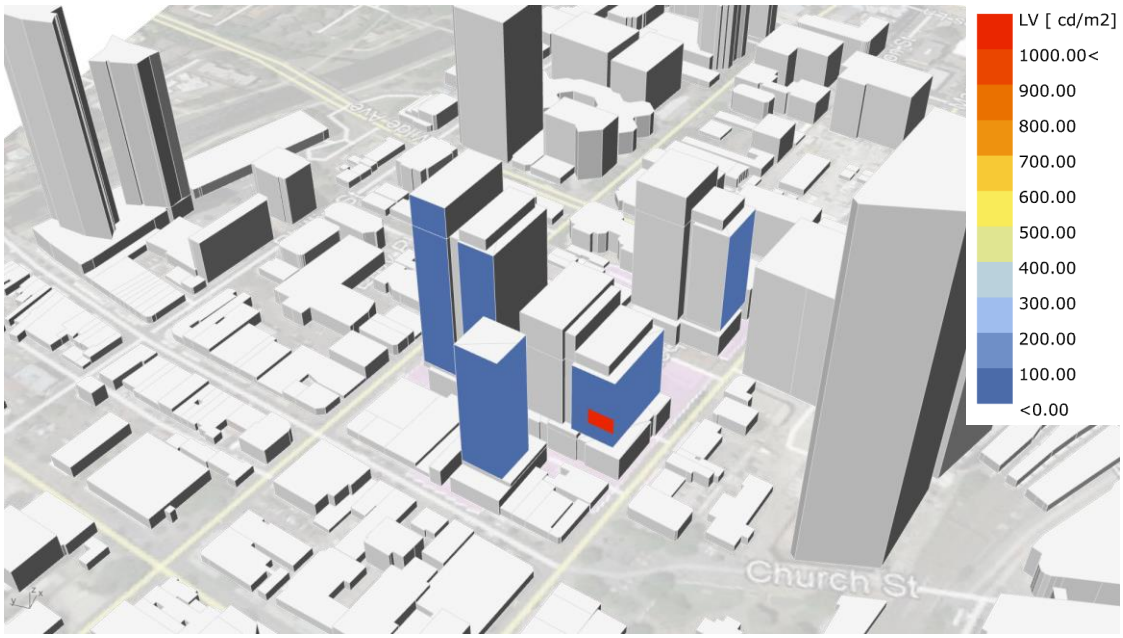

Figure B-8 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

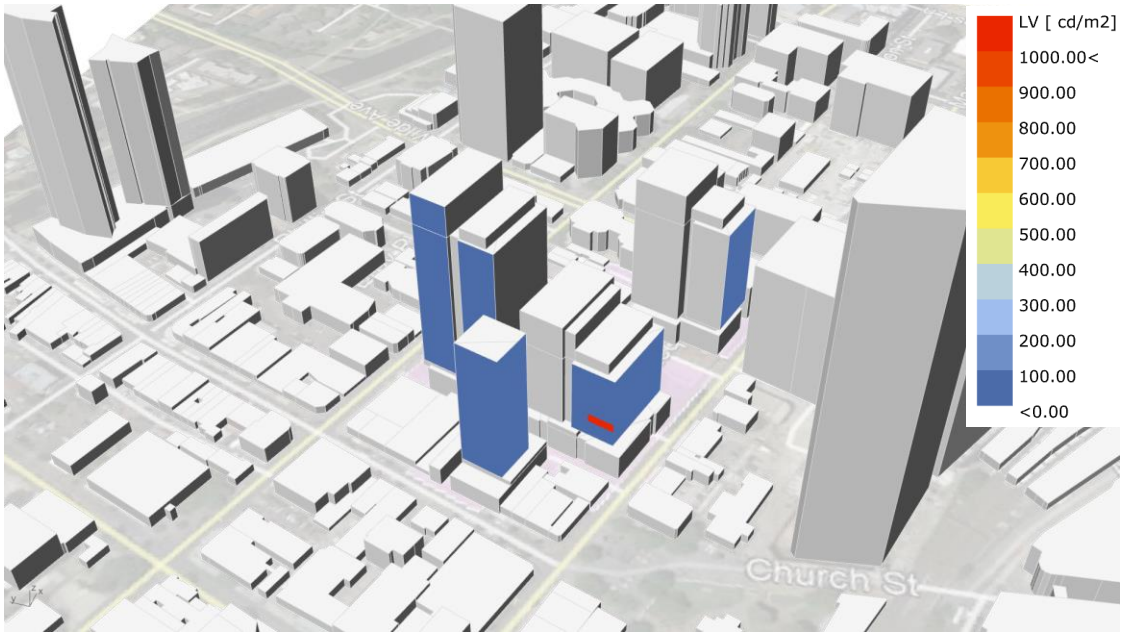

Figure B-9 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

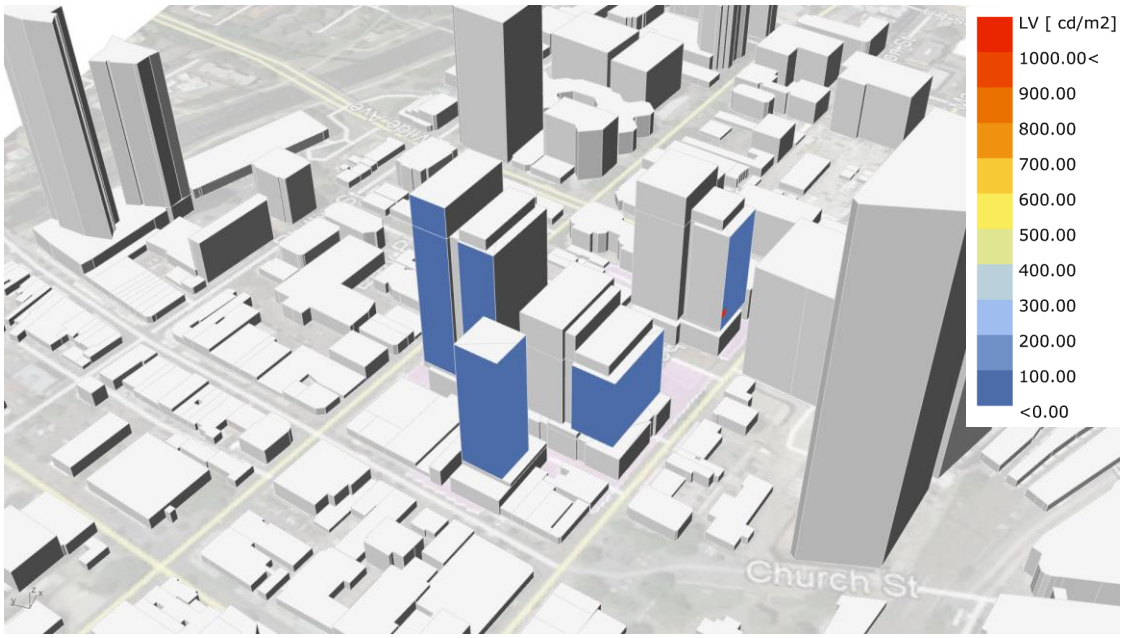

Figure B-10 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

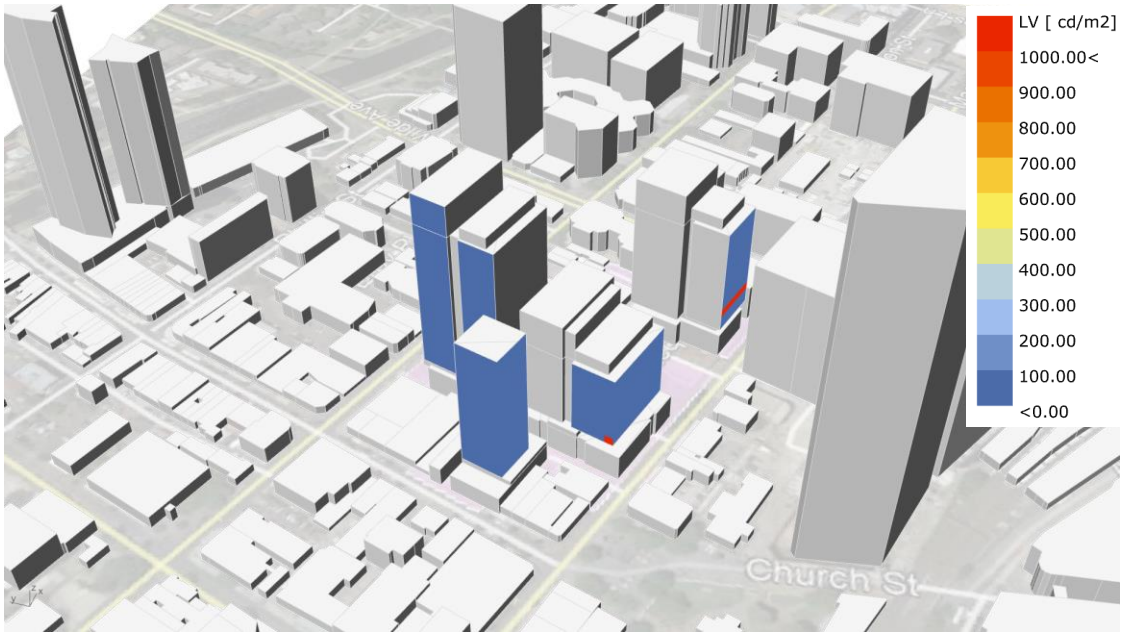

Figure B-11 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

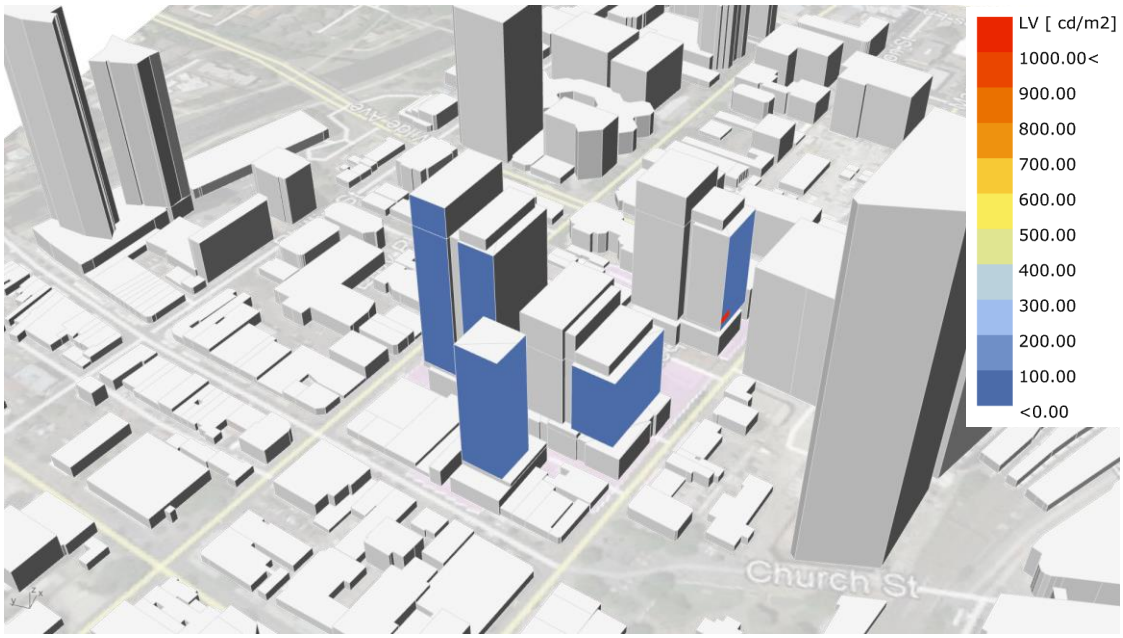

Figure B-12 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

B.3 Route 5

This route was assessed for vehicles travelling northwest along George Street.

Based on the assessment, some exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur along route 5 (refer to Table B-3). These were typically found to occur in the early morning summer and late afternoon in autumn, winter, and spring.

View of the assessed facades and their veiling luminance are shown in Figure B-13 to Figure B-18 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table B-3 Reflectivity impacts on vehicles travelling northwest along George Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	0
3	70	• Early morning in January, November, and December • Late afternoon in September	1,140
4	86	• Early morning in January, November, and December • Late afternoon in April, August, and September	5,700
5	5	• Late afternoon in March, April, August, and September	3,840
6	14	• Late afternoon in March, April, August, and September	3,600

Location	Number of hours LV is expected to exceed 500 cd/m² in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m²]
7	1	• Late afternoon in April	2,100
8	8	• Late afternoon in April and August	940
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

