Source: City of Vancouver

RESEARCHING LIGHTING AND INTERSECTIONALITY TO IMPROVE COMFORT AND SAFETY ON VANCOUVER'S CYCLE ROUTES

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Source: Dylan Passmore, 2012

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TABLE OF CONTENTS

Source: Paul Krueger, 2018

EXECUTIVE SUMMARY

NOTE: Throughout this report, I will be using the term "cycle" instead of "bike" or "bicycle" in order to represent the diversity of cycle types and cyclists.

Introduction

Often times in cycling-related city documentation, perceived safety and comfort are discussed with respect to automobile proximity and as such, quantitative indicators are used to measure comfort and safety. While this is an important consideration it misses the fact that a) perceived cycle route safety and comfort is not limited to exposure to motor vehicles, and b) perceived safety and comfort are not necessarily quantiative factors. Comfort and safety can also include elements such as isolation of a route, fear/risk of crime, sense of belonging, accessibility etc. Therefore, this research is centred on examining lighting and intersectionality to improve perceived comfort and safety on Vancouver's cycle routes.

Approach

To conduct this research an initial literature review was conducted. It was supplemented with a jurisdictional scan of precedents and innovations to showcase the unique approaches cities are taking to address comfort and safety concerns with respect to lighting and intersectionality on cycling routes. An informal needs assessment was also conducted for several different cyclist identities. Lastly, several site visits and a GIS analysis were completed to spatially understand comfort and safety on Vancouver's cycling routes.

Lighting

Research around lighting revealed that there are no dedicated standards for different cycle route typologies. Standards often defer to roadway standards or consolidate pedestrian pathways and cycle routes. Setting these standards is difficult as lighting can be quite context-dependent and complicated due to considerations such as trees, blue light and its impacts on humans, the impact on wildlife, neighbourhood character, surface reflectivity etc. However, it is important to have a consistent definition of lighting for these routes to enable comfort and safety. It is also important to note that lighting should not be siloed as a factor of comfort and safety, it must work hand in hand with designing for natural surveillance, accessibility, a sense of belonging etc. An analysis of lighting on cycle routes in Vancouver revealed that routes that intersect with parks are often missing lighting.

Intersectionality

Intersectionality means that many of us experience comfort and cycle lanes on cycle routes differently. The key finding from examining the different safety and comfort concerns of a diversity of users (BIMPOC, women, people with disabilities, children, seniors, low-income individuals, people moving goods or cargo, LGBTQ2S+, and immigrant individuals) was that representation is lacking and can result in a lack of sense of belonging and that more data needs to be collected to cater towards the routes these cyclists take.

Recommendations

Some of the high level recommendations are:

- To redefine AAA lighting in the AAA design guidelines
- To provide lighting on cycle routes that intersect with parks
- To use the term "cycle" instead of "bicycle"
- To offer a diversity of cycle parking
- To represent the diversity of cyclists and cycle types
- To conduct more qualitative data collection

1.1 Context

Climate Change Context

In January of 2019, the City of Vancouver became one of relatively few cities to declare a climate emergency. This declaration was a result of the *IPCC Special Report on Global Warming of 1.5°C* which warned of the dire consequences of anthropogenic emissions in the coming years (IPCC, 2018). Many argue that a declaration of this magnitude is necessary for cities across the world given that despite only occupying 3% of Earth's land base, they comprise over 50% of the global population, consume over 60% of the world's energy, and produce over 70% of global CO_2 emissions (C40, 2021; UNDP, 2021). In November of 2020 then, Vancouver's City Council adopted a *Climate Emergency Action Plan* which put forth a series of "Big Moves" for the city to address the climate emergency. Big Move #2 specifically requires **that by 2030, 2/3 of all trips in Vancouver will be made on foot, bike or transit** (City of Vancouver, 2020). This is an important target given that gas and diesel vehicles comprise 39% of Vancouver's sources of carbon pollution (City of Vancouver, 2019a).

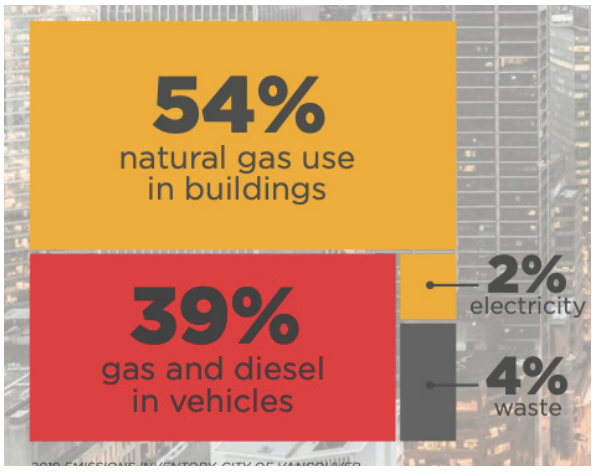


Figure 1. Vancouver's 2019 carbon pollution sources. (City of Vancouver, 2019).

Cycling

The city has already been making strong progress towards "Big Move #2" by increasing the sustainable transportation network and working to make sustainable transportation choices accessible for all ages and abilities. For cycling in particular this has been augmented through the MOBI Cycle Share program, the *5-year Cycling Network: Additions and Upgrades Plan*, and the *All Ages and Abilities (AAA) Cycling Routes Design Guidelines*. The most recent transportation panel survey reveals that 54% of trips made in 2019 were walking, cycling or on transit (McElhanney, 2020). While cycling was the lowest proportion of trips made by sustainable modes of transportation, nearly 13% of commute trips and 9% of all trips in Vancouver are by cycles, which is on track to achieve the 2040 target of 12% (McElhanney, 2020). Not only that, but the city expanded the cycling network to 331 km in 2021 and designated 25% of these segments as AAA facilities as of 2018 (City of Vancouver, 2019b; City of Vancouver, 2021). The aim is to make cycling **"safe, convenient, comfortable and fun for all ages and abilities"** (City of Vancouver, 2017).

Safety and Comfort on Cycle Routes

Vancouver's *AAA Cycling Routes Design Guidelines* provide a series of rules to consider in the design and designation of AAA cycle routes. For the most part, these rules come in the form of tangible numbers formulated to prevent collisions and traffic conflicts with motor vehicles, other cyclists, and pedestrians – with attributes such as target cycle lane widths, motor vehicle volumes, grades, and more. While these are necessary and integral to safety and comfort in cycle lane design, they

are missing two important considerations:

1. Perceived cycle route safety and comfort is not limited to exposure to motor vehicles.

2. Perceived safety and comfort aren't necessarily quantitative factors.

In her article, "Public Safety at the City's Core" placemaker and author, Jay Pitter, argues,

"there is no universal or static safety – no two humans experience a public space in the exact same manner and all of us have distinct life experiences that shape our perception of safety."

This quote highlights that, perceived safety and comfort in the public sphere and therefore on cycle lanes, is complex. It is not just about cars, it is highly context dependent, it differs from person to person as many of us have intersecting identities that experience comfort and safety differently and therefore it isn't something that can be easily defined with a set of rules or numbers. Events from this past year such as the rise in racism, discrimination, and violence in the public sphere, as well as the historical precedent of "bike lanes as white lanes" signifies the importance of thinking beyond numbers and guidelines and thinking directly about the people who use cycle lanes and also just as importantly, those who don't.

As such this research study is centred on examining lighting and intersectionality to help improve perceived comfort and safety on Vancouver's cycle routes. Lighting is important to consider here not only for its relevance to visibility on cycle routes or safety in relation to motor vehicle proximity, but also for its relevance to perceived safety and comfort (specifically concerning personal security) on cycle routes.

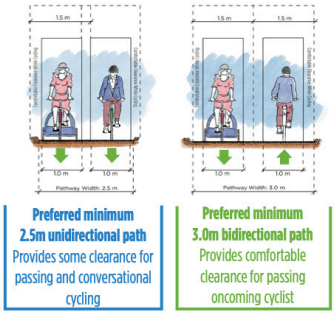


Figure 2. Cycle lane widths for comfortable passing in *Vancouver's AAA Cycling Routes Design Guidelines*.

For many marginalized identities, the outdoors can be an unsafe environment due to the potential for harassment or violence (City of Vancouver, 2019c). While the research on the link between lighting and crime is quite varied, it is clear that street lighting provides an added layer of "reassurance" for people in the public realm (Fotios & Castleton, 2015). Intersectionality ties into perceptions of safety and comfort as well. As mentioned previously, intersectionality means that many of us experience cycle lanes differently. Due to similar fears around harassment and violence as well as feelings of not belonging, people may be choosing not to cycle (Hoffmann, 2016). It is crucial therefore to understand these barriers and adapt the AAA guidelines, programming, and future work in the Transportation Division in order for cycling to be truly safe and comfortable for people of all ages and abilities.

1.2 Objectives

Vancouver's *AAA Cycling Routes Design Guidelines* and *Engineering Design Manual* provide guidance on designing cycle lanes to increase physical safety and comfort in relation to elements such as automobile proximity, separation between cyclists and pedestrians, and surfaces of adequate grade and smoothness. As a result, there is a gap regarding the social aspect of safety and comfort. Specifically, there is no explicit guidance in these documents on the provision of "adequate lighting" on cycle routes and, on cycle lane design to consider people's intersecting identities to ensure safety and comfort. Therefore, there are five primary objectives for this research study:

1. To review the literature to determine how lighting and intersectionality are discussed with regard to perceived comfort and safety on cycle routes.
2. To conduct a jurisdictional scan to understand how leading cycling cities incorporate and evaluate lighting and intersectionality in their design guidelines and programming.
3. To produce a methodology for evaluating lighting and intersectionality on cycle routes in Vancouver.
4. To understand existing comfort and safety barriers by evaluating lighting and intersectionality on select cycle routes in Vancouver.
5. To provide recommendations for Vancouver's AAA design guidelines, future improvements on cycle routes, data collection, and programming based on these findings.

1.3 Methods

To reach these objectives, a review of academic and grey literature was initially conducted. The resources examined were divided into categories based on their differing topics such as perceived safety and comfort, design, lighting design, and intersectionality. Some of the documents reviewed included: a) lighting design guidelines, b) cycle plans and strategies, c) cycle lane design guidelines, d) journal articles discussing both lighting and intersectionality, e) cycling advocacy webpages, f) inclusive cycling reports, g) cycling audits and more.

A jurisdictional and innovations scan for lighting accompanies this literature review to allow for comparison across cities. For the jurisdictional scan, the cities were chosen based on the availability and interpretability of lighting strategies, lighting master plans, and/or lighting guidelines and standards. As such the focus is on English-speaking countries. The innovations component for lighting was centred on precedents that address some of the concerns raised about lighting and to showcase some of the unique concepts that other cities are exploring. For the intersectionality component, an informal needs assessment was conducted as part of the literature review to highlight the needs of different cyclist users. As such the innovations section for intersectionality includes precedents that address these needs.

The subsequent components of my research have included GIS analysis and in-person site visits to review existing lighting on cycle routes as well as some informal interviews and discussions with city staff including staff from the Parks Board, the Transportation Division, and the Traffic, Electrical, Operations & Design Branch.

2.1 Safety & Comfort

Before delving into the specifics of lighting and intersectionality on cycle lanes, it is imperative to understand what safety and comfort on cycle lanes really means. According to the Oxford Languages online dictionary, the definition of safety is, "the condition of being protected from or unlikely to case danger, risk or injury." Comfort is then defined as, "a state of physical ease and freedom from pain or constraint."

From the North American jurisdictions I reviewed (Edmonton, Calgary, Toronto, Seattle, Portland, Colorado, and Massachusetts) regarding lighting and intersectionality, these definitions seem to be quite aligned. Safety is discussed largely in relation to roadway user behavior (mainly automobiles) and components of infrastructure or design such as grade and network connectivity (Portland Bureau of Transportation, 2010; Seattle Department of Transportation, 2021). Comfort is discussed as the ease of use of cycle lanes and the reduction of interactions between cycles and cars (Massachusetts Department of Transportation, 2015; Portland Bureau of Transportation, 2010). For the most part then, these definitions discuss the relation between cyclists and automobiles. While this is an important consideration for cycling safety and comfort, it is not the only component to consider.

If we look towards *London's Cycling Design Standards* and the *CROW Design Manual for Bicycle Traffic*, we see a two-fold definition of safety – one that discusses the interactions between cycles and automobiles and another that discusses elements of social safety such as lighting, isolated routes, the presence of other cyclists and more (Transport for London, 2016; CROW, 2015). In her article, "Public Safety at the City's Core," Jay Pitter expands on this definition of safety by declaring that:

"public safety is not merely the absence of physical threat…it is the visceral yet indescribable sense of belonging that is experienced in spaces which invite rather than tolerate differences."

Together, these definitions provide a much more holistic understanding of what safety on cycle lanes means. Similarly for comfort, *The Bike Plan* for Edmonton describes comfort through the lens of personal security as well as health by considering issues such as "noise, vehicle pollution, headlight dazzle, and spray from passing vehicles." Therefore, for the purposes of this and future conversations around perceived comfort and safety on cycle lanes this report recommends the following definitions of comfort and safety:

Cycle Lane Design Factor	Definition
Safety	Cycle lane safety is the absence of perceived physical threat or danger (i.e. collision risk, harassment, isolated routes) and a feeling of belonging by all when on cycle lanes.
Comfort	Cycle lane comfort is the ease of use of cycle lanes, the level of harmony of interaction with other roadway users, and the maintenance of health while using cycle lanes (i.e. avoiding noise, vehicle pollution, headlight dazzle).

Table 1. A "redefinition" of safety and comfort on cycle lanes.

2.2 Lighting

Research shows that individual perceptions of comfort and safety in the public realm differ with the presence/intensity of lighting. It is anticipated that in the dark or in low visibility conditions, fear kicks in as the public realm becomes much more isolated and there is no opportunity for help from passerby's in the case of danger (Fotios et al., 2015). This is incredibly important to consider particularly for individuals who may experience safety and comfort differently due to fear around harassment in the public sphere because of their identity. Lighting is essential too when thinking about reduced visibility at nighttime or in harsh weather conditions. Research shows that an increased number of cycling-related collisions occur at night in comparison to the day, due to lower visibility (Niaki et al., 2016). Given that cyclists move at higher speeds than pedestrians, it is important that lighting be examined specifically for cycle routes to ensure high visibility of the roadway and roadway users for cyclists (BC Ministry of Transportation and Infrastructure, 2019). Therefore, lighting is essential both to increase visibility and reduce the risk of collision but also to provide personal safety and comfort.

2.2.1 Outdoor Lighting in Vancouver

Outdoor Lighting Strategy & Cycle Lanes

In February of 2015, Vancouver City Council approved a motion for city staff to start developing an outdoor lighting strategy. Adopted in 2019, Vancouver's *Street and Public Realm Lighting Design Guidelines* (outdoor lighting strategy) provide a series of design considerations, policy recommendations, and prioritization actions for lighting on both public and private properties in accordance with its 5 goals:

1. To improve public safety;
2. To enable accessible and inviting spaces;
3. To reduce light pollution;
4. To reduce energy use and;
5. To avoid ecological and human health impacts.

While cycle lanes are not an exclusive focus of this document, they are an important consideration. Goal #1 of this strategy calls for improved public safety through lighting. As this goal is expanded on in the strategy it highlights an intersectional lens by specifying its objective to **"improve pedestrian comfort and sense of security on streets and in public spaces, especially for persons with low-vision or those who may be more vulnerable to harassment or violence."** This goal aligns with the purpose of this research of examining safety and comfort on cycle lanes. It highlights the importance of understanding the different ways in which people with intersecting identities may experience the public sphere and therefore cycle lanes. This goal also examines safety and comfort from the perspective of adjacency to motor vehicles and reduced visibility at night. In the prioritization and planning guidance component of this report, pedestrian priority and cycling routes (ex. greenways) are highlighted as priority areas for sidewalk lighting improvements. Local cycle routes are also identified as strong contenders for lighting pilot projects (ex. dimming, trialing motion sensors).

