Bus Stop Urban Design

by

Kevin Jingyi Zhang

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www.kjzhang.com
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Abstract

Bus Stop Urban Design (BSUD) seeks to improve the waiting environment at bus stops through urban design techniques. Because bus stops are embedded into the neighbourhood, improvements will not only benefit the riders, but also the immediate urban realm. A more comfortable waiting environment leads to greater rider satisfaction and shorter perceived wait times, leading to higher ridership. A well designed public space may lead to greater walkability in the area and a safer environment that is more conducive towards active transportation for local residents.

The project identifies 7 major goals in designing a good bus stop: safety, thermal comfort, acoustic comfort, wind protection, visual comfort, accessibility, and integration. The goals are achieved by 9 techniques: lighting, seating and surfaces, cover, amenities, information, vegetation, traffic management, pedestrian infrastructure and bicycle infrastructure. These 9 techniques are then applied to 9 bus stops in Metro Vancouver, ranging from major exchanges to remote stops. Beyond testing the identified goals and techniques in existing settings, the design section also demonstrates that with appropriate urban design expertise, municipalities can quickly develop and visualize public space designs with low costs and widely available technology.
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photo: Andrea Maccioni
Figure 1.1.1: Space occupied by 28 single occupancy drivers
Source: Complete Streets for Canada

Space occupied by 28 cyclists

Space occupied by 28 bus riders
1.1 Project Summary

Bus Stop Urban Design (BSUD) aims to improve the waiting environment of bus stops and their adjacent neighbourhoods through the development and application of 9 design techniques. Topics of focus include station amenities, non-vehicular access, and neighbourhood integration. It is hoped that better walking and waiting environments will lead to higher active transportation and transit mode shares, thereby reducing transportation related greenhouse gases and improving overall health.

This project contains five sections. First, the author reviews current literature on issues relating to urban design, transit, and commuter behaviour. Second, the research results give rise to a set of 7 goals for urban design around bus stops. Third, the author identifies 9 design techniques for achieving the goals. Fourth, the author demonstrates each of the 9 techniques at a bus stop in Metro Vancouver. Fifth, the author makes recommendations for further actions and research.

1.2 Background and Rationale

According to UN reports, the urban population now amounts to 50 percent of total global population and will rise to about 75 percent by 2030 (United Nations, 2007). This poses dramatic transportation challenges for the major cities of the world. In British Columbia, half of household carbon emissions and one third of overall carbon emissions result from transportation, which consists largely of private automobile use (BC Ministry of Environment, 2008). Therefore, reducing car use can play a pivotal role in transitioning into a low carbon emissions economy. However, at the same time, we must improve transit service to ensure that mobility is not limited when car use decreases.
1.3 Focus on Design

Regional transit ridership is affected by a variety of factors such as regional geography, metropolitan economy, population characteristics, and the built environment (Taylor, Miller, Iseki, & Fink, 2009). Further, the effect of the built environment on ridership is often broken down into 5 D’s: density of development, diversity of land uses, design of the environment, destination accessibility, and distance to transit (Ewing & Cervero, 2010). The third factor, design of the environment, is the focus of this report. Studies show strong connections between the urban realm and mode choice. A recent study commissioned by TransLink showed that 45% of residents along Main Street in Vancouver are more likely to choose transit after improvements to sidewalks and bus shelters were made in 2005 (NRG Research Group, 2010). Because riders expend a great deal of the time, energy and patience outside of buses while waiting or transferring (Taylor, Iseki, Miller, & Smart, 2007), enhanced passenger amenities are greatly valued by passengers (Jenks, 1998). Alternatively, lack of adequate design leads to commuters feeling undervalued and thereby view the waiting experience as an impediment to choosing transit (Hess, 2012; Wardman, 2001).

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<tr>
<th>Overall Goal</th>
<th>Contributing Factors</th>
<th>Components</th>
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<td>Increase Transit Ridership</td>
<td>Metropolitan Economy</td>
<td>Density of Development</td>
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<td>Built Environment</td>
<td>Diversity of Land Uses</td>
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<td>Distance to Transit</td>
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Figure 1.3.1: Project Context
1.4 Trends

In most North American cities, transit mode share declined dramatically after the 1930’s and have remained low since the 1970’s (Taylor et al., 2009). Part of this phenomenon is caused by the domination of automobile oriented design of cities after World War II (Lillebye, 1996). Such principles made cities easy for driving, but hard for walking and cycling, which are the primary feeder modes for transit. As a result, many feel that the walk to and the wait at bus stops have become too physically and emotionally demanding compared to travelling in a private car (Wardman, Hine, & Stradling, 2001).

However, as the recognition of the environmental impacts of transportation related GHGs have grown in recent years, many cities have initiated traffic calming and pedestrian network enhancement programs to restore the walking environment and make taking transit easier (Ewing, 2008). Although the effects of these actions are slow to be seen, most cities understand that such incremental transformations build off one another, have long term benefits, and are worth investing in (Van Dyck, Deforche, Cardon, & De Bourdeaudhuij, 2009). This report aims to contribute to this transformation.

Figure 1.4.1: Annual Unlinked Transit Trips per Capita in the United States
Source: American Public Transportation Association Historical Ridership Report
2.0 LITERATURE REVIEW
2.1 Urban Realm and Transit Ridership

2.1.1 Proximity to Transit

There are many urban realm factors that affect bus ridership; many of which relate to the trip that connects one's home to the bus stop, which is often by walking or cycling. Studies have shown that greatest predictor of transit use is proximity (Cervero, 2002; Gutiérrez & García-Palomares, 2008). The closer one lives to a transit stop, the more likely one will take transit (Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 2005). The typical catchment for a bus stop is contained within a 400 metre radius around the stop and can be larger for faster forms of transit (Gutiérrez, Cardozo, & García-Palomares, 2011).

2.1.2 Physical Environment Quality

More recent studies show that this catchment area is not static. The quality of the walking and cycling environment around the stop can greatly affect how far people are willing to travel to reach the bus stop (Taylor & Fink, 2011). These findings make intuitive sense because significant portions of transit trips, unlike private automobile trips, are spent outside of the vehicle. As a result, walkable environments can encourage walking to transit (Martens, 2004), where as inadequate outdoor environments can be a barrier to riding transit (Hess, 2012). Walkable environments are often identified as areas that have more pedestrian traffic, environmental and social safety, pleasing aesthetics, natural features, pedestrian amenities, and land use diversity (Brown, Werner, Amburgey, & Szalay, 2007). Less walk able environments are often the result of auto-centric planning, using vehicular roads as the organizing structure of a city (Lillebye, 1996). This effect of the physical environment on people's decisions to take transit varies on an individual basis. While improvements in station surroundings have little effect on dependent riders, they are an effective way of attracting infrequent or choice riders (Reconnecting America, 2011). Therefore, providing high-quality and comfortable service is key in improving the public image of transit and increasing customer satisfaction (Jenks, 1998).
2.2 Urban Realm and Active Transportation

2.2.1 General Effect

Active transportation refers to human-powered forms of travel, such as walking, cycling, skating, and manual wheelchairs (Litman, 2003). Because most transit trips start and end with walking trips, it is important to determine how active transportation is affected by the physical environment. In general, living in a highly walkable neighbourhood is associated with more walking for transportation purposes (Van Dyck et al., 2009). More specifically, traffic calming measures increase the proportion of walking trips (Susilo, Williams, Lindsay, & Dair, 2012). In addition, studies show that walkable environments can also induce casual walking among local residents (Cao, Mokhtarian, & Handy, 2009; Hoehner et al., 2005).

2.2.2 Demographic Differences

Improvements to pedestrian and cycling networks such as new routes and lighting improvements to existing paths around a transit stop can have positive effects for the entire neighbourhood. However, the magnitude of the effect varies with different segments of the population. Urban realm improvements encourage more children to walk and bike to school, if parents also have high levels of perceived safety (Gallimore, Brown, & Werner, 2011). Increased accessibility of the outdoors mean that older adults who previously found the urban environment to be a barrier are also more likely to enjoy public spaces (Hess, 2012). Women are also found to be more sensitive to the physical environment when choosing travel modes as compared to men (Humpel, Owen, Iverson, Leslie, & Bauman, 2004). Research also shows that those with less positive attitudes towards walking and cycling are more affected by such enhancements (Van Dyck et al., 2009).