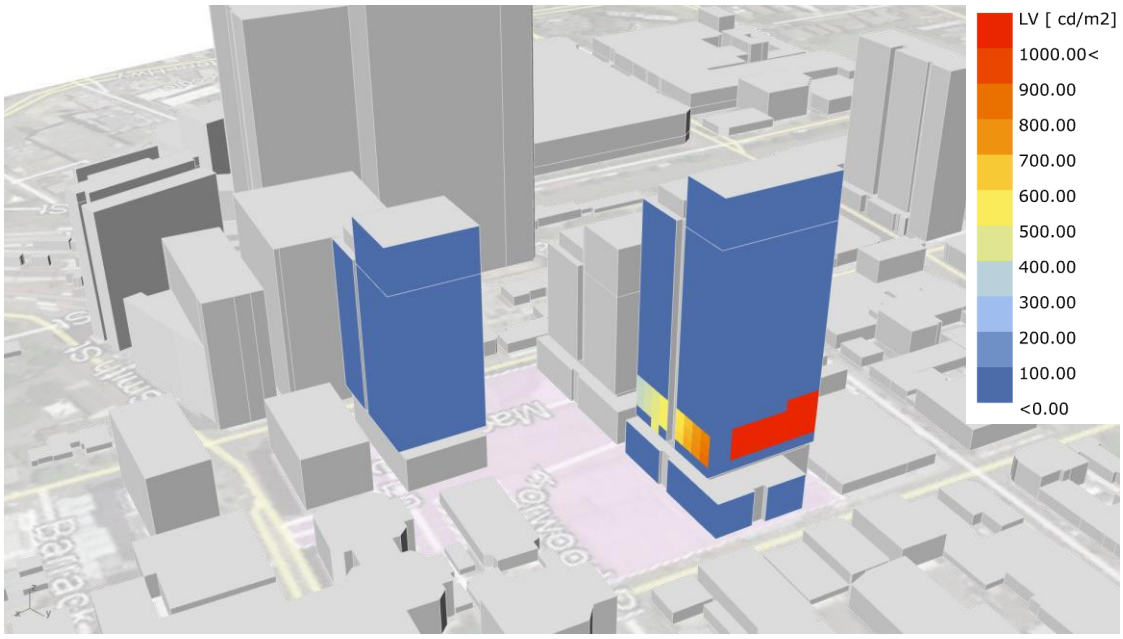

Figure B-13 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

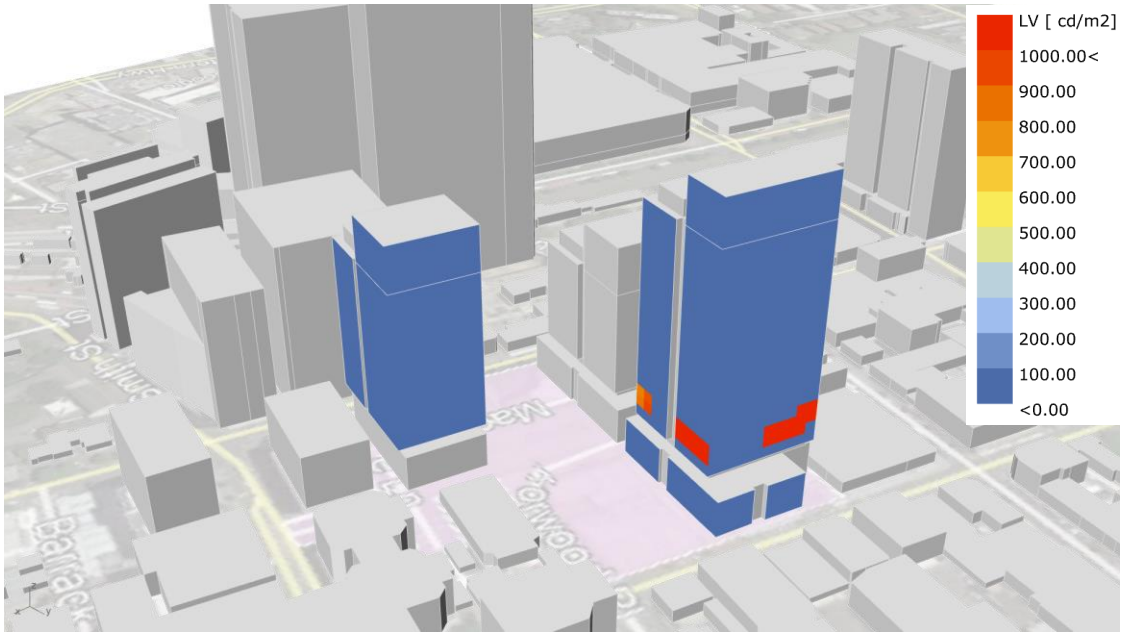

Figure B-14 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

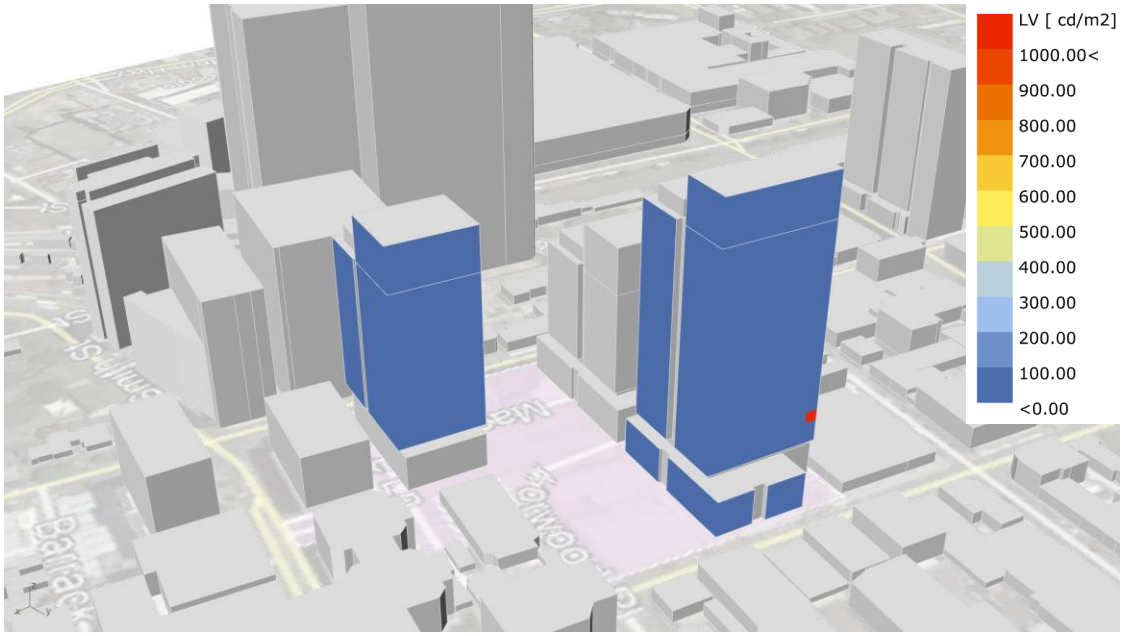

Figure B-15 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

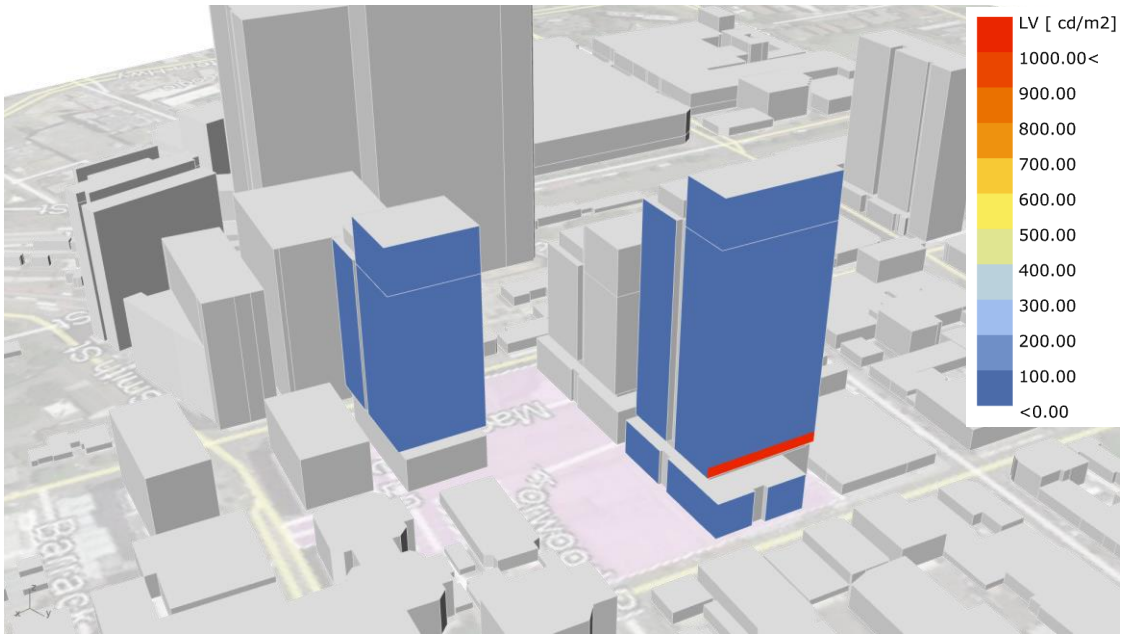

Figure B-16 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

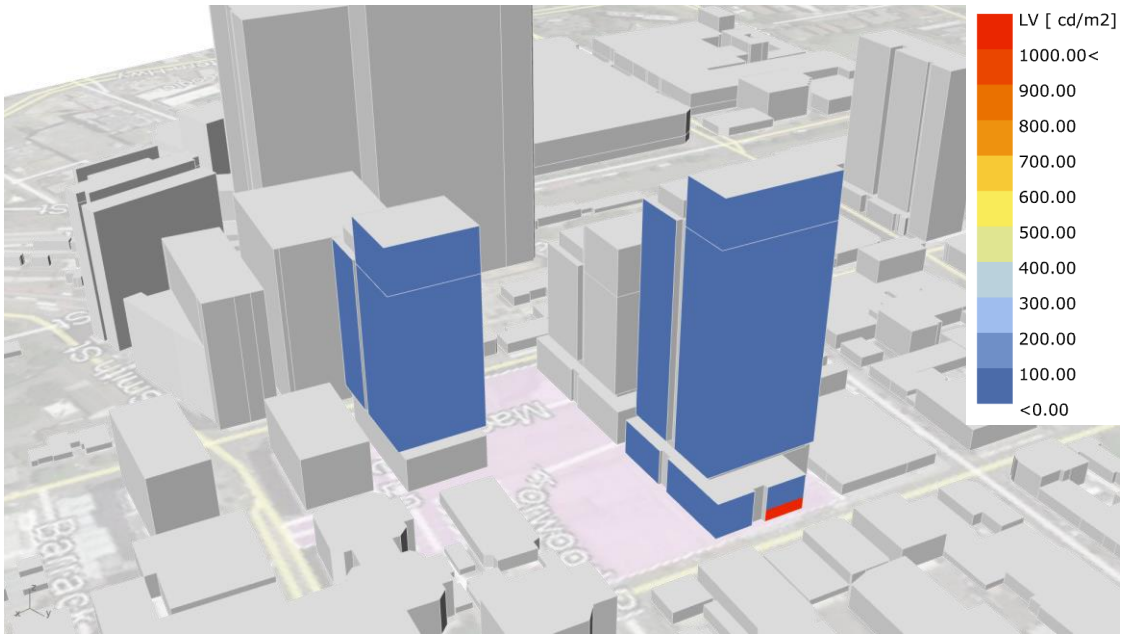

Figure B-17 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

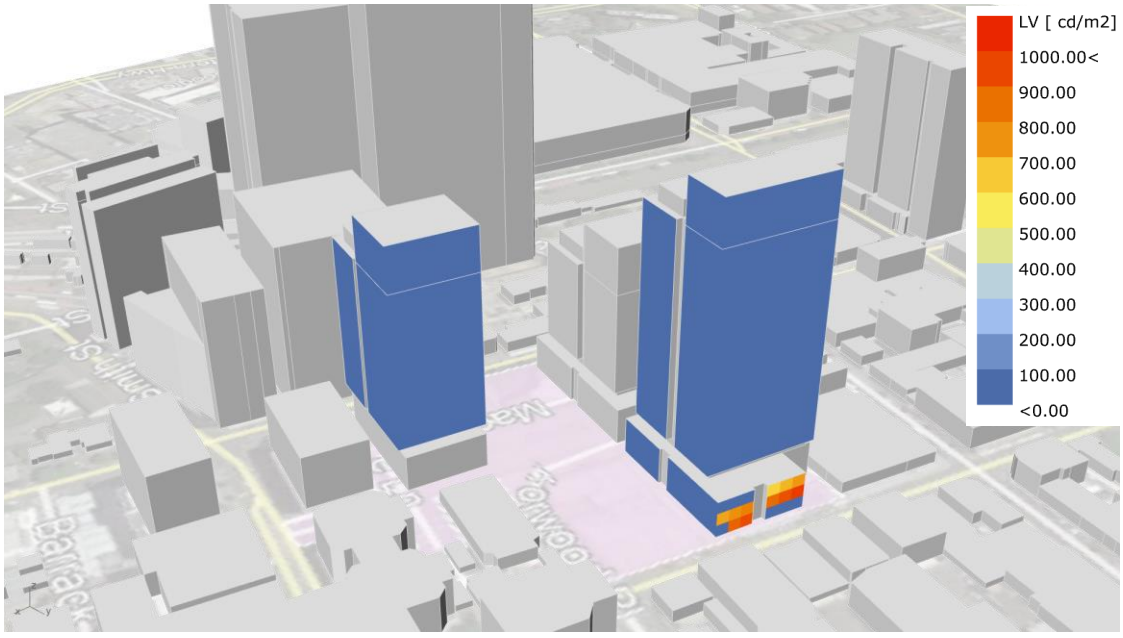

Figure B-18 Development façades at risk of posing disability glare at Location 8, and their reflectivity impacts

B.4 Route 6

This route was assessed for vehicles travelling southeast along George Street.

Based on the assessment, some exceedances of the 500cd/m^2 veiling luminance criteria are expected to occur along route 5 (refer to Table B-4). These were typically found to occur in the early morning summer and spring and late afternoon in autumn, and spring.