This document also provides recommendations for a series of street typologies. Highlighted in Table 2 is the

	Light levels	Colour temperature	Luminaires	Possible controls	Aesthetic Design
Conventional street and sidewalk	General guidance from IES RP-8 based on pedestrian and vehicular traffic volumes. Overall levels may vary and be adjusted due to environmental factors	3000K – warm white source to balance aesthetic with safety	Standard pole-mounted roadway luminaire	Programmed scheduling of light levels; eg. higher levels during peak hours, lower after curfew	Consistent with surroundings: poles, fixture style, colour, and existing guidelines
Priority pedestrian and cycling route (greenways, seawall)	May be adjusted to operate with surrounding ambient light levels and land use	Up to 3000K – warmer sources may be considered to meet ambience objectives	Low-glare pedestrian level lighting encouraged	Programmed dimmed light levels after curfew, with motion sensor to gradually raise levels when in use	Consider selection of fixtures that would provide a consistent public realm along the network

Table 2. Framework for lighting design for different typologies (specifically conventional street and sidewalks and priority pedestrian and cycling routes) provided in Vancouver's *Street and Public Realm Lighting Design Guidelines*.

recommendation for conventional streets and sidewalks as well as priority pedestrian and cycling routes based on five design considerations: light levels, colour temperature, luminaires, possible controls, and aesthetic design.

Important to note here is that exact light levels are not provided as this document defers to the Illuminating Engineering Society of North America's (IESNA) *RP-8 Recommended Practice for Roadway Lighting* or the Transportation Association of Canada's (TAC) *Guide for the Design of Roadway Lighting*. However the report does highlight the need to adjust lighting levels depending on context-specific factors. For example, lower lighting levels may be more acceptable in areas with reflective surfaces. Similarly with colour temperature, cool white lights at a maximum of 4000K are acceptable for high collision areas whereas warm white lights of 3000K are more feasible on cycling routes and sidewalks. Ultimately this highlights that while guidelines like this exist, lighting design will be different across cycling routes and roadways based on site conditions.

Vancouver's Lighting Guidelines

While Vancouver's *Street and Public Realm Lighting Design Guidelines*, provide a set of design recommendations around lighting, the documents that take precedence when it comes to lighting design are in fact the Illuminating Engineering Society of North America's (IESNA) *RP-8 Recommended*

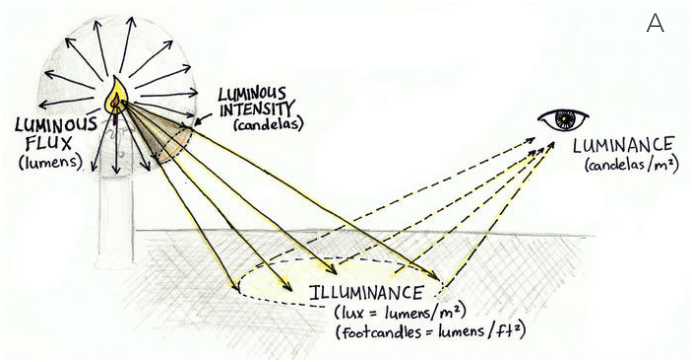
Practice for Roadway Lighting and the Transportation Association of Canada's (TAC) *Guide for the Design of Roadway Lighting*.

The IESNA document in particular is quite popular as all the North American cities reviewed in the jurisdictional scan of this project, defer to IESNA's standards. It is important to note however, that over time (between 2000 and 2011) it appears that IESNA's standards have evolved to recommend a much more custom approach (Hebert et al., 2013). Where these two documents diverge, Vancouver's *Engineering Design Manual* is the next document to consult in this hierarchy. This manual contains the city's design preferences with Chapter 10 dedicated to street lighting. There is also the *BC Active Transportation Design Guide* which consists of a series of recommended best practices for the planning, selection, design, implementation, and maintenance of active transportation facilities in BC. Since the IESNA and TAC documents were unavailable for the purposes of this research project due to copyright issues, the cycle lane lighting guidelines within the *Engineering Design Manual* and the *BC Active Transportation Design Guide* will be highlighted.

Engineering Design Manual

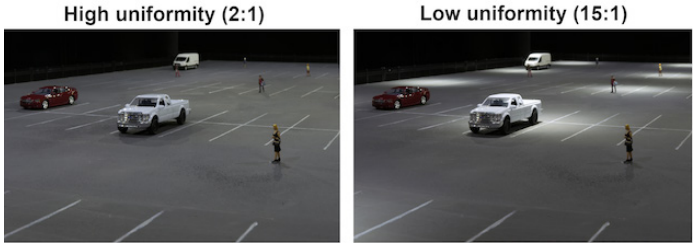
Vancouver's *Engineering Design Manual* designates lighting based on the road typology (arterial, collector, and local street) and pedestrian night activity (high, medium, low). These classifications are then determined by the lighting designer who will be able to establish the required luminance or illuminance, uniformity, and veiling luminance requirements as listed in the Appendix (data taken from IENSA-RP8/TAC documents). For on-street cycling facilities then, these are the primary guidelines to consider. Essentially, a higher luminance, higher uniformity ratio, and higher veiling luminance ratio is provided for arterial roads in comparison to collector and local roads and this level will vary dependent on the level of pedestrian activity.

A



Source: Autodesk, 2018

B



Source: Bullough et al., 2020

C

Source: FHWA, 2018

Figure 3. Images used to explain the definition of a) luminance and illuminance, b) uniformity, and c) veiling illuminance.

DEFINITIONS:

Luminance – concentration of light (intensity) reflected toward the eyes per unit area of surface (used when discussing straight sections of road). Units include candela/m², fc (footcandles), and lux.

Illuminance – measure of light incident on a given area (used when discussing cycleways/walkways). Units include candela/m², fc (footcandles), and lux.

Uniformity – evenness of light over a given area. Even lighting would have a ratio of 1:1; generally a higher ratio is favourable (ex. 2:1 has a higher uniformity than 15:1). See Figure 3b.

Veiling luminance – a measure of disability glare (reduces contrast). This ratio is altered to manage this glare. See Figure 3c.

For multi-use pathways and cycle paths separate from roadways (i.e. off-street facilities), the following table specifies the guidelines in the manual:

Maintained average horizontal illuminance	5 lux or greater for general guidance
Maintained vertical illuminance	Where security is of concern, a minimum level of 5 lux
Maximum-to-minimum horizontal uniformity ratio	10:1 or less for guidance or 5:1 or less for security

Table 3. Luminance criteria for multi-use pathways and off-street cycle lanes/paths provided in *Vancouver's Engineering Design Manual*.

Asides from this there is no further discussion around cycle lane lighting. There are some guidelines set around lighting pole heights too which specify the two primary types: davit style which are 7.5 m or 9 m high and pedestrian scale poles which are 4 – 6 m high.

BC Active Transportation Design Guide

The *BC Active Transportation Design Guide* provides the same lighting standards as seen in the *Engineering Design Manual* but provides some more specificity with respect to on-street and off-street facilities. It first highlights that if a cycling pathway were further than 5 m from a road then it would require its own lighting system. It also emphasizes the importance of human-scale design for off-street facilities by recommending the use of pedestrian-scale lamps, illuminated bollards, or in-ground lighting. In terms of specific facilities, it recommends that AAA facilities should be illuminated along the entire route while certain recreation routes should not be illuminated continuously with the potential for use of activated lighting systems. For local cycle routes, this document recommends that lighting designers reassess lighting conditions as the illumination along local roads may not be appropriate for the route.

2.2.2 Jurisdictional Scan

The initial jurisdictional scan undertaken in this research project centred on the North American context. The cities examined were Edmonton, Calgary, Toronto, Seattle, Portland, Colorado, and Massachusetts. After an initial scan of the lighting design guidelines and cycling strategies for these cities it became apparent that they largely consult with the *IESNA RP-8 Standards*, the *TAC Standards*, or for the American cities – the *American Association of State Highway and Transportation Officials Roadway Lighting Design Guide*. To augment this scan then,

London, Queensland, Melbourne, Vienna, and the *CROW Design Manual for Bicycle Traffic* were also considered. Note that this scan will only highlight those cities that have a unique approach to lighting design or those that should be further considered for conversations around cycle lane lighting.

Edmonton, Canada

Edmonton's *Road and Walkway Lighting Design Manual* references the TAC Guide for the *Design of Roadway Lighting* in its entirety. Any discussion around cycle lane lighting is deferred to the TAC guide with no further discussion or explanation. Their city-wide *Bike Plan* however recognizes a gap in lighting standards for different cycling facility types. It calls for an update to the design standards to include illuminance levels, lighting typology, location, placement and height, colour and uniformity, and power sources. They also recommend an assessment of existing lighting on on-street and off-street facilities to see how they compare to best practices. While Edmonton's standards at present are not unique, they are aspiring towards much more detailed lighting standards for cycle routes and therefore there is an opportunity for the City of Vancouver to collaborate and correspond with them.

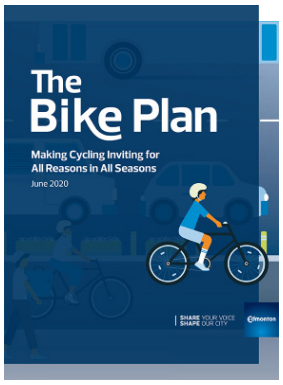


Figure 4. City of Edmonton's Bike Plan.

Portland, USA

Figure 5. A cycle route in Portland (Dylan Passmore, 2021).

In 2017, the Portland Bureau of Transportation conducted an evaluation of its roadway lighting guidelines to compare them to current lighting best practices. They also wanted to identify new minimum recommended light levels that were specific to users and their needs. This resulted in the development of the *PBOT Lighting Level Guidelines* which consist of a set of weighted values that can be applied to initial functional roadway classifications based on additional characteristics such as cycle route typology. This would entail the designer to complete a series of steps:

1. Determine the street functional classification in Table 4 and the average horizontal lighting value.
2. Select from the detailed roadway types in Table 5.
3. Sum the two values
4. Determine the adjusted horizontal lighting value from Table 6.
5. Compare this adjusted value to the lighting value from step 1, the value with the highest light level and lower uniformity ratio is used for the roadway segment.

Street functional classification	Average maintained horizontal level (fc)	Uniformity ratio (E_{ave}/E_{min})
Major traffic/ major transit/ traffic access	1.0	3
District collector	0.7	4
Neighbourhood collector - major transit	0.7	4
Neighbourhood collector - minor transit	0.6	4
Local service	0.2	6

Table 4. Minimum recommended City of Portland light level guidelines. Note that 1fc = 10.76 lux.

Roadway parameter	Options	Weighted value
Posted speed	>35 mph	2
	30 mph	1
	<25 mph	0
Traffic volume (vehicles/day)	>15000	2
	5000-15000	1
	< 5000	0
Bicycle traffic	Major city bikeways	2
	City bikeways	1
	Local service bikeways	0
Pedestrian traffic	Pedestrian-transit streets/ major city walkways	2
	City walkways	1
	Neighbourhood walkways	0

Table 5. Roadway parameters and weighted values from the *PBOT Lighting Level Guidelines*.

Overall weighting value	Average maintained horizontal value (fc)	Uniformity ratio (E_{ave}/E_{min})
>6	1.8	3
5	1.5	3
4	1.2	4
3	0.9	4
2	0.6	4
<1	0.3	6

Table 6. Overall intersection weighting and adjusted lighting values from the *PBOT Lighting Level Guidelines*.

There are also separate considerations for special treatment zones such as multi-use paths as seen in Table 8.

Special treatment zone	Average maintained (fc)	Average vertical maintained (fc)	Uniformity ratio (E_{ave}/E_{min})
Multi-use path	0.4-0.2	0.2-1.0	4

Table 7. Special treatment zone illuminance guidelines from the *PBOT Lighting Level Guidelines*.

Portland's tailored approach to lighting design is unique as it separates cycle routes to ensure that users' lighting needs are being met. The classifications it uses are major city bikeways, city bikeways, and local service bikeways. It is apparent here that there is a hierarchy for the level of lighting on these routes with major city cycling routes requiring the highest level. There is no detail in these guidelines on how these weighted values were achieved, therefore there is an opportunity to connect with Portland city staff to understand their methodology and overall approach to determine if it would work for Vancouver's cycling routes.

PORTLAND'S CYCLEWAYS CLASSIFICATION:
Major city bikeways – are intended to serve high volumes of traffic.
City bikeways – are intended to establish a direct and convenient cycle access to significant destinations, to provide access to major city bikeways, and provide coverage within three city blocks of any given point.
Local service bikeways – are intended to serve local circulation needs for cycles and provide access to adjacent properties.

CROW CYCLEWAYS CLASSIFICATION:
Main cycle routes – encompass the connections that are desirable from the perspective of functional considerations (i.e. travelling for work, education, shopping, socially). Includes cycle highways.
Basic network – are not explicitly detailed but appear to be the equivalent to Portland's local service bikeways.
Recreational routes – refers to routes used for touring cycles, racing cycles, and mountain cycles.

Crow Design Manual for Bicycle Traffic, Netherlands

The *CROW Design Manual for Bicycle Traffic* is a manual that discusses cycle transportation planning and engineering in the Netherlands. In discussing lighting, like Portland, it also presents a hierarchy. It is argued that main cycle routes which are frequently used should have the highest requirements for lighting which may vary based on designated speed (higher speed, higher the sight distance). For the basic network on the other hand, it is recommended that the existing street lighting will be appropriate. Recreational routes which are considered to be frequented primarily through the day do not require lighting according to the manual. Where lighting is absolutely necessary, careful attention should be paid to avoid disruption to ecological systems. It is also specified that dedicated lighting for off-street cycle facilities is needed only if the cycle path is more than 2 m away from the main roadway.

London, UK

Lighting and Darkness in the City/A Lighting Vision for the City of London is London's lighting strategy created to provide a vision, methodology, standards, and guidance to provide lighting that is both aesthetically pleasing and that meets the needs of the public. Unlike its North American counterparts, in this document London directly identifies sites and provides images where lighting across the city fails to serve its purpose (see Figure 6).

Figure 6. An image of an overlit site in London (Speirs + Major LLP, 2018).

It is also unique as its lighting standard values vary dependent on both the street typology and the time of night as seen in Table 8. This change in light level throughout time is possible due to lighting control technologies. "Side roads" and "Footway/Alleyway" in Table 8 are roads that are conducive to cycle routes. In terms of timing, peak time refers to 5:00 – 21:00, off-peak time refers to 21:00 – 0:00, and nighttime refers to 0:00-5:00. The "Incident" header refers to times of emergency. As Table 8 highlights, the horizontal lighting luminance levels decrease from peak time to nighttime. However, this strategy does recommend that the control system be adjusted to instead rely on levels of daylight in conjunction with the time of day so that the system will turn off in response to daylight.

	Uniformity ratio	Peak (lx)	Off peak (lx)	Incident (lx)	Night (lx)
Main Roads	0.4	20lx	10lx	50lx	10lx
Side Roads	0.4	15lx	7.5lx	30lx	7.5-5lx
Footway/ Alleyway	0.2-0.4	10lx	7.5lx	20lx	7.5-5lx
Riverbank	0.2-0.4	7.5lx	5lx	15lx	--

Table 8. London's lighting standards.

