UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Evaluating the Effectiveness of Bicycle Wayfinding Signage

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Bicycle Diversion Evaluation Project

Evaluating the effectiveness of bicycle wayfinding signage in encouraging cyclists to use designated bicycle routes

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Executive Summary

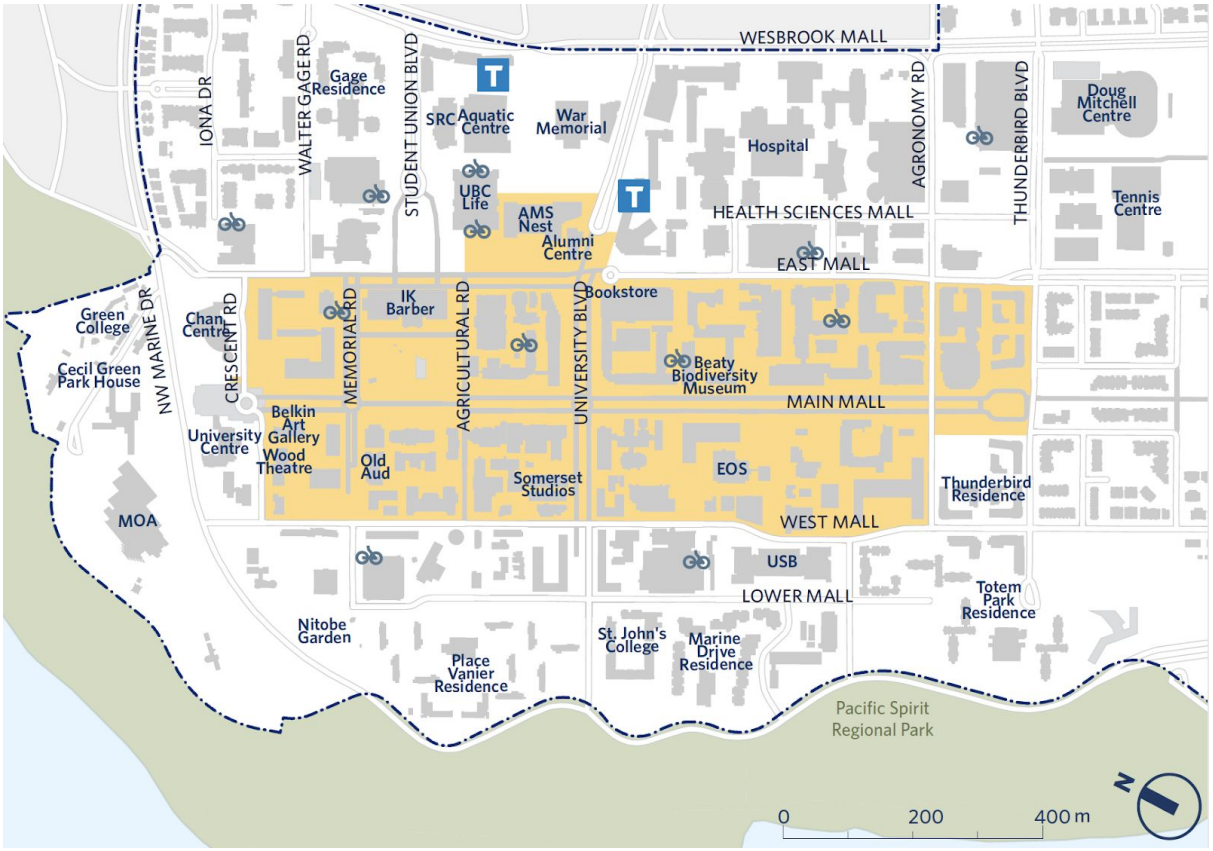
The primary purpose of the *Bicycle Diversion Evaluation Project* ("The BDE Project") is to determine whether or not wayfinding signage specifically targeted at cyclists, is effective at changing the behaviour of cyclists by encouraging cyclists to use designated bicycle routes. The goal of the wayfinding signs is to encourage cyclists to use routes that are less busy in order to reduce the number of pedestrian-cyclist conflicts on the UBC Vancouver campus. The BDE Project fills a gap in the literature as it is unique. The case studies that were examined in the literature review broadly suggests that signage is effective in changing the behaviour of pedestrians, cyclists or drivers. Despite not clearly being able to identify that bike wayfinding can alter the route choice behaviour of cyclists, the case studies suggest that wayfinding signs will be successful in altering cyclist route choice behaviour. As there is no case study that directly answers the research question being posed in the BDE Project, the BDE Project is an important study that fills a gap in the academic literature on the effectiveness of bike wayfinding signage at changing the behaviour of cyclists.

Results from the BDE Project show that the percent change in cyclists choosing to travel away from the Pedestrian Priority Zone in the before-implementation and after-implementation counting period is not significantly different. As a result, the BDE Project cannot confidently conclude that the specific bike wayfinding signs that have been implemented on the UBC Vancouver campus have an effect at altering the route choice behaviour of cyclists. Despite this finding, it is important to understand that there are a number of limitations that likely contributed to this result. One major limitation is the lack of time between the implementation of the wayfinding signs and the beginning of the post-implementation counting. Another limitation of the wayfinding signs is that they are not placed at consistent locations in intersections and have small font size making them hard to read. Further studies looking at the design of bike wayfinding signs are recommended and need to be done before it can be concluded that all bike wayfinding signs are ineffective at altering the route choice behaviour of cyclists.

Introduction

The primary purpose of the *Bicycle Diversion Evaluation Project* (“The BDE Project”) is to determine whether or not wayfinding signage specifically targeted at cyclists, are effective at changing the behaviour of cyclists by encouraging cyclists to use designated bicycle routes, out of the Pedestrian Priority Zone (PPZ). The PPZ is an area on the University of British Columbia (UBC) Vancouver campus where pedestrians are prioritized by limiting vehicular access and encouraging cyclists, skateboarders and electric vehicles to travel slowly. Figure 1 shows the UBC Vancouver campus with the PPZ area highlighted in yellow.

Figure 1. UBC Vancouver Campus Pedestrian Priority Zone.



The BDE Project is being conducted as a response to the large number of pedestrian-cyclist conflicts identified in the PPZ from Gkekas & Bigazzi’s *Conflicts and Collisions between Pedestrians and Cyclists: Case Study of the University of British Columbia Vancouver Campus*. The goal of tinstalling wayfinding signs is to encourage cyclists to bike around the PPZ to reach their destination instead of biking through it. The routes shown on the bicycle wayfinding signs were chosen by UBC Campus and Community Planning in an effort to direct cyclists around the PPZ while minimizing the amount of time it takes for cyclists to reach their on campus destinations.

In the 2017/2018 academic year the UBC Vancouver campus had and enrollment of over 55,000 students (The University of British Columbia, n.d.). According to the Fall 2016 *UBC Vancouver Transportation Status Report* the majority of these students commute to and from campus by car or by transit; however, the *UBC Vancouver Transportation Status*

Report, shows that there are 1400 people commuting to and from campus by bike everyday (Campus and Community Planning, 2017). Additionally, many of the people commuting to the UBC Vancouver campus by car or transit will walk or cycle in the PPZ while they are on campus and travelling between classes. This can create a busy public place in the PPZ, especially during the times between classes. The *Experienced and Perceived Safety of Pedestrians and Cyclists on the University of British Columbia Vancouver Campus* by Gkekas found that there are a large number of bicycle-pedestrian conflicts on campus. As a response to the large number of pedestrian-cyclist accidents discovered in the Gkekas study, the UBC Vancouver Campus and Community Planning Department commissioned bicycle wayfinding signs in an effort to re-route cyclists around the PPZ and reduce the number of bicycle-pedestrian conflicts that occur on campus.