View of the assessed facades and their veiling luminance are shown in Figure B-19 to Figure B-21 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table B-4 Reflectivity impacts on vehicles travelling southeast along George Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	54	• Early morning in January, February, October, and November • Late afternoon in February, March, August, and September	5,710
2	69	• Early morning in January, February, October, and November • Late afternoon in February, March, September, and October	4,730
3	128	• Early morning in February, October, and November • Late afternoon in February, March, September, October, and November	4,090
4	0	• Not applicable	0
5	0	• Not applicable	0
6	0	• Not applicable	0
7	0	• Not applicable	0
8	0	• Not applicable	0
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

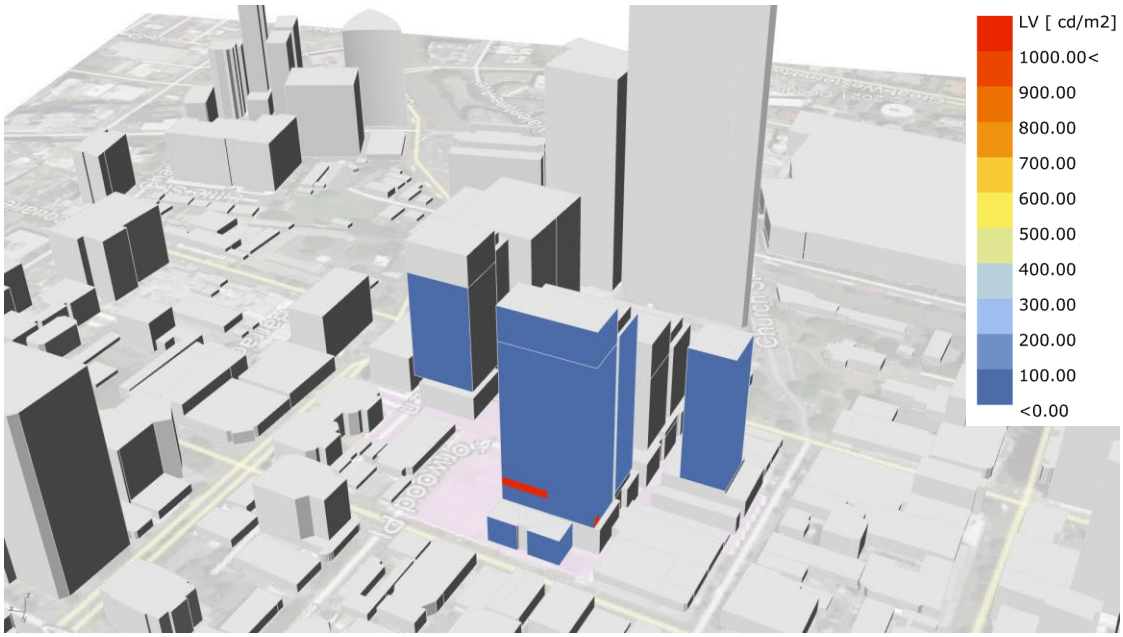

Figure B-19 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

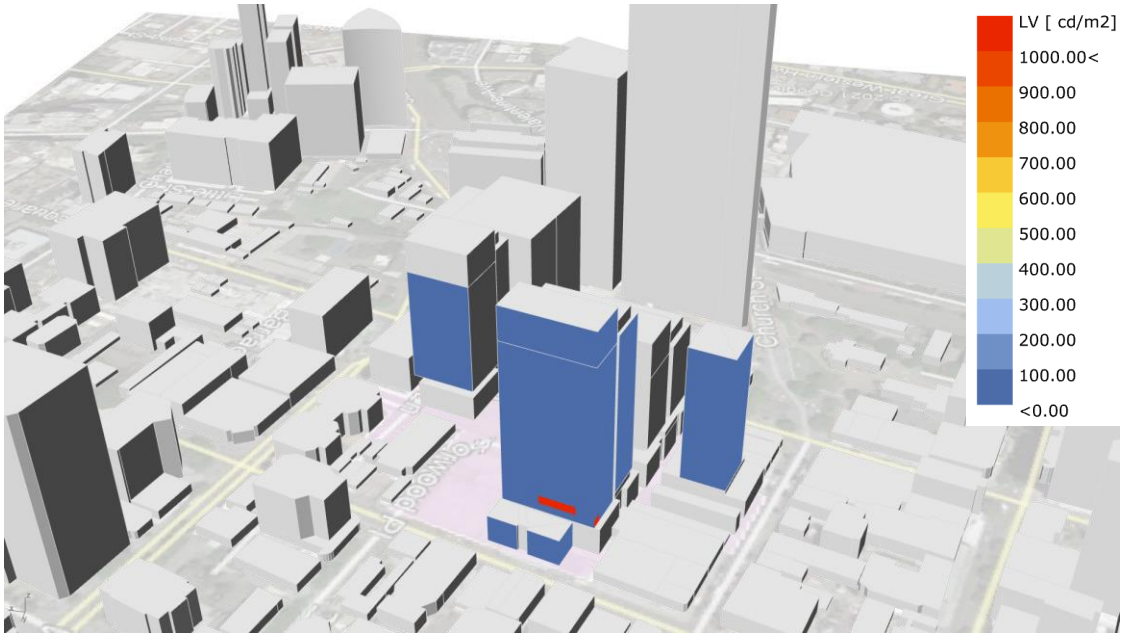

Figure B-20 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

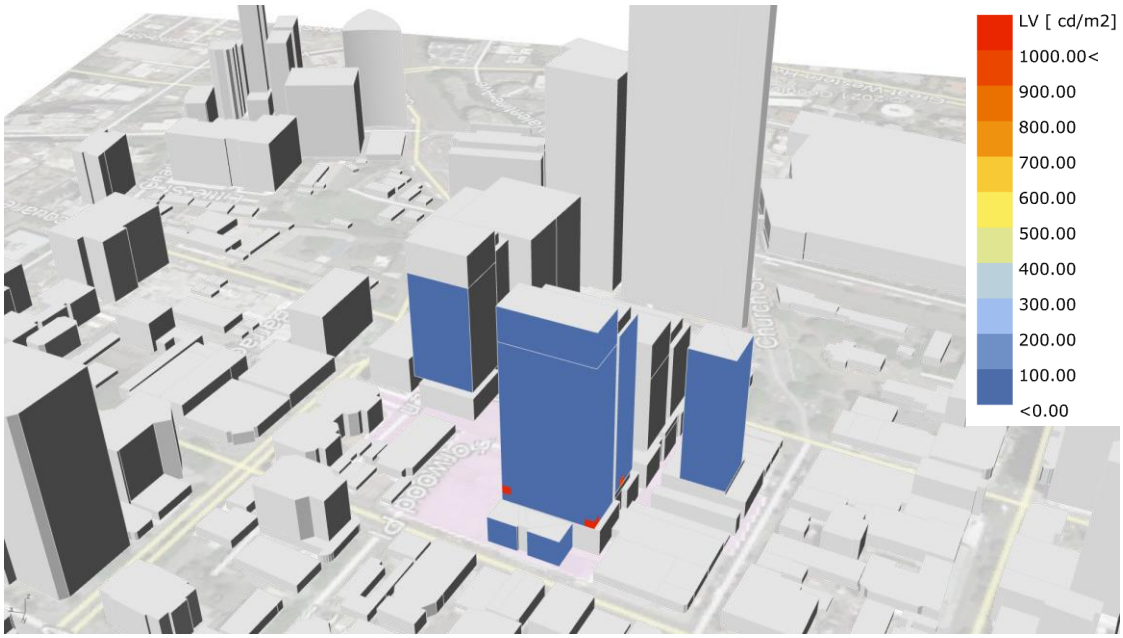

Figure B-21 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

Appendix C Results low reflectivity glazing sun visor

Results presented in this appendix are for assessments assuming that all facades are glazed using low reflectivity glazing and all vehicles are using their sun visor (Section 4.5). Note: only results that have veiling luminance (i.e., > 0 cd/m^2) are presented in this appendix.

C.1 Route 1

This route was assessed for light rails travelling northwest along Macquarie Street.

Based on the assessment, minimal exceedances of the 500 cd/m^2 veiling luminance criteria are expected to occur along route 1 (refer to Table C-1). These were typically found to occur in the late afternoon in autumn and spring.

View of the assessed facades and their veiling luminance are shown in Figure C-1 to Figure C-5 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-1 Reflectivity impacts on light rail operators travelling northwest along Macquarie Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	0
3	3	• Late afternoon in March and September	5,620
4	6	• Late afternoon in March and September	4,360
5	7	• Late afternoon in March and September	3,210
6	8	• Late afternoon in March and September	2,250
7	6	• Late afternoon in March and September	1,430
8	0	• Not applicable	0
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