Queensland, Australia

Queensland's *Road Planning and Design Manual – Lighting* contains information on the design, installation, and maintenance of public lighting on roads and cycle routes. It does not specify details on luminance values, but it states its compliance with the Australian standards which put cycle routes in the P2, P3 or P4 category of lighting dependent on the level of cyclist activity. These categories equate to horizontal illuminance values of 3.5lx, 1.75lx, and 0.85lx respectively (data taken from AS/NZS1158 parameters). These illuminance values are much lower than the 5-10 lx recommendations seen in North America and Europe (Schreder, 2019). However, this document is notable mostly for its criteria for prioritization of cycle route lighting projects. Essentially, this criterion assesses safety, security, usage, and proximity to existing lighting facilities on its cycle routes to determine the priority with which to light a route. For each of these components there is a table with a set of criteria spanning scores from 1-5 with 5 being of highest priority and 1 being lowest priority. An example for security is listed below in Table 9. This criterion may be used to evaluate the current state of lighting on cycle routes in Vancouver. See appendix for more.

Score	Description
1	Best practice design and meets CPTED principles (whole bikeways can be seen from nearby land uses); frequent contact opportunities with other users; no reported security incidents over the last five years
2	Good casual surveillance (about 70% of the bikeway can be seen from nearby land uses or roads); regular contact opportunities with other users; one reported security incident over the last five years
3	Moderate casual surveillance (about 50% of the bikeway can be seen from nearby land uses or roads); some contact opportunities with other users; two reported security incident over the last five years
4	Some casual surveillance (about 30% of the bikeway can be seen from nearby land uses or roads); limited contact opportunities with other users; three reported security incident over the last five years
5	Isolated, poor casual surveillance (none of the bikeway can be seen from nearby land uses); very limited contact opportunities with other users; four reported security incidents over the last five years

Table 9. Queensland's assessment of security with respect to lighting on cycle routes.

ARUP - Melbourne, Australia

This is an example of a research study conducted with the ARUP consultancy firm in Melbourne. This is an important precedent to include as it appears to be the first study of its kind identifying that lighting in the public realm does not align with the "one size fits all" concept. This study began with the collaboration between Monash University's XYX Lab and PLAN International who came together to analyze the data from the Free to Be Campaign which asked young women and girls in Melbourne to highlight their experiences in the city (ARUP, 2019a). There are many insights from this researchwhich will be discussed through this report but for this scan it is important to highlight that the researchers found that lighting standards fail to take human experiences into account as they use illuminance and uniformity values that don't consider how people actually perceive brightness (ARUP, 2019a). Therefore, they developed a new methodology to design

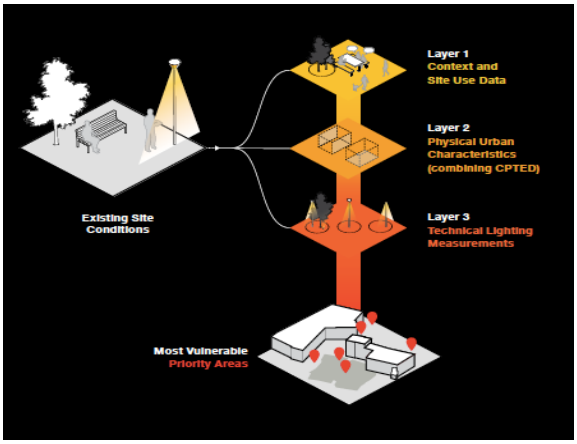


Figure 7. An image of the LVA methodology (ARUP, 2019).

lighting – the Lighting Vulnerability Assessment (LVA). This methodology considers a) context and site use data (ex. how people are moving through the site at present and what existing security measures exist); b) physical urban characteristics (ex. how light engages with the physical design of the site to affect safety); c) technical lighting measurements (ex. colour rendering, colour temperature, and luminance); and d) consistent community engagement (ARUP, 2019a). This methodology could be useful for the City of Vancouver to tailor its lighting to each cycle route.

2.2.3 Cycle Route Lighting Design Considerations

The research on lighting experience is quite varied as some point to brighter lighting that makes people feel safer at night while others point to a smaller change between day and night light levels or even more distributed lighting to improve safety (Utlley, Monteiro, & Fotios, 2018; Fotios & Castleton, 2015). Nonetheless, it appears to be largely inconclusive as to what the best practice is and therefore this section highlights some considerations to keep in mind around lighting design.

Considerations for Specific Cyclist Groups

In thinking about lighting design on cycle routes it is important to consider the multiplicity of identities that may be affected by lighting differently. Below is a non-exhaustive list of groups of individuals who may require consultation and additional consideration when designing lighting on cycle routes.

Cyclists with Low-Vision

Cyclists with low-vision may require differing lighting levels due to their differing needs. Based on a study conducted in the Netherlands, 197 low-vision cyclists reported

that the greatest difficulties of cycling for them were light to dark transitions, identifying obstacles or other roadway users, too much light, and identifying objects far away. Of the cyclists that responded, 59% mentioned that they would avoid cycling in the dark (Jelijs et al., 2019). It is important here to understand that too much light can be just as detrimental as no light.

Cyclists With Adaptive Cycles

In HUB Cycling's most recent webinar on adaptive cycling, Jocelyn Maffin, an avid hand cyclist, discussed some of the different types of adaptive cycles as well as their advantages and disadvantages (Maffin, 2021). She highlighted the way in which some adaptive cycles are lower to the ground (hand cycles in particular) which can thereby limit visibility. This highlights the importance of human-scale design particularly when thinking about street lighting pole

Figure 8. Handcycle with low stance and recumbent riding position. (Wannee, 2005).

Cyclists With Different Identities

In Vancouver, only 41% of women 75+ and 47% of women aged 18-24 feel safe walking in the night (City of Vancouver, 2018b). Additionally, only 44% of Indigenous women and 42% of Chinese women feel safe walking in the dark (City of Vancouver, 2018b). ARUP's research from Melbourne emphasizes that 1/3 of their respondents felt that lighting contributed to their nighttime experience whether it was good or bad (ARUP, 2019a). Furthermore, many respondents emphasized that brighter lighting did not necessarily create safer spaces. Rather they preferred consistent, layered, warm lighting with multiple light sources and where the reflectivity of surfaces is considered (Kalms, 2019; ARUP 2019a). Women aren't the only demographic impacted by this, there are many other groups of people who because of their gender, sex, race, religion, or differing abilities are less likely to be in the outdoors at night for fear of harassment, discrimination, violence, or general discomfort. This is evident when we examine for example the 717% rise in anti-Asian hate crimes in Vancouver this past year (Vancouver Police Board, 2021). While there is no explicit data highlighting personal safety/security as a barrier to cycling, by examining the walking data and the increase in discrimination, we can infer that people may be having similar concerns around cycling.

Additional Considerations

Listed below are some further considerations to take into account around cycle lane lighting design. While all these factors have been discussed in various documents, it is necessary to reiterate them to provide a holistic picture of lighting.

Wildlife

Street lighting has been discovered to have varying degrees of detrimental impacts for wildlife. Recent research shows that animals such as turtles, birds, frogs, and bats, can be impacted. Turtle hatchlings for example are often drawn inland due to artificial lighting

where they might end up on roadways (International Dark Sky Association, 2021). Birds and insects also face similar confusion as they may get trapped in patches of light created by street lighting. This is a growing concern as cities get brighter with incandescent LED lighting and as birds get drawn into developed areas increasing their risk of mortality (Mclaren et al., 2018). The nocturnal migratory movements of birds may also be affected by artificial lighting at night, thereby impeding their orientation and navigation (Van Doren et al., 2017). Street lighting can also be problematic for other nocturnal mammals that avoid moonlit conditions, and that therefore may be discouraged to engage in foraging activity due to bright lighting (Rich & Longcore, 2006).

In a study conducted at the University of South California, the hues of LED street lamps were evaluated to determine how they affect insects, moths, bees, sea turtles, salmon and Newell's shearwater (a sea bird). The results highlighted that blue and white lights were most detrimental, while yellow, green, and amber were much less impactful (Longcore et al., 2018). Another study conducted in the North Sea revealed that nocturnally migrating birds in particular were less disoriented by blue and green lighting in comparison to red and white lighting (Poot et al., 2008).

Figure 9. Blue-green street lights on Ameland Island for birds (Halper, 2017).

Yet it is unclear how other species are affected by these colour temperatures. Given the variability and uncertainty of street lighting impacts on wildlife, it is recommended that in ecologically sensitive areas, light fixtures are full cutoff and shielded. Other alternatives may be embedded roadway lighting or adaptive lighting (National Park Service, 2017). For cycle route lighting, this means that careful detail must be paid to the ecology of the site, particularly for routes that intersect with parks or other natural habitats.

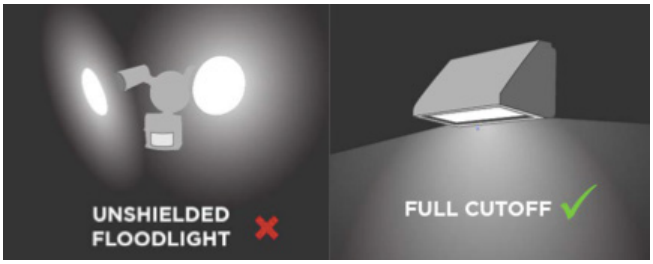


Figure 10. Full cutoff vs unshielded floodlight (City of Vancouver, 2018).

LED Lighting

A city-wide retrofit to LED lighting is one of the key priorities in Vancouver's *Public Realm Lighting Design Guidelines* (outdoor lighting strategy). The majority of the 55,000 luminaires in Vancouver as of 2019 were HPS (high-pressure sodium) lamps. However, the city has been working since 2015 to gradually install LEDs at priority locations, particularly at intersections known for high collisions (City of Vancouver, 2018c). Data from these intersections has shown dramatic decreases in collisions, injuries, and fatalities. LED lighting, therefore, has been quite popular as many cities including Vancouver are transitioning to this lighting typology. LED lighting, lights roadways much more evenly, has improved

colour rendering, is energy efficient, is much more reliable, is directional, has a longer lifespan and has lower maintenance costs in comparison to HPS lamps (City of Vancouver, 2018c; Go Green LED International, 2021).

However, there has been emerging research regarding the negative health impacts of LED lighting. The blue-light produced by LEDs has been deemed to have a greater potential to act as a suppressant for melatonin, which is the hormone in our bodies that suppresses tumours (Rea & Figueiro, 2016). Exposure to this lighting can also work to activate our daytime physiologies. Based on studies conducted with shift workers, this level of circadian disruption could be carcinogenic to humans (IARC, 2019). Yet, there are many factors to consider here including level and length of exposure.

Blue-rich LED lighting is also concerning when thinking about skyglow and light pollution (International Dark-Sky Association, 2021). The "New World Atlas of Artificial Night Sky Brightness" emphasizes that city-wide transitions to 4000K white LED lighting could increase light pollution by 2.5 times (Falchi et al., 2016). Not only is this harmful to wildlife and humans but this also impacts data collected for astronomy and dark sky preserves.

Vancouver's *Outdoor Lighting Consultation Paper* identifies these concerns and recommends that the municipality should advance with the LED transition but work to implement lighting with lesser blue light and once again ensure that light fixtures are full cut-off and shielded.

Neighbourhood Character & Resident Concerns

Aesthetic design was a key consideration in the outdoor lighting strategy. The strategy highlighted the importance of considering "how lighting may be designed to enhance, and remain, compatible with, the area character." It may be that the design guidelines of certain heritage areas are at odds with the need for lighting on cycle lanes for safety, resulting in tradeoffs. In Chinatown's *HA-1 Design Guidelines* for example, there are guidelines that require pedestrian-scale lighting "not to be overly intense and to fit the historic character of the neighbourhood". In conjunction with character, residents' perceptions and concerns must also be examined. A key example is the Comox-Helmcken greenway project which raised concerns among residents due to excessively bright lights (Fleming, 2013). It is therefore necessary to consider how cycle lane lighting may be perceived by those that live around them.

Figure 11. Comox-Helmcken Greenway (Don Marce, 2018).

Trees

Vancouver has a 25.9% green canopy and therefore trees are an important consideration in lighting design (Li et al., 2019). The *Engineering Design Manual* recognizes that trees can be obstructive and recommends the use of extended custom arms for light installations, pedestrian-scale lighting, and tree pruning to mitigate the light loss factor of 10-20% that they may cause (IESNA, 2014). Discussions with the electrical engineering team reveal that pruning can be difficult and may not frequently be conducted. A light loss factor of that magnitude may have the potential to create perceptions of unsafe and uncomfortable cycle routes particularly at night. Therefore trees or wooded areas around these routes should be considered and users should be consulted on their perceptions of safety and comfort regarding trees or other obstructions.

Figure 12. Mandel cycle path in Roeselare, Belgium (Schreder, 2021).

End-of-Trip Facilities

End-of-trip cycling amenities provided by the municipality such as cycle parking and storage facilities are not discussed in any of the lighting design guideline documents. While these facilities are out of the scope of this project, they are worthwhile considering as amenities that are just as important as cycle lanes. HUB Cycling's Report, "Not Just Bike Racks - Informing Design for End of Trip Cycling Amenities in Vancouver Real Estate," while focussed on the private building perspective, provides relevant data for municipalities to consider. A survey conducted with residents revealed that 29% and 36% of respondents were very and somewhat interested in "outdoor bike parking with enhanced weather protection, lighting or security features" (HUB Cycling, 2017).

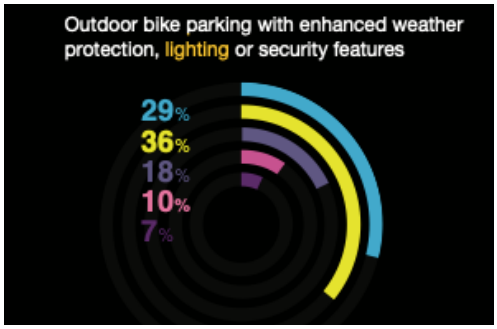


Figure 14. HUB Cycling amenities survey results.

There may be room here for data collection with regards to cycling amenity safety to understand how users feel.

2.2.4 Lighting Innovations

While we have examined jurisdictional behaviours towards street and cycle route lighting, it is necessary to also examine singular cycling projects to determine how they may be able to address the concerns around cycle lane lighting design addressed above. Therefore, this is a precedent analysis partially to address

these concerns and to explore the extent of cycle lane/roadway lighting innovation.

Adaptive Lighting

The follow innovations examine the use of adaptive street lighting which adapts to the movement of people by dimming in the absence and brightening again in the presence of people. Adaptive lighting has been piloted in Vancouver on the Comox-Helmcken Greenway but BC Hydro currently controls the dimming technology and there is yet to be a city-wide retrofit for this adaptation.

A. Bahnstadt District - Heidelberg, Germany

The 3.5 km cycling path in the Bahnstadht district, is fitted with infra-red sensors connected to LED lamps which dim in the absence of cyclists and then light up as cyclists approach (Schreder, 2021a). The lighting caught the attention of residents from the adjacent neighbourhood who asked for the same lighting on their cycle route (Schreder, 2021a).

B. Hole, Norway

The city of Hole has also implemented radar sensors on its street lighting poles along a 9 km roadway adjacent to the Tyrifjorden Lake. As the sensors sense roadway users they light up to full intensity and as the roadway becomes empty, they lower to 20% (Rayner, 2018). Residents adjacent to the road have been pleased with the level of safety and comfort that the lights provide, while the city has been plased with the savings in energy costs this lighting has provided (LED Magazine, 2019).