As a compendium to the installation of bike wayfinding signage, UBC Campus and Community Planning and the SEEDS Sustainability Program are interested in finding out how effective bike wayfinding signage is at re-routing cyclists around the PPZ in an attempt to reduce the number of pedestrian-cyclist conflicts. The question being asked is: Are bicycle wayfinding signs an effective way to encourage cyclists to use designated bicycle routes outside of a designated area? In the BDE Project the designated area is the PPZ. There are two ways to understand effectiveness of bicycle wayfinding signs. One way is to conduct a literature review and the other way is to conduct bike counts before and after implementation of wayfinding signage.

There is little research showing the effects of bike wayfinding signs on changing the route choice behaviour of cyclists. For this reason, the scope of the literature review includes academic works that are not identical to the circumstance identified in the BDE Project; however, all of the literature discussed in the literature review has some similarity to the BDE Project and is therefore relevant to the research question being asked in the BDE Project.

A Review of Related Literature

While conducting a literature review on bicycle wayfinding signs related to changing the route choice behaviour of cyclists, the most striking observation is the very limited information available on the topic. There is a huge gap in the literature which underlies the importance of undertaking the BDE Project to evaluate the effectiveness of bicycle wayfinding signage in encouraging cyclists to use designated bicycle routes.

The BDE Project is needed by the academic and professional community as academic literature and best practice guides agree that bicycle wayfinding is a necessary component to have on a world class cycling network, yet there is minimal information available on the ability of bicycle wayfinding signs to alter cyclists behaviour. It is important to note that the BDE Project is not intended to determine the effectiveness of wayfinding signs in motivating people to bike, but rather to measure the effectiveness of the signs in changing the behaviour of people that already cycle on the UBC Vancouver campus.

To help inform this literature review studies from around the world were examined. This literature review will highlight some agreements and disagreements within the reviewed literature and be followed by a breakdown of the articles into three related topics of relevant literature. The topics covered in the literature review are:

1. Case Studies examining wayfinding signs for cyclists that do not contain information on the ability to alter cyclists route choices with wayfinding signs, yet discuss bicycle wayfinding or behavioural changes in some way.
2. Car and pedestrian wayfinding case studies showing the ability of wayfinding signs to change user behaviour.
3. A non-academic look at wayfinding signage guidelines developed by national transportation agencies, or municipalities in British Columbia.

The description of each of these resources will be augmented by an explanation of what the similarities and differences are when compared to the BDE Project. Relevant methodologies in each of the case studies that helped to inform the BDE Project will be highlighted and discussed in further detail in the 'Methodology' section.

Case Studies

Part A. Case studies looking at wayfinding signs for cyclists that do not contain information on the ability to alter cyclists route choice behaviour

Evaluation of Shared-Use Markings for Cyclists in Auckland (the Auckland Study)

The Auckland Study looked at the effect of sharrow markings (Shown in Figure 2) to "create a safer shared lane facility for cyclists in low volume, low speed environments." (Pol, Prasad, Costello, Patel, & Hancock, 2015, p.1) Researchers used video footage "to determine if the sharrow markings influenced cyclist behaviour" (Pol et al., 2015, p.1) by comparing the cyclists' positioning within the road before and after the sharrow markings were painted onto the road. The results of this case study showed that the sharrow markings were generally successful in influencing the cyclists to bike closer to the sharrow markings that were painted on the road therefore encouraging cyclists to bike further away from the curb.

The Auckland Study is relevant to the BDE Project as both studies examine the ability of signage to alter the behaviour of cyclists in some way. The Auckland Study showed that markings aimed specifically at cyclists were effective in altering cyclist behaviour in some way.

One key difference between the Auckland Study and the BDE Project is that in the Auckland Study the signage used was painted on the road and not in the form of an elevated sign. However, the biggest difference is that while the Auckland study substantiates the idea that cyclist behaviour can be affected by road markings specifically targeted at cyclists, it does not measure whether or not sharrows or other bike wayfinding signage is effective in changing the route choice of cyclists as the Auckland study examines the ability of sharrows to alter the cyclists positioning on the road relative to the curb.

The Auckland study helped inform the methodology for the BDE Project as the idea of comparing before and after data to determine if there was a behavioural change when all other factors remained the same was used in the BDE Project.

Figure 2. Reference the Auckland study for the specific type of 'sharrow' markings that are painted on the road in the Auckland study.

Evaluation of Bicycle Sharrows within the Norwegian context (the Norway Study)

The Norway Study looks at how effective sharrows are in influencing the behaviour of cyclists on the road. Contrary to the Auckland Study, the Norway Study did not show that cyclists positioning in the road was affected by the sharrows. Despite finding that road positioning was not affected by sharrows "a decrease in sidewalk cycling among adult cyclists was observed" (Vasilev, Pitera, & Jonsson, 2017, p.1097). This finding is relevant for the BDE Project since it is possible that the decrease in sidewalk cycling could have resulted from the sharrow markings making cyclists feel more comfortable cycling on the road signaling a change in cyclist behaviour.

The authors of the Norway Study suggest that "the results of the study are not entirely conclusive" (Vasilev et al., 2017, p.1097) because there were changes to the street beyond the addition of the sharrow markings. For example, changes to the street that happened throughout the study included: widening of sidewalks, implementing raised pedestrian crosswalks and building a nearby school.

Similar looking sharrow markings were used in the Auckland and Norway Studies (see Figure 1.); however sharrows are "not included in Norwegian design standards" (Vasilev et al., p.1098) and despite users understanding the purpose of the sharrows, Norwegian cyclists may feel less confident embracing the use of sharrows as they are not commonly used throughout Norway.

The Norway Study is similar to the BDE Project as they are both studying the potential for signage/markings to affect a behavioural change in cyclists. The Norway Study is relevant because it is possible that in the BDE Project, cyclists also become aware of the wayfinding signs, but decide to ignore them and continue biking in and through the PPZ to get to their destinations. The Norway Study is also relevant because the sharrow markings may be responsible for the decrease in sidewalk cycling, potentially showing that markings can cause behavioural changes in cyclists.

The Norway Study focused on the impact of sharrows being added to the roadway, yet, contrary to the BDE Project, the behavioural data studied was not about wayfinding, but rather it was focused on cyclists' positioning within the roadway and whether or not sidewalk cycling was reduced. Despite the somewhat inconclusive results, the Norway Study was helpful for informing the methodology of the BDE project and also helping to inform the BDE Project of what works and does not work within the research area of signage/road markings' ability to change the behaviour of cyclists.

The BDE Project used a similar methodology to the Norway Study as data was collected through observation before and after a new marking/sign aimed at cyclists was added to the road area. In the Norway Study "observers manually collected information on the number of cyclists and motorists" (Vasilev et al., p.1100) prior to reconstruction of the street as well as 1 year after reconstruction of the street which included adding sharrow markings. The idea of allowing time for cyclists to become familiar with the markings was something the BDE Project tried to follow; however, delays implementing the signs meant that some intersections on the UBC campus received signage less than one week before the post-implementation data collection began. Lastly, the Norway study observed a total of 1777 cyclists throughout the study (Vasilev et al., p.1100). This influenced the BDE Project to aim for 2000 total observations (Vasilev et al., p.1100). Even though the Norway Study results were not entirely conclusive due to a number of factors that could not be controlled for, the methodology was informative and allowed the BDE Project to learn from things that

did not work well in the Norway study. One example of this is that the BDE Project chose study areas (intersections) where no planned changes, other than the implementation of bike wayfinding signs, were anticipated.

Guiding the Way: Exploring Cycle Tourists' Needs and Preferences for Cycling Route Maps and Signage (the Cycle Tourism Study)

The Cycle Tourism Study talks about the preferred wayfinding aids for cycle tourists, yet does not discuss whether or not the behaviours for route preferences can be changed via bike wayfinding signs. The Cycle Tourism Study underscores the importance of effective bike wayfinding signage for the mental health and safety of cyclists. The focus of the Cycle Tourism Study is to determine what information should be put on wayfinding signs for cyclists as well as to look at "links between wayfinding aids and cycle tourists' destination selection processes." (Lamont & Causley, 2010, p.498)

This case study is relevant to the BDE Project as cycle tourists could be compared to new cyclists on the UBC Vancouver campus who are unfamiliar with their surroundings. The limitation of this comparison is that over time new cyclists, unlike tourists, will become more familiar with the campus and may decide to choose a route through the PPZ despite what the wayfinding signs suggest.