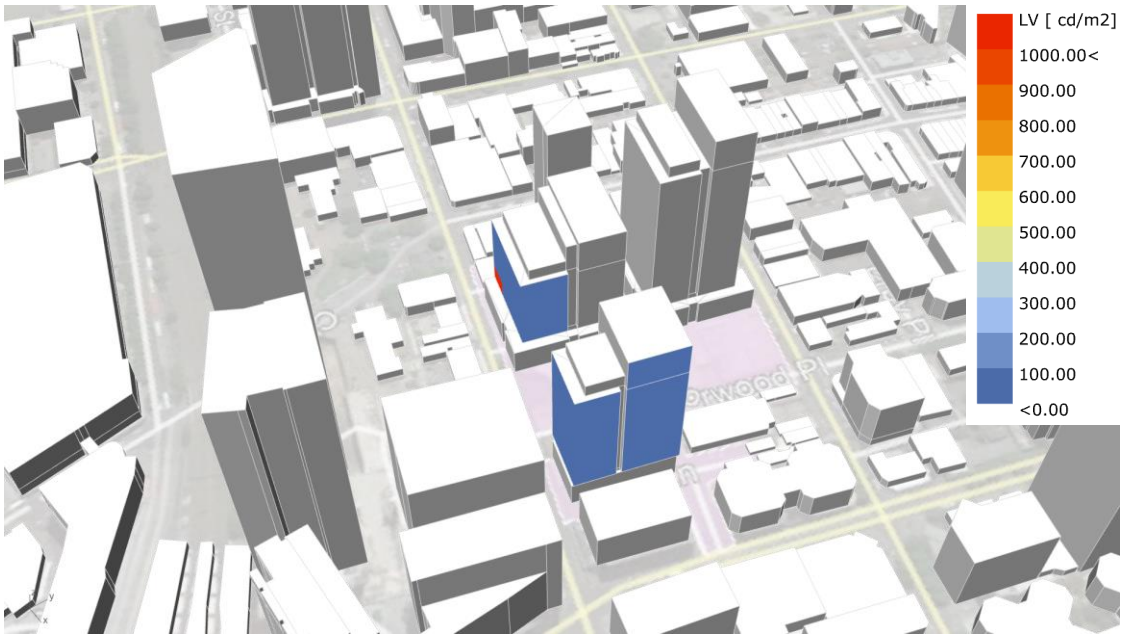

Figure C-1 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

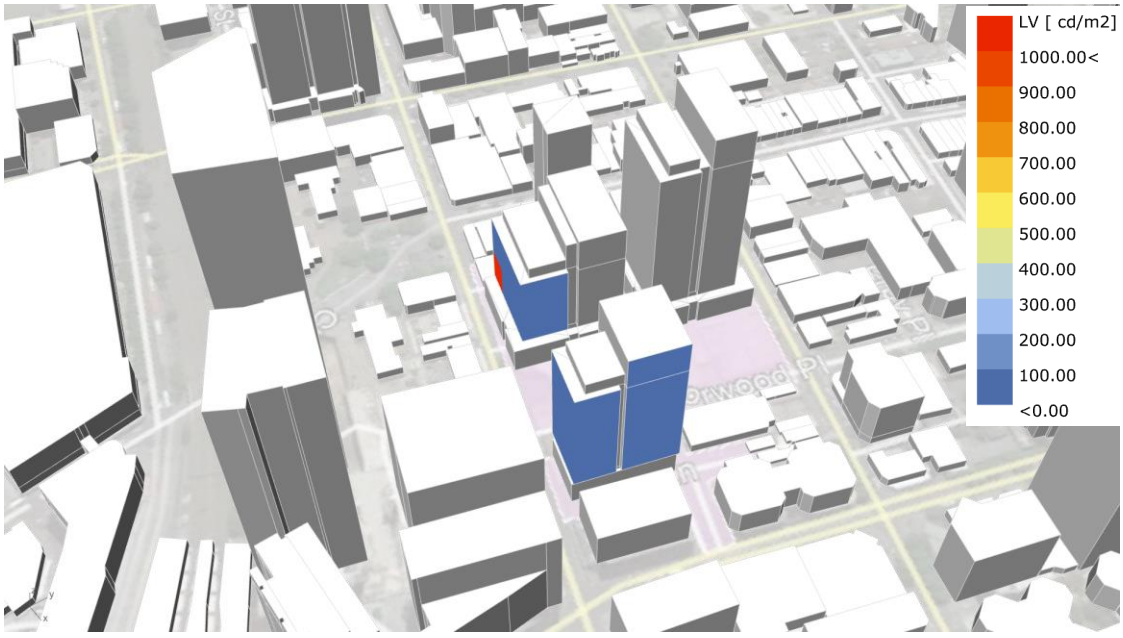

Figure C-2 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

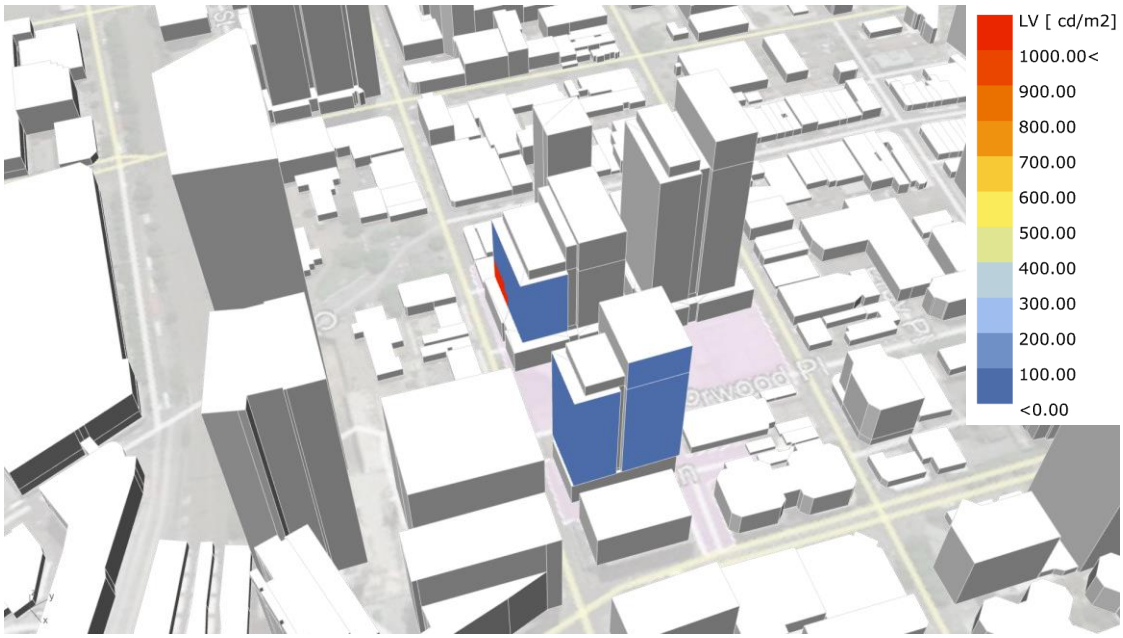

Figure C-3 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

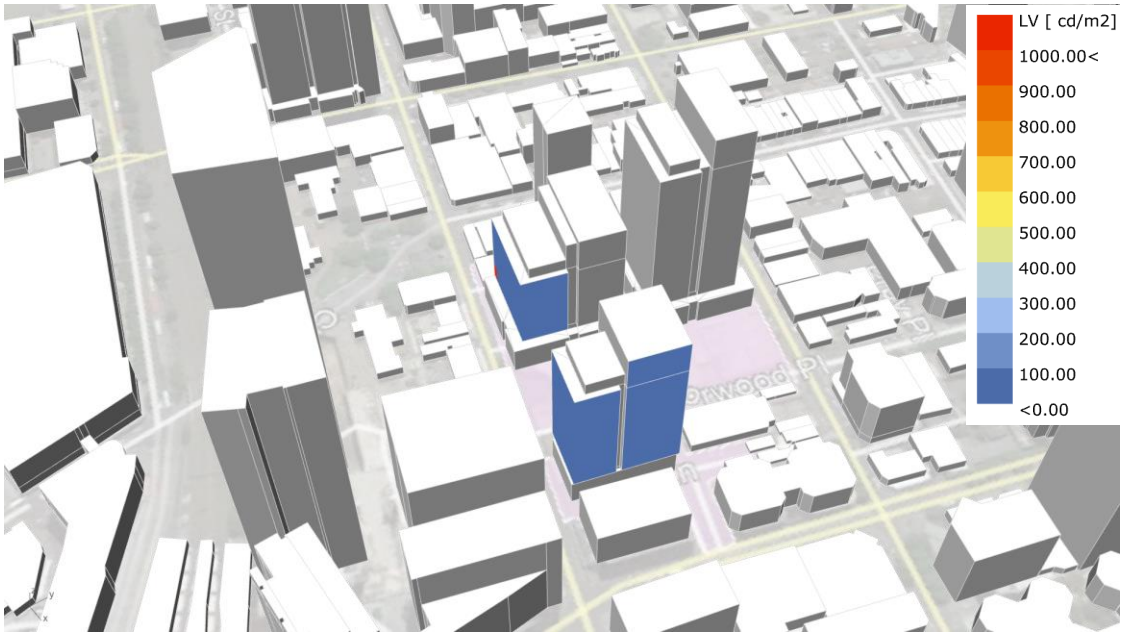

Figure C-4 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

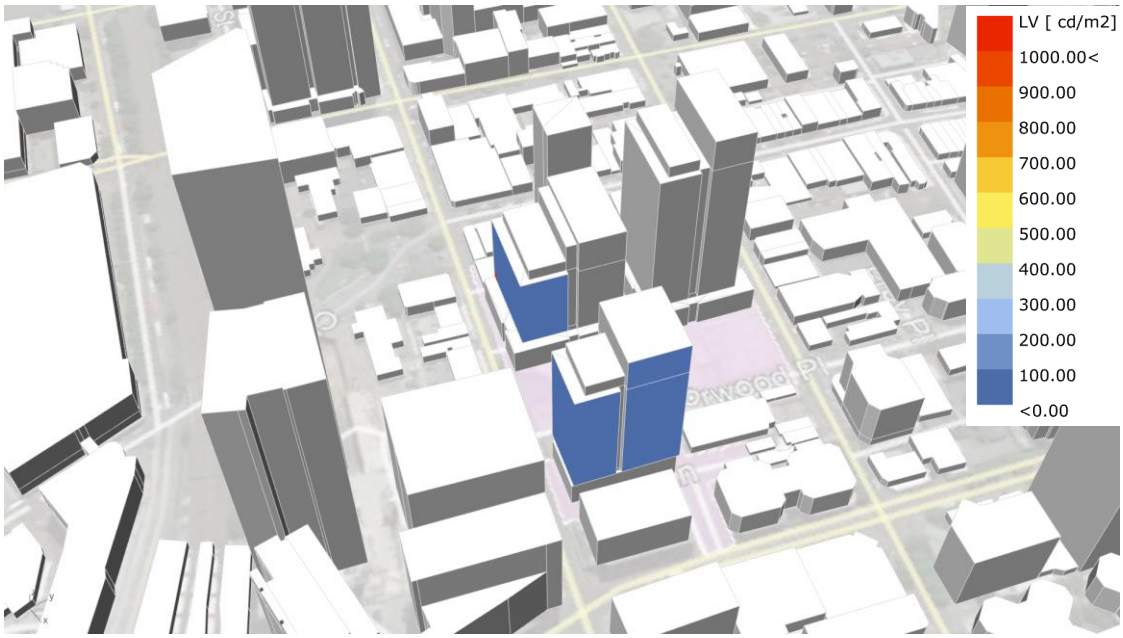

Figure C-5 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

C.2 Route 4

This route was assessed for vehicles travelling southeast along Macquarie Street.

Based on the assessment, some exceedances of the 500 cd/m^2 veiling luminance criteria is expected to occur along route 4 (refer to Table C-2). These were typically found to occur in the late afternoon in autumn, and spring.

View of the assessed facades and their veiling luminance are shown in Figure C-6 to Figure C-12 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-2 Reflectivity impacts on vehicles travelling southeast along Macquarie Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	33	• Late afternoon in April, August, and September	2,430
2	31	• Late afternoon in April, August, and September	2,030
3	31	• Late afternoon in April, August, and September	1,210
4	27	• Late afternoon in April, August, and September	930
5	0	• Not applicable	0
6	1	• Early morning in February	1,230
7	1	• Early morning in November	2,470
8	1	• Early morning in November	2,370
9	0	• Not applicable	0

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
10	0	• Not applicable	0
11	0	• Not applicable	0