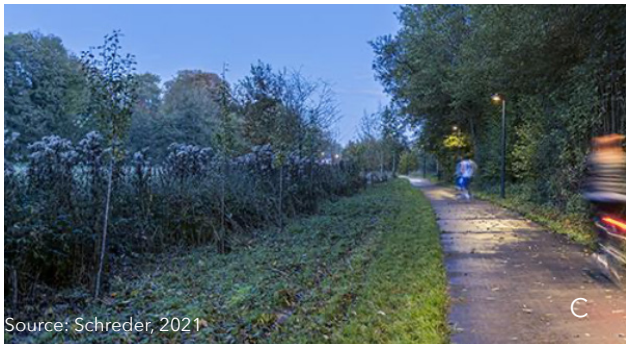


Figure 15. Adaptive lighting innovations in a) Germany, b) Norway, c) Belgium, and d) the Netherlands.

C. RAVeL, Belgium
The RAVeL cycle path has sensors on its luminaires that increase lighting intensity to 100% as cyclists approach and then dim to 70% when there has been an absence of users for 4 minutes (Schreder, 2021b).

D. Atlas Park, Amsterdam
Amsterdam has taken adaptive lighting further by allowing users of Atlas park to control the brightness of the lighting through their smartphones in an app called GeoLight. Adaptive lighting also exists across the city such that authorities can control brightness in case of emergency events (Tomorrow.City, 2019).

LED Coloured Light Innovations
The following innovations examine the use of LED lighting innovations that use colour temperature in a unique fashion. It should be noted that coloured lighting is often not used as it has been seen to hinder facial recognition (Victoria State Government, 2021).

A. RijnWaalpad - Bemmel, Netherlands
The RijnWaalpad cycle tunnel consists of an installation of LED luminaires in various colours. The tunnel is also linked to an app called Bicycle Buddy that allows users to change the colours (Archello, 2021).

B. Illumilane - Vancouver
The Illumilane was a project emerging from CityStudio that integrated a series of colourful lights along a multi-use pathway in the Northeast False Creek Area that would light up based on pressure sensors recognizing cyclist speeds (hfhourstudio, 2016). Lights turned red as cyclists rode at 20km/h and then turned rainbow-coloured below speeds of 20 km/h (CityStudio, 2016).

A

B

Figure 16. LED lighting innovations in a) Bemmel, Netherlands and b) Vancouver.

Unique Pathway Lighting
The follow innovations examine unique pathways and the different ways they are lit up or infused with colour.

A. Van Gogh Path - Eindhoven, Netherlands
This 600 m cycle path consists of twinkling blue and green stones which charge in the day and glow at night as a representation of Vincent Van Gogh's Starry Night (Roosegarde, 2018).

B. Te Ara|Whiti (Lightpath) - Auckland, New Zealand
This 600 m multi-use pathway on the site of an

abdandoned former highway was designed with a bright pink surface as well as sensor-controlled LED lighting (archdaily, 2015). Aluminum plates dispersed along the barrier consist of Maori art engravings. The purpose of this path was to both invite cyclists and create elements of exploration and discovery (LandLab, 2016).

C. Glow-in-the-Dark Cycle Lane - Texas, United States

At Texas A&M University, a glow-in-the-dark cycle lane was implemented. In the day the lane absorbs sunlight and then glows at night due to its photoluminescent material (Peters, 2017). Immediately after the installation cyclists appeared to be avoiding the lane but it is expected that cyclists will adjust and the university is planning on conducting research to determine if the lane and the implemented Dutch junction help increase visibility and safety (Begley, 2016).

D. Luminumpave - A35 Motorway, Netherlands

Luminumpave, a light coloured asphalt was implemented on the A35 Motorway in the Netherlands in order to cut back on roadway lighting (Naus & Voskuilen, 2016). It was discovered that this asphalt reflects light two times more to drivers than dark coloured asphalt which allows for a greater amount of luminance sent back to the driver. Ultimately the study found a reduction of street lighting of 40% would be feasible with this asphalt (Naus & Voskuilen, 2016).

Figure 17. Unique pathway lighting in a) the Netherlands, b) New Zealand, c) the US, and d) the Netherlands again.

Ecological Lighting

The follow innovations examine the use of lighting designed specifically with ecological considerations in mind such as the preferences of different wildlife species.

A. Zuidhoek-Nieuwkoop, Netherlands

This town in the Netherlands implemented red LED lighting which is optimal specifically for bats who are unable to see red lighting as brightly as other hues. This lighting ensures that the nocturnal activities of bats who are light-sensitive remain unaffected (SmartCitiesWorld, 2018). The lighting is also connected to a software that allows for remote management (Signify, 2018).

B. Ameland, Netherlands

The dutch island of Ameland, in collaboration with Philips ClearSky technology has implemented blue-green LED lighting which is ideal for birds and other nocturnal animals. This blue-green lighting is also anticipated to improve visibility for humans at night too (SmartCitiesWorld, 2017).

C. Parc de la Citadelle - Lille, France

To ensure the health of animals and plants within Parc de la Citadelle, a nocturnal corridor has been developed with LED lighting of differing colour temperatures (amber, 2200K, and 2700K. The brighter white LEDs turn on in the presence of cyclists/roadway users and then switch to amber in their absence (Schreder, 2021c).

D. Town Quay Bridge - United Kingdom

This bridge for drivers and cyclists has LED lighting installed within its handrails to mitigate light spill down to the river below which is an integral feeding area for bats in the surrounding area (Schreder, 2021c).

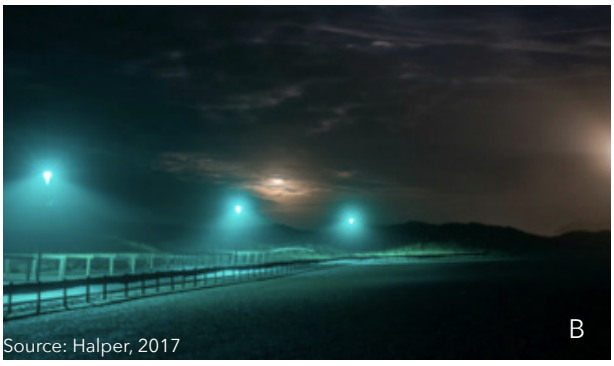


Figure 18. Ecological lighting innovations in the Netherlands, France, and the UK.

2.3 Intersectionality

The City of Vancouver's Equity Framework is supported by the concept of intersectionality. This term originated in Indigenous and Black women's activism and was further developed by Kimberlé Crenshaw, a black legal scholar, in her 1989 paper, "Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics." She highlighted intersectionality as a prism to examine the way in which different forms of discrimination intersect to create a series of detrimental effects. She used the term in several discrimination-based lawsuits to emphasize that Black women in the workplace were experiencing both race-based and sex-based discrimination and that the two were not mutually exclusive (Smith, 2021). Krenshaw remarks that,

"intersectionality is a lens through which you can see where power comes and collides, where it interlocks and intersects. It's not simply that there's a race problem here, a gender problem here, and a class or LGBTQ problem there."

She raises a very important point here that is integral to this research - many of us have different experiences with inequality due to oppressive systems that can be compounded when you have a multitude of identities (Crenshaw, 1989).

Public spaces in cities have historically been designed to function easier for the cis-gendered, able-bodied, heterosexual, upper-class, white male, effectively excluding many marginalized intersecting identities (Allick, 2020; The World Bank, 2020). This is evident too in cycling spaces where events such as inequities in cycle lane access for certain racialized identities; the erasure and criminalization of low-income cyclists; the physical and mental barriers faced by disabled cyclists; and more, all of which have occurred in Vancouver, have continued to perpetuate systemic inequality. As a result many have made a call to action for an intersectional approach to cycling, one that is centred directly on the experiences of marginalized cyclists to help make cycling inclusive and ultimately move towards more equitable cities (Torres, 2019; Mazumder & Doucet, 2020). Therefore, it felt necessary to go beyond lighting when discussing comfort and safety on cycle routes in Vancouver, to understand how cyclists with a multitude of identities experience comfort and safety differently in ways that may be negatively impacting them and resulting in them avoiding cycling as a transportation option.

Figure 19. Image denoting intersectionality (City of Vancouver, 2020).

2.3.1 The All Ages and Abilities User

Cycling plans, design guidelines, and advocacy work often prioritize infrastructure and frame it for the "all ages and abilities user". However, by focusing on infrastructure, it misses the users itself (Lopez, 2018). This is most notably evident in both Vancouver's *AAA Cycling Routes Design Guidelines* and Calgary's *Always Available for All Ages and Abilities (5A) Network Principles* report. Thus, the following sections center on a non-exhaustive list (taken from NACTO's *Designing for All Ages and Abilities* report and with additions from research) of all ages and abilities users and their experiences and design needs first. While these users have been listed separately it is important to remember here again that many individuals have intersecting identities and therefore there may be an overlap in their design needs and design and programming considerations for them to feel safe and comfortable on cycle lanes in Vancouver.

Black, Indigenous, Multiracial, People(s) of Colour (BIMPOC)

BIMPOC individuals face many different concerns being in the public sphere irrespective of cycling. The 2013/2014 Canadian Community Health Survey data shows that BIMPOC cyclists are 32% less likely to cycle for leisure and 38% less likely to cycle for commuting and leisure purposes (Firth et al., 2021). Some of their concerns exist due to racial profiling, discrimination, and a feeling of not belonging (Hoffmann, 2016; NACTO, 2017). For example:

- Policy researcher Mirusha Yogarajah from Toronto speaks of her experience of being racially profiled by a police officer for unintentionally passing through a red light while a white counterpart was not stopped (Yogarajah, 2021).
- In May of this year, an incident along the Maple Ridges Dykes Trail in Metro Vancouver occurred where a cyclist faced racist comments from passerby's (Shepert, 2021).
- A study out of Tufts University in Massachussetts, revealed that POC students believed cycling to be something "only white people should do" (Briseno et al., 2019).

Figure 20. Image of a cycling group called the Cycle Sisters (Amaliah Team, 2020).

This feeling of not belonging is further compounded when there is a lack of representation of BIMPOC identities and their cultural practices in mainstream cycling (Hoffmann, 2016). Muslim women for example may need to wear their helmet with their scarf and wear a long skirt while cycling (Hoffmann, 2016). However, mainstream cycling media and the outdoor industry continues to perpetuate the stereotypical image of a middle-aged

white male clad in lycra leaving BIPOC identities with an understanding of cycling as an elitist activity that they cannot identify with (Amaliah, 2020; Hoffmann, 2016). Data from the US also highlights that many Black and Latinx cyclists feel uncomfortable in conventional cycle lanes and that a lack of infrastructure can be a barrier to cycling for them (NACTO, 2017).

While the provision of infrastructure such as protected cycle lanes is imperative for cycling safety and comfortability, more needs to be done to avoid the perpetuation of "bike lanes as white lanes." Urban anthropologist and mobility justice advocate, Adonia Lugo in her book, Bicycle/Race: Transportation, Culture and Resistance, talks about what empowerment on a cycle can mean for BIMPOC individuals - specifically:

"Being able to ride without fear of being pulled over by authorities and by seeing others that look like you, riding next to you."

Given the racial disparity in police checks in Vancouver, there is a need for a greater commitment to stop racial profiling as it can be a barrier to cycling (Woodward, 2020). This is seen among the Black and Latinx population in the US who often don't see cycling as "worth it" out of fear for their safety in police checks (Cox & Brown, 2017). This also highlights the need for greater representation of BIMPOC cyclists in mainstream cycling media and in city documents such as design guidelines and cycling plans. Urban planner, Tamika Butler, encourages cities and advocacy groups, to think beyond the typical "bike month" or "bike week" to include BIMPOC individuals (Butler, 2020). Coupled with more holistic cycle counts (beyond the downtown core), stronger representation and programming, and a push to end racial profiling in Vancouver, could have a positive impact on creating safer and more comfortable spaces for BIMPOC cyclists (Agyeman, 2020).

Women

HUB Cycling's *Benchmarking the State of Cycling in Metro Vancouver* report highlights the increase in female cyclists in Vancouver from 32% in 1996 to 39% in 2016 (HUB Cycling, 2019). While this is an improvement, a gender gap in cycling continues to prevail around the globe. In the UK for example, surveys reveal that 76% of women don't believe cycling is for them (Sustrans, 2019). Part of this, is a result of a lack of supportive cycling infrastructure such as protected cycle lanes and cycle lanes that align with women's travel patterns (Jelly, 2021).

Figure 21. Image of cargo cyclist (Unsplash, 2018).

Women are more likely to take shorter trips

and off-road routes from the outer-to-outer city throughout their day (Bellis, 2021; Jelly 2021). They are also more likely to trip-chain as they do 75% of the global unpaid care work (Bellis 2020; Criado-Perez, 2019). However, female cyclists also have concerns around social safety and comfort. Women must contend with the fact that they are more likely to become victims of crime and experience sexual harassment (Canadian Women's Foundation, 2021). In Vancouver's public survey "Action for Women" one of the responses detailed some of this experience:

"Sometimes at night I do not feel comfortable walking home – I do not want to feel unsafe in my own neighbourhood. As well being sexually harassed by walking down the street, for example getting honked at and cat called."

There is a need here then to prioritize safe, comfortable, and connected routes that allow women to feel like they belong as they conduct their daily care work (Bellis, 2021). In Japan, despite the lack of protected cycling infrastructure, adoption of the 15-minute city concept throughout the country allows for shorter trips that support female cyclists (Wilson, 2021; Bellis, 2021). Research from the Twin Cities also shows that female cyclists would specifically prefer cycle-tracks for leisure and commuting purposes due to perceptions around safety (Judge, 2011). Simultaneously, detail must be paid to ensure that these routes feel secure for female cyclists. Areas that tend to cause concerns for women are dark doorways, parks at night, empty and badly lit streets, public transit, underground parks, and pedestrian underpasses (Khosla, 2021; Davidson, 2019; Criado-Perez, 2019). Ultimately there also needs to be more rigorous data collection on the female cyclist experience in Vancouver to understand their contextual design needs and problem areas along cycle routes.

People with Disabilities

People with disabilities are also often overlooked in mainstream cycle culture and cycle planning, therefore infrastructure, programming, and representation is severely lacking (Inckle, 2019). Language has been particularly exclusionary. The use of the term "bicycle" can work to prevent a sense of belonging (Wheels for Wellbeing, 2021). It implies that a 2-wheeled cycle is universal when in actuality cycles can have more than two wheels, they can be operated with the hands or feet, and they can come in different adaptations to cater towards the needs of different users (Inckle, 2019; Clayton, Parkin & Billington, 2017). Therefore, it is important to note that "cycle" is the preferred term as it is more inclusive of all cycle types and cycle users.

Figure 22. Image of signage depicting a "standard" cycle (Wheels for Wellbeing, 2020).

This concern around language is also

manifested in the imagery around, and representation of disabled cyclists. Icons on city signs and images in cycling plans as well as design guidelines often fail to incorporate adaptive cycles and disabled cyclists (Wheels for Wellbeing, 2021). For the most part too, design-oriented documents either disregard disabled cyclists altogether or provide little guidance on addressing the barriers that disabled cyclists face (Clayton, Parkin & Billington, 2017).

Beyond representation however, there are also many other barriers that can disrupt the comfortability and sense of belonging of disabled cyclists. Adaptive cycles for example often have wider dimensions and therefore may require wider turning radii (City of London, 2016; Sustrans, 2018). Therefore, it is important that cities take this into account when designating cycle lane widths and ensuring consistency of this width across routes. Physical barriers such as dismount gates, closed routes, stairs, and bollards, that encourage cyclists to dismount can also be problematic for disabled cyclists that are unable to dismount (Maffin, 2021). In terms of end-of-trip facilities too, barriers exist as many adaptive cycles may not fit into "standard" cycle racks (Wheels for Wellbeing, 2019). On top of this all, disabled cyclists must contend with perceptions in mainstream cycle culture that deem cycling to be for the able-bodied and e-assist to be a form of cheating (Wheels for Wellbeing, 2019). They may face additional discrimination too dependent on the visibility of their disability (Clayton, Parkin & Billington, 2017).