One difference between the Cycle Tourism Study and the BDE Project is that cycle tourists are a unique group as they are likely unfamiliar with the area and are reliant on "wayfinding aids to facilitate trip planning" (Lamont & Causley, p. 497). In the BDE Project the majority of cyclists are likely familiar with the area as they commute frequently on the UBC Vancouver campus. Another key difference is that in the BDE Project the information on the wayfinding signs is not being studied, it is the ability of those signs to influence cyclist behavior that is the main focus if the BDE Project.

Operational Evaluation of Central Sharrows and Dooring Zone Treatment on Road User Behaviour in Ottawa, Canada (the Ottawa Study)

The Ottawa Study measured the effectiveness of road markings in altering cyclists behaviour. This was done by painting sharrows onto the road as well as adding "an extra text indication in both English and French….to indicate where cyclists are at risk of dooring" (Kassim, Ismail, & McGuire, 2018, p.2). Dooring refers to occasions when cyclists bike on the road and are close enough to parked cars that when the driver opens their door they can hit a cyclist with their door or the cyclist does not have enough time to avoid the car door and crash into it.

In the Ottawa Study, before treatment and after treatment data are used to compare the effectiveness of the road markings. Results from this study show that painting both images and text on roads were effective in changing where cyclists positioned themselves on the road. Painting both images and text on roads made it more likely that cyclists would bike in the center of the lane as well as the increase likelihood of motor vehicles to drive behind cyclists instead of passing them in a potentially unsafe manner.

The Ottawa Study is relevant to the BDE Project as both studies examine the ability of signage with text to alter the behaviour of cyclists. The Ottawa Study showed that road markings with text aimed specifically at cyclists were effective in altering cyclist behaviour in some way. This suggests that signs with text that are not located on the road will also be effective in altering the behaviour of cyclists.

While the Ottawa Study uses images and text to modify cyclist behaviour, key differences when compared to the BDE Project are that the text and images used in the Ottawa Study were painted onto the road and not in the form of a stand-up sign. Additionally the Ottawa Study measures the ability of signs to impact the positioning of cyclists in the road whereas the BDE Project measured the cyclist route choice. The last key difference between the studies is that the Ottawa Study is measuring the effect of the signs for cyclists and motor vehicles on the road whereas the BDE Project is measuring the effectiveness of signs that are only targeted towards cyclists.

While studies where 'sharrows' and on-street car-cyclists interactions are important resources, they do not reduce the gap in academic literature to study the effectiveness of wayfinding signs in modifying the route choice behaviour of cyclists.

Part B. Car and Pedestrian Wayfinding studies showing the ability of signs to change user behaviour.

The Value of Wayfinding (the Australia Study)

The Australia Study is a literature review that looks at multiple studies, some of which where signs are targeted at cyclists and some where signs are targeted at pedestrians or vehicle drivers. The Australia Study highlights the need for more information on the effectiveness wayfinding signs specifically targeted at cyclists. When discussing the availability of research on the topic, Australia Study comments that "little research has been undertaken on the influence of wayfinding signage on cycling participation" and case studies examined by the authors focus largely on promotional activity to incentivize people to bike.

In the *Legible London* case study referenced by the authors, the effect of signage on route choice for pedestrians was examined and found that 83% of users agreed *Legible London* wayfinding signs helped navigate to a destination (Harridge & Roozenburg, 2014). Additionally, results from the *Legible London* study showed that the "number of pedestrians getting lost on a journey fell by 65%" (Harridge & Roozenburg) which indicates that the majority of pedestrians were positively influenced by the wayfinding signage.

Without mentioning route choice behaviour, the Australia Study is relevant to the BDE Project as it suggests that wayfinding signs are able to increase cycling participation which ultimately means a change in behaviour.

The big difference between the case studies examined in the Australia Study and the BDE Project is that the BDE Project is trying to alter the route choice behaviour of people who have already chosen to cycle, rather than convincing non-cyclists to cycle. The Australia Study also looks at best practices for wayfinding signage and destinations being signed; however, these considerations are beyond the scope of the BDE Project. Another difference is that the case studies reviewed in the Australia Study are not implementing signage with the view to reduce cyclist-pedestrian conflicts, but are instead looking to increase the overall number of cyclists or pedestrians.

Investigating the Effectiveness of the Least-Angle Strategy for Wayfinding in Unknown Street Networks (the Pedestrian Study)

The Least-Angle Study is primarily focused on pedestrian route choice behaviour and compares the behaviour of pedestrians, cyclists and cars. The Least-Angle Study is conducted in situations where the navigator does not have an understanding of the area and where the navigator is unable to find their specific destination on any traffic signs. The Least-Angle Study looks at the Least Angle (LA) Strategy. LA strategy is where a navigator knows their destination and the direction of the streets. It is a fabricated scenario, but may be a useful temporary strategy in a situation where there is nobody around and no signs in the area. In LA strategy, the navigator must take streets most in line with the direction towards the target destination and always be proceeding in the direction of their destination.

The results of the Least-Angle Study show that pedestrians are more likely than cyclists or cars to reach their destination; however, this does not answer whether or not wayfinding signs are effective ways to change the route selection of cyclists.

The Least-Angle Study is still relevant to the BDE Project as the findings show that for human route selection behaviour, “shortest distance and least time have been found to be the dominant choice criteria in various wayfinding studies” (Hochimar, 2005, p.676). Furthermore, the Least-Angle Study “suggests that preference for most direct direction plays an important role in human route choice within street networks.” (Hochimar, 2005, p.673) While this may not always be the case for cyclists, it is likely that distance and time will also impact the route selection of cyclists at UBC. Since bikes are generally not motorized and there can be limited time between classes it seems likely that the more efficient routes in terms of time will be the preferred choice of cyclists.

One difference between the Least-Angle Study and the BDE Project is that cyclists at UBC are most likely aware of where they are going since it is likely that most cyclists on campus have been commuting to the same buildings all semester or they live on campus and are therefore familiar with the area.

Another key difference between the Least-Angle Study and the BDE Project is that in the Least-Angle Study there is no effort to change the behaviour of pedestrians, cyclists or cars through wayfinding signs.

Driver Response to Variable Message Signs (VMS): A Stated Preference Investigation (the VMS Study)

The VMS Study is one of few studies that looks at how signs can be used to deliberately affect route choice and therefore change the behaviour of drivers. This study is similar to the BDE Project as it looks at the effect of signs on route choice, the main differences are that the VMS Study focused on cars instead of cyclists and the signs are ‘Variable Message Signs’. VMS are electronic signs and are used to update drivers about current road conditions.

One of the main findings from the VMS Study is that drivers value their time and are more likely to choose a route that takes less time. Another finding from the VMS Study shows that “route choice can be strongly influenced by information about traffic conditions ahead” (Wardman, Bonsall, & Shires, 1997, p.389) which signals that it might be possible to influence cyclists with signs. The VMS Study also shows that the Variable Message Signs

are most effective if drivers believe they are reliable and therefore beneficial to the driver, and not an attempt by traffic authorities to influence traffic flow in a way that would not be in the best interest of the driver (Wardman et al., p.403). Although beyond the scope of this report, sign design and trust in UBC signage may be important factors in the route choice behaviour of cyclists

The VMS Study is also relevant to the BDE Project both studies are looking at the ability of signage to change route choice behaviour. The VMS Study proves this is possible for vehicles as "evidence suggests that messages on VMS can persuade somewhere between 5 and 80% of drivers" (Wardman et al.,p. 389) to change their route choice.

One difference between the studies is the data collection methodology. In the VMS Study, questionnaires were sent out to get an idea of the drivers preferred route choice and therefore gain a better idea of their final destination; however, in the BDE Project, route choice behaviour was observed manually. This means that the BDE Project is not aware of the final destination of the cyclists.