2.3 Physical Activity and Health

Several studies provide evidence that as a person engages in more low to moderate physical activity on a daily basis, the associated health benefits become larger (Morris, Clayton, Everitt, Semmence, & Burgess, 1990; Paffenbarger, Hyde, Wing, & Hsieh, 1986; Sandvik et al., 1993). Walking or biking to bus stops can easily fulfill this requirement due to the trips’ short duration, regularity, and moderate level of effort (Hoehner
et al., 2005). In fact, brisk walking alone has been identified as protective of physical health, independent of the benefits of more vigorous activity (Saelens, Sallis, & Frank, 2003). Although the level of exertion may be minor, the health impacts are significant. Studies observe the most major increases in physical and mental health occur between individuals that do not exercise and those that engage in some physical activity for 16-48 minutes (Leon, Connett, Jacobs, & Rauramaa, 1987). The marginal benefit of daily exercise beyond 48 minutes decreases (Leon et al., 1987). However, if combined with other intense forms of exercise on a weekly basis, active transportation can significantly improve overall health of an individual (Rodriguez, Khattak, & Evenson, 2006). These health benefits have been quantified to a savings of $400 to $4000 in medical costs per person (Boarnet, Greenwald, & McMillan, 2008).

## 2.4 Commuter’s Value of Time

For urban realm improvements to be successful, one must understand the transit user market (Buys & Miller, 2011). One of these factors is the rider’s valuation of time. A commuter’s value of travel time is a combination of the opportunity cost of the entire time spent travelling and the cumulative disutility of walking, waiting, and travelling (Wardman, 2004). The disutility of walking stems mostly from the physical effort required and any negative perceptions of the route (Wardman, 2004). The disutility of waiting results from the uncertainty of arrival times and the inability to use the waiting time productively. While the amount of disutility of transit times vary from person to person (Taylor et al., 2009), a review of past studies suggests that most riders value out-of-vehicle travel time at 2 to 3 times the value of in-vehicle travel time (Daly & Zachary, 1975; Davies & Rogers, 1973). This factor is found to be higher for women (+26%) when compared to men, and for people over the age of 50 (+23%) (Wardman, 2001). However, new research shows that with the steady improvement of bus stop design such as having real-time information displays and wireless internet connectivity, and with advancement in mobile technology such as smart phones and laptops, waiting time is only valued at 1.6 times more than riding time (Wardman, 2004).
2.5 Hierarchy of Elements

Often times, there is limited funding for public realm improvement projects. Therefore, it is important to identify which elements to focus on first. The performance of a public good should not be separated from its costs (Fukahori & Kubota, 2003). A survey of transit user preferences in Los Angeles found that commuters required the stations to be, in order of importance: easy to get around, feel safe during day, easy to find, well lit at night, clean, sheltered, have places to sit, and have food and washrooms nearby (Taylor et al., 2007). A more recent survey of transit riders in Ottawa found that factors that influence ridership are, in order of importance: bus information, on-street service, station safety, customer service, safety en-route, reduced fare, cleanliness, and general attitudes towards transit (Taylor & Fink, 2011). One can see that accessibility and safety top both lists. Another study from Japan looked the relationship between the pedestrian-perceived value gained of an improvement and the cost of installation (Fukahori & Kubota, 2003). The researchers found that paving, lighting, and vegetation had the most perceived benefit per dollar over their life spans.

2.6 Urban Space Design Concepts

2.6.1 Placemaking

Placemaking is a design and planning concept that capitalizes on the local community’s assets, inspiration, and potential, ultimately creating good public spaces that promote people’s health, happiness, and well being (Project for Public Spaces, 2012). Placemaking stresses the value of what already exists in the neighbourhood, ranging from shops and services to community expertise. This strategy for designing urban spaces is strongly influenced by residents (J. Jacobs, 1961). Results of such planning are usually more functional, contextual and inclusive (Project for Public Spaces, 2012). Some physical attributes of spaces that characterize successful places include short blocks, human scaled amenities, and clever uses of vegetation (A. B. Jacobs, 1995; Whyte, 1980). These spaces tend to generate a greater sense of ownership among the community rather than top-down designs implemented without consultation.
2.6.2 Shared Space

Shared space is a design concept for public spaces that promotes removing the separation between modes of transport in order to create more pedestrian friendly environments (Hamilton-Baillie & Jones, 2005). The idea of removing ground markings for traffic, which are painted in the name of safety, seem counter intuitive at first, but the result is more eye contact, slower speeds and heightened awareness. However, implementation of shared spaces in a region that has never had such urban features may be a challenge. The success of such shared space zones is extremely dependent on people's familiarity with these areas (Kaparias, Bell, Miri, Chan, & Mount, 2012). Since the safety of pedestrians in such zones is reliant on drivers' heightened awareness, it is important that adequate driver education exists before shared space is implemented. The study also shows that the more familiar people are with shared spaces, the more likely they will be in favour of such features in their city. Therefore, the first shared spaces will require considerable work from all parties involved. If there is initial success, subsequent shared spaces may come much easier.

2.6.3 Style

Because public spaces such as bus stops affect the daily lives of many, the styles of these elements are important (Lillebye, 1996). From survey results, it is shown that most people prefer public spaces that are backdrop-like, that blend in with the surroundings and do not seek attention (Gjerde, 2011). The general public likes patterns of conformity and order more than design professionals (Gjerde, 2011). These preferences speak to the desire of people for a more integrated travel experience that benefits from the latest advances in design but also has a relatively conservative look that maintains its attractiveness over time (Fung, 2012; Thomsen, 2011). In addition, it is important to not be carried away by over urbanizing spaces, for there are many factors of lower density developments, such as long views, that are conducive towards active transportation (Susilo et al., 2012). Other principles such as Crime Prevention Trough Environmental Design (CPTED) are also popular in the field of public space design (Alliance Against Crime, 2011; Saraiva & Pinho, 2011), and will be discussed later in the report.
2.7 Public Project Implementation

2.7.1 Collaboration

While there is usually support for public space improvement projects as they are often on city owned land (Giddings, Charlton, & Horne, 2011) and for environmentally sustainable agendas (Susilo et al., 2012), there are still major road blocks. Common difficulties of public space projects include issues of public versus private realm, constrained roadway widths, aligning multiple funding sources and stakeholders, and coordination of utilities, streetscaping and infrastructure (Reconnecting America, 2011). Various design elements may become points of contention. Therefore, it is recommended that the public be involved at all stages of the process (Borst, Miedema, de Vries, Graham, & van Dongen, 2008; J. Jacobs, 1961). Due diligence in this aspect will ensure there is adequate support for the project and that the final design reflects the needs of the neighbourhood and commuters alike (Chrisomallidou, Chrisomallidis, & Theodosiou, 2004). Great designs are often the result of planners, architects, and engineers coming together to realize an integrative urban vision (Kashef, 2008). Other non-design parties that are significant to the process include area businesses, local employers, development professionals, local associations and law enforcement personnel (Reconnecting America, 2011).

2.7.2 Financing

Financing is another important issue in the implementation of bus stop improvements. While cost can vary widely depending on design, studies have found that substantial cost savings can be achieved if stops are efficiently designed (Hamilton-Baillie & Jones, 2005). The use of modular structures and passive heating are techniques that can save capital and operational costs (see 5.12). If bus stop enhancements can generate significant pedestrian traffic and are well integrated with adjacent businesses, area business associations may be willing to contribute financially (Zacharias, Zhang, & Nakajima, 2011). In addition, surveys show that if citizens perceive significant amenity improvements arising from public projects, they are more likely to approve the required public spending (Fukahori & Kubota, 2003). Therefore, it is important to employ creative and reliable methods to communicate the benefits of such projects to the general public (Jenks, 1998). Also, it is demonstrated in multiple cities that adjusting parking prices is an efficient way of generating revenue to finance urban realm improvements (Dueker, Strathman, & Bianco, 1998). Finally, because urban realm projects usually add to the desirability of an area and increase surrounding land values, amenities contributions can be negotiated with developers to finance bus stop improvements (Garmendia, de Urena, Ribalaygua, Leal, & Coronado, 2008).
3.0 BUS STOP URBAN DESIGN
GOALS
The Bus Stop Urban Design Goals is a set of principles that should guide decisions when designing bus stops. Each goal is supplemented with research and visual examples. The 7 goals are: safety, thermal comfort, acoustic comfort, wind protection, visual comfort, accessibility, and integration.
Safety
CPTED measures and accessible design reduce the risk for crime and accidents. Natural surveillance through design is preferred.

Wind Protection
Wind can have both mechanical and thermal impacts on the bus rider. Wind should be carefully mitigated as its cooling effects may be desired.

Visual Comfort
Sufficient lighting should be provided for safety and to conduct productive activities at a bus stop. Excessive light such as glare should be minimized.

Integration
Being nodes within neighbourhoods, bus stops should cater to the needs of their surroundings and reflect the identity of the community.

Thermal Comfort
Thermal condition is the most important factor determining comfort. Passive and active controls can be used to maintain a desired temperature range.