For many people with disabilities, cycling is often a chance discovery as it is never really presented as an option due to the deficit model of disability that assumes "to be disabled is to be defined as entirely without ability" (Inckle, 2019). To counter this and to make cycling more inclusive for disabled cyclists there needs to be more representation of these cyclists and updates to signage. For the City of Vancouver this could mean highlighting disabled cyclists in cycling documents such as the *AAA Cycling Routes Design Guidelines* and creating a more inclusive cycle logo. City-wide data collection could also be more inclusive of disabled cyclists to capture their needs and preferences. Infrastructure barriers such as dismount gates and bollards along cycle routes in the city, must be removed (ex. Stanley Park) to allow disabled cyclists to move comfortably and wider cycle racks must be implemented.

Figure 22. Dismount gate at Third Beach at Stanley Park (@LucyinCanada, 2020).

Inclusive cycling campaigns have also advocated for policy changes in cities to officially recognize cycles as mobility aids given that for many disabled cyclists, cycling is much easier to engage in, in comparison to using a wheelchair (Inckle, 2019). This

could further assist in increasing a sense of belonging for disabled cyclists.

Children

Children must also be carefully considered in cycle infrastructure design as they have a smaller frame and therefore may be less visible to other roadway users (NACTO, 2017). They may also have a decreased ability to sense danger and respond quick enough (NACTO, 2017). There is a wide perception of cycling as being a risk intensive and unsafe activity for children to engage in alone (Marstrand-Taussig, 2021). This is understandable given the concerns parents may have around the predominance of motor vehicles, however cycling related fatalities for children in BC for example, are very low (Babin, 2016).

Figure 23. HUB Cycling's online cycle safety course (HUB Cycling, 2021).

Overall, there is little research on children's perceptions of comfort and safety on cycling routes but it is apparent that road safety education paints a picture of fear and danger around roadways (Horton, 2015; McDonald, 2012). Children have also experienced a reduction in their freedom of movement over the last 10 years which is in many ways due to increased reliance on automobiles and fear of stranger danger (Marstrand-Taussig, 2021; McDonald, 2012). Given that cycling has a range of benefits for children from increased cognitive development to greater independence and overall joy and may accommodate the shorter trip patterns of children, it is important that cycling feel safe and comfortable for them (Marstrand-Taussig, 2021; McDonald, 2012).

NACTO's Designing Streets for Kids provides specific design recommendations for designing the public realm to prioritize the needs of children. Listed are some of these recommendations specifically around child cyclists (NACTO 2020).

- Cycle lanes should be wide enough for children to cycle beside their caregivers. Side-by-side riding for one child and one adult can be accomplished in 2.2 m of cycleway clear path, but 2.4 m is preferrable, allowing for social riding. At minimum the cycle lane should be 1.8 to 2 m for unidirectional paths and at least 3.6 m for bidirectional paths.
- Buffers should be implemented between cycle lanes and motorized traffic or parked cars, providing physical protection and improved comfort for families cycling.
- Convenient and secure places to park and lock bicycles, including children's and cargo cycles should be provided.

The ultimate recommendation is that while children may be able to navigate alongside automobiles, protected cycle tracks are much more favorable as they allow for an overall sense of safety and comfort (NACTO, 2020). In addition to these design guidelines, there should also be a greater emphasis

on cycle safety educational programs as they have been found in many cases to increase knowledge around safety, reduce the likelihood of crashes, and improve children's abilities to make various maneuvers (Ellis, 2014). These programs should also ensure that through safety education a fear of cycling is not instilled within children (Horton, 2007). There is also a dearth of data regarding children's recreational trips and trips in general as it is tough for city-wide data collection to account for these trips (as seen in Vancouver's Transportation Panel Survey that collects data for cyclists 18+) and therefore there may be an opportunity to prioritize data of this sort.

Seniors

Like children, seniors are also a vulnerable user group. As a result of aging, many seniors may have reduced judgment, balance, coordination, peripheral vision, and cognitive function (Ikpeze et al., 2018). These effects can be compounded by additional health issues. The American Automobile Association predicts that seniors may be surpassing their safe driving capabilities by 7-10 years (Bruntlett & Bruntlett, 2021). Cycling is therefore a much safer and healthier option. However, careful attention must be paid to the grade, smoothness of cycle routes, and wayfinding to enable a safe and comfortable experience for seniors. They may also experience reductions in stamina with aging and may therefore require greater opportunities for repose and rest along cycle routes (Bruntlett & Bruntlett, 2021). Based on a study conducted of Vancouver's Arbutus Greenway it appears that some seniors are also concerned for their personal safety with respect to crime (Ottoni, Sims-Gould & Winters, 2021). Data from a US-wide survey of senior cyclists in 2020 reinforces some of these concerns as it highlights that the top five factors that affect where seniors ride, include 1) an overall feeling of being safe; 2) roads in good condition and clear of debris; 3) few or no cars; 4) benches to take a break; and 5) protected cycle routes (Kachadoorian, 2021). Some additional factors included neighborhood streets with lower speeds, efficient cycle parking, bathrooms and drinking fountains, and places to stop and eat and shop along the way.

Figure 24. Benches along the seawall by Charleson Park (City of Vancouver, 2019).

It is important then to ensure that all seniors can experience the benefits of cycling, particularly in Vancouver where we are experiencing an aging population (Kloppenborg, 2010). Design considerations such as the provision of protected cycle lanes, cycle route amenities (i.e. benches, bathrooms), routes with even paving (made of plastic and bricks based on a study of park pathway preferences) and adequate gradients, wayfinding elements (i.e. signage, art, landmarks etc), and colocation of cycling routes with community infrastructure (i.e. shops, community centers, health care facilities etc.) (ARUP, 2019). Many seniors

fear crime in the public realm and therefore additional attention must be paid to the design of cycle routes such that there is an element of security through natural surveillance (Green, 2017). Research also shows that older adults in North America choose not to cycle. While part of this may be due to health conditions, they may also have perceptions around not belonging in cycling culture (TCAT, 2019; Aldred, Woodcock, & Goodman, 2016). Therefore, there is an opportunity to increase representation of senior cyclists in mainstream cycle culture and in city documents.

Low-Income Riders

The term "rolling signification of cycling" comes from Melody Hoffmann's book, *Bike Lanes are White Lanes*. It highlights the fact that the symbolic meaning of a cycle will alter in different spaces and cultures. For some, cycling is seen as a means to protect the Earth and combat the negative impacts of climate change, while for others it denotes poverty and crime (Hoffman, 2016). For some, cycling is one of many options for transportation purposes, while for others it is their only option to travel (Lopez, 2018). This rolling signification is important to consider here not only because of the way it paints marginalized riders but also for the way it siloes cycling as a leisurely activity only for some. This is especially the case with low-income cyclists.

In the article, "Welcome to Vancouver's Underground Bicycle Economy," author Jeanette Steinmann interviews five cyclists from the Downtown Eastside. These residents' cycle both for leisure and commuting purposes for their work as "binners" who work to collect recyclable containers. Cycling is also a much more beneficial mode of transportation as it allows them to traverse with heavy bags through remote locations and it eases chronic pain from health conditions (Steinmann, 2021).

Figure 25. Image of Steve Nelson, a binner in Vancouver who uses his cycle to get around (Cheung, 2021).

Despite the work that these cyclists put in to move waste from landfills for which they get paid very little, they face issues of safety and comfort due to harassment from roadway users as well as the police who view them as criminals. For example, research from the US shows that helmet laws can result in disproportionate targeting of low-income and BIPOC cyclists. The routes they must use to travel to bottle depots are also very inconvenient. Overall, individuals of lower income tend to walk and cycle more than people of higher income (Zimmerman et al., 2005). However, cycling can often be and feel inaccessible for this group due to lack of safe infrastructure for cycling in low-income neighborhoods, the unaffordability of cycles, and the lack of representation of low-income cyclists (Weigand, 2012; Community Cycling Center, 2021). To enable safer and more

comfortable cycling for low-income cyclists there needs to be more representation of these cyclists both in advocacy campaigns and in city documents. This kind of representation will help low-income individuals that don't cycle, recognize that it can be a possibility for them and help reduce the stigma around cycling and poverty. Engagement and surveys that target these groups will also be beneficial to understand what routes they use daily and how they can be improved or how additional cycling routes can be added to support their needs. Exploring helmet laws and their impact on this community would also help.

People Moving Goods or Cargo

Cycles that move goods or cargo are unique in that they allow cyclists to carry additional weight but as a result these cycles hold weight differently, may take wider turns, and may require additional manoeuvring to handle (Schwartz, 2016). Therefore, while the width of cargo cycles is supported by most cycle route width standards, for many cargo cyclists there may be a feeling of discomfort. In a study conducted in Amsterdam and Stockholm, it was discovered that for cargo cyclists, the volume of heavy vehicles, the type of infrastructure, cycle route smoothness, and the traffic volume of cars are the four most important elements in shaping the route choice of cargo cycle users (Liu et al., 2020). In a separate study conducted with women cargo cyclists in the US it was revealed that factors that contributed to the women feeling uncomfortable included getting used to the weight of the cycle, having multiple kids on the cycle, congested roadways with fast-moving traffic, the lack of cycle infrastructure, and aggressive driver behaviour (Schwartz, 2016). There can be a barrier to entry for cargo cycling too due to confusion around regulations and parking (C40, 2020). It is also important to consider delivery cyclists here which have been a relatively newer and smaller scale addition to Vancouver's cycling scene. However there has been research from New York that shows the way in which food delivery cyclists are negatively portrayed in the media and othered (Lee, 2018). While this has not been the discourse in Vancouver it is still important to consider.

Figure 26. Photo of cargo e-cycle cyclist in Vancouver (BC Government, 2021).

Similar to other user groups there is a need for greater separation between cargo cyclists and motor vehicles. The study from the US also emphasizes design strategies such as painting cycle routes with bright colours and adding sharrows to provide additional comfort and safety for these cyclists. This study also revealed that many of the women were comfortable riding cargo cycles but this comfort and feeling of safety primarily came from the cycle education they received to navigate cargo cycles (Schwartz, 2016). Cities can also ensure regulations and infrastructure are in place to provide access to cycle lanes.

Lesbian, Gay, Bisexual, Transgender, Queer or Questioning and Two-Spirit (LGBTQ2S+) Cyclists

While not included in NACTO's list of all ages and abilities users, LBGTQ2S+ people are an important user group. Ultimately there is no real data on LGBTQ2S+ cyclists but there is a lot of research around their experiences of comfort and safety in the public realm. While LGBTQ2S+ acceptance may appear to be increasing in parts of the world, many individuals that identify as LBGTQ2S+ continue to face rampant discrimination and hate crimes due to their sexual orientation (Ostergard & Lee, 2017). Statistics Canada data from 2015 shows that the "odds of being a victim of violent victimization were two times higher among lesbian, gay or bisexual Canadians" (Simpson, 2018). Trans women of colour as a whole face disproportionate rates of murder and harassment and will often avoid public spaces altogether (Marchia, 2017; ARUP 2019b).

As a result, many LBGTQ2S+ people must hide their identities to feel safe in the public realm (ARUP, 2019b). This feeling of unsafeness and vulnerability is particularly prevalent in the nighttime (ARUP, 2019b). Urban planning has historically excluded LGBTQ2S+ individuals as their activities have been considered as part of the private not public realm (Addamo et al., 2016). Therefore, while there is no concrete data on LGBTQ2S+ cyclist experiences, it is important to use these experiences in the public realm to ensure they have a safe and comfortable experience while on cycling routes in Vancouver.

The ARUP firm published a report in collaboration with the University of Westminster on "Queering Public Space." This report details many strategies to create public spaces inclusive of all. Listed below are some of these design strategies:

- The implementation of micro-interventions such as rainbow crossings, public art and artistic lighting can signal inclusion to LGBTQ2S+ people.
- Queer-inclusive spaces have a diverse feel to them. They don't need to be uniform; they can offer a range of sightlines; they can be softened by greenery and bodies of water rather than harsh surfaces.
- "Cosy corners" mentioned by LGBT+ respondents, provide much needed privacy in public space, where they can see but not be seen.

Figure 27. Vancouver's rainbow crosswalk on Davie Street (Sherwood411, 2016).

While these aren't listed with respect to cycle routes many of these strategies are applicable. Rainbow crossings exist in many cities across the world including in Vancouver and could be

applied to entire cycle paths like the rainbow cycle path in Utrecht, Netherlands (Cloutier, 2021). Similarly, public art along cycle routes, representing diverse gender identities could also be implemented. These implementations could also assist in ensuring that cycle routes have a diverse feeling to them. The city could also work to do more engagement with LGBTQ2S+ cyclists to understand their specific safety concerns with respect to cycling.

Immigrant Cyclists

Immigrant cyclists were another group not listed in the NACTO all ages and abilities user list. They are an important user group to consider with respect to safety and comfort on cycle lanes because they may not be familiar with the cycle lanes and cycling rules and regulations in Vancouver. Data from the US shows that immigrants are disproportionality represented in pedestrian and cyclist crashes (Chen, Lin, & Loo, 2012). This may be in part due to mismatches in understanding of safety culture. On top of that, they must contend with learning so many other things about living in a new city and it doesn't help that mainstream cycling and the outdoor industry perpetuates images of the stereotypical cyclist that they may not identify with (Barajas, 2018). While inadequate cycling infrastructure is definitely a barrier, lack of representation, a fear of bicycles and the fact that cycling may not have been common in their community may further contribute to a lack of sense of belonging (Hirsi, 2018).

To enable immigrant cyclists to feel safe and comfortable there needs to be a greater effort to understanding their walking and cycling patterns. Also, an emphasis on cycle education programs and programming could help to encourage cycling among these groups. Research shows that close-knit social networks played a important role in knowledge about and encouragement of cycling (Barajas, 2018).

Figure 28. Image from HUB Cycling's Newcomer Bike Host Program (HUB Cycling, 2018).

2.3.2 Jurisdictional Scan/Innovations

Listed below is an amalgamation of innovations and jurisdictional precedents that address some of the cycling needs of all ages and abilities users to improve comfort and safety on cycle routes. This scan is set to prioritize precedents that are spearheaded by municipalities or have been used by municipalities at some level.

Representation

The following precedents highlight advancements made in cities to include and represent a diversity of cyclists and cycle types in their cycling infrastructure design.

A. City of London – United Kingdom

Chapter 3 of the City of London's *Cycling Design Standards* incorporates "non-standard" cycles into its cycle design parameters by identifying their length, width, and turning radii. The document recognizes that there are no set inclusive cycle infrastructure guidelines due to the differing dimensions of various cycles however by acknowledging this, they have made some general assumptions around inclusive design for cycling. These assumptions cover changes in grade, turning radii, access point widths, and recommended elevator dimensions (The City of London, 2016). It appears that this is one of the first cycling design standards document that has made this acknowledgement and it signals improvement in inclusivity of a wide diversity of cyclists (Andrews, Clement, & Aldred, 2018).

B. Walk Ride Bath – Bath, United Kingdom

Walk Ride Bath is a community advocacy organization working towards a future where walking and cycling is inclusive for people of all ages and abilities (Walk Ride Bath, 2021). They have made great strides in terms of representation of different cyclists particularly disabled cyclists. They have created a map that highlights inclusive cycling routes which allow for comfortable cycling with a wheelchair cycle (1.2 m wide and 2.8 m long) and they have also ensured that their banner and site imagery depicts a wide range of "non-standard cycles" (Wheels for Wellbeing, 2020).