Part C. Reviews non-academic articles that look at wayfinding signage guidelines developed by national transportation agencies or British Columbia municipalities

Urban Bikeway Design Guide from the National Association of City Transportation Officials (NACTO) (the NACTO Guide)

The NACTO Guide draws on literature and best practices from around the world with the purpose of sharing solutions for creating complete streets that are safe for cyclists. The NACTO Guide explains that a wayfinding system should consist of comprehensive signing or pavement markings to "guide cyclists to their preferred destination along preferential bike routes" (National Association of City Transportation Officials, 2014, p.139). The NACTO Guide looks at the benefits of wayfinding signs for cyclists as well as the different types of signs that can be used to convey information to cyclists.

Looking at the NACTO Guide is relevant to the BDE Project as the NACTO guide suggests that bike wayfinding signs are usually placed at "the intersection of two or more bikeways/key routes." (National Association of City Transportation Officials, p.139). This is the case for all three of the intersections where observations are being taken for the BDE Project and confirms that the BDE Project is using best practices for locating bike wayfinding signs.

The difference between the NACTO Guide and the BDE Project is that the NACTO Guide does not discuss whether or not these signs are effective in changing the route choice behaviour of cyclists. Additionally, the NACTO Guide outlines where bike signs should be placed and what information should be on the wayfinding signs; however, the NACTO Guide does not attempt to determine whether or not wayfinding signs are effective in altering the route choice behaviour of cyclists.

Capital Regional District (CRD) Cycling Destination Wayfinding Guidelines (the CRD Guide)

The CRD is located in Southern part of Vancouver Island. The CRD Guide was developed to “assist municipalities within the CRD to prepare wayfinding signage plans for cyclists.” (Capital Regional District, 2014, p.2) The CRD Guide provides best practices for signage design as well as the benefits of having wayfinding signs for cyclists and pedestrians.

The CRD Guide is relevant to the BDE Project as it suggests that once cyclists trust that they will encounter consistent and predictable info, new journeys can be made more easily. (Capital Regional District, p.10) This suggests that in the BDE Project, behaviour change can be accomplished through bike signage.

The CRD Guide provides a comprehensive set of guidelines for cycling destination wayfinding; however, the guidelines are not supported by any academic studies that show the effectiveness of the signage in altering the route choice behaviour of cyclists. This is an important reason why the BDE Project fills a gap in the academic literature surrounding bike wayfinding signs.

D. Conclusions

Many of the case studies that were reviewed impacted the methodology of the BDE Project. The two studies that were the most influential for shaping the methodology of the BDE Project were the Auckland and the Norway case studies. Both of these case studies compared before and after bike count data to determine if sharrows were effective in altering the behaviour of cyclists with regard to their positioning on the road. Sharrows are a type of painted marking applied to the road to indicate that cyclists are entitled to share the roadway with cars and other motorized forms of transportation. In the Norway study, the data was collected manually and the number of observations gave the BDE Project a targeted number of observations to aim for.

Lastly, the authors of the Norway Study described what was unsuccessful so that studies like the BDE project could avoid making the same mistakes. In the Norway Study there were a number of changes to the street beyond the sharrows that were painted on the roadway such as widening sidewalks, raising pedestrian crosswalks and ongoing construction preventing cyclists from using some areas of the street during the collection of before count data. Additionally, between the before and after data collection periods, a new school was added in the area which resulted in more cyclists using the route to get to school in the after collection period. All of these factors could have influenced the behaviour of the cyclists which therefore made the impact of the sharrows somewhat uncertain. The BDE Project learned from the Norway Study and chose intersections where there was no planned construction or changes to the intersection beyond the implementation of wayfinding signs that could influence cyclist behaviour.

Similarities and differences in the reviewed literature

This section looks at some similarities and disagreements in the reviewed literature. Comparisons between the articles are made; however, the articles are often not directly comparable because the majority of the articles reviewed are fundamentally different since they study different aspects of wayfinding signage. Selecting studies that are not directly

comparable to each other was an intentional decision so that information on a broad range of topics could be reviewed.

Similarities in the literature

The majority of the articles included in the literature review conclude that drivers, pedestrians and cyclists tend to choose routes that take the least amount of time. This factor was considered when UBC Campus and Community Planning designed the suggested routes for cyclists that are displayed on the wayfinding signs. UBC Campus and Community Planning attempted to ensure that the suggested routes around the PPZ would be similar in time to the route through the PPZ.

A common theme found throughout the relevant literature was that signage (including road markings) is able to impact the behaviour of cyclists, pedestrians and cars in some way; however, some of these studies reviewed examined cars or pedestrians and not just cyclists. Additionally, some of the studies used road markings (Sharrows) or Variable Messaging Signs (VMS) that were different to the signs used in the BDE Project. (Eg. As featured in the Wardman et al. study, VMS are electronic and often used on roadways to give drivers updates on road conditions or unexpected events). In addition, some studies such as the Harridge and Roozenburg literature review are primarily looking to increase participation in either walking or cycling rather than focusing on the ability of signs to change the route choice behaviour of cyclists or pedestrians.

Differences in the literature

One difference in the case studies that were reviewed is that sharrows can look different even though they advocate for the same thing, which is for cyclists and vehicles to share the road. The Auckland study found that Sharrows influenced cyclists positioning in the road; however the Norway study did not show that cyclists positioning in the road was affected by the sharrows.

Additionally, the techniques that the various studies used to influence or alter cyclist behaviour in each of the studies is different. For example, some of the studies used sharrows to influence the positioning of cyclists on the road, the Wardman study used standing VMS signs and the case study in Ottawa used a combination of sharrow road markings and text painted on the road. Additionally, some studies such as the Hochimar and Cycle tourism study looked at cyclists that are not familiar with their surroundings.

After reviewing related literature the most striking observation was that there is very little information available on the topic of wayfinding signs for cyclists, in particular the ability for bike wayfinding signs to influence the route choices of cyclists. This gap in the literature underlies the importance of the BDE Project which provides a practical evaluation of the effectiveness of bike wayfinding signs. Despite the limited amount of information available on bike wayfinding signage, similar studies looking at sharrows, pedestrians and vehicles were available. The BDE Project is needed by the academic and professional community as academic literature and best practice guides agree that bicycle wayfinding is a necessary component to have on a world class cycling network, yet there is minimal information available on the ability of bicycle wayfinding signs to alter cyclists behaviour.

Methodology

The BDE Project involved manual bike counts to determine the effectiveness of bike wayfinding signage. The counts were conducted before and after the bicycle wayfinding signs were installed on March 11, 2019. The before implementation counts took place from October 10th, 2018 through November 20th, 2018. The after implementation counts took place from March 12, 2019 to March 21, 2019. Bike counts were conducted at three divergent sites. The divergent sites are road intersections where cyclists have the choice of turning into the PPZ or continuing on the road that runs parallel to the PPZ. The three divergent sites are the intersection of:

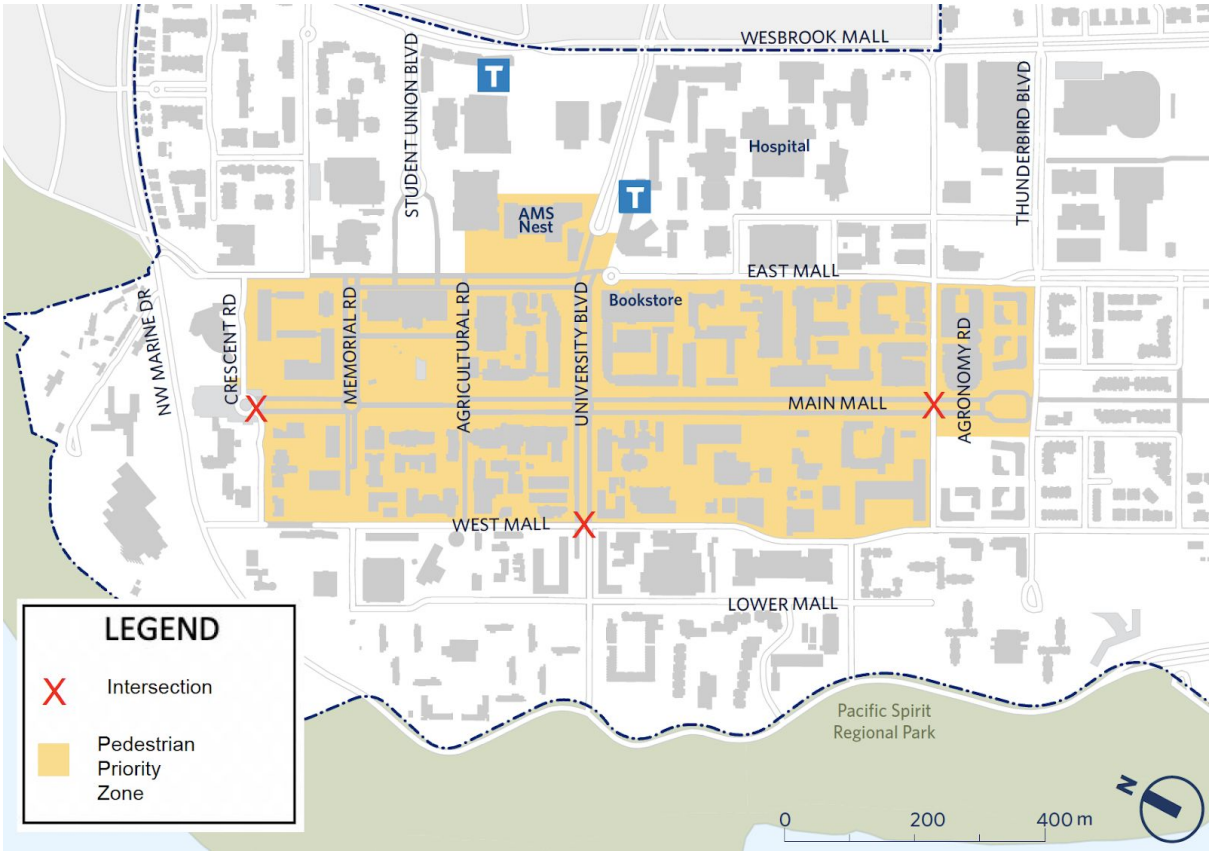
- Agronomy Road & Main Mall,
- West Mall & University Boulevard, and
- Crescent Road & Main Mall. (See Figure 3)

Only cyclists travelling along the adjacent road, in either direction, are counted during the bike counts. For all three intersections, cyclist are not counted who:

- Approached the intersections from within the PPZ as they do not have the choice of turning into the PPZ or continuing away from the PPZ,
- Approached the Agronomy Rd. intersection from Main Mall
- Approached the West Mall intersection from University Blvd.

This is done to ensure the consistency of the study as there will be no wayfinding sign that targets cyclists approaching the PPZ from Main Mall. Cyclists travelling on Agronomy Rd. and on West Mall (both parallel to the PPZ) that turn away from the PPZ are not counted. Finally, approaching the Crescent Rd. intersection from Main Mall is not possible since Main Mall ends at the Crescent Rd. intersection.

Figure 3. Shows the location of all the intersections/divergent points where the data was collected.



Noting the use of DropBike is intended to examine the uptake of DropBikes on the UBC Vancouver campus. An example of the chart that was used to collect the data is shown in Figure 4.

Figure 4. An example of the chart used to manually tally cyclists.

Date: Location: Start Time: End Time: Temperature (°C): Expected Daily Precipitation (mm):	Not using DropBike	Using DropBike
Cyclists **continuing** on Agronomy Rd. (Away from PPZ)		
Cyclists **turning** onto Main Mall (into the PPZ)		

Bike counts were conducted in the UBC winter term leading up to the implementation of the wayfinding signs, until the number of observations from all three sites combined to

reach at least 1000. The bike counts took place on weekdays (Monday-Friday) during the hours of 7:30 am and 2:30 pm as these are the most common times for cyclists to commute to and within the PPZ. After 2:30pm the number of cyclists within the PPZ decreases therefore reducing the likelihood of pedestrian-cyclist conflicts. Additionally, after 2:30pm the majority of cyclists within the PPZ begin to commute away from campus using Main Mall or University Blvd, instead of the adjacent roads meaning that they are not counted in the BDE Project. To ensure the consistency of bike count data, bike counts only occured during weekdays when regular classes were in session. No bike counts were conducted on Weekends, holidays or during exam period as these times are not representative of typical conditions on the UBC Vancouver campus.

The majority of the bike counts took place in 20-30 minute increments so that the counts covered the busy inter-class trip times when the pedestrian-cyclist conflicts are most likely to occur due to the high volume of pedestrians and cyclists in the PPZ at the same time. Additionally, counting in 20-30 minute intervals during inter-class times allowed the bike counter to rotate locations while maximizing the number of observations. Slight variations in bike count duration do not impact the BDE Project as the length of time that is spent counting is not important, the decisions that the cyclists make is the most important information to capture.

The bike counts were only conducted on 'fair weather' days. Fair weather days were considered to be days with 5mm or less expected rainfall and where the air temperature during the time of the counts is always 5^{o}C or greater. As shown in the study done by Bocker and Thorsson, days with precipitation greater than 5mm have negative effects on the number of cyclists (Bocker and Thorsson, 2014, p.474). The Bocker and Thorsson study also shows "bell-shaped effects for the thermal variables…..which flattens out on the lower extreme." (Bocker and Thorsson, p.474). For this reason, data was not be collected when the air temperature was less than 5^{o}C as the Bocker and Thorsson study shows that bike use is significantly reduced when the air temperature is below 5^{o}C. Capturing cyclists in less favourable conditions may not be representative of the typical cyclist that bikes on the UBC Vancouver campus.

Determining if the scheduled data collection day will be a fair weather day (and therefore acceptable for conducting a bike count) were be determined 48 hours before collecting the data by checking the 7-day Weather Network Forecast for Vancouver (The Forecast) (The Weather Network, n.d.) The Forecast shows the anticipated temperature and predicted amount of rain in a 24 hour period.

Sample size for bike counts was estimated at approximately 40 cyclists per hour, per location at UBC. Estimated sample size per hour was based on the *Fall 2016 UBC Transportation Status Report* and data observation testing. The Status Report documented an average of 1300 trips to campus per day by bike on the weekdays (Campus and Community Planning, 2017). The assumption was that there are minimal trips to campus late at night and very early in the morning therefore the number of trips to/from campus by bike is averaged over a 7 hour time period. Based on these numbers it was expected that there are approximately 200 cyclists per hour travelling to campus. This number will be split between all the entry points to campus and does not consider trips made between classes that remain on campus. After conducting a trial count, the average hourly cyclists at a given location was 42. Based on these findings and the desire to obtain as many observations as possible, a

call for volunteer counters was put out to the Sustainability Students Network at UBC to obtain additional volunteer counters.

The same before implementation counting methods were used to conduct counts after implementation. While the timing for the after implementation counts does not allow riders much time to become aware of the signs and potential modify their behaviour, it did ensure that external influencers such as changes to the weather and school schedules do not become a factor. These counts were also conducted on weekdays between 7:30am to 2:30pm with an effort to ensure similar weather to pre-implementation counts.