Accessibility
The bus stop should be easily accessible by all segments of the population, of all physical abilities, and through all travel modes.

Acoustic Comfort
Traffic noise negatively affects both riders and adjacent residents. Elements should be arranged to best shield or absorb noise.
3.1 Safety

In a survey of bus riders and confirmed by many other studies, safety is consistently ranked as one of the highest priorities at a bus stop (Taylor et al., 2007). It is understandable that personal safety is the basis upon which all other improvements can be made. Without an adequate level of perceived safety, commuters will simply choose not to use the bus stop (Nabors et al., 2007). Issues of safety may result from criminal activity or physical hazards, such as high vehicular traffic or slippery surfaces. It is important to note the differences between perceived risk and actual risk, which may be correlated or inversely correlated depending on the type of risk (Cho, Rodríguez, & Khattak, 2009).

3.1.1 Risk of Accident

Risk of accidents at a bus stop is usually associated with pedestrians being in close proximity to heavy or fast vehicular traffic (Tan, Wang, Lu, & Bian, 2007). To ensure the safety of commuters, adequate pedestrian protection must be provided. Strategies that have proven effective are more traffic lights, crosswalks and barriers between modes of travel (Rodríguez, Brisson, & Estupiñán, 2009). Traffic calming techniques that slow down vehicles are also beneficial. However, most traffic calming programs in North America have not fundamentally shifted their emphasis towards the needs of pedestrians, bicyclists, and the town environment (Ewing, 2008). One particular take on traffic calming is the concept of shared space, in which separations (curbs, lines) between travel modes are removed, encouraging eye contact between all users (Hamilton-Baillie & Jones, 2005). Studies show these areas have lower accident rates because when there is higher perceived danger, people will act more carefully, resulting in a safer environment (Kaparias et al., 2012). This strategy is worth investigating, especially for locations with multiple bus stops and high density residential.

3.1.2 Risk of Crime

Crime in public spaces occur mostly because there exist windows of opportunity (Saraiva & Pinho, 2011). Therefore, reducing these opportunities is the preferred method for reducing risk for crime around bus stops. While increased surveillance by transit police and cameras are options, they may cause excessive target hardening and lead to a fortress mentality (Saraiva & Pinho, 2011). Many have pointed out that measures to keep out “undesirables” cause more detriment to a public
space than the original problem (J. Jacobs, 1961). Crime prevention through environmental design (CPTED) is a popular school of thought that focuses on natural surveillance (Susilo et al., 2012). Natural surveillance refers to creating a safer environment through means that also make the space more welcoming. Strategies for bus stops include making the space easily observable from the surrounding, avoiding hiding spaces, ensuring sufficient lighting at all times, and maintaining station upkeep (Nikolopoulou, Kleissl, Linden, & Lykoudis, 2011; Saraiva & Pinho, 2011).

### 3.1.3 Individual Perceptions

Individuals will evaluate the risk of an area based on their own attributes such as age, gender, and familiarity with the area. Studies show that commuters who are older, female, or new to the area have lower thresholds for what is considered a safe environment (Leslie et al., 2005). Residents of a bus stop’s catchment area and those who walk around the bus stop area for exercise have lower levels of perceived risk of traffic accidents and crime (Humpel et al., 2004; Owen, Humpel, Leslie, Bauman, & Sallis, 2004). Such findings are beneficial in refining the amount of CPTED measures required to ensure a safe environment for commuters.

### 3.2 Thermal Comfort

Surveys of bus stop users show that overall comfort is determined primarily by the thermal environment (Nikolopoulou et al., 2011). In areas of extreme heat or extreme cold, it is important that the designer develop a level of “radiant” sensitivity (Scudo, Dessi, & Rogora, 2004). At the bus stop level, the microclimate is determined both by regional factors such as solar gains, local factors like the urban heat island effect, and site factors like surface temperatures (Kleerekoper, van Esch, & Salcedo, 2011; Scudo et al., 2004). As a result, it is important to consider the ventilation of the site, albedo of materials used as they affect the overall thermal environment (Asaeda & Thanh, 1996).

Ambient temperature is found to be one of the strongest factors for both men and women choosing to walk when other modes are available (Owen et al., 2004). A temperature of 24 degrees Celsius is most desired by those waiting outdoors (Chun & Tamura, 2005). While 24 degrees is ideal, people are found to be more accepting of variations in outdoor environments. In general, comfort range for commuters is +/- 3
degrees Celsius in the winter, and +/- 10 degrees Celsius during other seasons (bin Saleh & Pitts, 2004). Another major factor in determining the comfort level of a stop is past experience. People's perceptions of what is comfortable is often set by their past experience in that location (Chun & Tamura, 2005). Even when thermal conditions are not ideal, people will engage in adaptive behaviours up to a certain point, such as drinking cool fluids or adjusting clothing (Katzschner, Bosch, & Roettgen, 2004). While thermal comfort is of primary concern at a bus stop, there is no need for narrow range HVAC systems in most circumstances due to these adaptive behaviours (Chun & Tamura, 2005).

### 3.3 Acoustic Comfort

While important to the overall comfort of the commuter, the acoustic environment is often least discussed (Kang, Yang, & Zhang, 2004). Sound in urban spaces can be categorized into keynotes and sound marks, more commonly referred to as background and foreground sounds respectively (Schafer, 1976). Background sounds can consist of traffic and other urban noises, while foreground sounds usually relay information, such as crosswalk rings and announcements. In public spaces, people will be accepting of noise levels between 40-70 dB, up to a maximum of 73 dB (Giddings et al., 2011; Yang & Kang, 2005). As with temperature, people can tolerate variations depending on the situation. Pleasant sounds like birds songs, live music and the sound of water can create acoustic comfort even when noise levels are high (Kang et al., 2004). It is also found that acoustic comfort interacts significantly with other factors. For example, if a bus stop is particularly visually pleasing, this can equate to a 10 dB reduction in noise (Kang et al., 2004). Finally, it is important to note differences in audience. Commuters may have different cultural and personal preferences to sound and music (Yang & Kang, 2003). Also, residents who live close to bus stations are likely to have much lower tolerances for noise as they are not in an outside environment.

### 3.4 Wind Protection

The effects of wind can be divided into two main categories, mechanical and thermal (Penwarden & Wise, 1975). Wind under 5 m/s can be considered a light breeze and pleasant. Above 5 m/s, mechanical and thermal effects can both be felt. At wind speed of 10 m/s, walking becomes unpleasant (Giddings et al., 2011; Penwarden & Wise, 1975).
Wind is a difficult factor to design for as it is welcomed in some situations and unwanted in others. Wind environment is also difficult to foresee and control because it is influenced by a number of global, regional and local factors (Gaardsted Esbensen Consulting Engineers Ltd., 2004). Similar to thermal conditions, data from meteorological stations cannot adequately represent the microclimatic conditions of sites as small as a bus station (Nikolopoulou, 2004). Such locations’ wind environment is determined by its orientation to access streets, size of the urban space, height of its surrounding buildings, and objects in the area that acts as windbreaks (Gaardsted Esbensen Consulting Engineers Ltd., 2004). Therefore, the best solution is to provide a variety of spaces so that people may choose the type of environment that best suits them. Generally, it is ideal to keep both wind speed and turbulence to a minimum in public spaces.

3.5 Visual Comfort

Visual comfort can be broken down into three factors: adequate lighting for desired activities, lack of glare or other uncomfortable visual stimuli, and points of interest for the commuter to focus on. While people are highly adaptive when it comes to the amount of lighting provided, they almost always welcome more light, especially sunshine (Compagnon & Goyette-Pernot, 2004). Studies also show that most visual attention is directed towards the open part of the site or towards some type of activity. This seems to be in line with other urban design theories that state people feel most comfortable being on the edges of urban spaces, looking inward on the action (Gehl, 1987). Another important measurement is the maximum distance between users that allows for face recognition, which is 24 metres. To ensure a comfortable visual environment during the day, the sun should reach between 20-80% of the site at all times (Compagnon & Goyette-Pernot, 2004). It is also shown that visual comfort interacts widely with other factors. Most notably, visually stimulating objects and activities in a location can compensate for many unwanted attributes, such as extended wait times and high levels of noise (Kang et al., 2004). Therefore, creating a visually comfortable and interesting environment is extremely beneficial, as it can both draw people to and keep people at a public space.