C. Bike Portrait Project – New York, US

The Bike Portrait Project came out of a collaboration between the NYC Department of Transportation and the Biking Public Project which is an organization working to advocate for marginalized and underrepresented cyclists including women, people of color, and delivery cyclists (The Biking Public Project, 2018). The portrait project centered on photographing this diversity of cyclists to increase visibility (Sierra Project, 2012).

Applications

The following innovations are a set of

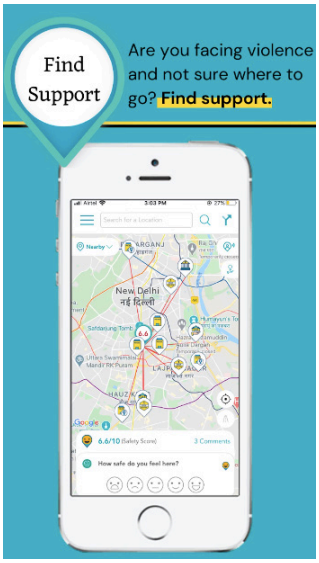
A

B

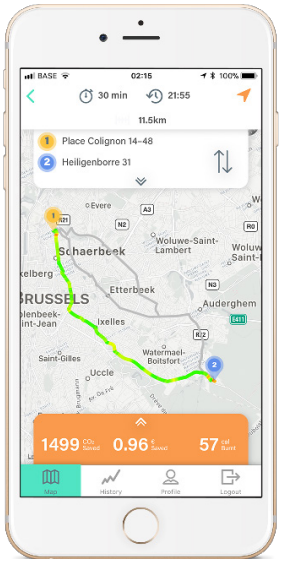
C

Figure 29. Image of a) London's cycling design standards and its incorporation of "non-standard" cycles (City of London, 2016), b) Walk Ride Bath's inclusive cycling banner, and c) some cyclists as part of NY's bike portrait project.

A



B



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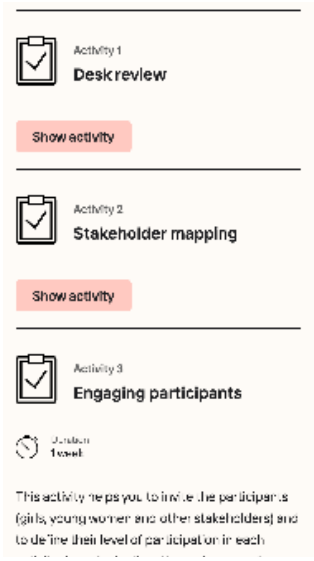


Figure 30. Image of a) the safest route feature in the My Safetipin app (Safetipin, 2021), b) the safest route feature in the Horizontal Cities app (Horizontal Cities, 2021), and c) some of the initial activities in the Her City toolbox (United Nations Human Settlements Programme, 2021).

applications/toolkits that work differently to help ensure safety and comfort in the public realm and that may be useful for cycle routes.

A. My Safetipin

Safetipin is an organization that centers its work on making the public realm safer and inclusive for women through data collection (Safetipin, 2021). Their app My Safetipin allows users to input a set of safety ratings out of 5 for an area for factors such as lighting, openness, visibility, people, security, walk path, public transport, gender usage, and feeling. The results of the app are then crowdsourced to produce a safety score. This data can then be provided to governments, NGO's, corporations, and portals for these stakeholders to make necessary changes on a policy/design level. For users themselves too this data can provide information on the safest routes. This tool has potential for city-wide use to identify concerns on cycle routes.

B. Horizontal Cities

The Horizontal Cities application informs the user of the most ideal cycle route avoiding hills or steep inclinations. Their mission is to make cycling much more energy efficient for all users. The app uses topographic data as well as the physical profile of the consumers to collect the slope of every single street segment and relay back the flattest and safest routes (safety based on proximity to heavy motor vehicle traffic) (Horizontal Cities, 2021).

C. Her City – UN Habitat & Global Utmaning

The Her City initiative is a digital toolbox curated to plan cities from a girls' perspective in order to increase girls' involvement in urban planning (United Nations Human Settlements Programme, 2021). The toolbox follows the three phases of the urban development process - assessment, design, and implementation (United Nations Human Settlements Programme, 2021). It contains a series of tools to support each of these phases, such as checklists, calendars, agendas, manuals, forms, boards, apps and templates (United Nations Human Settlements Programme & Global Utmaning, 2021). A tool like this may have potential to ensure that planning for cyclists is much more inclusive.

Programming

Listed below are a series of jurisdictional precedents regarding programming implementations (at the municipal level and smaller) to make cycling safe and comfortable for all users.

A. "Try Before you Bike" Lambeth – London, UK

In 2018, the Lambeth Council in collaboration with the organizations Wheels for Wellbeing and Peddle my Wheels, extended their "try before you bike" scheme to disabled cyclists. This program allows cyclists to book a session with Wheels for Wellbeing to try out various types of non-standard cycles to see what suits their needs and have a follow-up session to determine the right cycle and whether any adaptations are necessary (Wheels for Wellbeing, 2020). Users can trial the cycle for rent (100 pounds/month for adaptive cycles) or purchase it for a discounted price. This program has been expanded out to several other London boroughs as of 2020 and appears to be very successful (Lambeth, 2021).

B. Adaptive Biketown Portland – Oregon, US

Adaptive Biketown is Portland's adaptive cycle rental project implemented in 2016 after requests were received to expand its BIKETOWN cycle share project. The project provides short-term (1-3 hours) adaptive cycle rentals, fitting for the available adaptive cycles, cycle helmet rental, mobility storage during rental time, and crate storage of service animals during rental time (PBOT, 2021). Discounted rates for users who qualify for a TriMet Honoured Citizens Pass are $5 for 1 hour and $12 for 3 hours. Standard rates vary dependent on the type of cycle (Adaptive Biketown, 2021). The initial pilot project expanded from 2017 to be a permanent project.

Figure 31. Portland's Adaptive Biketown program (Adaptive Biketown, 2021).

C. Mini Bicicletar – Fortaleza, Brazil

This program implemented in 2017 by City Hall and Unimed Fortaleza provides 50 children's cycles with retractable training wheels across five city stations. In the first 6 months, 6,531 rides were taken. The programs' costs are covered primarily by sponsorship from a private company so only a small portion is required of user fees (Cox, 2018).

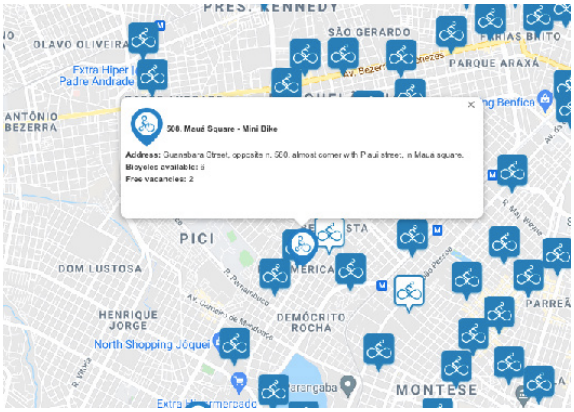


Figure 32. Map showing the availability of children's cycles (Bicicletar, 2021).

Infrastructure/Design Strategies

Listed below are a series of precedents

Figure 33. Image of a) cargo cycle stands in Malmo, Sweden (Copenhagenize, 2014), b) the rainbow cycle path in Utrecht (BicycleDutch, 2021), and c) pavement tiles in Amsterdam's kindlint (Wikipedia, 2018).

emphasizing design/infrastructure elements that can make cycling safer and more comfortable and inclusive of all.

A. Inclusive Cycle Stands – Malmo, Sweden

The Bike & Ride parking facility at Central Station in Malmo, Sweden is an example of inclusive parking for all cyclists. This facility provides half-height and longer cycle stands for tricycles and cargo cycles (Wheels for Wellbeing, 2020). Asides from parking the facility also provides air pumps, a cycle shop, lockers, screens showing train departure and arrival times, restrooms, a lounge, and even a shower (Copenhagenize.com, 2014).

B. Rainbow Cycle Path – Utrecht, Netherlands

The rainbow cycle path located in Utrecht Science Park in Utrecht is the longest rainbow cycle path in the world with a length of 570 m. While the rainbow flag applied to the cycle path is a symbol of the LGBTQ2S+ community, its purpose here is to signal that everyone is welcome to the park regardless of their ethnicity, sexual orientation, disability, income etc (Utrecht University, 2021).

C. Kindlint (Child Route/Ribbon) – Amsterdam, Netherlands

The Kindlint or child route/ribbon is a concept created by SOAB, a traffic consultancy firm, to reclaim streets for children and make them safer for their travel by walking or cycling (Reframing Studio, 2021). The purpose is to provide a safe route with special markings and traffic calming to connect destinations important to children such as schools and playgrounds (McDonald, 2012). This was implemented first in 2007 in the Spaarndammerbuurt in Amsterdam. The Kindlint consisted of blue pavement tiles with images of animals to signal when children should wait, walk, etc. (Krishnamurthy, 2018). An evaluation of the project revealed that while children were more independent and walked to school more, often the indicated route was not followed as children were unclear what the signs meant and parents still accompanied children (Westerweele, 2017; Krishnamurthy, 2018). It is recommended that adoption of this concept in the future should require attention to the type of neighbourhood type, residents needs, and existing measures of traffic calming (Krishnamurthy, 2018).

3.1 GIS Spatial Analysis

In order to identify gaps in lighting across the cycling network, I conducted a GIS analysis. The results as seen in Figure 34 below highlight that lighting is absent where cycle routes intersect with parks in Vancouver. Specifically: Stanley Park, Vanier Park, Jericho Beach Park, Locarno Beach Park, Spanish Banks Beach Park, CRAB park, Hastings Park, and John Hendry Park (Trout Lake Park). Lighting is also absent along the seawall where the convention centre is located and for a brief portion of Terminal Avenue. It is important to note however that at this scale we are not able to see much detail. Upon zooming in we are able to see areas where lighting exists only along one side of the roadway (ex. Windsor Street between east 26th and 29th Avenues) or only exists in areas adjacent to the pathway (ex. Arbutus Greenway south of of West 37th Avenue).

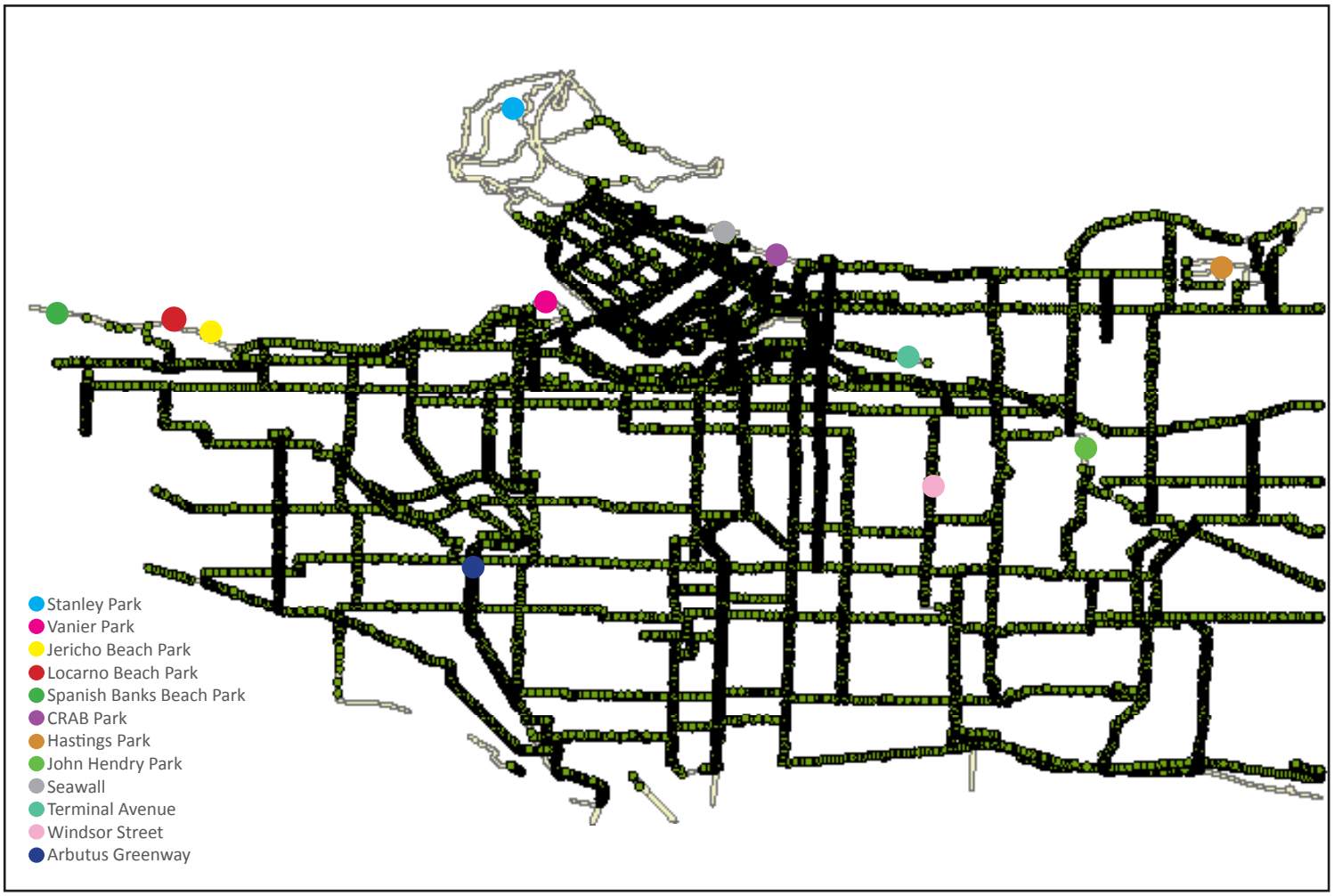


Figure 34. GIS analysis depicting all the lighting (in green) on Vancouver's cycle routes (in yellow).

3.2 Evaluating Comfort and Safety

In order to evaluate the comfort and safety on Vancouver's cycle routes I developed an evaluation methodology using TPL's previous AAA check system for lighting while also incorporating elements from the City of London's Cycling Level of Service Assessment Matrix and Queensland's criteria for prioritization of cycle route lighting projects (see Appendix). I included several different indicators of safety and comfort for which I have established criterion that would score a route with an AAA, Adequate or Inadequate rating. A zero score for a particular indicator may prompt an evaluation for the cycle route dependent on the importance of that factor. Note that indicators such as collision risk and feelings of safety with respect to automobiles are not emphasized here.