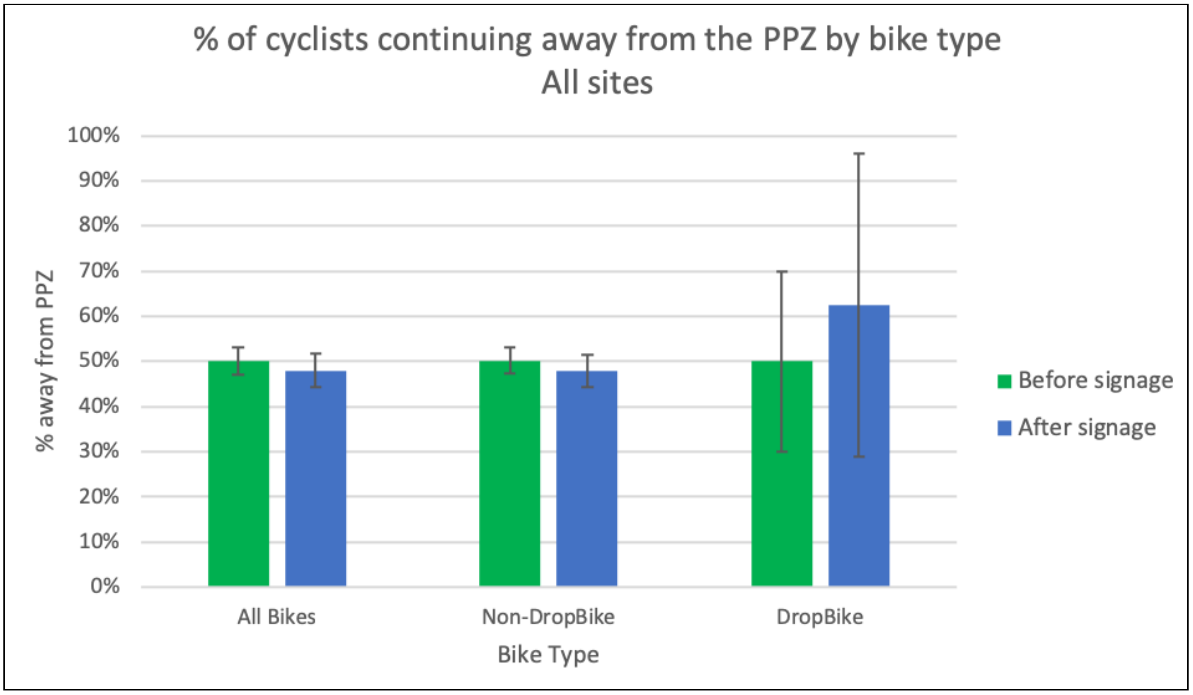
Results

In total, 1092 cyclists were observed before implementation of the wayfinding signs at the three intersections including 463 observations at the Agronomy Rd. intersection, 492 observations at the West Mall intersection and 137 observations at the Crescent Rd. intersection. The percentage of cyclists continuing to bike away from the PPZ before implementation of the bike wayfinding signs is as follows: 36.5% at the Agronomy Rd. intersection, 67.3% at the West Mall intersection and 35.0% at the Crescent Rd. intersection. The breakdown between non-DropBike riders and DropBike riders can be found in the Appendix.

After implementation of the wayfinding signs a total of 742 cyclists were observed including 343 observations at the Agronomy Rd. intersection, 344 observations at the West Mall intersection and 55 observations at the Crescent Rd. intersection. The percentage of cyclists continuing to bike away from the PPZ after implementation of the bike wayfinding signs is as follows: 39.4% at the Agronomy Rd. intersection, 59.0% at the West Mall intersection and 32.7% at the Crescent Rd. intersection. These numbers are further broken down to distinguish between non-DropBike riders and DropBike riders and can be found in Appendix 2. The data table in Appendix 1 shows that despite changes in the percentage of cyclists continuing away from the PPZ, given the margin of error, none of the sites showed a significant difference in the percent of cyclists biking away from the PPZ when comparing the data from before and after the wayfinding signs were implemented. Figure 5 shows an example of the wayfinding signs that were implemented on the UBC Vancouver campus.

Figure 5. Two examples of the wayfinding signs implemented near the PPZ. The left image is Crescent Rd. facing East, the image on the right is facing West on Agronomy Rd.

Figure 6. Compares the before and after data to show the percentage of cyclists continuing away from the PPZ for all types of bikes across all sites. See Appendix 2 for charts at each site.



When looking at all of the sites combined, the percentage of cyclists continuing away from the PPZ before implementation of the wayfinding signs was 50.2% with a 3.0% margin of error. After implementation of the wayfinding signs it was found that 48.0% of cyclists continued away from the PPZ with a 3.6% margin of error. Given the margin of error for the before and after numbers, the BDE Project cannot confidently conclude that there is a significant difference between the numbers. As a result, the BDE Project cannot confidently conclude that the wayfinding signs have an effect on the route choice selection of cyclists.

Discussion and Limitations of the BDE Project

During the after implementation counting phase, the BDE Project tried to ensure that the conditions when counting were as similar as possible to the before implementation conditions.

In both the before and after implementation counting phases the temperatures ranged from 5ºC to 14ºC; however, the average temperature during the after implementation counting phase was approximately 1ºC warmer when compared to the before implementation counting phase. This temperature difference is unlikely to have significantly impacted the results of the BDE Project.

The counts always took place between the hours of 7:30 and 14:30 on weekdays with an emphasis on capturing data during the 10 minute period when the majority of students change classes. On Monday, Wednesday and Friday most classes change every hour and on Tuesday and Thursday classes typically change every 1.5 hours. Timing of counting and day of the week was always within the parameters described in the Methodology; however, there was variation on the amount of data that was collected on any given day of the week. The reason for the variation is that the class schedule of the lead researcher and volunteers impacted when data could be collected. Despite the slight variation of the times and days that data was collected it remains unlikely that the Results would be significantly affected as time is not what was being studied, it is the route choice behaviours of cyclists that was looked at.

Lastly, precipitation was controlled for as counting would not be scheduled on days where the expected rainfall 48hours in advance exceeded 5mm. Data for this study was only collected across three days (two before, one after) where there was any expected precipitation and the expected precipitation was never over 2mm. Due to the infrequent and small proportion of data that was collected on days with any amount of precipitation it is unlikely that precipitation significantly impacted the results of the BDE Project.

In addition to the data in the Results section of the BDE Project, many qualitative observations were made during the before and after bike counting phases that could help inform future studies or explain why the impact of the wayfinding signs did not produce a significant change to the percentage of cyclists continuing to bike away from the PPZ.

The first observation is that there were large numbers of cyclists already biking in the PPZ and approaching the studied intersections from within the PPZ that did not enter the PPZ from one of the three studied intersections. This shows that there are other intersections where cyclists are entering the PPZ. Additionally, the bike racks located within the PPZ are well utilized suggesting that once cyclists enter the PPZ, they will remain in the PPZ for more than one trip.

At the West Mall intersection there are a number of people that approach the PPZ from University Blvd. and although they are not counted the majority of these cyclists choose to enter the PPZ instead of turning left or right onto West Mall. Another observation at the West Mall intersection is that the majority of cyclists approaching the intersection from the PPZ continue straight through onto University Blvd. instead of turning onto West Mall.

At the Agronomy Rd. intersection (Like at the West Mall intersection) the majority of the cyclists approaching the PPZ from Main Mall choose to continue into the PPZ instead of turning right or left onto Agronomy Rd.

Another observation across all intersections is that the cyclists who appear more confident and prepared (cyclists with a helmet and bike specific gear) are more likely to continue away from the PPZ whereas the less confident cyclists will more often turn into the PPZ. This could mean that a reason some cyclists don't use the adjacent roads is because there is nothing to separate themselves from the cars and they don't feel safe. This is important to note in the BDE Project as the wayfinding signs are not making the road any safer through physical changes to the roadway and therefore unlikely to change the behaviour of cyclists who feel unsafe cycling amongst vehicles.

There are six limitations identified in the BDE Project that could be responsible for the results of the before and after counts not being statistically different.

The 1st limitation of the BDE Project is the design and placement of the wayfinding signs. Sign design was not within the scope of the BDE Project; however, there are some aspects of the signs that may be responsible for the lack of change in the route choice behaviour of cyclists. The font is so small that the majority of cyclists will likely need to stop and get off their bikes in order to property read the sign. Additionally, the wayfinding signs are located high off the ground and therefore do not appear in the natural viewpoint for most cyclists. Another potential issue is that the wayfinding signs are often located on the same poll as signs that are not directed at cyclists. This can potentially be confusing to cyclists or reduce the likelihood that the signs are viewed at all. One more limitation of the wayfinding sign is that the sign shows directional arrows and distance to various buildings; however, these buildings may not be the final destinations cyclists want to arrive at and may cause cyclists to completely disregard the sign.