Figure 3.5.1: People like waiting in areas where extreme sunlight is mitigated, reducing glare.
3.6 Accessibility

Accessibility refers to the access of the bus stop by all segments of the population and through all modes. It is found that better connections between the neighborhood and the surroundings encourage individuals to walk or cycle more (Susilo et al., 2012). Assuming basic accessibility is met, such as minimum widths needed for pedestrian comfort (Tan et al., 2007), this section discusses possible avenues of improvement of access to expand a bus stop’s area of influence (Reconnecting America, 2011). In particular, the specific needs of the elderly and families must be accommodated at station access points and loading points (TransLink, 2011). With growing popularity of active transportation, it is important to ensure that there is sufficient pedestrian and cycling network connectivity around the bus stop to serve these modes (Cole, Burke, Leslie, Donald, & Owen, 2010). Cycling infrastructure is especially important in and around suburban stops, as the distances travelled to bus stops are usually greater. As a result, commuters are more likely to cycle (2km to 5km) to transit if the option exists (Martens, 2004). Public education of the cycling network is also extremely important as commuters’ tendency to cycle is associated with perceived access to bike lanes. Unfortunately, many people are simply not aware of their existence (Larsen & El-Geneidy, 2011).

3.7 Integration

Like any urban open space, bus stops can benefit greatly by being integrated with its surroundings in multiple facets (Gjerde, 2011). With cooperation from the municipality, transit agency, and adjacent land owners, it is possible to create bus stops that not only serve commuters, but also seamlessly connects with neighbouring activities (Wardman et al., 2001; Zacharias et al., 2011). The orientation of and amenities at the stop should be compatible with the surrounding establishments, whether it’s providing extra surfaces for stops near grocery stores or appropriately sized seats for stops near elementary schools. Designers should also be aware that the use of the bus stop may vary between seasons. Therefore it is important that amenities underused by commuters can be repurposed by local users (Chrisomallidou et al., 2004).

Integration is not only for the benefit of the neighbours. Studies show that being close to shops, catering establishments, and businesses contributed to the attractiveness of a bus stop (Borst et al., 2008). In some cases, where a newer neighbourhood grows from a major
transit station, the station acts as the default “gateway” for the area (Garmendia et al., 2008). Therefore, the need for the transit node to present a positive image of the rest of the neighbourhood is even more important (Taylor et al., 2007). With guaranteed foot traffic, there exist opportunities to integrate the stop with local businesses or populate the stop with community amenities that turn the location into a convenient place of gathering for neighbours. Ideally, the station would feel like a part of the locality and embody the community’s spirit (Cole et al., 2010). Studies show that the most successful spaces are those that are defined by the buildings around it, rather than simply artifacts in space, despite however many design resources are dedicated to it (Giddings et al., 2011). Integration with the stop’s surrounding land uses means that people can easily cross the boundaries of the site and that there exists cohesion of the programming. It is this convenience that attracts higher densities of movement (Ozbil, Peponis, & Keeping, 2011). Businesses also benefit from such arrangements as guaranteed traffic from a busy bus stop provides them with great exposure (Cole et al., 2010).

Figure 3.7.1: Eugensplatz station is well integrated with the adjacent park. The stairs leading to the platform double as seating around the open space. Table tennis tables provide transit riders with entertainment while they wait.
4.0 BUS STOP URBAN DESIGN TECHNIQUES
The Bus Stop Urban Design Techniques are a set of parameters for the design of many aspects of a bus stop in hope of achieving the goals set out in the previous section. Each goal is supplemented with research and precedents. The 9 techniques address: lighting, seating, cover, amenities, information, vegetation, traffic management, pedestrian infrastructure, and bicycle infrastructure.
Lighting
Even, white light with minimal shadows provides the best environment for activities and enhances safety. Pedestrian scale lighting adds to the character of the location.

Seating and Surfaces
Adequate seating with a variety of microclimatic conditions is important for comfort and allows riders to adapt to their preferences. Special paving can denote pedestrian priority.

Cover
Cover provides primary weather protection from precipitation and excessive solar exposure. Where possible, cover may be achieved by adjacent awnings or vegetation.

Amenities
Amenities such as public art, drinking fountains, and waste bins not only improve the experience of the bus user, but they also benefit the immediate neighbourhood.

Information
Transit information provided at a stop can greatly reduce rider anxiety in waiting. Extra space may be dedicated to displaying community information if the stop is in a high traffic area.

Vegetation
Vegetation can manage the microclimate of a stop by providing shade, cover, and wind blocks. It can also be used to enhance the aesthetics of the location.

Traffic Management
Traffic management techniques focus on reducing vehicular speeds around bus stops and making biking and walking in the area safer and more pleasant.

Pedestrian Infrastructure
The pedestrian network around a stop is an extension of the transit line. Therefore, it is important to have high quality walking environments to attract new riders.

Bicycle Infrastructure
Many residents would bike to bus stops if it were more convenient. To encourage such behaviour, adequate bike paths and bike parking must be provided.
4.1 Lighting

4.1.1 Lighting and Safety

Lighting at a bus stop is important for safety, access, and character. Studies show that commuters who identified safety as their primary concern also named lighting to be the most effective solution (Hess, 2012). As most public crimes are triggered by windows of opportunity (Saraiva & Pinho, 2011), it is important to keep areas around stops adequately lit at night as well as during other times of the day. Even lighting throughout the stop, rather than spot-lighting, provides an ambient environment with lower contrast shadows. This condition is desired as commuters feel safer in areas that have visual and spatial permeability because all activity at the site can be easily observed (J. Jacobs, 1961; Saraiva & Pinho, 2011).

4.1.2 Lighting and Character

In terms of character, pedestrian scale lighting does a better job of creating a comfortable environment for the commuter and is more likely to fit with the surroundings than standard street lights. Pedestrian scale lighting refers to lights that are lower, smaller and usually more visually interesting (Hamilton-Baillie & Jones, 2005). Lower lights that are less intense and spaced closer together offer more even and comfortable lighting for pedestrians (A. B. Jacobs, 1995). A survey in Japan identified that lighting spaced at 30 metre intervals had the most pedestrian benefit to cost ratio (Fukahori & Kubota, 2003). The lights may be integrated with the bus shelter, be integrated with other pieces of furniture at the stop, or be stand-alone. Choosing lighting styles that complement the architectural style of adjacent developments can enhance the visual coherence and attractiveness of the setting (Kostic & Djokic, 2009). Such improvements can be beneficial, as studies show a correlation between a commuter’s subjective measures of a stop and their frequency of use of the stop (Carr, Dunsiger, & Marcus, 2010).

4.2 Seating and Surfaces

Seating is one of the most fundamental components of a bus stop. The amount of seating should match the average number of commuters simultaneously occupying the stop, given that it does not impede access (Tan et al., 2007). Being able to sit while waiting for the bus and being able to put down any heavy belongings significantly reduces the stress
experienced by the commuter (Buys & Miller, 2011). As a result, the disutility of waiting at the stop can be reduced, making transit a more pleasant experience (Wardman, 2004). This chain effect can ultimately lead to an increased catchment area and ridership as studies show that people are willing to walk farther to stations if they know the waiting environment is comfortable (Jiang, Zegras, & Mehndiratta, 2012).

Because materials of the urban environment play an important roles in modifying the microclimate and thermal comfort conditions, it is important to consider the albedo, reflectivity, and other thermal attributes of the seats in order to avoid unnecessary heat gain or glare (Asaeda & Thanh, 1996). However, having seating does not guarantee a successful bus stop. Many well-used stops have a variety of seating options. This diversity gives the commuter more freedom of choice and will better serve people of different physical attributes, social habits, and in different weather conditions (Schmidt, Nemeth, & Botsford, 2011). It is not required that all seating for a bus stop be provided and maintained by one entity. With cooperation between designers and developers, between commuters and neighbours, the best case scenario would be seating that is seamlessly integrated with, or created from the surrounding urban landscape. When this is the case, it beneficial to have the seating on the periphery of the site, as it is the preferred configuration by most people (Gehl, 1987). Such seats should also be able to serve non-commuters during non-rush hours and be sufficiently shielded from vehicular traffic.

4.3 Cover

Cover refers to anything that offers weather protection at a bus stop, which includes precipitation, wind, and excessive solar exposure (Nikolopoulou et al., 2011). Weather protection is a prime contributor to commuter comfort (Humpel et al., 2004). Surveys show ideal temperatures to be around 24 degrees Celsius, acceptable range for wind is between 3 and 5.5m/s, and acceptable range for noise is between 40 and 70 decibels (Chun & Tamura, 2005; Giddings et al., 2011). With clever design and the right materials, it may be possible to achieve all year comfort passively.