Factor	Indicator	AAA rating (2)	Adequate rating (1)	Inadequate rating (0)	Score
Safety Cycle lane safety is the absence of perceived physical threat or danger (i.e. collision risk, harassment, isolated routes) and a feeling of belonging by all when on cycle lanes.	Lighting	Lighting along entire route that is uniform and evenly distributed; lighting meets standards; no issues of glare; no obstructions; luminaire aligns with street/land typology; not overly bright	Variable lighting along route and there may be short stretches of darkness; lighting meets standards for the most part; some glare; may be some obstructions interfering with light; luminaire works with street /land typology; slightly bright	No lighting and/or long stretches of darkness; lighting fails to meet standards; presence of glare and obstructions that limit visibility; luminaire does not align with street typology (ex. floodlights in a park); overly bright	
	Isolation	Whole route can be seen from nearby land uses; frequent contact opportunities with other users	50-70% of the route can be seen from nearby land uses; regular contact opportunities with other users	Less than 30% of the route can be seen from nearby land uses; limited contact opportunities with other users	
	Risk/fear of crime	No fear of crime: high quality streetscene and pleasant interaction	Low risk: area is open, well designed and maintenance	High risk: "ambush spots", loitering, poor maintenance, no escape routes	
	Sense of belonging (user specific)	Presence of other cyclists that one identifies with; cycle route/roadway users treat each other with respect	Little presence of other cyclists that one identifies with; cycle route/roadway users sometimes treat each other with respect	No presence of other users that one identifies with; cycle route/ roadway users do not treat each other respectfully	
Comfort Cycle lane comfort is the ease of use of cycle lanes, the level of harmony of interaction with other roadway users, and the maintenance of health while using cycle lanes (i.e. avoiding noise, vehicle pollution, headlight dazzle).	Wayfinding	Consistent and inclusive signing of range of routes and destinations at decision points	Some cycle-specific direction signing	Basic direction signing (cyclists follow road signs and markings). Signage is not inclusive of a diversity of users	
	Health impacts	No concerns around noise, vehicle pollution, headlight dazzle	Few concerns around noise, vehicle pollution, headlight dazzle	Concerns around noise, vehicle pollution, headlight dazzle	
	Impact of roadway design on behaviour	Layout encourages civilized behaviour: negotiation and forgiveness	Layout controls behaviour throughout	Layout encourages aggressive behaviour (ex. roadway users too close)	
	Accessibility	Route is accessible by a diversity of cyclists and cycles	Route is accessible by most cyclists and cycles	Route is inaccessible for several cyclists and cycles (ex. dismount gates, bollards)	

Table 10. Evaluation methodology for comfort and safety on cycle routes.

3.3 In-Person Site Visits

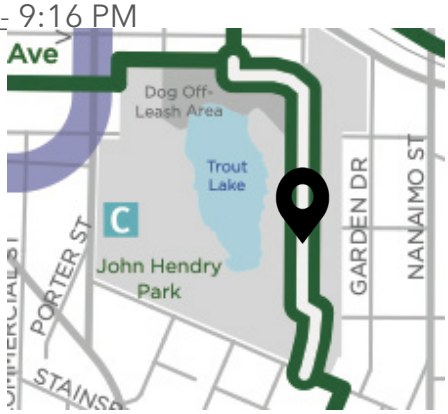
In order to truly understand comfort and safety on Vancouver's cycle routes I conducted a series of site visits in-person at Slocan Park, Trout Lake Park, the Central Valley Greenway, W 10th Avenue, W 37th Avenue, the Arbutus Greenway, and the Stanley Park seawall. Each have been informally evaluated on the basis of comfort and safety to determine how they rank as routes. The lighting was however the key focus of this examination.

1. Slocan Park (south of E 29th Avenue, east of Slocan Street); non-AAA route - 8:46 PM

The road along the edge of Slocan Park was illuminated however, the adjacent cycle/ pedestrian route was not. Further along in the park there are lighting poles yet they are only along the pedestrian path. The presence of trees along the path results in the light appearing through a soft green hue rather than white, potentially obstructing visibility. I noticed very few cyclists along the route but a lot of pedestrian users. The presence of bollards at the entrance and exit of the park while fairly spaced out could have been a deterrent. Overall it felt quite safe and comfortable but the time of the visit meant that it was fairly light out and so the full experience of lighting was not achieved. Therefore it receives an adequate rating.

Figure 35. Photos of Slocan Park taken by me.

2. Trout Lake Park (east side of lake); non-AAA route - 9:16 PM

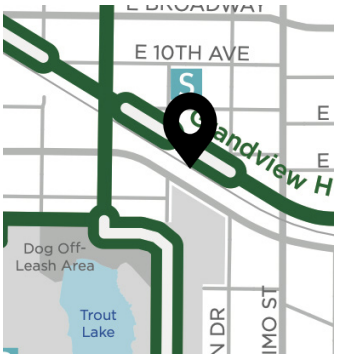


The multi-use path within this park does not contain any lighting. The only lighting that exists in the park is a few floodlights within the baseball field and lighting from adjacent roads. While trees and the lack of lighting created somewhat of a secluded environment along pockets of the pathway, the presence of a variety of users throughout the park provided a sense of comfort and safety. Given the dusk till dawn closure of the park however, this raises concerns for users of the route in the late hours. It is also worthwile noting that the cycle racks throughout

the park did not appear to be inclusive of all cycle types. This route would receive an adequate rating based on my experience at the time but I imagine as a user later in the night lighting as an indicator and comfort and safety as a whole would be inadequate.

Figure 36. Photos of Trout Lake Park taken by me.

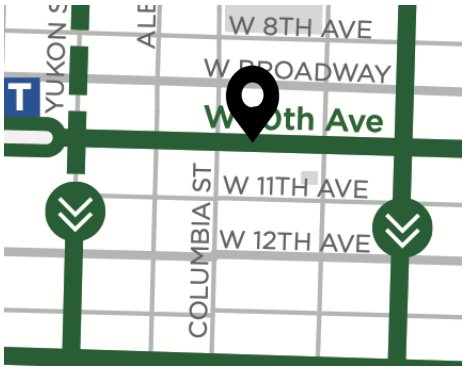
3. Central Valley Greenway (N Grandview Highway near Templeton Street); non-AAA - 9:56 PM



This site was quite isolated. I only encountered 1-2 cyclists. The presence of trees added to this secludedness as pockets of the pedestrian pathway were hidden. The tall white luminaires, which were distributed quite far, did provide lighting that illuminated the entire route. However, the lack of lighting from adjacent homes and the way in which many of the homes were setback created an uncomfortable environment. In terms of rating, it would receive an adequate rating as lighting was present and there was an element of casual surveiilance however it could benefit from more closely distributed pedestrian lamps.

Figure 37. Photos of CVG taken by me.

4. W 10th Avenue (Columbia St to Ontario St); non-AAA - 10:17 PM

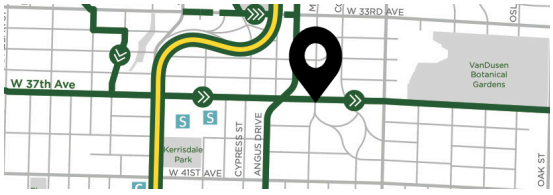


This road was illuminated with several spaced

out human-scale pedestrian luminaires as well as lighting from adjacent residences. The yellow lighting provided by both light sources created a comforting environment. There were many cyclists and pedestrians using this area despite it being quite late. The way in which the adjacent residences were not setback also provided a sense of safety and comfort. For these reasons this segment of road would receive a AAA rating.

Figure 38. Photos of W 10th Ave taken by me.

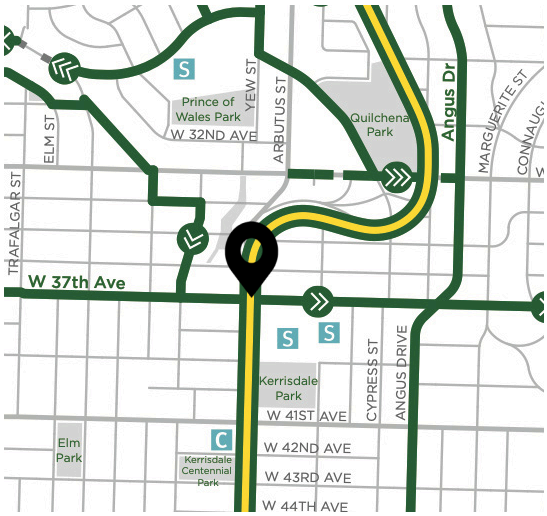
5. W 37th Avenue (west of Granville Street); non-AAA - 10:37 PM



While this cycle route had yellow pedestrian-scale lighting there were considerable distances between these lamps and therefore several patches of darkness. The way in which the houses were setback and in that they didn't provide any additional lighting also made the area feel quite isolated and dark. Overall this would receive an inadequate rating

Figure 39. Photos of W 37th Avenue by me.

6. Arbutus Greenway (N of W 37th Avenue); AAA route - 10:45 PM

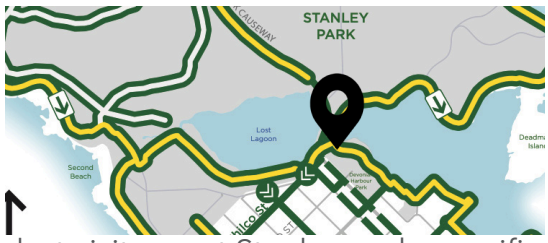


Despite being an AAA route, the Arbutus Greenway at night did not feel very safe. While there was light present it did not help the fact that the route in itself is enclosed and doesn't offer any escape routes and isn't readily seen by other land uses. The lighting is also only along one side of the greenway and then south of W 37th Avenue there is no lighting at all. Therefore this route would receive an inadequate rating as the presence of lighting is not sufficient

to provide comfort and safety, there must be elements of natural surveillance and the presence of others to instill this.

Figure 40. Photos of Arbutus Greenway taken by me.

7. Stanley Park Seawall (tunnel on the way to Lost Lagoon); AAA route - 7:39 PM



The last visit was at Stanley park, specifically examining the lighting in the tunnel along the route to Lost Lagoon. The yellow strip lighting along the walls of the tunnel created a safe and comfortable atmosphere that was likely augmented by the presence of cyclists and pedestrians. Due to the time of the visit, it was difficult to ascertain how this experience may have differed in darker conditions. It is also worthwhile noting that there were several closely spaced bollards located along the way to this tunnel that may be a barrier for certain cycle types (cargo cycles, hand cycles etc.). Ultimately, this route would receive an adequate rating.

Figure 41. Photos of Stanley Park taken by me.

It is also important to note that a common theme for all the sites I visited was that the signage and wayfinding features depicted images of "standard bicycles." This is a common theme in cities around the world too. But, as mentioned previously there is a diversity of different cycle types and representation in signage for example is an important step in making sure that all cyclists feel that they belong in the community.

Figure 42. Photos of cycling signage at various sites taken by me.

AAA Lighting

It is recommended that the City of Vancouver revise the definition of adequate or rather AAA lighting in the Transportation Design Guidelines for All Ages and Abilities Cycling Routes as such:

1. Lighting is perceived to increase safety and comfortability for many people at night (Utlley, Monteiro & Fotis, 2018). This is important for cyclists as cycles travel faster than pedestrians and therefore require higher visibility and it is also important for their social safety and overall comfortability (BC Ministry of Transportation and Infrastructure, 2019; Fotios et al., 2014). However, not everyone experiences lighting in the same way (ARUP, 2019a). While some research points towards brighter lighting to increase safety at night, other research highlights it as problematic, and then there are studies that defer to lighting uniformity to increase perceived safety (ARUP, 2019a; Utlley, Monteiro, & Fotios, 2018).

For AAA routes then, AAA lighting is:

- *Lighting that exists across the entirety of AAA cycle routes (BC Active Transportation Design Guide, 2019). Where a cycle route is further than 5 m from an adjacent road then it must have its own independent lighting system (BC Active Transportation Design Guide, 2019).*
- *Lighting that is evenly distributed (Victoria State Government, 2021; Utlley, Monteiro, & Fotios, 2018).*
- *Lighting that does not cause glare or light trespass (City of Vancouver, 2019; Colorado DOT, 2019).*
- *Lighting that is not impeded by trees or other obstructions (IESNA, 2014).*
- *Lighting that aligns with the land use and roadway typology of the cycle route where streetlamps may be more appropriate for on-street cycling facilities and pedestrian-scale lamps, bollards, and in-ground lighting may be ideal for off-street cycling facilities (BC Active Transportation Design Guide, 2019).*
- *Lighting that is not overly bright (Kalms, 2019; City of Toronto, 2017).*
- *Lighting that meets the standards specified in Vancouver's Engineering Design Manual. For on-street cycling facilities this means the standards provided for the relevant road typology and level of pedestrian activity (see Appendix) and for off-street cycling facilities see below. Security and safety may be of concern where there are high collision points; safety hazards; isolated sections of a route; poor casual surveillance; limited contact opportunities with other users; reported security incidents; inability of facial recognition/recognition of horizontal and vertical elements.*

Maintained average horizontal illuminance	*5 lux or greater for general guidance*
Maintained vertical illuminance	*Where security is of concern, a minimum level of 5 lux*
Maximum-to-minimum horizontal uniformity ratio	*10:1 or less for guidance or 5:1 or less for security*

Figure 1. Standards for off-street cycle routes

Considerations

- *For parks intersecting with cycling routes that choose to avoid lighting due to ecological concerns or concerns around loitering after closure, there may be additional options such as adaptive lighting*

(see page 19), coloured lighting (see page 22), or bollards/embedded lighting that may be less disruptive.

- *For cycle routes where lighting placement must intersect with trees or other vertical obstructions, custom lighting arms, pedestrian-scale lighting or regular tree pruning may be alternative options to ensure that visibility is not impacted.*
- *For cycle routes that are paved with highly reflective surfaces (ex. light-coloured surfaces, see page 21), it may be feasible to reduce brightness levels upon reviewing other contextual factors.*
- *For cycle routes that intersect with conflict points such as high-collision intersections the use of cool white lights may be ideal, while along all other cycle routes more warmer lighting is preferrable.*
- *Lighting alone is not enough to ensure that a cycle route is safe and comfortable. It works in conjunction with aspects such as isolation, risk/fear of crime, sense of belonging, wayfinding, health impacts, impact of roadway design on behaviour, and accessibility (see Table 10 on page 39).*
- *While the definition of AAA lighting above provides specific guidelines, it is necessary to recognize that there is not a one-size fits all approach to lighting in the public realm. Each cycle route is unique and will possess its own contextual and design factors that will need to be considered with respect to lighting.*
- *Recreational routes and local cycle routes are often disregarded in the lighting conversation. While it may appear that these routes are not frequented in the nighttime hours, they should still be illuminated especially if they are AAA routes as the lack of lighting (or insufficient roadway lighting) may be a barrier for some.*

2. In terms of specific sites that require lighting upgrades or greater consideration around design, it is recommended that the cycle routes through Trout Lake Park, W 37th Avenue (west of Granville Street), and the Arbutus Greenway (S of W 37th Avenue) be considered.

3. Currently there are several cycling facilities (ex. Stanley Park, Vanier Park, Jericho Beach Park, Locarno Beach Park, Spanish Banks Beach Park, CRAB park, Hastings Park, and John Hendry Park) that intersect with parks and do not contain lighting. Given that there are precedents that exist where multi-use paths connecting to parks are illuminated (ex. Slocan Park, Harbour Green Park) it is recommended that the Parks Board and Engineering formalize these examples and collaborate to consider the illumination of cycle routes that are missing lighting and on future parks upgrade initiatives.

4. It is recommended that further engagement be conducted around lighting on Vancouver's cycling routes to understand how different users may be experiencing lighting and how that may be intersecting with their experiences of safety and comfort.

5. It is recommended that further research be conducted around lighting and improving the safety and comfort of end-of-trip cycling facilities.

Safety and Comfort

1. Safety and comfort in cycling often refers to the proximity to automobiles and collision risks. This report has determined that safety and comfort are not limited to this definition. It is recommended that in planning for and evaluating cycling routes as well as in the *Transportation Design Guidelines for All Ages and Abilities Cycling Routes*, a redefinition of safety and comfort be implemented as indicated below (also see page 39 Table 10):

Cycle Lane Design Factor	Definition
Safety	Cycle lane safety is the absence of perceived physical threat or danger (i.e. collision risk, harassment, isolated routes) and a feeling of belonging by all when on cycle lanes.
Comfort	Cycle lane comfort is the ease of use of cycle lanes, the level of harmony of interaction with other roadway users, and the maintenance of health while using cycle lanes (i.e. avoiding noise, vehicle pollution, headlight dazzle).

Figure 2. A redefinition of comfort and safety.

2. It is recommended that the city adopt and asapt the safety and comfort evaluation methodology in Table 10 on page 39 as part of its AAA checks.