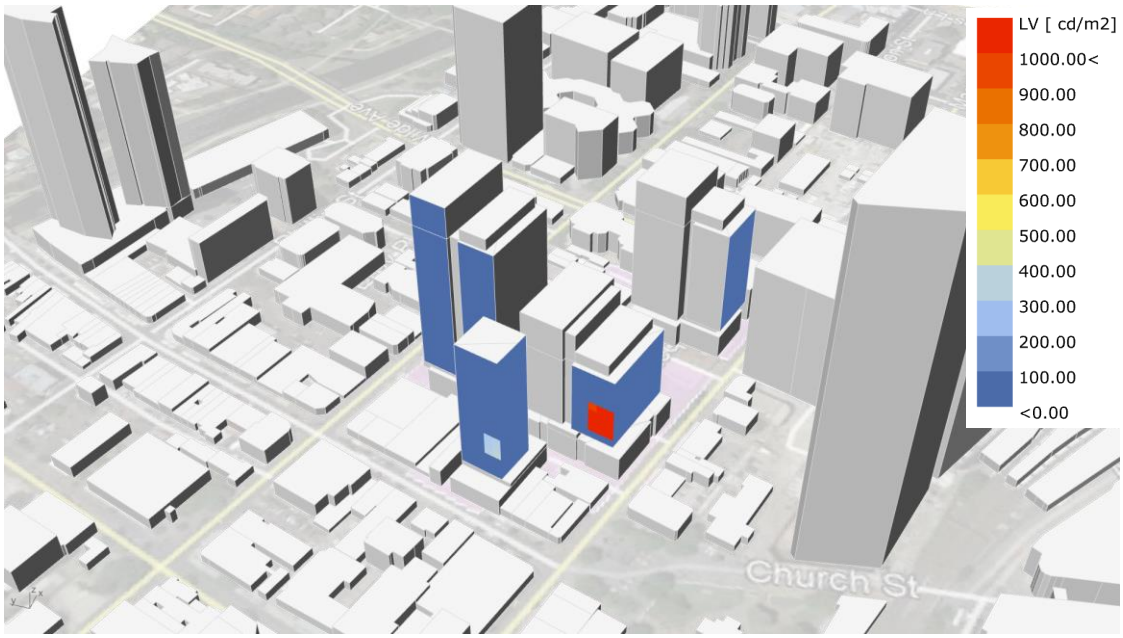

Figure C-6 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

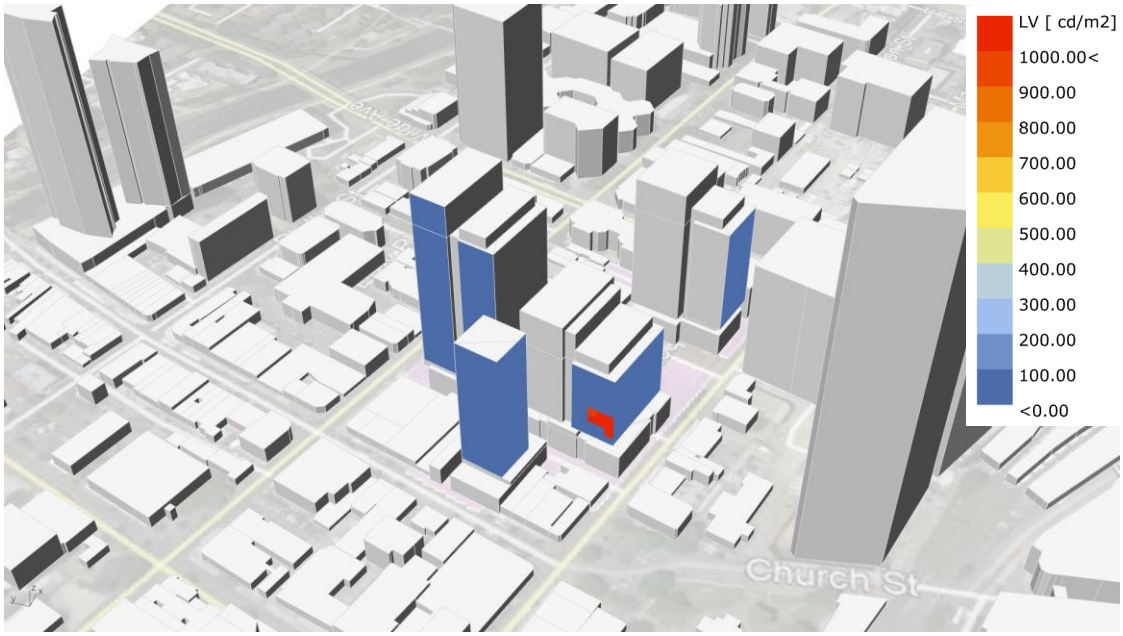

Figure C-7 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

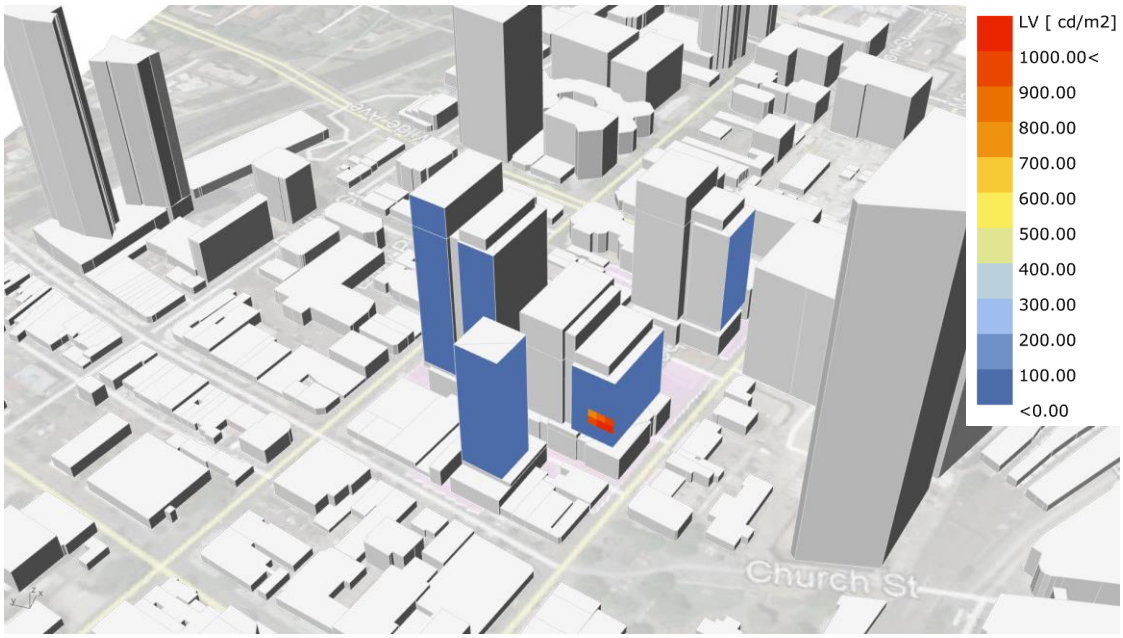

Figure C-8 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

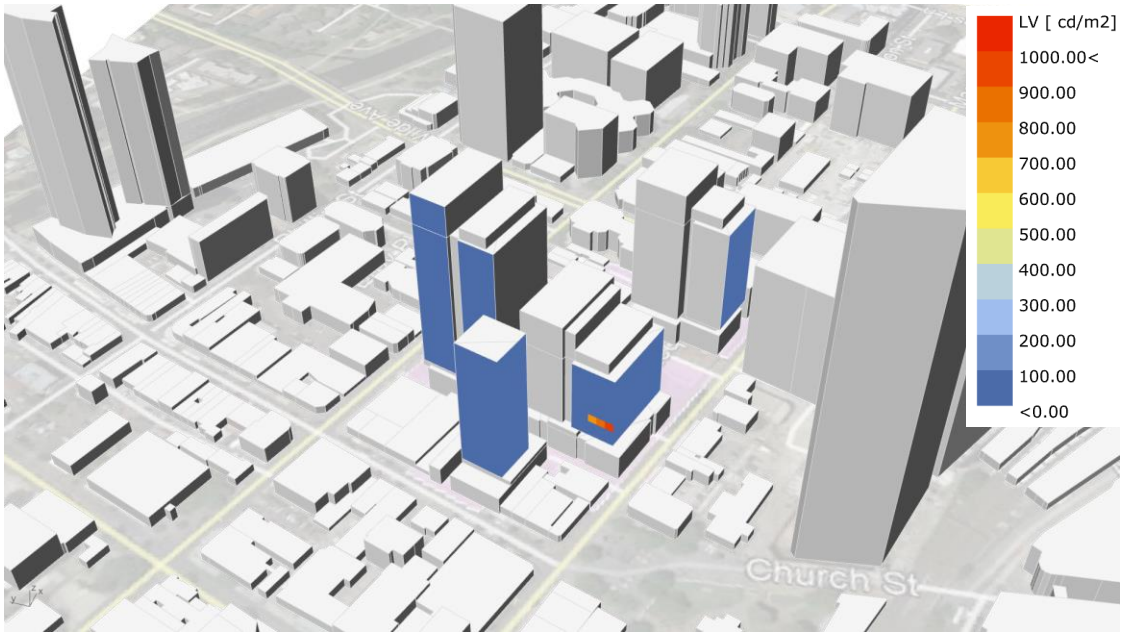

Figure C-9 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

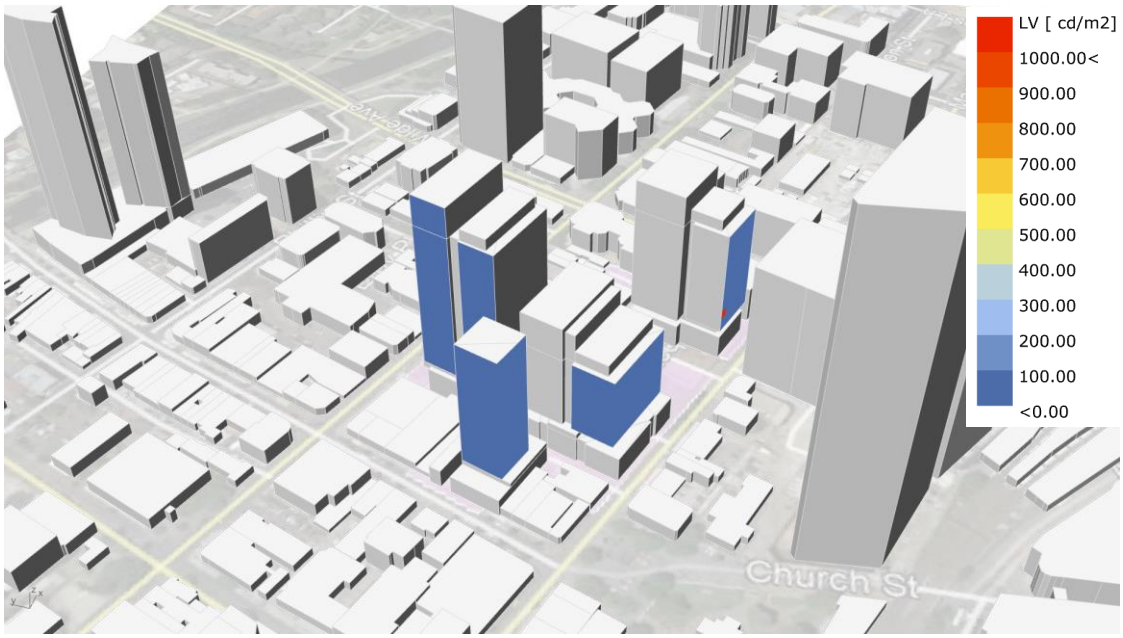

Figure C-10 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

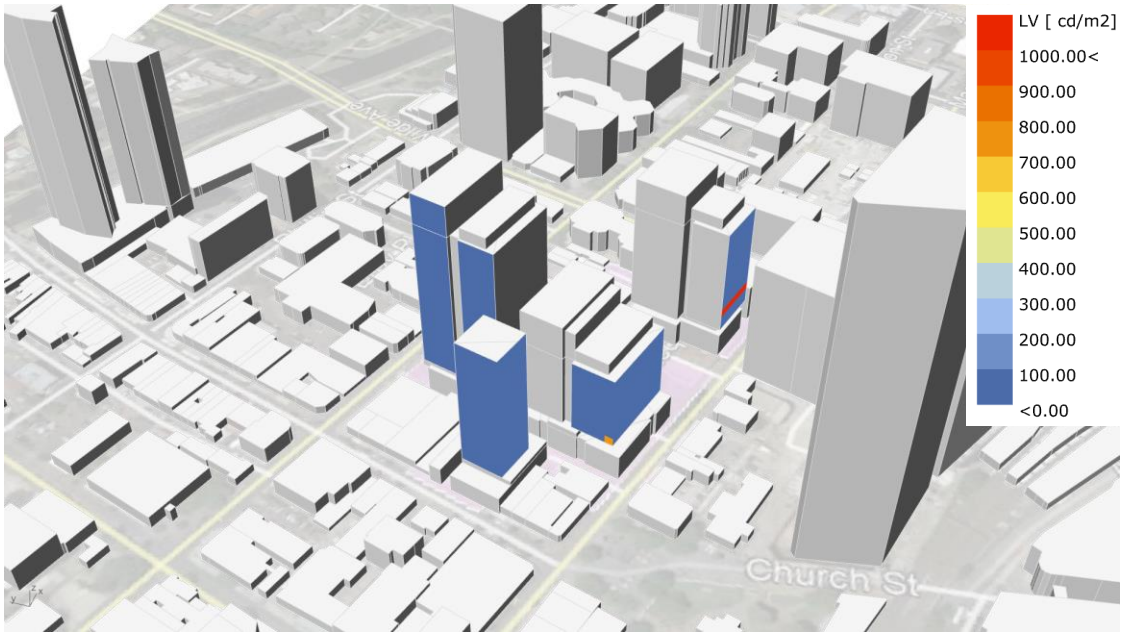

Figure C-11 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

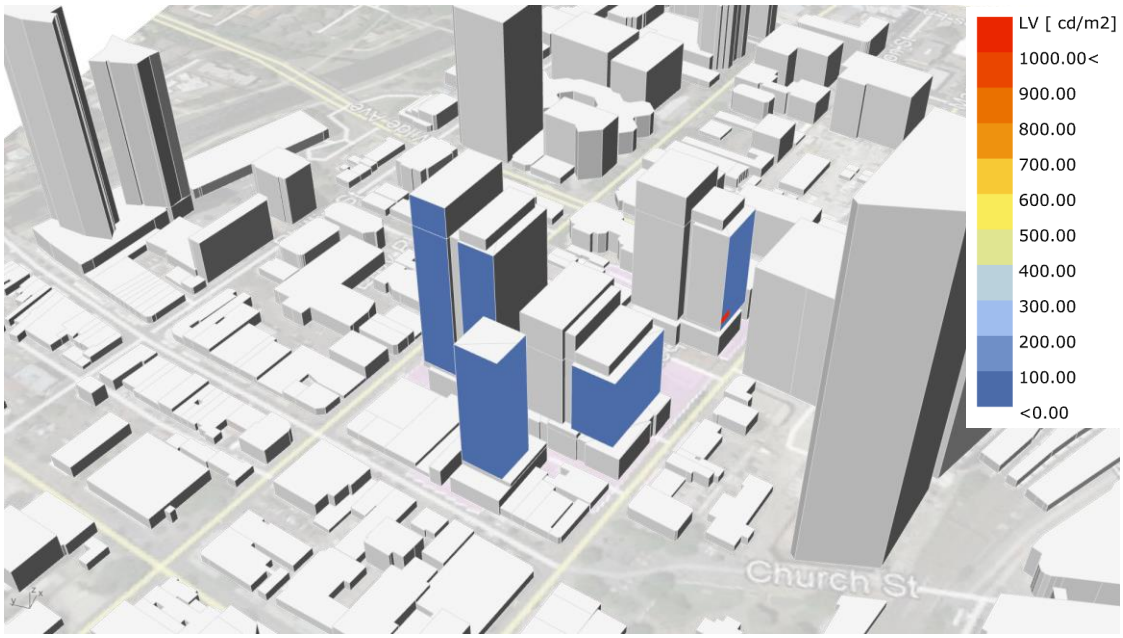

Figure C-12 Development façades at risk of posing disability glare at Location 8, and their reflectivity impacts

C.3 Route 5

This route was assessed for vehicles travelling northwest along George Street.

Based on the assessment, some exceedances of the 500 cd/m^2 veiling luminance criteria are expected to occur along route 5 (refer to Table C-3). These were typically found to occur in the early morning summer and late afternoon in autumn, winter, and spring.

View of the assessed facades and their veiling luminance are shown in Figure C-13 to Figure C-18 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-3 Reflectivity impacts on vehicles travelling northwest along George Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	0
3	1	• Late afternoon in September	530
4	82	• Early morning in January, November, and December • Late afternoon in April, August, and September	2,570
5	3	• Late afternoon in March, April, August, and September	1,740
6	8	• Late afternoon in March, April, August, and September	1,630
7	1	• Late afternoon in April	940
8	0	• Not applicable	420

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

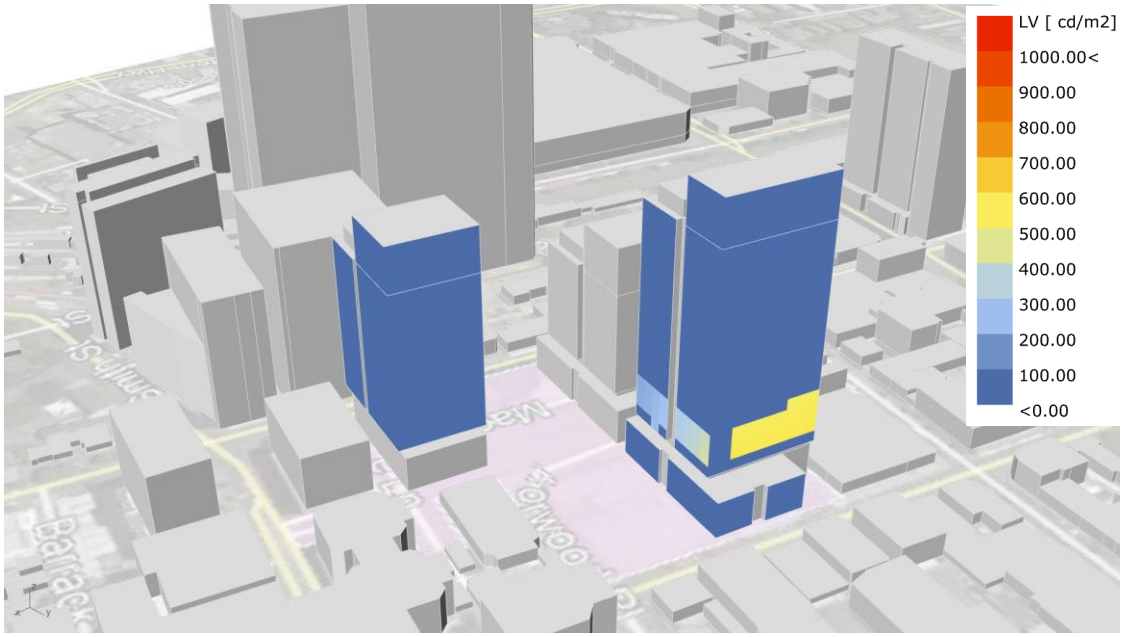

Figure C-13 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

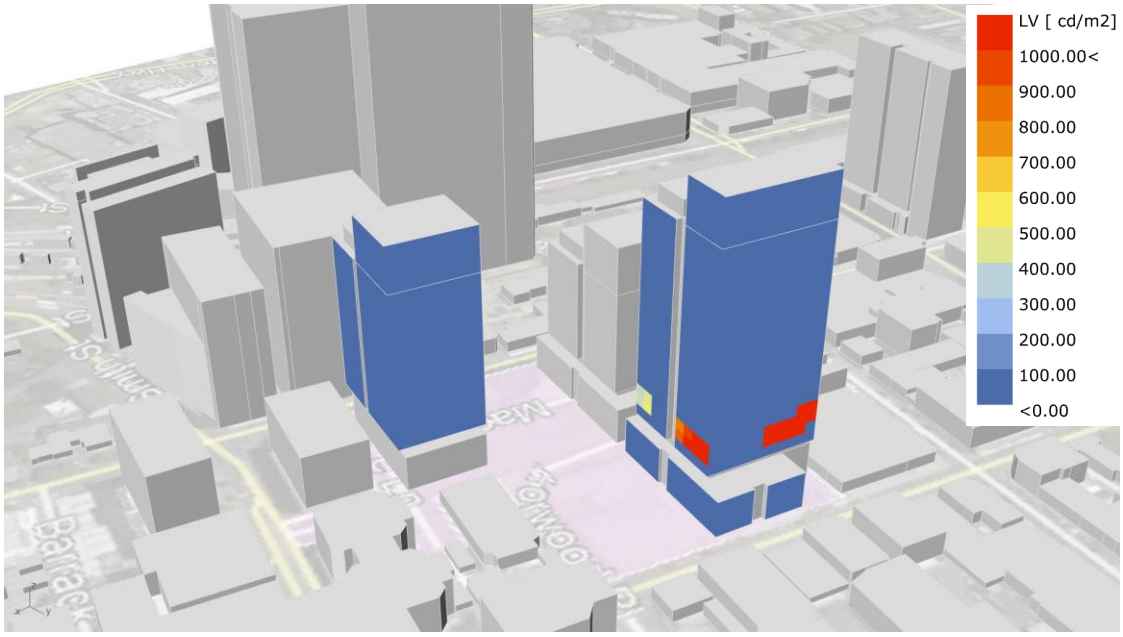

Figure C-14 Development façades at risk of posing disability glare at Location 4, and their reflectivity impacts