There are many ways of achieving weather protection at a bus stop, with sheltering being the primary component. While it is often cheaper to standardize shelters across the city, shelters should ideally be fitted to the microclimate of the site (Schmidt et al., 2011). Possible
techniques range from wrap-around designs, which offer the most protection, to open designs, which encourage natural ventilation. The albedo, reflectivity, and other thermal attributes should also be considered in order to avoid unnecessary heat gain or glare (Asaeda & Thanh, 1996). If the bus stop is located near tall buildings, it is important to have structures such as awnings or verandas that buffer the downwash (Gaardsted Esbensen Consulting Engineers Ltd., 2004). Fences can also serve as wind block in open areas. Studies show that fences with 35% to 40% opening provide the best wind buffer while maintaining visual permeability and not generating too much turbulence elsewhere (Nikolopoulou, 2004). Orientation of the shelter is also a key consideration given the solar and prevailing wind directions (Chrisomallidou et al., 2004). In all instances where insulation is desired, it is important to make sure design features do not inadvertently cause leaks. Wherever possible, the design of the stop should strive to take advantage of the physical forms adjacent to it, such as large awnings of businesses to minimize costs (Steemers, Ramos, & Sinou, 2004). The end goal is to create a diversity of microclimates at the stop so that even if the conditions are not ideal, people will have the opportunity to choose different environments or engage in adaptive behaviour (Schmidt et al., 2011).

4.4 Amenities

Amenities refer to objects at the bus stop that enhance the experience of waiting but are not absolutely necessary. Examples of amenities include waste bins, newspaper boxes, public art, and public phones (York Regional Transit, 2009). Other design-oriented amenities such as signs, lights, and canopies contribute to the sense of place in a public space (A. B. Jacobs, 1995). Aside from their intended uses, they also act as objects that attract the visual attention of the commuters, thereby reducing the boredom that may result from long wait times (Compagnon & Goyette-Pernot, 2004). When deciding on amenities, it is important to take into account adjacent land uses and programming. Well used amenities are ones that suit the needs of the neighbourhood. Stops beside daycares may include playful public art; stops beside grocery stores may include extra shelves for people to rest their goods while waiting for the bus. Because the effect of these amenities can extend to roughly 15 meters beyond the station, one should consider the possibility that non-commuters may also use these amenities (Learnihan, Van Niel, Giles-Corti, & Knuiman, 2011). Design and placement of these amenities
should not cause any obstructions, thereby lowering the level of service for pedestrians and cyclists (Tan et al., 2007). Large amenities, such as community bulletin boards not only provide relevant information, but they also provide shading, wind protection, and acoustic separation (Chrisomallidou et al., 2004; Kang et al., 2004). Therefore, it is important to consider microclimatic conditions of the site when placing amenities so as to extract maximum benefit from the investment.

4.5 Information

Information plays an important role in the performance of a bus stop. Ideally, schedule information will be presented both in real time and in static form (Wardman et al., 2001). While arrival information is best suited for digital display, transit maps are best presented in print form, especially for those without smart devices. A variety of media ensure that the information is accessible to everyone. If the bus stop becomes a natural place of gathering for the immediate neighbourhood, community information should also be incorporated into the station displays where possible. Community organizations would benefit from the assured pedestrian traffic flow to generate exposure for their messages (Zacharias et al., 2011). Other information that is less common but would be valuable are pedestrian, cycling, and green infrastructure maps for the specific neighbourhood (Kelly, Tight, Hodgson, & Page, 2010). Contextual variations such as this have been shown the increase the sense of ownership of a public space (Ercoskun & Karaaslan, 2011). For stops in less densely populated areas, it is sometimes beneficial to have way-finding signs that direct the commuter towards the stop. By labelling the remaining distance to the stop, such signage are helpful to seniors who many plan their stop choice based on the walking time required (Hess, 2012).

4.6 Vegetation

Vegetation has long been avoided at bus stops because they were seen as something that creates safety hazard, blocks sight lines and limits circulation space (Eck & McGee, 2008). However, with careful design and plant selection, vegetation and related natural features, such as flowing water, are being reintroduced to the public spaces around transit for their aesthetic and functional values (Kleerekoper et al., 2011). Studies show that vegetation can make a positive contribution to almost every comfort aspect of a bus station. Vegetation also contributes to the

Figure 4.6.1: Vegetation can function well to provide cover and denote space.
visual attractiveness of a bus stop. Using a visual preferences survey, Ewing found that almost all commuters prefer trees along the path leading to the stop over treeless paths (Ewing, 2001). Planting can also be used to define pedestrian spaces and create a sense of security and it shields pedestrians from heavy traffic, physically, visually, and acoustically. In fact, surveys show that the presence of vegetation is found to affect 65% of the population in their decisions to cross streets (Sisiopiku & Akin, 2003).

4.6.1 Microclimate

With an average albedo of 0.2 to 0.25, vegetation also mitigates the local microclimate by reducing air temperatures, shading, and providing wind protection (Dimoudi & Nikolopoulou, 2003). Studies show that trees and hedges can reduce the surrounding air temperature by 1 to 3 degrees Celsius due to reduced solar gains (-20% to -60%), reduced convective heat gain, and the addition of moisture to the air (Dimoudi & Nikolopoulou, 2003; Kleerekoper et al., 2011). Unlike fixed, solid objects, vegetation is also excellent for wind breaking as they slow down wind without creating much turbulence or greater wind speed elsewhere (Gaardsted Esbensen Consulting Engineers Ltd., 2004). Studies show that on average, vegetation can reduce wind speeds by around 20% (Dimoudi & Nikolopoulou, 2003). Placement of plants must be carefully considered because both their thermal and wind blocking effects can be felt for up to 4-5 times the height of the plant belt away from vegetation (Houlberg, 1979). Vegetation has also been proven effective in noise mitigation in public spaces as they are able to block sound waves without causing multiple reflections (Yang & Kang, 2003). It is important to note that microclimatic effect of vegetation ultimately depends on its type and growth; mature trees have foliage temperatures below ambient air temperature, while the opposite is true for young trees (Scudo et al., 2004). Deciduous trees work well in fairer climates as it provides shading in the summer and permits solar exposure in the winter; evergreens provide shading and wind breaks all year round (Chrisomallidou et al., 2004). Insufficient foliage may result in little or even opposite effects (Scudo et al., 2004).

4.6.2 Community

Because of the pedestrian exposure bus stops are guaranteed to receive, it is a great location to test and demonstrate new ecology-based systems (Ercoskun & Karaaslan, 2011). Bio-swales and green walls
are excellent candidates for such locations and serve as didactic tools while contributing to the overall function of the stop. In some cities in the Netherlands, community interaction is taken further as neighbours volunteer to take care of the vegetation (Kleerekoper et al., 2011). On a larger scale, it is important for the site vegetation to be integrated with neighbourhood green infrastructure if opportunities exist (Walmsley, 1995).

4.7 Traffic Management

There are many traffic management techniques that can be used to make the area surrounding bus stops safer for commuters. Most of these strategies focus on reducing the speed of vehicles that are in close proximity to pedestrians to around 30 kph (Hamilton-Baillie, 2004; Hamilton-Baillie & Jones, 2005; Kaparias et al., 2012). When traffic is slowed to such speeds, risk of fatal accidents is significantly lowered and pedestrians no longer feel the need to hide at the margins of the street (Gallimore et al., 2011; Rosén & Sander, 2009). Traffic calming elements such as chokers, raised crosswalks, bicycle bypasses are already popular in many major European cities (Ewing, 2008). More options are available in many engineering publications (Cho et al., 2009). Where traffic cannot be slowed down, physical separation and crossing lights greatly increase the comfort of pedestrians (Tan et al., 2007). Trees and shrubs lower than 6 meters are recommended because they not only provide visual and acoustic separation, but they also add to the attractiveness and contribute to the thermal comfort of the setting (Fukahori & Kubota, 2003).

4.8 Pedestrian Infrastructure

4.8.1 Measuring Walkability

Several indices and audits have been developed to measure the walkability of an environment. They look at elements such as the street wall, sidewalk width, amenities, and many more. Three well known publications are the Irvine-Minnesota Physical Environment Audit (Brown et al., 2007), the Scottish Walkability Assessment Tool (Millington et al., 2009), and the Illustrated Field Manual for Measuring Urban Design Qualities (Clemente, Ewing, Handy, & Brownson, 2010).
4.8.2 Enhancing Quality

Elements of a good walking environment include wide sidewalks, shaded corridors, sufficient lighting, interesting streets, land use diversity, natural features, and other pedestrians (Brown et al., 2007; Cao, Mokhtarian, & Handy, 2008; Jiang et al., 2012; Saraiva & Pinho, 2011). When pedestrian paths are in close proximity with other modes, it is important to denote their presence clearly to drivers through separation, paving materials, or other design methods (Kaparias et al., 2012). As a further measure, traffic calming techniques should be employed where pedestrian flows are high (Susilo et al., 2012). Such actions will increase the comfort and confidence of commuters. Focusing on the pedestrian path itself, studies show that pedestrian comfort increments with sidewalk width gradually (Tan et al., 2007). Well maintained walking surfaces are also a key determining factor for those with greater difficulty walking (Borst et al., 2008). Therefore, it is crucial to provide a sufficient level of service for the expected pedestrian flow (Mori & Tsukaguchi, 1987).