Inclusive Cycling

1. The term "bicycle" assumes that a cycle with two wheels is the standard but this is not the case. There are a multitude of cycles ranging from tricycles, tandem cycles, hand cycles, recumbent cycles, wheelchair tandem cycles, cargo cycles and more. It is recommended then that rather than using the term "bicycle" or "bike" in city documents, the term "cycle" is used instead to be more inclusive of the different cycle types and cyclists.

2. Signs and logos across Vancouver's pavements and wayfinding seigns depict the image of "standard" cycles. Not everyone rides a "bicycle" with two wheels. It is recommended that signage and cycle logos across the city be updated to reflect the diversity of cycle types and cycle users. Walk, Ride Bath is an organization that has created its own logo to depict this diversity.

3. Given the diversity of cycle types and sizes, it is important to consider their widths and turning radii needs. While it appears that many cycles fit within the cycle lane widths provided in Vancouver's AAA design guidelines, it is recommended that the guidelines provide a segment that explore and recognize these differences.

4. Cycling-related city documents in Vancouver are not representing the entire scope of different cyclists. It is recommended that imagery of disabled cyclists, BIMPOC cyclists, low-income cyclists etc. to be included to signal to these individuals that cycling is for everyone.

5. The presence of dismount gates across Stanley Park and bollards across the city are disruptive for cyclists who may be unable to dismount or navigate through bollards. It is recommended that these barriers be removed and replaced with signage where necessary while providing disabled cyclists with additional routes where dismounting is required.

6. There appears to be a lack of inclusive cycle parking infrastructure in Vancouver particularly

for those cyclists who are not using "standard" cycles". It is recommended that as with car parking, there should be a proportion of cycle parking for people who use non-standard cycles such as cargo cyclists, hand cyclists, recumbent cyclists etc.

7. It is recommended that the design of cycle routes should take into account the different needs of different cyclists in order to make cycling safe and comfortable for them. For example, women tend to make shorter trips on off-road routes and low-income cyclists that are binners, benefit from routes that colocate facilities such as recycling depots.

8. It is recommended that further engagement be conducted with the different cyclists mentioned in this report (BIMPOC, women, people with disabilities, children, seniors, low-income riders, people moving goods or cargo, LBGTQ2S+, and immigrant cyclists) to better understand how different users may be experiencing comfort and safety on cycle routes in Vancouver.

Panel Survey

1. Based on the design and programming needs of the diverse cyclists addressed in this report, it is clear that there is a need for greater qualitative data collection in order for the city to ascertain and address the safety concerns of these cyclists. Therefore it is recommended that future panel surveys incorporate questions that can retrieve qualitative data on the safety and comfortability of cyclists. The existing question on safety/personal security for example could be expanded to ask cyclists why they felt afraid for their security if they chose that option with options such as lighting, physical threat, lack of sense of belonging etc. Additional questions include:

- What makes a cycling route safe or comfortable for you?
- What makes a cycling route unsafe or uncomfortable for you?
- How has your experience with lighting on cycling routes been? (safe/unsafe)
- What has made this experience safe/ unsafe?

Policy

1. Riding a cycle can be significantly easier than walking or traversing by wheelchair for disabled cyclists. However, cycles have not been legally recognized as mobility aids and a as a result many disabled cyclists have been asked to dismount when they are unable to do so. It is recommended that awareness be brought to the fact that for many disabled cyclists, cycles are a mobility aid and that this legal recognition be achieved.

2. Research from the US has revealed that helmet laws can often result in police disproportionately targeting low-income and BIPOC cyclists. It is recommended that further research be conducted on this in the Canadian context.

Conclusion

Lighting and intersectionality on cycle routes impact the way in which people perceive safety and comfort. It is difficult to address these components because we all experience safety and comfort differently and safety and comfort have many facets to them. Nonetheless it is necessary to consider lighting design strategies to ensure visibility in addition to design practices and inclusive planning which can be a step towards Vancouver as a AAA city.

APPENDIX

1. Luminance criteria for streets/on-street cycle routes as provided in Vancouver's *Engineering Design Manual*. Note that 1 lux is the equivalent to 1 cd/m^2.

Pedestrian activity	Average luminance (cd/m^2)	Average-to-minimum uniformity ratio	Maximum-to-minimum uniformity ratio	Maximum-to-average veiling luminance ratio
Arterial				
High	≥1.2	≤3.0	≤5.0	≤0.3
Medium	≥0.9	≤3.0	≤5.0	≤0.3
Low	≥0.6	≤3.5	≤6.0	≤0.3
Collector				
High	≥0.8	≤3.0	≤5.0	≤0.4
Medium	≥0.6	≤3.5	≤6.0	≤0.4
Low	≥0.4	≤4.0	≤8.0	≤0.4
Local				
High	≥0.6	≤6.0	≤10.0	≤0.4
Medium	≥0.5	≤6.0	≤10.0	≤0.4
Low	≥0.3	≤6.0	≤10.0	≤0.4

2. Queensland's criteria for prioritization of cycle route lighting projects. Safety, security, usage, and proximity to existing lighting facilities are used as criteria. Each lighting potential lighting project is scored from a range between 1 and 5 where 1 is a low priority project while 5 is the highest priority project. These tables have been taken from Queensland's *Road Planning and Design Manual - Volume 6: Lighting*.

A) Safety

Score	Description
1	No reported safety (crash) incidents in the last five years; complies with current Australian Standards; contains no safety hazards
2	One reported safety (crash) incident in the last five years; contains some safety hazards
3	Two to three reported safety (crash) incidents in the last five years; contains a few safety hazards
4	Three to five reported safety (crash) incidents in the last five years; contains several safety hazards
5	Five or more reported safety (crash) incidents in the last five years; does not comply with current Australian Standards and contains numerous safety hazards

B) Security

Score	Description
1	Best practice design and meets CPTED principles (the whole bikeway can be seen from nearby land uses or roads); frequent contact opportunities with other users; no reported security incidents over the last five years
2	Good casual surveillance (about 70% of the bikeway can be seen from nearby land uses or roads); regular contact opportunities with other users; one reported security incident over the last five years
3	Moderate casual surveillance (about 50% of the bikeway can be seen from nearby land uses or roads); some contact opportunities with other users; two reported security incidents over the last five years
4	Some casual surveillance (about 30% of the bikeway can be seen from nearby land uses or roads); limited contact opportunities with other users; three reported security incidents over the last five years
5	Isolated, poor casual surveillance (none of the bikeway can be seen from nearby land uses or roads); very limited contact opportunities with other users; four reported security incidents over the last five years

C) Usage

Score	Description
1	Very low average daily usage (<60 per day) and little latent demand (more than 5 km from a major attractor or generator of cycling); no obvious pedestrian use
2	Low average daily usage (60–100 / day), minor latent demand (more than 4 km from a major attractor or generator of cycling); no obvious pedestrian use
3	Medium daily cycling demand (100–150 / day), some latent demand (within 4 km of a major attractor or generator of cycling); some obvious pedestrian use
4	High daily cycling demand (150–200 / day), reasonable latent demand (within 3 km of at least two major attractors or generators of cycling); regular use by pedestrians
5	Very high daily cycling demand (>200 / day), high latent demand (within 2 km of at least four major attractors or generators of cycling); regular use by pedestrians.

D) Proximity to existing lighting facilities

Score	Description
1	>80% of the pathway is already lit (but less than P3 level) from existing lighting around the pathway
2	60–80% of the pathway is already lit (but less than P3 level) from existing lighting around the pathway
3	40–60% of the pathway is already lit (but less than P3 level) from existing lighting around the pathway
4	20–40% of the pathway is already lit (but less than P3 level) from existing lighting around the pathway
5	<20% of the pathway is lit as there is no existing lighting around the pathway

3. London's Cycling Level of Service Assessment Matrix. Each indicator has a set of descriptions and score values - either 0, 1, or 2. A score of 0 for an indicator may signal a need for improvement but this is dependent on the weight of the indicator and the context of the route. Note that the highlight indicators are considered critical and it is recommended that their scores be multiplied by 3.

Factor	Indicator	Critical*	Basic CLoS (score=0)	Good CLoS (score=1)	Highest CLoS (score=2)	Score
Safety						(48)
Collision risk	Left/right hook at junctions	Heavy streams of turning traffic cut across main cycling stream	Side road junctions frequent and/or unmarked. Conflicting movements at major junctions not separated	Fewer side road junctions. Use of entry treatments. Conflicting movements on cycle routes are separated at major junctions	Side roads closed or footway is continuous. All conflicting streams separated at major junctions	
	Collision alongside or from behind	Nearside lane in range 3.7m to 4.0m	Cyclists in wide (4m+) nearside traffic lanes or cycle lanes less than 2m wide	Cyclists in dedicated cycle lanes at least 2m wide	Cyclists separated from motorised traffic	
	Kerbside activity or risk of collision with door	Cycle lanes < 1.5m alongside parking / loading with no buffer	Frequent kerbside activity / effective width for cyclists of 1.5m	Less frequent kerbside activity / effective width for cyclists of 2 m	No kerbside activity / No interaction with vehicles parking or loading	
	Other vehicle fails to give way or disobeys signals		Poor visibility, no route continuity across junctions and unclear priority	Clear route continuity through junctions, good visibility, priority clear for all users, visual priority for cyclists across side roads	Cycle priority at signalised junctions; visual priority for cyclists across side roads	
Feeling of safety	Separation from heavy traffic		Cyclists in general traffic lanes or cycle lanes less than 2m	Cycle lanes at least 2m wide	Cyclists physically separated from other traffic at junctions and on links, or no heavy freight	
	Speed of traffic (where cyclists are not separated)	85th percentile greater than 30mph	85th percentile greater than 25mph	85th percentile 20-25mph	85th percentile less than 20mph	
	Total volume of traffic (where cyclists are not separated)	>1,000 vehicles/ hour at peak	500 - 1,000 vehicles / hour at peak (but becomes 'critical' if 5 per cent or more are HGVs)	200 - 500 vehicles / hour at peak (but becomes 'basic' if 2 per cent or more are HGVs)	<200 vehicles / hour at peak	
	Interaction with HGVs	Frequent, close interaction	Frequent interaction	Occasional interaction	No interaction	

APPENDIX

Factor	Indicator	Critical*	Basic CLoS (score=0)	Good CLoS (score=1)	Highest CLoS (score=2)	Score
Social safety	Risk/fear of crime		High risk: 'ambush spots', loitering, poor maintenance	Low risk: area is open, well designed and maintained	No fear of crime: high quality streetscene and pleasant interaction	
	Lighting		Long stretches of darkness	Short stretches of darkness	Route lit thoroughly	
	Isolation		Route passes far from other activity, for most of the day	Route close to activity, for all of the day	Route always overlooked	
	Impact of highway design on behaviour		Layout encourages aggressive behaviour	Layout controls behaviour throughout	Layout encourages civilised behaviour: negotiation and forgiveness	
Directness						(8)
Journey time	Ability to maintain own speed on links		Cyclists travel at speed of slowest vehicle ahead (including other cyclists)	Cyclists can usually pass other vehicles (including cyclists)	Cyclists can always pass other vehicles	
	Delay to cyclists at junctions		Journey time longer than motor vehicles	Journey time around the same as motor vehicles	Journey time less than motor vehicles	
Value of time	For cyclists compared to private car use (normal weather conditions)		VOT greater than private car use value due to some site-specific factors	VOT equivalent to private car use value: similar delay-inducing factors and convenience	VOT less than private car use value due to attractive nature of route	
Direct-ness	Deviation of route (against straight line or nearest main road alternative)		Deviation factor greater than 40 per cent	Deviation factor 20-40 per cent	Deviation factor less than 20 per cent	

Factor	Indicator	Critical*	Basic CLoS (score=0)	Good CLoS (score=1)	Highest CLoS (score=2)	Score
Coherence						(5)
Connec-tions	Ability to join/leave route safely and easily		Cyclists cannot connect to other routes without dismounting	Cyclists share connections with motor traffic	Cyclists have dedicated connections to other routes	
	Density of other routes		Network density mesh width >400m	Network density mesh width 250-400m	Network density mesh width <250m	
Way-finding	Signing		Basic direction signing (cyclists follow road signs and markings)	Some cycle-specific direction signing	Consistent signing of range of routes and destinations at decision points	
Comfort						(20)
Surface quality	Defects: non cycle friendly ironworks, raised/ sunken covers/gullies	Major defects	Many minor defects	Few minor defects	Smooth, high-grip surface	
Surface material	Construction		Hand-laid asphalt or unstable blocks/sets	Machine laid asphalt concrete or HRA; smooth blocks	Machine laid asphalt concrete; smooth and firm blocks undisturbed by turning vehicles	
Effective width without conflict	Clear nearside space in secondary position or motor vehicle speed/ volume in primary position	Secondary: <1.5m Primary: high motor vehicle flow	Secondary: 1.5m Primary: medium motor vehicle flow	Secondary: 1.5-2.0m Primary: low motor vehicle flow	Secondary: >2.0m Primary: no overtaking by motor vehicles	
Gradient	Uphill gradient over 100m		>5 per cent	3-5 per cent	<3 per cent	
Deflect-ions	Pinch points caused by horizontal deflections		'Remaining' lane width <3.2m	(Remaining) lane width >4.0m or <3.0m (low motor vehicle flow)	Traffic is calmed so no need for horizontal deflections	
Undu-lations	Vertical deflections		Round top humps	Sinusoidal humps	No vertical deflections	

Factor	Indicator	Critical*	Basic CLoS *(score=0)*	Good CLoS *(score=1)*	Highest CLoS *(score=2)*	Score
Attractiveness						(12)
Impact on walking	Pedestrian Comfort Level (PCL)		Reduction in PCL to C, D or E	No impact on pedestrian provision or PCL never lower than B	Pedestrian provision enhanced by cycling provision or PCL A	
Greening	Green infrastructure or sustainable materials incorporated into design		No greening element	Some greening elements	Full integration of greening elements	
Air quality	PM10 & NOX values referenced from concentration maps		Medium to High	Low to Medium	Low	
Noise pollution	Noise level from recommended riding range		>78DB	65-78DB	<65DB	
Minimise street clutter	Signing required to support scheme layout		Large amounts of regulatory signing to conform with complex layout	Moderate amount of signing, particularly around junctions	Minimal signing, eg for wayfinding purposes only	
Secure cycle parking	Ease of access to secure cycle parking on- and off-street		No additional secure cycle parking	Minimum levels of cycle parking provided (ie to London Plan standards)	Cycle parking is provided to meet future demand and is of good quality and securely located	

Factor	Indicator	Critical*	Basic CLoS *(score=0)*	Good CLoS *(score=1)*	Highest CLoS *(score=2)*	Score
Adaptability						(6)
Public transport inte-gration	Smooth transition between modes or route continuity maintained through interchanges		No consideration for cyclists within interchange area	Cycle route continuity maintained through interchange and some cycle parking available	Cycle route continuity maintained and secure cycle parking provided. Transport of cycles available.	
Flexibility	Facility can be expanded or layouts adopted within area constraints		No adjustments are possible within constraints. Road works may require some closure	Links can be adjusted to meet demand but junctions are constrained by vehicle capacity limitations. Road works will not require closure; cycling will be maintained although route quality may be compromised to some extent	Layout can be adapted freely without constrain to meet demand or collision risk. Adjustments can be made to maintain full route quality when roadworks are present	
Growth enabled	Route matches predicted usage and has exceedence built into the design		Provision does not match current levels of demand	Provision is matched to predicted demand flows	Provision has spare capacity for large increases in predicted cycle use	
TOTAL (max 100)						(100)

**For highlighted critical indicators, score is multiplied by 3 (basic = 0, good = 3, highest = 6)*

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