The final issue of the wayfinding signs is that they are not consistently located in the same place at each of the intersections so cyclists are not able to anticipate seeing a wayfinding sign. For example, in some locations the wayfinding signs are located above a stop sign immediately before the intersection and sometimes the wayfinding signs are set at least 20 feet back from the intersection and located on a different sign post. There is no better example of this that at the West Mall intersection as the sign on the North side of the intersection is located above the stop sign at the intersection and the sign on the South side of the intersection, is located on a lamp post at least 20ft away from the intersection (see Figure 7). Indeed during the manual counts one of the volunteers did not notice the sign and asked that the sign be pointed out so that they knew what it looked like.

Figure 7. Inconsistent signage locations at the West Mall intersection.

The 2nd major limitation of this study is the lack of time for cyclists to become aware of the wayfinding signs in advance of the after implementation counts. Due to unforeseen delays the last sign was installed on March 11, 2019. In order to do after implementation counts before the end of regularly scheduled classes, counting began the following day. The importance of counting before the end of regularly scheduled classes is so that the data remains consistent before and after the wayfinding signs are implemented and because after regularly scheduled classes end the majority of students are not on campus consistently therefore reducing the population of the PPZ and the likelihood of conflicts between pedestrians and cyclists. The BDE Project looked to capture data in the busiest times on campus as these times are when the majority of pedestrian-cyclists conflicts are likely to occur.

The 3rd limitation of the BDE Project is that there are classes located within the PPZ. With bike parking near buildings within the PPZ, cyclists need to enter the PPZ at some location in order to park their bike. Additionally, some cyclists may choose to commute between classes without leaving the PPZ and the BDE Project does not measure cyclists that make multiple trips within the PPZ.

The 4th limitation of the BDE Project is the class schedule of the lead researcher and volunteer data counters. Due to this scheduling, counts were not done at the exact same time during the before and after counting phases. Additionally, the schedules of the cyclists on campus are also likely to change as the counts were conducted in different terms and students often have a different class schedule between terms making it likely that route choice preferences are different.

The 5th limitation of the BDE Project is that the final destination of cyclists is unknown. As a result of not knowing the final destination of the cyclists it is unknown if the decision of not to turning into the PPZ is a reasonable choice. For example, it would be

unreasonable to expect a cyclists to bike around the PPZ if the route was considerable longer when compared to the route through the PPZ. Additionally, it is unreasonable to expect that cyclists who have classes within the PPZ will not enter the PPZ at some point, especially when bike racks outside buildings within the PPZ promote cycling.

The 6th limitation is that the BDE Project does not consider cyclists approaching the PPZ while travelling on Main Mall or University Blvd. This to ensure consistency as University Blvd. has a wayfinding sign, but Main Mall does not. Based on qualitative observation, this is a limitation as the majority of cyclists who approached the PPZ from these roads chose to enter the PPZ rather than using roads that run parallel to the PPZ. Therefore it is expected that an even higher percentage of cyclists are entering the PPZ than is shown in the results of the BDE Project.

Recommendations

Based on the results and limitations there are three primary recommendations that should be considered in future bike wayfinding studies on the the UBC Vancouver campus.

1. Conduct a follow-up study next year from October 2019 to November 2019 using the same methodology to see if more time with signs encourages more cyclists to bike around the PPZ. The BDE Project can be easily replicated with potentially minor variations in weather and precipitation if the methodology is followed.
2. Conduct a study that examines the final destinations of cyclists. Given that the bike racks within the PPZ are well occupied, it might be that the location of bike parking is a more important factor in the route choice behaviour of cyclists than suggested routes on bike wayfinding signs.
3. Conduct a study that examines best practices for bike wayfinding sign design. Aspects of this study that should be examined include: overall sign size, text size, sign colour(s), height above ground, distance to the intersection, and directions being signalled on the sign. Once a sign is designed that incorporates all best practices, the BDE Project could be replicated so that the importance of good sign design can be examined.

Conclusion

The BDE Project fills a gap in the literature as it is the only study that evaluates the effectiveness of wayfinding signs at altering the route choice selection of cyclists on a university campus. The related literature broadly suggests that wayfinding signage is effective in changing the behaviour of pedestrians, cyclists or drivers; therefore suggesting that wayfinding signs will be successful in altering cyclist route choice behaviour. However, all of the reviewed articles are unable to determine the effectiveness of wayfinding signage solely targeted at cyclists at altering the route choice behaviour of cyclists. This underscores the importance of the BDE Project to fill a gap in the academic literature on bike wayfinding signage topics.

Many of the studies in the reviewed literature helped to inform the methodology for the BDE Project by showing what worked and did not work with previous studies. One of the key concepts taken from the literature include the importance of comparing data before a

change was made to after the change was made while attempting to keep all other factors the same in order to ensure consistency of results and allow researchers to draw more accurate conclusions.

Results from the BDE Project show that the percent change in cyclists choosing to travel away from the PPZ in the before and after counting period is not significantly different. As a result, the BDE Project cannot confidently conclude that the wayfinding signs have an effect at altering the route choice behaviour of cyclists. Despite this finding it is important to understand that there are a number of limitations that likely contributed to this result. Further studies looking at the design of bike wayfinding signs are recommended and need to be conducted before it can be concluded that all bike wayfinding signs are ineffective at altering the route choice behaviour of cyclists.