4.8.3 Increasing connectivity

Walking time is consistently valued at around 1.5 to 2 times higher than the time spent in vehicle. Therefore, to promote walking to bus stops, the walking path must be comfortable and perceptually short. It is shown that neighbourhoods with greater density of intersections correlates with higher walking rates (Ewing & Cervero, 2010). This is because pedestrians are given a greater range of choice of routes and have more direct paths to their destinations. Therefore, strategies for increasing connectivity of the pedestrian network include placing cross walks to break up long blocks, connecting sidewalks with the local trails, and formalizing shortcuts so that the shortest route can also be comfortable and safe (Learnihan et al., 2011).

4.9 Bicycle Infrastructure

4.9.1 Station Level Accommodations

Cycling is substantially faster than walking and more flexible than driving in regard to travelling to a bus stop (Martens, 2004). Many transit agencies around the world have already implemented bike parking in various forms, ranging from individual bike racks to purpose-built bike storage buildings. A survey of bicycle parking programs in North America showed that most transit agencies have experienced dramatic increases in the use of bike parking, ranging from increase of 50% to 80% from
2000 to 2005 (Transportation Research Board, 2005). We can see that the demand for such facilities is increasing steadily.

Bicycle parking should be provided to match the minimum expected ridership. Ideally, the design of the parking system would be able to accommodate expansions in the future. When possible, it is beneficial to include other professionals such as industrial designers, artists and engineers to ensure that parking facilities not only function well but also adds to the visual intrigue of the environment (Kashef, 2008). Bicycle parking can also be integrated with and used as a traffic calming feature (Ewing, 2008). With multiple modes accessing the bus stop, it is important that bicycle traffic and parking are compatible with pedestrian flow and other amenities (Transportation Research Board, 2005).

4.9.2 Increasing connectivity

Analysis should be conducted layering the existing bicycle network with the transit network to find where vital connections can be made and where new routes should be established. The latter step will benefit greatly from on-site observation and interviews with local riders. By providing adequate bicycle parking at bus stops and ensuring cycling connectivity around stops, transit agencies can significantly strengthen the economic performance of transit lines by increasing the catchment area and alleviating the stress involved in accessing transit (Martens, 2004).
5.0 DESIGN APPLICATIONS
5.1 Design Process

In addition to developing and applying techniques to bus stops, this project also demonstrates a process that can be applied to many other urban design tasks. This process shows that with appropriate urban design expertise, site analysis, design, and visualization can be accomplished with minimal costs and widely available technology. All the tools used this process are either already available to municipalities or are free to acquire.

The process is as follows:

1. Map bus stops, density, municipal zoning, parks and streetlight data with ArcMap
2. Select sites that cover a wide range of bus stop types and locations
3. Construct existing plans with satellite photos and site photos
4. Analyze the pedestrian flows, shadows and visibility* of each stop
5. Gather ideas from fellow bus riders and literature review
6. Model and render bus stop designs with SketchUp
7. Review and revise designs with municipal planners and urban designers
8. Combine final designs with relevant information for publication

* Visibility diagrams are constructed using UCI Depth Map. This program calculates the total viewable distance in all directions from every point on the site. Each point is given a colour from the spectrum based on their total viewable distance. Once every point is calculated, the pixels of colour are combined into one image, mapping which locations on the site can see more of its surroundings and which locations can see less.
5.2 Regional Bus Stop Analysis

For the purposes of this urban design project, bus stops in Metro Vancouver are placed into 5 urban form categories based on their adjacent zoning. Each category has its own needs and opportunities. The following are descriptions of the categories.

**Cat. 1: Stops In Highly Developed Areas**
Few of these locations exist, mostly in city centre areas. Due to the abundance of activities nearby, the design of the stop can benefit both transit riders and nearby merchants and pedestrians. Because these stops are usually adjacent to major development sites, it is possible to work with the developers to come up with a bus stop that is integrated right from the design stage, giving the best possible result.

**Cat. 2: Stops By Businesses Or Community Amenities**
Such locations are scattered throughout the region, each a node within their respective neighbourhoods. Opportunities exist for these stops to contribute to neighbourhood identity. Consultation with neighbouring businesses is key to providing complementary amenities that enhance the overall space.

**Cat. 3: Stops In Medium Density Residential Neighbourhoods**
These stops are numerous in the region. Ridership is often high at these stops. Therefore it is important to cater to the needs of the riders. Due to the high vehicular and pedestrian traffic in such areas and their relative importance as nodes of activity, the design can either be ad-supported or funded by the city.

**Cat. 4: Stops In Single Family Residential Neighbourhoods**
These stops are extremely common, so it is important to have an easily replicable design. Because wait times are often long, rider comfort and safety are crucial. Here, the emphasis is on providing the basic needs such as seating, cover, lighting, and access.

**Cat. 5: Stops Adjacent To Parks Or Open Spaces**
These stops are also fairly numerous in the region. Because the stops are often on city owned land, the designs of these stops can be less conventional, take up more space, and serve as amenities or markers in the park. Due to the low traffic in such areas, it is unlikely for ad-supported stops to be feasible. However, if the stops are well designed and benefit the park goers, it is possible for funding to come from parks and other related departments.
5.2.1 Bus Stop Mapping

As Category 1 stops are very rare and subject to many factors, they are not mapped. Category 2, 3, 4, and 5 bus stops are mapped using ArcMap and GIS data provided by municipalities.
Figure 5.2.3: Cat. 4: Stops In Single Family Residential Neighbourhoods
Note: Data for Richmond and Burnaby unavailable at time of study.

Figure 5.2.4: Cat. 5: Stops Adjacent To Parks Or Open Spaces
Figure 5.2.5: Bus Stops and Residential Density
Bus stops are coloured corresponding to the residential density of their respective neighbourhoods. Source: 2006 Canadian Census

Figure 5.2.6: Bus Stops and Lighting
Bus stops that are more than 25m away from street lights are identified. Note: Data for Richmond and Burnaby unavailable at time of study.
Figure 5.2.7: Bus Stops and Walkability
Bus stops are overlaid over a walkability map of Metro Vancouver.
Source: UBC Active Transportation Collaboratory

Figure 5.2.8: Bus Stops Sized by Projected Daily Boardings
Bus stops are mapped based on daily boardings, ranging from 10 to 11,000
Source: TransLink
### 5.2.2 Bus Stop Selection

Nine stops in Metro Vancouver are chosen to illustrate each of the BSUD techniques. In addition to showcasing the techniques, the stops need to exhibit a wide range of environmental factors. To accomplish this, I checked the candidate stops with the analysis depicted in Figures 5.2.1 to 5.2.8. This assured that the stops are adjacent to a wide range of developments, reside in many different density neighbourhoods, have multiple lighting conditions, and have different levels of walkability and bus ridership. This multitude of selection criteria ensures that the final nine stops selected represent the overall network well. Other minor factors also affected the selection process, such as the desire to cover multiple municipalities in Metro Vancouver and limitations caused by lack of data in some locations.

<table>
<thead>
<tr>
<th>#</th>
<th>Urban Form</th>
<th>BSUD Technique</th>
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<tbody>
<tr>
<td>1</td>
<td>King George Blvd. and 88th Ave, Surrey</td>
<td>5 Lighting</td>
</tr>
<tr>
<td>2</td>
<td>Lonsdale Ave. and 15th St, City of North Vancouver</td>
<td>2 Seating and Surfaces</td>
</tr>
<tr>
<td>3</td>
<td>Imperial St. and Dow Ave Burnaby</td>
<td>3 Cover</td>
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<tr>
<td>4</td>
<td>Cambie St. and 41st Ave, Vancouver</td>
<td>1 Amenities</td>
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<td>5</td>
<td>Oak St. and 70th Ave, Vancouver</td>
<td>3 Information</td>
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<tr>
<td>6</td>
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<td>7</td>
<td>Fraser St. and 45th Ave, Vancouver</td>
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<td>8</td>
<td>Nanaimo St. and Grant Ave, Vancouver</td>
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<td>9</td>
<td>NW Marine Dr. and Sasamat St, Vancouver</td>
<td>5 Bicycle Infrastructure</td>
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</tbody>
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Figure 5.2.9: Map of Selected Stops
5.6 Lighting for Safety
King George Blvd. and 88th Ave, Surrey

- Main BSUD Technique: Lighting
- Urban Form Category: 5
- Population Density: Low (1154 ppl/km2)
- Lighting Condition: Bad
- Walkability: Low
- Ridership: Low

**Design Intent**
This design demonstrates the BSUD technique of using lighting to improve the safety at remote bus stops. This stop is located in the Green Timbers neighbourhood in Surrey, adjacent to Bear Creek Park. This park is home to the Surrey Art Gallery and many sports facilities. New refracted, white light illuminates the stop with fewer shadows. More importantly, an open design allows for the surrounding to be lit as well, giving the bus rider more awareness of the environment (see 5.12).