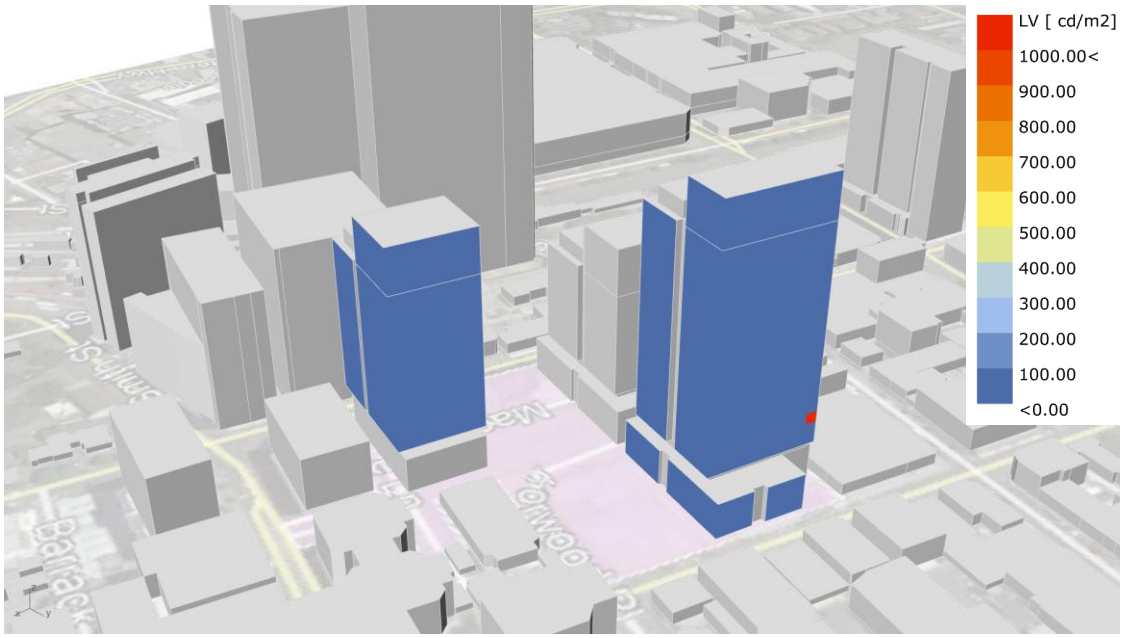

Figure C-15 Development façades at risk of posing disability glare at Location 5, and their reflectivity impacts

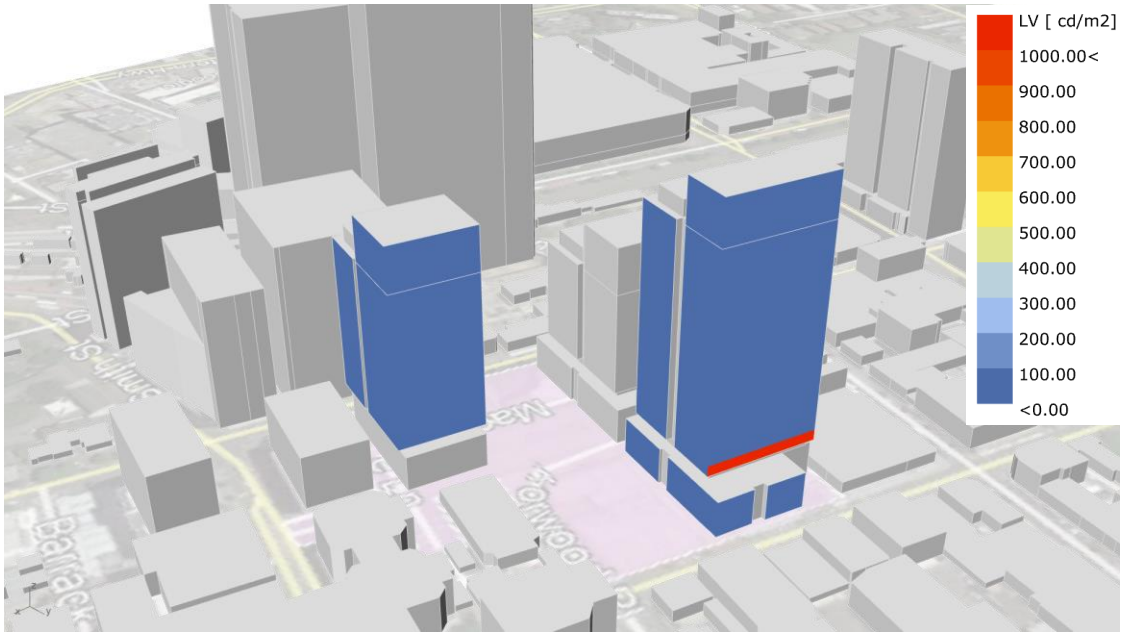

Figure C-16 Development façades at risk of posing disability glare at Location 6, and their reflectivity impacts

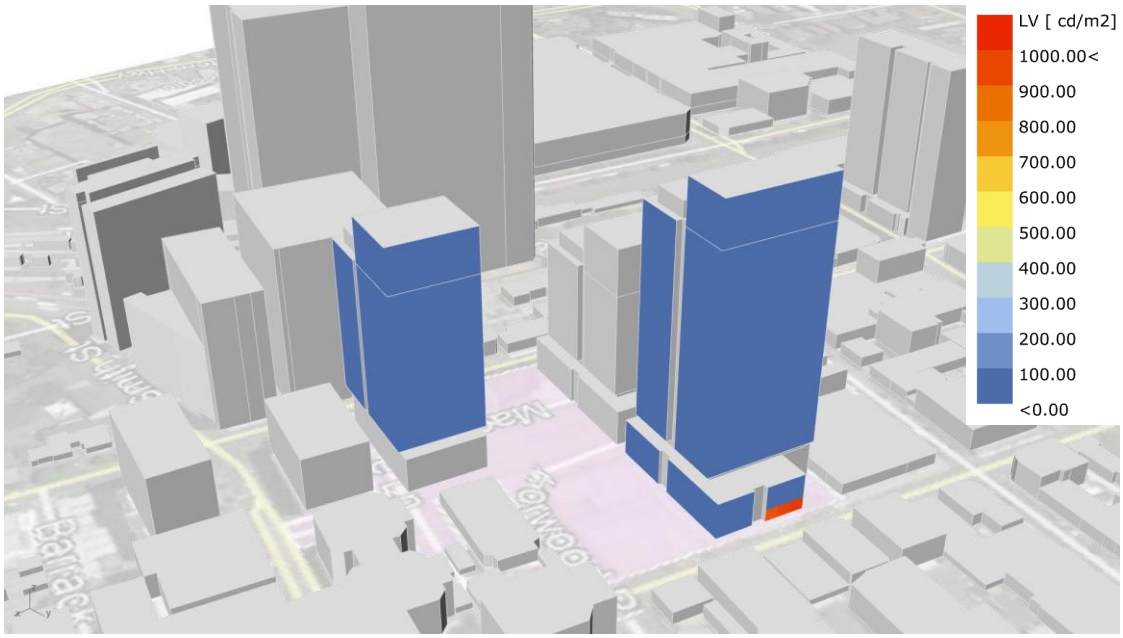

Figure C-17 Development façades at risk of posing disability glare at Location 7, and their reflectivity impacts

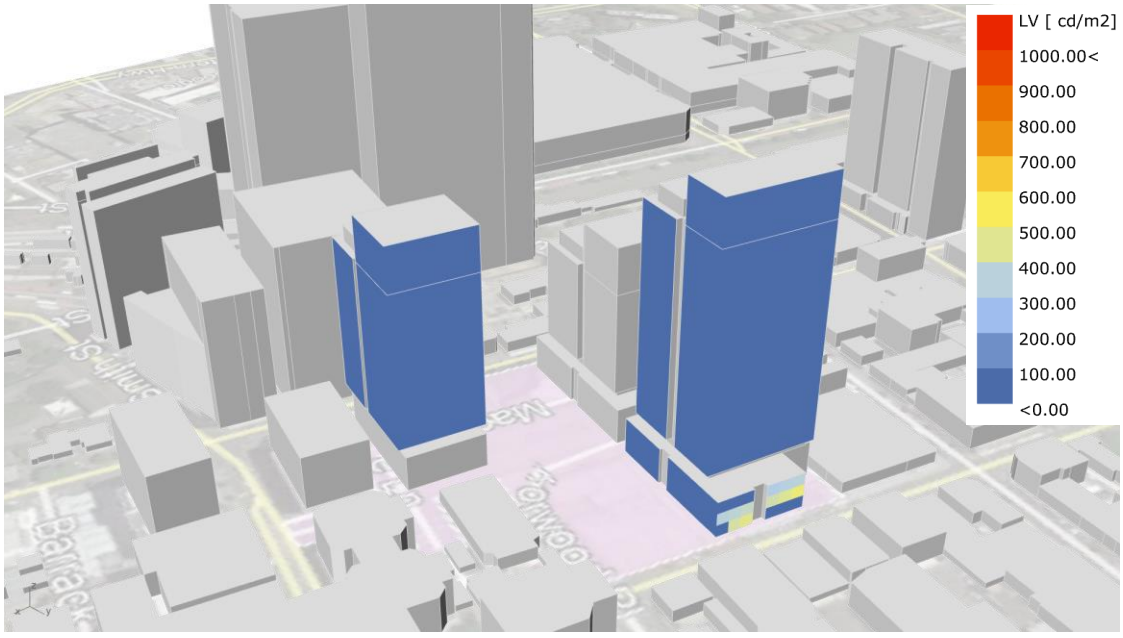

Figure C-18 Development façades at risk of posing disability glare at Location 8, and their reflectivity impacts

C.4 Route 6

This route was assessed for vehicles travelling southeast along George Street.

Based on the assessment, some exceedances of the 500 cd/m^2 veiling luminance criteria are expected to occur along route 5 (refer to Table C-4). These were typically found to occur in the early morning summer and spring and late afternoon in autumn, and spring.

View of the assessed facades and their veiling luminance are shown in Figure C-19 to Figure C-21 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-4 Reflectivity impacts on vehicles travelling southeast along George Street

Location	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	54	• Early morning in January, February, October, and November • Late afternoon in February, March, August, and September	2,580
2	69	• Early morning in January, February, October, and November • Late afternoon in February, March, September, and October	2,140
3	87	• Early morning in February, October, and November • Late afternoon in February, March, September, October, and November	1,850
4	0	• Not applicable	0
5	0	• Not applicable	0
6	0	• Not applicable	0
7	0	• Not applicable	0
8	0	• Not applicable	0
9	0	• Not applicable	0
10	0	• Not applicable	0
11	0	• Not applicable	0

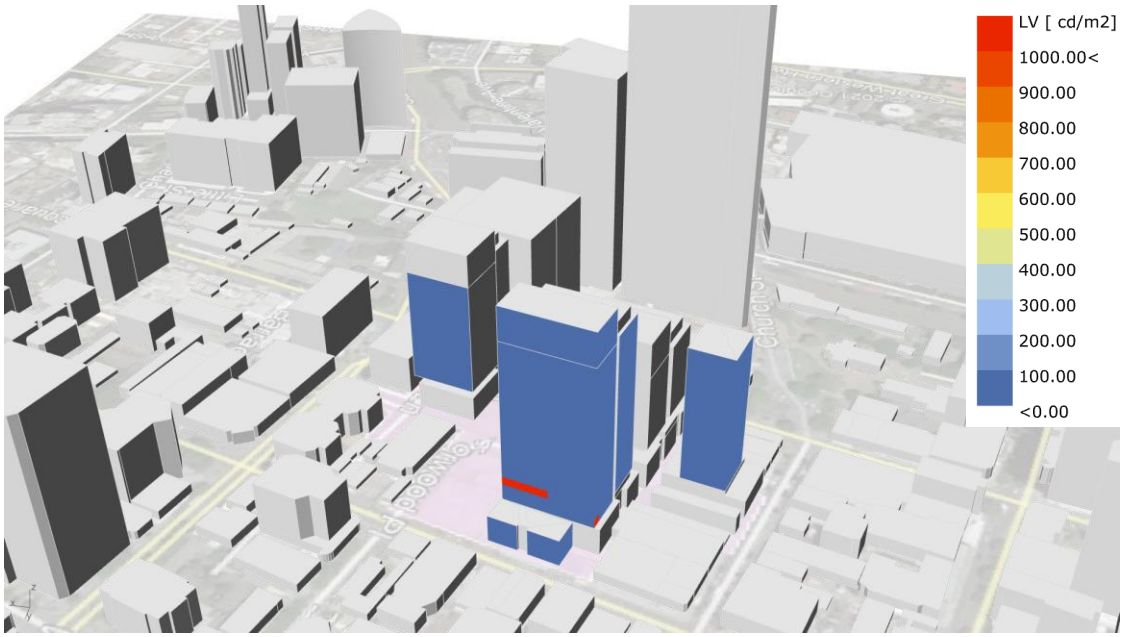

Figure C-19 Development façades at risk of posing disability glare at Location 1, and their reflectivity impacts

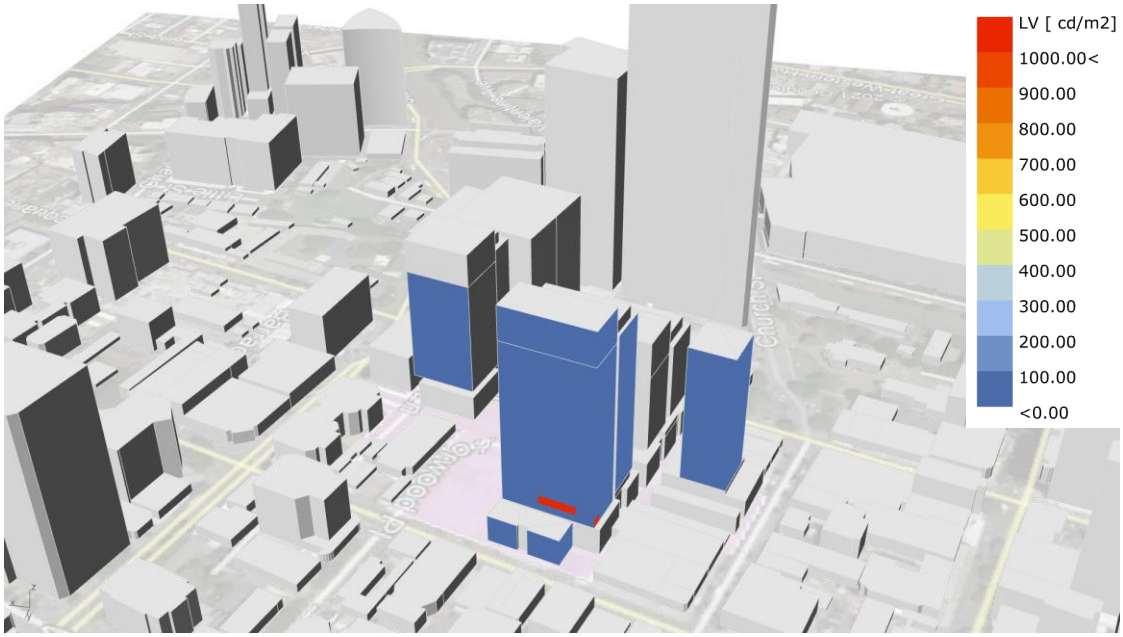

Figure C-20 Development façades at risk of posing disability glare at Location 2, and their reflectivity impacts