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Appendix

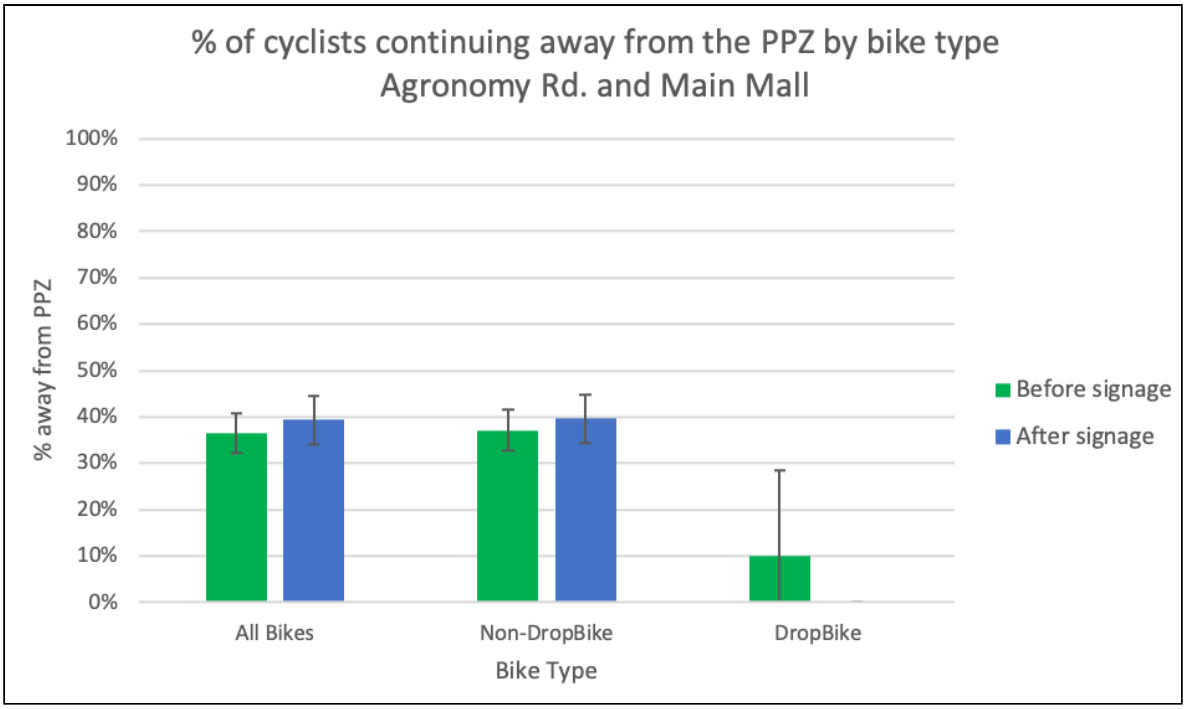
Appendix 1. Data and Analysis

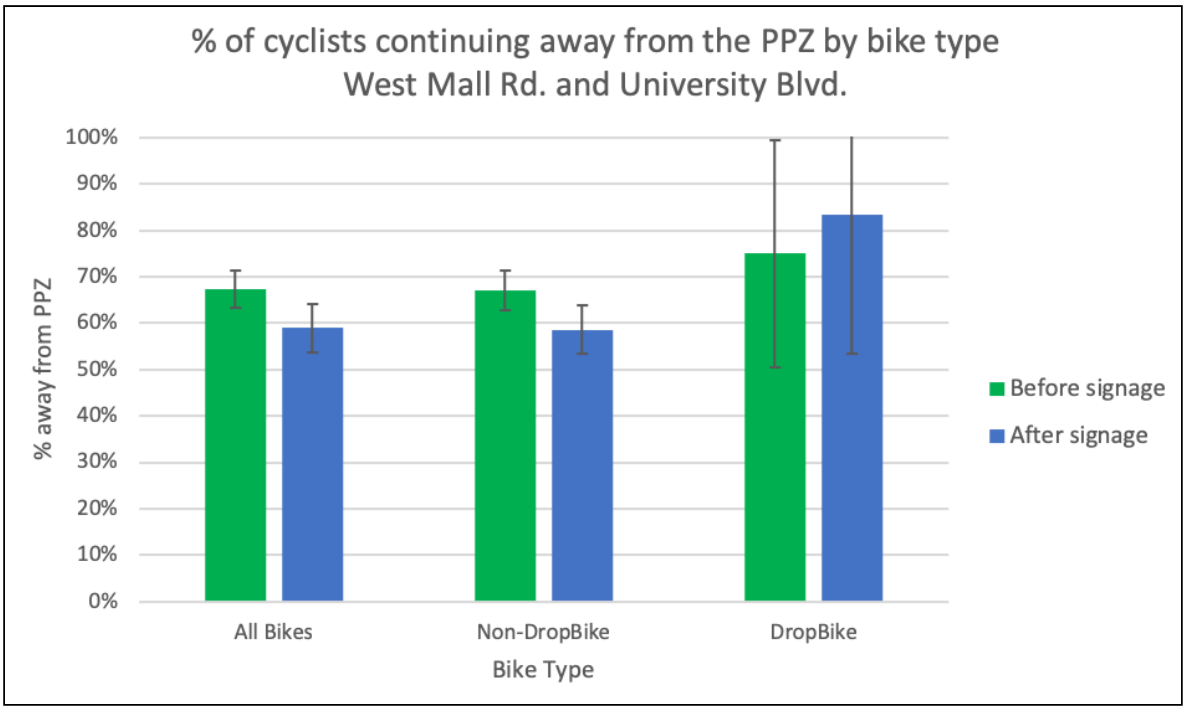
Data Collection

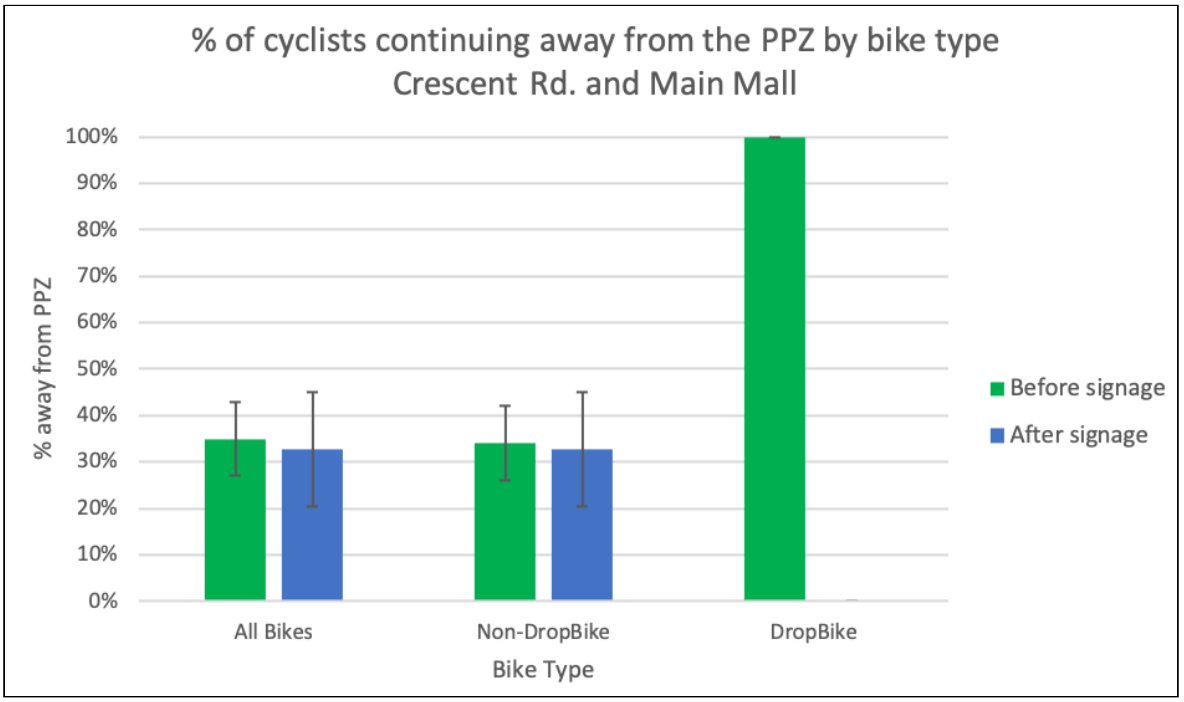
		NDB-AWAY	NDB-IN	DB-AWAY	DB-IN	Total	NDB Total	DB Total
BEFORE	Agronomy	168	285	1	9	463	453	10
	West Mall	322	158	9	3	492	480	12
	Crescent	46	89	2	0	137	135	2
	ALL	536	532	12	12	1092	1068	24
AFTER	Agronomy	135	206	0	2	343	341	2
	West Mall	198	140	5	1	344	338	6
	Crescent	18	37	0	0	55	55	0
	ALL	351	383	5	3	742	734	8

Data Analysis		% Away from PPZ All	% Away from PPZ Non-Dropbike	% Away from PPZ Dropbike	Margin of error All	Margin of error Non-Dropbike	Margin of error Dropbike
Before	Agronomy	36.5%	37.1%	10.0%	4.4%	4.4%	18.6%
	West Mall	67.3%	67.1%	75.0%	4.1%	4.2%	24.5%
	Crescent	35.0%	34.1%	100.0%	8.0%	8.0%	0.0%
	ALL	50.2%	50.2%	50.0%	3.0%	3.0%	20.0%
After	Agronomy	39.4%	39.6%	0.0%	5.2%	5.2%	0.0%
	West Mall	59.0%	58.6%	83.3%	5.2%	5.3%	29.8%
	Crescent	32.7%	32.7%	N/A	12.4%	12.4%	N/A
	ALL	48.0%	47.8%	62.5%	12.4%	12.4%	33.5%

Appendix 2. Graphic representation of data




% of cyclists continuing away from the PPZ by bike type
West Mall Rd. and University Blvd.
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% away from PPZ
All Bikes
Non-DropBike
DropBike
Bike Type
Before signage
After signage


% of cyclists continuing away from the PPZ by bike type
Crescent Rd. and Main Mall
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% away from PPZ
All Bikes
Non-DropBike
DropBike
Bike Type
Before signage
After signage