Very few pedestrians travel on this block except for those waiting for the bus and local residents walking to the park.

This site receives most of its solar exposure in the afternoon due to large trees to the east.

Visibility is extremely high at all parts of the bus stop because the site is not bound by any developments.
Kevin Jingyi Zhang 2012

There is no cover or lighting available to the bus stop. This creates issues of safety and accessibility. It is also located on a very narrow site that is extremely close to heavy traffic.

Refractive white light illuminates both the stop and the surrounding area evenly, providing a greater sense of safety and increased passive surveillance.
5.4 Seating the Public
Lonsdale Ave. and 15th St, City of North Vancouver

- Main BSUD Technique: Seating and Surfaces
- Urban Form Category: 2
- Population Density: High (15736 ppl/km²)
- Lighting Condition: Good
- Walkability: Medium
- Ridership: High

**Design Intent**

This design demonstrates the BSUD technique of providing seating that serves both bus riders and local pedestrians. This stop is at one of the major intersections in the Central Lonsdale neighbourhood. It is close to city hall, city library, grocery stores, and many small businesses. As a result, many people at this active street corner can benefit from the added covered seating that is carefully designed to integrate with the surrounding urban form.

* Stop

**Figure 5.4.2: Pedestrian Flow**

The majority of pedestrian flow is along Lonsdale Avenue. Most of the pedestrians on this corner are there waiting for the bus.

**Figure 5.4.3: Shadow Study**

The bus stops is on the brightest corner of the intersection, giving it opportunity to become a warm and comfortable outdoor space.

**Figure 5.4.4: Visibility Diagram**

Visibility on the site is quite good due to the wide spaces and lack of vegetation.
This stop is adjacent to high volume streets. There is also a medium slope along the site.

Figure 5.4.5: Design Perspective

1. Extra awning match existing building
2. Distinctive paving denote public space and create visual separation from street
3. Large public seating for transit customers, pedestrians, and business patrons
4. Bollards and vegetation create separation from traffic as well as shielding from noise and wind
5. Natural cover provided by trees and existing building overhang
6. Bicycle parking with ramped entrance from road
7. Community information board for events and notices
8. Pedestrian scale lighting evenly illuminates area
5.5 Complementary Cover
Imperial St. and Dow Ave, Burnaby

- Main BSUD Technique: Cover
- Urban Form Category: 3
- Population Density: High (19111 ppl/km2)
- Lighting Condition: Medium
- Walkability: Medium
- Ridership: Low

Design Intent
This design demonstrates the BSUD technique of providing cover that is visually integrated with the surroundings. This stop is located in the Maywood neighbourhood of Burnaby, on a pedestrian corridor that connects the residential area to the south with the Metrotown core to the north. Cover is provided by strategically planted trees and subtly designed canopies (see 5.12). While both are new additions, they reinforce the visual continuity of the street.

Two main groups of pedestrians using this area are people waiting for the bus and people walking through to get to Metrotown.

The bus stops is on the brightest corner of the intersection, giving it opportunity to become a warm and comfortable outdoor space.

Visibility is excellent on the site with far vistas in every direction except north.
This stop is cut off from the south by fast traffic on Imperial street. It also lacks cover and visual interest in its vicinity.

**Figure 5.5.5: Design Perspective**

1. Bollards and vegetation create separation from traffic and slow down vehicles
2. Simple seating integrated with existing stone wall
3. Cover provided by shelter and trees that also enhance the surrounding landscape (see 5.12)

**Figure 5.5.6: Existing Condition/Issues**

This stop is cut off from the south by fast traffic on Imperial street. It also lacks cover and visual interest in its vicinity.
5.6 Amenities Abound
Cambie St. and 41st Ave, Vancouver

- Main BSUD Technique: Amenities
- Urban Form Category: 1
- Population Density: Medium (4448 ppl/km2)
- Lighting Condition: Good
- Walkability: Medium
- Ridership: High

**Design Intent**
This design demonstrates the BSUD technique of providing amenities that serve both bus riders and the surrounding community. This plaza outside the Oakridge Shopping Centre is a major transfer node between the Canada Line Skytrain and the 41, 43, and 15 buses. It is also an important public open space that will serve the transit-oriented development that will be built in the future. These transportation and development conditions create ample demand for amenities such as public seating, fountains, food carts, and flexible open spaces.

**5.6 Amenities Abound**
Cambie St. and 41st Ave, Vancouver

Pedestrian paths between bus stop, SkyTrain stop, and mall entrance all cross at the existing triangular sign in the northeast corner of the plaza.

- **Figure 5.6.1: Satellite View**
- **Figure 5.6.2: Pedestrian Flow**
- **Figure 5.6.3: Shadow Study**
- **Figure 5.6.4: Visibility Diagram**

The plaza has good visibility to the surroundings at all points. However, this plaza lacks a sense of enclosure.

The brightest part of the site can be found in the middle, conveniently not in a pedestrian pathway and on a south facing slope.
The plaza is bound by two major arterial roads that make crossing difficult and creates noise and pollution. In addition, there is limited cover and sometimes high winds.

Figure 5.6.5: Design Perspective

1. Awnings extended to cover new storefronts
2. Distinctive paving denote public space
3. Bollards create separation from traffic
4. Natural cover provided by trees and existing building overhang
5. Bicycle parking with ramped entrance from road
6. Fountains and other amenities serve both bus stop and public space
7. Pedestrian scale lighting evenly illuminates area
8. Covered sidewalk provide weather protection and frame public space
9. New seating oriented for solar exposure and pedestrian flow

Figure 5.6.6: Existing Condition/Issues
5.7 Informative Bus Stop  
Oak St. and 70th Ave, Vancouver

- Main BSUD Technique: Information  
- Urban Form Category: 3  
- Population Density: High (8581 ppl/km2)  
- Lighting Condition: Bad  
- Walkability: Medium  
- Ridership: High

**Design Intent**
This design demonstrates the BSUD technique of providing transit and community information at a bus stop. This stop is in the heart of the Marpole neighbourhood. Because it is in an apartment neighbourhood, there is relatively higher ridership. Due to the narrowness of the site, the shelter is configured to allow for leaning seats and maximum pedestrian flow (see 5.12). This setup also allows for the stop to have ample posting area to promote community events to those passing by.

Pedestrian flow is highly constricted on this block of Oak street as the sidewalks are narrow and extremely close to high speed traffic.

Visibility is medium as this stop. The sense of enclosure is fairly strong with taller buildings that are also closer.
This stop lacks cover and is extremely close to heavy traffic. Safety is a primary concern here. There is also very little space to work with.

1. Pedestrian scale lighting evenly illuminates area
2. Bollards and vegetation create separation from traffic and slow down vehicles
3. Vegetation improves aesthetics while keeping in style with neighbouring property
4. Modular stop configured with leaning-seats and ample room for transit and community information (see 5.12)
5. Benches serve both riders and residents
6. Cover placed with awareness of shading already provided by trees
5.8 Versatile Vegetation
Cottonwood Ave. and Fairview St, Coquitlam

- Main BSUD Technique: Vegetation
- Urban Form Category: 5
- Population Density: Low (362 ppl/km²)
- Lighting Condition: Bad
- Walkability: Medium
- Ridership: Low

Design Intent
This design demonstrates the BSUD technique of using vegetation strategically at a bus stop. This stop is located in the Cariboo neighbourhood of Coquitlam, which is mainly single family residential. It is close to parks and an elementary school. Bioswales installed here make the waiting environment more comfortable while filtering run-off from the street. It also helps educate the public on issues of environmental protection through landscape design.

Figure 5.8.1: Satellite View

Figure 5.8.2: Pedestrian Flow
Very few pedestrians walk on this side of the street as there is no sidewalk.

Figure 5.8.3: Shadow Study
This stop is often shaded due to the large amount and size of trees adjacent to the stop.

Figure 5.8.4: Visibility Diagram
This site has high visibility as it is at the corner of a T-intersection. The high exposure can be taken advantage of to display sustainable landscape systems.
Although in a well maintained area, there is no cover, lighting, or sidewalk available to the bus stop. This creates issues of safety and accessibility.