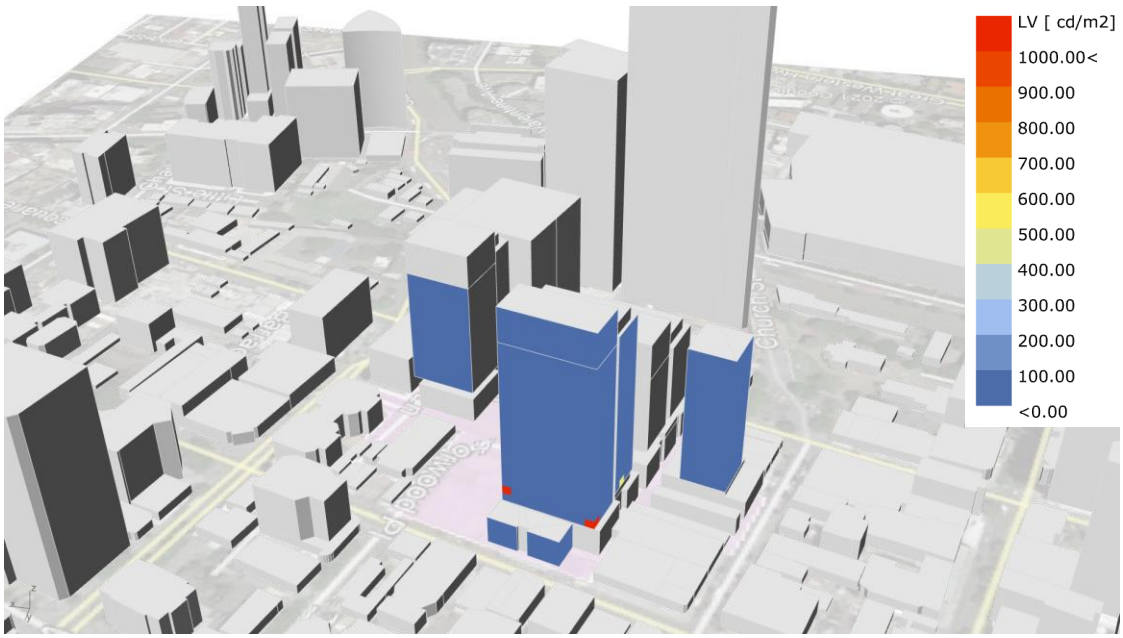

Figure C-21 Development façades at risk of posing disability glare at Location 3, and their reflectivity impacts

C.5 Pedestrian 1

This provides the first assessment for a pedestrian located in the public domain.

Based on the assessment, some exceedances of the 500 cd/m^2 veiling luminance are expected to occur at pedestrian location 1 (refer to Table C-5). These were typically found to occur in the late afternoon during Autumn and Spring.

View of the assessed facades and their veiling luminance are shown in Figure C-22 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-5 Reflectivity impacts on a pedestrian at Location 1 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	26	• Late afternoon in March, April, August, and September	11,350

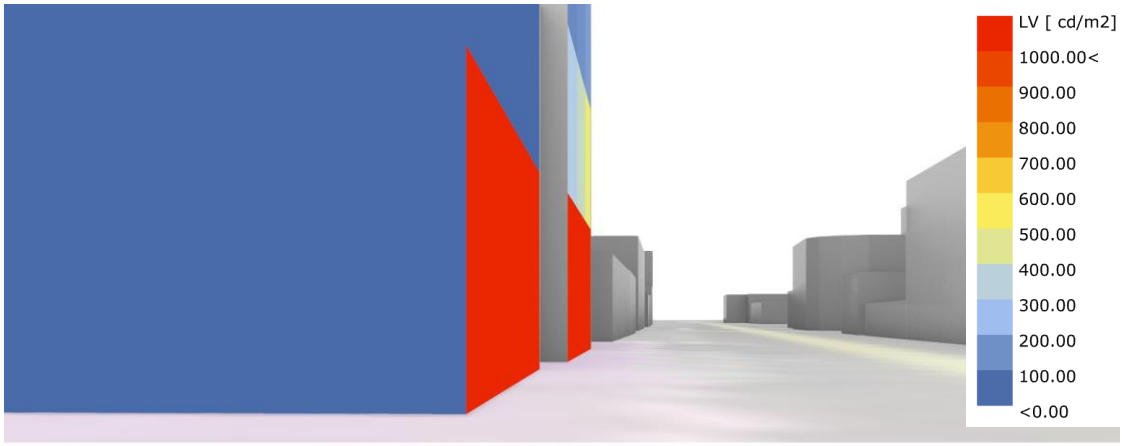

Figure C-22 Development façades at risk of posing disability glare for Direction 1, and their reflectivity impacts

C.6 Pedestrian 2

This provides the second assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 2 has no expected exceedances (refer to Table C-6) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure C-23 and Figure C-24 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-6 Reflectivity impacts on a pedestrian at Location 2 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	190
3	0	• Not applicable	200
4	0	• Not applicable	0

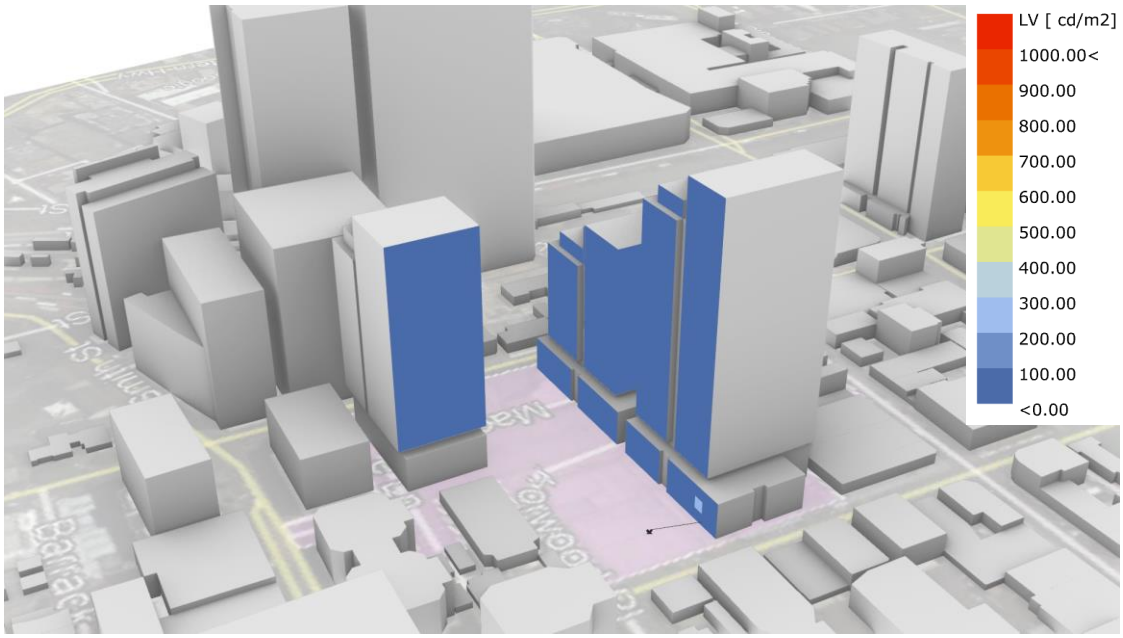

Figure C-23 Development façades at risk of posing disability glare Direction 2, and their reflectivity impacts

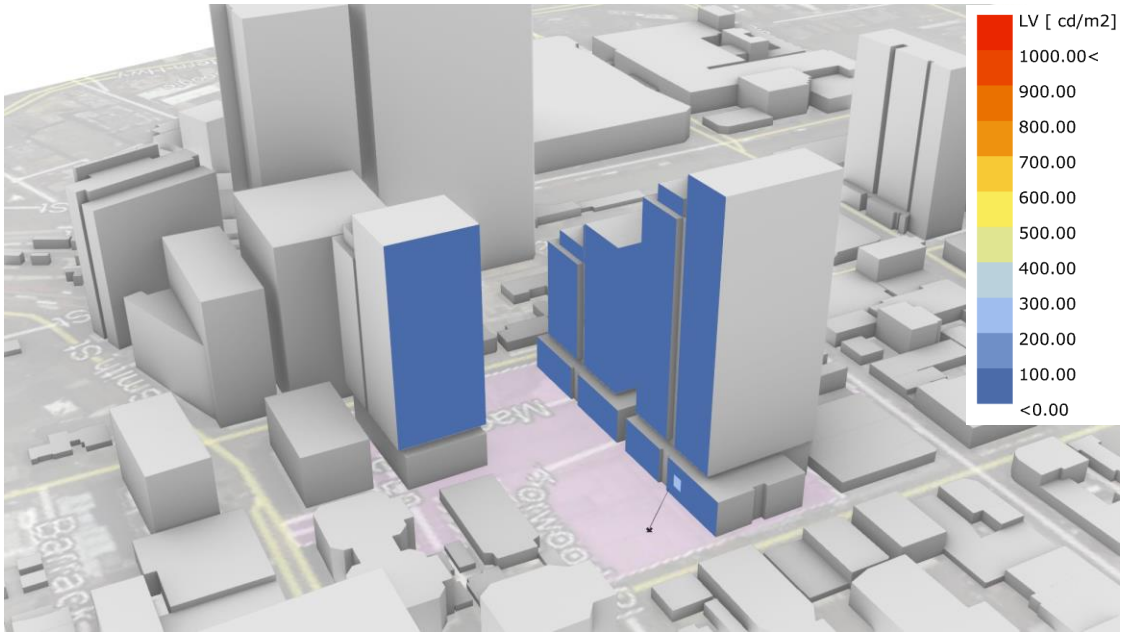

Figure C-24 Development façades at risk of posing disability glare for Direction 3, and their reflectivity impacts

C.7 Pedestrian 3

This provides the third assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 3 has no expected exceedances (refer to Table C-7) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure C-25 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-7 Reflectivity impacts on a pedestrian at Location 3 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	170
3	0	• Not applicable	0
4	0	• Not applicable	0

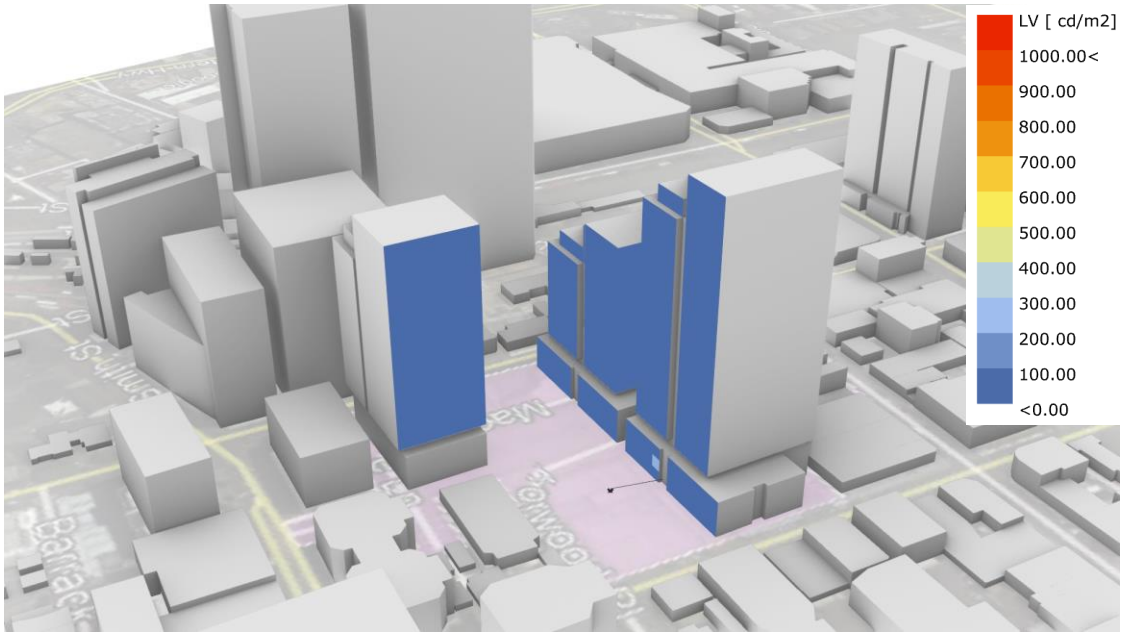

Figure C-25 Development façades at risk of posing disability glare for Direction 2, and their reflectivity impacts

C.8 Pedestrian 4

This provides the fourth assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 4 has no expected exceedances (refer to Table C-8) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure C-26 and Figure C-27 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-8 Reflectivity impacts on a pedestrian at Location 4 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m² in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m²]
1	0	• Not applicable	0
2	0	• Not applicable	150
3	0	• Not applicable	0
4	0	• Not applicable	20

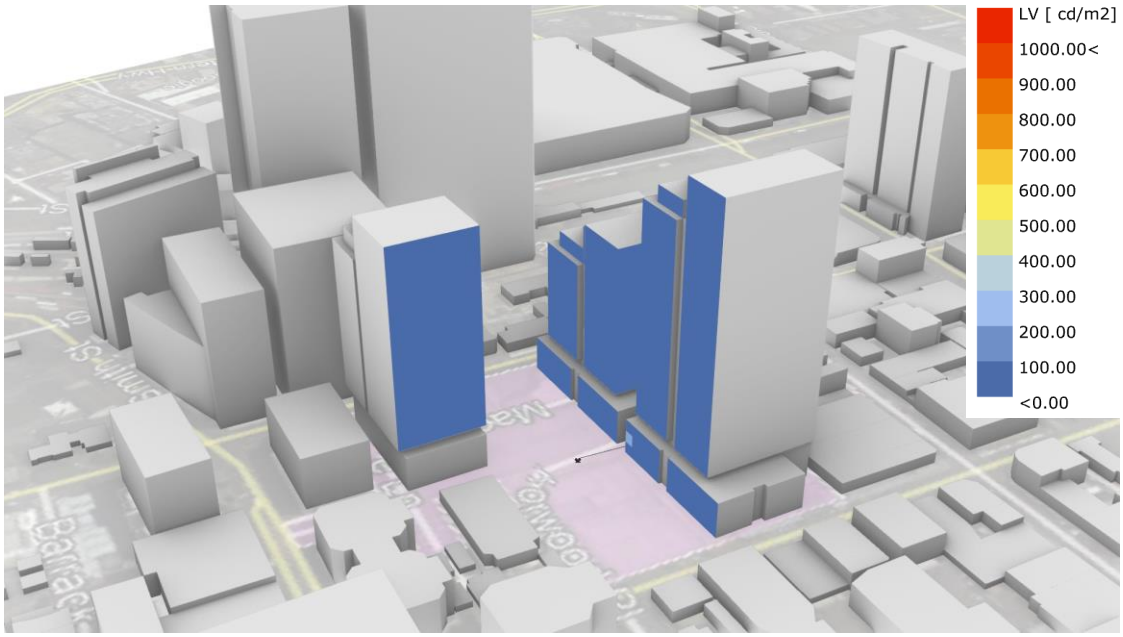

Figure C-26 Development façades at risk of posing disability glare for Direction 2, and their reflectivity impacts