Figure 5.8.5: Design Perspective

1. Sidewalk increases accessibility
2. Cover for passengers (see 5.12)
3. Bioswale built with didactic signage
4. Bench seating framed by existing trees

Figure 5.8.6: Existing Condition/Issues

Although in a well maintained area, there is no cover, lighting, or sidewalk available to the bus stop. This creates issues of safety and accessibility.
5.9 Parting with Traffic
Fraser St. and 45th Ave, Vancouver

- Main BSUD Technique: Traffic Management
- Urban Form Category: 2
- Population Density: Low (2108 ppl/km2)
- Lighting Condition: Good
- Walkability: High
- Ridership: Medium

Design Intent
This design demonstrates the BSUD technique of managing traffic adjacent to bus stops and civic buildings. This bus stop serves the #8 bus along Fraser Street in the heart of the Sunset neighbourhood in Vancouver. It is located adjacent to the South Hill Library which receives much pedestrian traffic. Bollards, planters, trees, and lighting not only enhance the public space in front of the library, but they also provide physical, visual, and acoustic separation from traffic in a subtle manner.

Pedestrians follow paths typical of an intersection, with the exception of the extra foot traffic in front of the library, which may require extra space.

Most of the shadows cast on the bus stop is from the adjacent buildings.

This site has medium visibility, with views only in north and south directions. Therefore, this can be an area where the visual focus is situated within the design.
This location experiences high volumes of traffic and related noise.

Figure 5.9.5: Design Perspective

1. Play area for kids with seating for parents around
2. Distinctive paving denotes public space
3. Bollards and vegetation create separation from traffic as well as shielding from noise and wind
4. Natural cover provided by trees and existing building overhang
5. Bicycle parking with ramped entrance from road
6. Drinking fountains and other amenities serve both bus stop and public space
7. Pedestrian scale lighting evenly illuminates area

Figure 5.9.6: Existing Condition/Issues

This location experiences high volumes of traffic and related noise.
5.10 Walkable Block
Nanaimo St. and Grant Ave, Vancouver

- Main BSUD Technique: Pedestrian Infrastructure
- Urban Form Category: 4
- Population Density: Medium (3958 ppl/km2)
- Lighting Condition: Medium
- Walkability: Good
- Ridership: Medium

Design Intent
This design demonstrates the BSUD technique of improving the bus stop while increasing the general walkability of the block. This stop is located in the Renfrew neighbourhood. It is close to small shops, single family houses and on a school route. Extra seating, improved paving, low vegetation, and pedestrian scale lighting make waiting for the bus at this stop and walking through this block much more pleasant.

Pedestrians on this block are usually local residents and children on the way to and from school.

Due to small trees, this site receives ample amount of sun at all times of the year.

Visibility is high at all points within this stop.
This stop currently has no cover and is extremely close to fast traffic. The street is also difficult to cross.

Figure 5.10.5: Design Perspective

1 Bicycle parking provided
2 Extra paving increases accessibility
3 Sound blocking panels minimize noise experienced by neighbours
4 Modular stop configured with benches and leaning seats allow for easy access from sidewalk (see 5.12)
5 Extra benches serve both riders and residents
6 Cover provided for riders
7 Transit information panels
5.11 Cycling Convenience
NW Marine Dr. and Sasamat St, Vancouver

- Main BSUD Technique: Bicycle Infrastructure
- Urban Form Category: 5
- Population Density: Low (1154 ppl/km2)
- Lighting Condition: Bad
- Walkability: Low
- Ridership: Low

Design Intent
This design demonstrates the BSUD technique of providing bicycle amenities that add to the overall cycling infrastructure of the neighbourhood. This stop is along Locarno Beach, situated between single family residential houses and a park. While many people bike to the park, there are limited bike racks. Therefore, this stop can act as a gateway to the park and a hub for bicycle parking.

Pedestrian flow at this intersection is similar to others. However, most of the pedestrians are travelling for recreational purposes and often in groups.

Being in a wide open area, this stop receives ample amount of sunlight.

This bus stop has extremely high visibility as it is next to an open park by a beach. It is important that the new design maintains these views for the riders.
There is no cover, lighting, or sidewalk available to the bus stop. This creates issues of safety and accessibility.

Figure 5.11.5: Design Perspective

1. Paved bus stop for better accessibility
2. Cover provided for transit users
3. Views to the ocean preserved
4. Extra seating and water fountain
5. Beach signage
6. Bicycle parking provided for park goers

Figure 5.11.6: Existing Condition/Issues

There is no cover, lighting, or sidewalk available to the bus stop. This creates issues of safety and accessibility.
5.12 Modular Shelter Design

This design for bus shelters allows the shelter to adapt to the unique constraints of each site. A kit of parts easily assembles into different configurations, allowing for easy customization, maintenance, and replacement.

5.12.1 Components

Roof
Roofs can be made of a variety of materials, ensuring there is sufficient light penetration while not over heating the area below. Photovoltaics can be embedded to make the stop self sufficient with the help of a battery. The roof can also act as an illuminating device if LEDs are embedded or if the underside is reflective. Upward lighting reflected off of the ceiling can provide much more even lighting with reduced shadows. Roofs shall be extended enough beyond the designated waiting area to ensure coverage given a rain shadow of 20 degrees. Rain baffles may be used to minimize overhang and decrease susceptibility to damage from strong winds.

Main Structure
The main structure consists of posts set 1.5 metres apart. This grid structure allows the frame to be flexible enough to fit various the constraints of each site. Add-ons such as seats and bike racks are attached to the frame. The height for each add-on varies depending on which notch of the post it is latched on to.

Add-ons
A kit of parts can be built to fit the main structure. Add-ons include benches, bike racks, information panels and others. These component should reflect a continuous design language. Add-ons can be configured to fit the specific needs of the bus stop. Fold-up seats (similar to those on buses) allow a stop to have maximum flexibility when accommodating wheelchairs. Add-ons should be concentrated at one end of the bus stop to ensure that the remaining space has maximum flexibility in accommodating those standing.

Surface
Tactile surfaces should placed on the perimeter of the bus stop to ensure cane detection and audible detection by those with visual impairments. This is especially important for designs that include cantilevered components as those may be obstructive if not identified early.
5.12.2 Configurations

With a single post and chair, this basic design is meant to be placed at stops that currently have nothing except a bus pole. The bench is offset to one side to make room for a wheelchair.

Double chairs with half backs are good for stops where riders often have large bags.

Leaning seats are used in locations where the space is extremely narrow. The information panel also creates separation from traffic.

Medium sized, double post design can accommodate more passengers waiting at a stop.

Bike racks can be attached. Back panels can either be transparent to provide more visibility, or display information such as route maps or community events.

Triple post designs can be configured in many ways, tailored to the specific needs of the intersection.
6.0 CONCLUSION
6.1 Summary

The bus stop, like many public spaces, can be a complex knot of social, economic and cultural activities in the local community (Avdelidi, 2004). This projected attempted to categorize and improve such spaces through a rigorous process. It identified seven goals for urban design around bus stops and nine techniques through a literature review for achieving those goals. Nine stops were selected for design application after careful analysis of the bus network. Then, the techniques were applied to nine stops in Metro Vancouver. Throughout the process, I found that many stops in addition to the nine selected are in need of improvements; most of them requiring upgrades in the cover, seating, and lighting categories. There are also many stops in rapidly developing urban core areas that can undergo changes similar to those at Oakridge Centre.

All the improvements displayed in this project aimed to not only make the wait at a bus stop more comfortable for the rider, but also to make this space a valued asset in the community. Extra seating makes waiting more comfortable and also serves as park signage. Pedestrian scaled lighting makes riders feel safer and also increases the general walkability of the neighbourhood. Bicycle parking increases modal connectivity and also adds to the cycling infrastructure of the area. As a result, this project shows that municipalities and transit organizations can work together to turn transit zones into coveted spaces rather than zones of lower value (Zacharias et al., 2011).
6.2 Recommendations and Further Studies

It is recommended for communities that are looking to invest in bus stop enhancements to work in collaboration with other community improvement initiatives as this project shows that many synergies exist. Changes that improve the waiting area at a bus stop generally also make the block more walkable. By integrating bus stop improvement programs with other planning goals, one can reach a more informed and effective outcome. Further research should look at how to implement a more publicly involved design process. Such input would add valuable insight and sense of ownership to the project. Additional research should focus on the implementation strategies for these designs as they vary between different municipalities and funding mechanisms. Such work would help bring the interventions to fruition. Finally, further research can look at how these principles can be scaled up to larger and less numerous transit stations, such as light rail, subways, and heavy rail.
7.0 BIBLIOGRAPHY


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