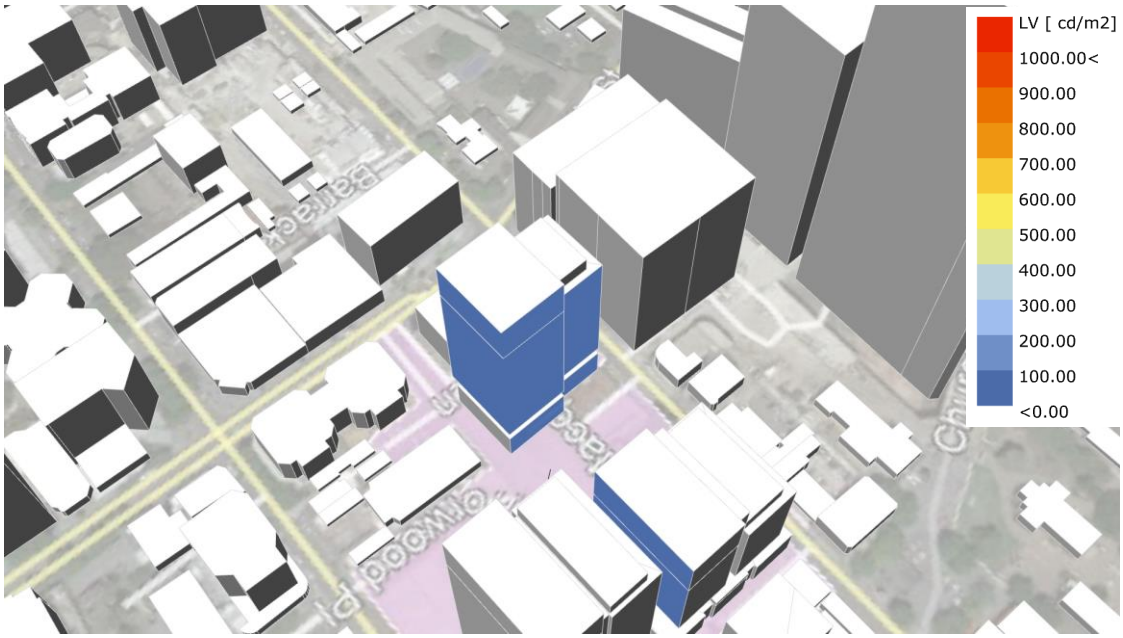

Figure C-27 Development façades at risk of posing disability glare for Direction 4, and their reflectivity impacts

C.9 Pedestrian 5

This provides the fifth assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 5 has no expected exceedances (refer to C-9) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure C-28 and Figure C-29 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-9 Reflectivity impacts on a pedestrian at Location 5 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	0
2	0	• Not applicable	0
3	0	• Not applicable	0
4	0	• Not applicable	160
5	0	• Not applicable	260

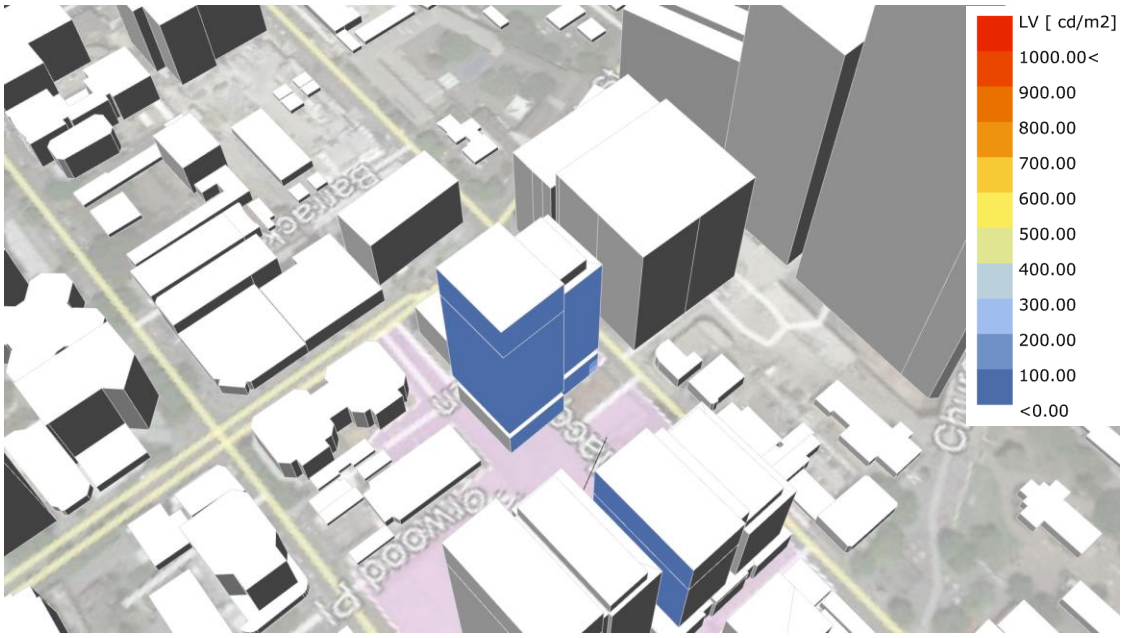

Figure C-28 Development façades at risk of posing disability glare for Direction 4, and their reflectivity impacts

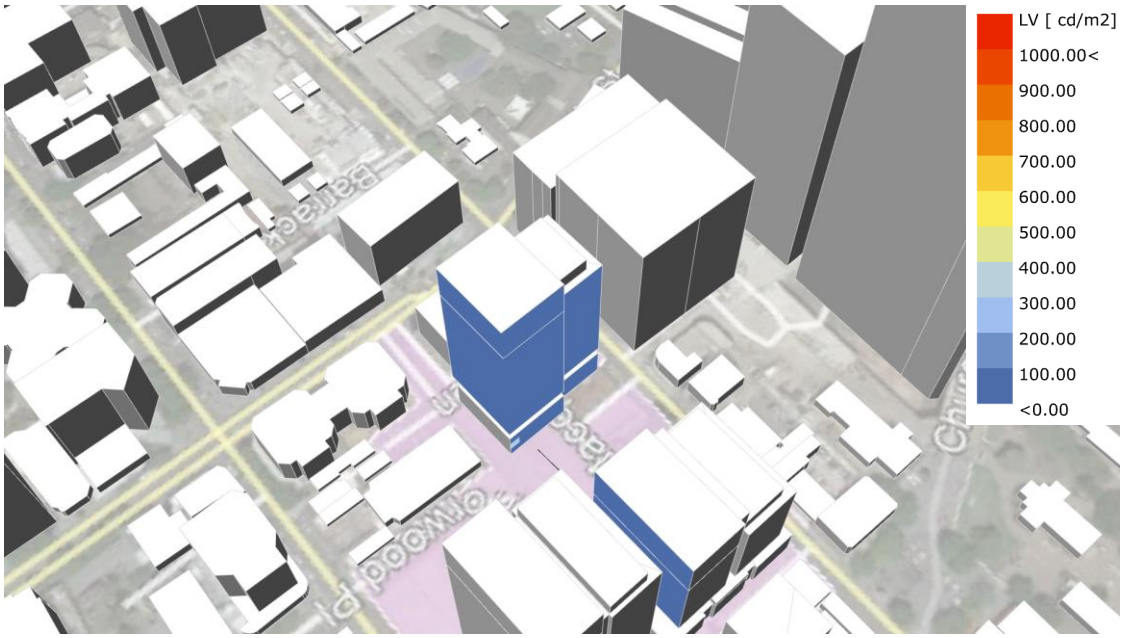

Figure C-29 Development façades at risk of posing disability glare for Direction 5, and their reflectivity impacts

C.10 Pedestrian 6

This provides the sixth assessment for a pedestrian located in the public domain.

Based on the assessment, pedestrian location 6 has no expected exceedances (refer to C-10) due to the sun's relative position in relation to the approach direction.

View of the assessed facades and their veiling luminance are shown in Figure C-30 and Figure C-31 for the worst-case hour at each assessment location for locations where there is veiling luminance is expected (i.e., > 0 cd/m^2).

Table C-10 Reflectivity impacts on a pedestrian at Location 6 in the public domain

Direction	Number of hours LV is expected to exceed 500 cd/m^2 in a year	Expected period of LV exceedances	Maximum veiling luminance [cd/m^2]
1	0	• Not applicable	400
2	0	• Not applicable	0
3	0	• Not applicable	0
4	0	• Not applicable	0
5	0	• Not applicable	210
6	0	• Not applicable	0

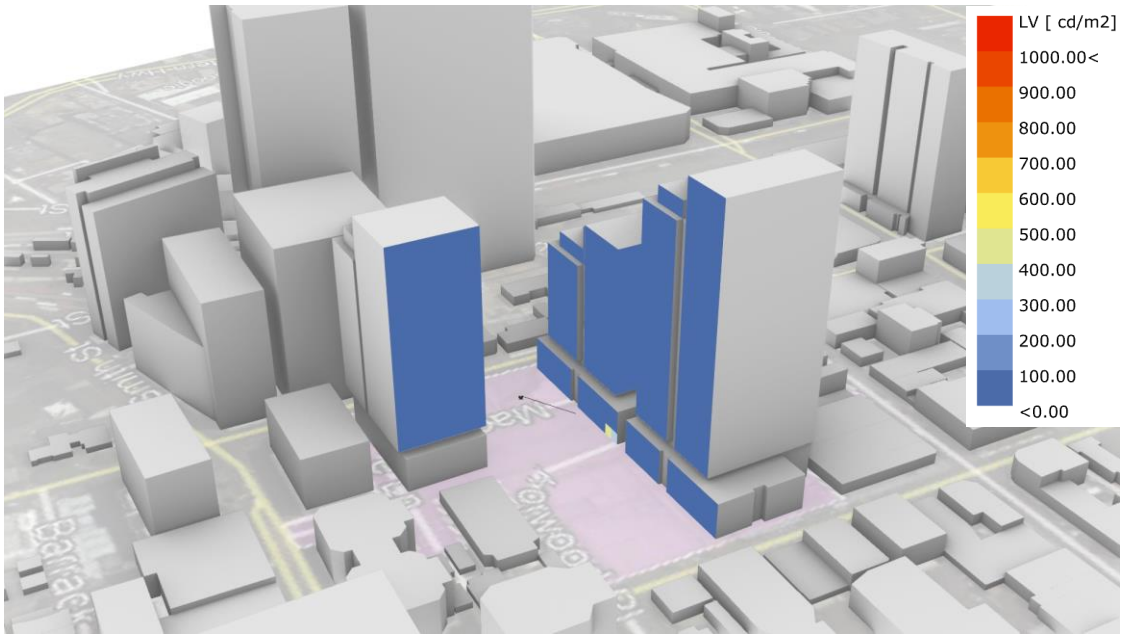

Figure C-30 Development façades at risk of posing disability glare for Direction 1, and their reflectivity impacts

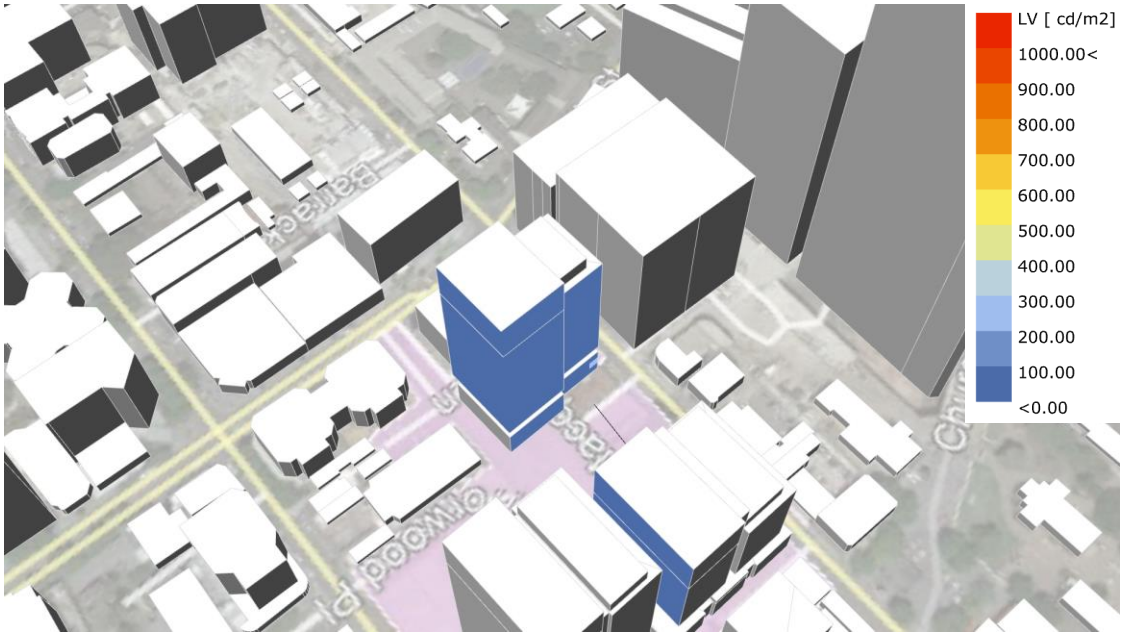

Figure C-31 Development façades at risk of posing disability glare for Direction 5, and their reflectivity impacts