An Investigation into Accessibility Issues on Campus and the Proposed Solutions

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“An Investigation into Accessibility Issues on Campus and the Proposed Solutions”

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ABSTRACT:

The purpose of this research was to aid Access and Diversity in making a Campus Accessibility Map which would aid students and faculty that live with or without a disability in traversing the campus. People with different disabilities encounter different struggles in their everyday lives, and even without a disability, navigating such a large and diverse campus can be overwhelming with the constant change in infrastructure and layout that UBC experiences constantly. Therefore, data was collected through the use of a survey distributed to students at UBC, as well as through secondary sources such as articles and textbooks that discuss the difficulties those living with a disability face in terms of navigating through areas of inaccessibility.

The two main disabilities that were tackled were visual and mobility impairments, simply because these disabilities had the most amount of research readily available, and because brainstorming led to the most interesting solutions when focusing on these disabilities. The main difficulties visually impaired people have is having a hard time navigating new territory they haven't experienced yet, as well as not being able to see obstacles in front of them as easily as someone with vision can. With UBC's constant construction and changing of routes one can and cannot take, the visually impaired must constantly learn new pathways and deal with uneven terrain when traversing the campus. Those with mobility impairments will often struggle with long distances, or in the case of a wheelchair user, have a hard time with inclines and slopes. Once again, uneven and gravel terrain due to construction and an ever-changing landscape also poses a challenge to the mobility impaired.

The solutions proposed are two phone applications which provide real time data on construction and elevation changes to aid those with mobility impairments, and a method of creating braille maps for the visually impaired to use. The phone applications use data collected from Google Maps and UBC's Campus + Planning website to map out the alternative routes created to bypass construction, and to find the routes that allow for the least amount of distance and elevation gain to minimize the difficulty of traveling long, difficult distances for the mobility impaired. The braille map is a method of using 3D printing or raised braille paper to produce physical copies of maps that can be mounted in specific locations on campus or printed for visual impaired individuals to carry with them. It should also be noted that during the research into finding solutions to the accessibility issues on campus, a handful of easy fixes that can be done cheaply and quickly to greatly improve cracks and tripping hazards from uneven ground were also found, and so have been included in this report as an alternate means of increasing accessibility to students, even though the solution is not in the form of a map.

By the end of this report, the conclusion that a mobile application that can be updated instantly and maintained at a very low cost was decided to be the best way to implement the accessibility map, due to the fact that most users are students who use these smartphones and so the largest amount of people can be benefitted through this method.

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SECTION 1.0 INTRODUCTION

The purpose of our project is to investigate the locations of greatest inaccessibility on campus based on the opinions of students and residents of the university. These accessibility issues can range from difficulties navigating through certain buildings due to ambiguous maps and signs, to difficulties traversing to the bus loop due to congestion caused by construction, to having problems accessing certain buildings in a wheelchair due to a lack of properly designed ramps. An online survey was conducted allowing us to collect data on the locations that had the greatest issues with accessibility and the individual responses as to what made these hotspots difficult to traverse. Moreover, we began to research secondary sources, such as articles, journals, and papers, on the challenges that people who are physically or visually impaired face when it comes to traveling from one place to another.

Figure 1: The two disabilities we focused on were visual and mobility impairments

This report summarizes the data we collected using the methods described above and outlines the potential solutions we have to each of the problems. Solutions include a breakdown of the social, economic, and environmental effects, as well as the advantages and disadvantages each recommendation has. Finally, we conclude our report with a summary of our recommendations and a verdict on which solution is the most viable under the accessibility issues we have proposed.

SECTION 2.0 INVESTIGATION METHODS

Before determining solutions for the Campus Accessibility Map, we gathered data from students on campus as well as from textbooks and articles. Our primary source of information on where the 'hot-spots' of inaccessibility were came from a Google Survey which asked students on campus that may or may not have a disability which areas they found the most difficult to traverse, and their reasons for their perceived challenges. Our secondary sources also provided us with information on what challenges people with visual and mobility impairments have, and the current efforts made to alleviate these issues with regards to maps and transportation.

SECTION 2.1 PRIMARY SOURCES

Our primary sources came from conducting an online survey which was distributed to students attending UBC via Facebook and e-mail. The survey targeted those who may or may not have a disability and collected information on six main areas between Wesbrook Mall and West Mall, as can be seen in Figure 2 below. These areas were selected due to the fact that the majority of classes are found within these areas, and so students visit them the most frequently. The survey asked where students found to be the most difficult areas to access and why they found these areas difficult to traverse.

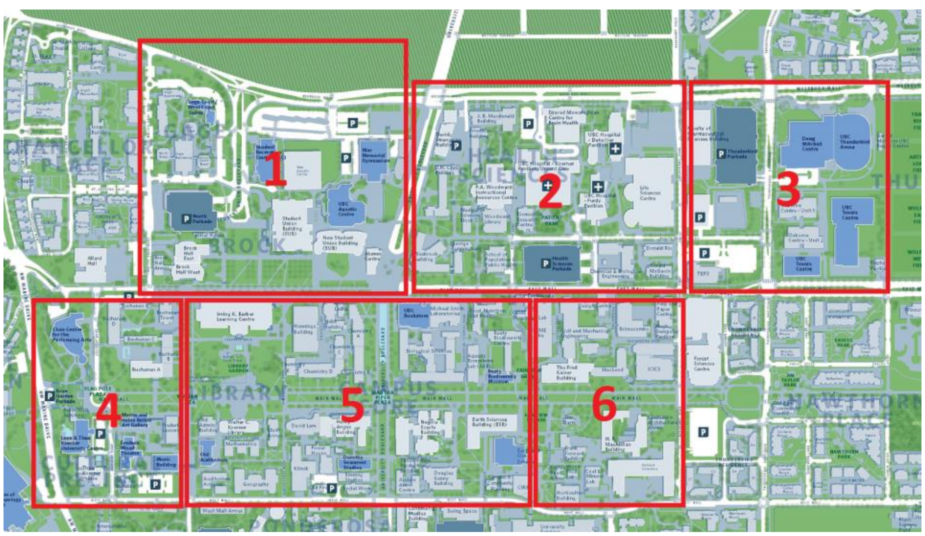

Figure 2: Overview of the six areas selected to be surveyed

As of April 6, 2016, we have collected a total of 17 responses from students that have no disabilities that express a huge lack of accessibility near the main bus loop and old Student Union Building due to the immense amount of construction in that area. The main reason for this area being of greatest concern is due to the fact that there is a large amount of construction that has taken place so close to the bus loop which already has a high volume of students throughout the day. This construction was first a result of the new Student Union Building being built, and is now from the new Aquatic Centre being built. The construction adds to the gridlock experienced because it limits the potential paths available for students to get to Main Mall.

Other areas of the campus did not seem to be on much concern to these 17 respondents, and unfortunately, we have not received any responses from the students apart of Access and Diversity yet. However, this survey has allowed us to find where the most major area of inaccessibility is to the common student.

This survey also served as a type of social indicator that would help guide our recommendations and solutions. By understanding the actual needs of students, we were able to come up with solutions that would target their particular priorities, instead of creating recommendations solely based on speculation of what students would want.

SECTION 2.2 SECONDARY SOURCES

Source: UBC Campus and Community Planning - Construction + Detours

This page on the UBC website provided us with information on the current and future construction projects taking place on the UBC campus. The page provides a map that is updated weekly, showing road closures, active construction projects, and upcoming work areas, for use by the UBC community. Furthermore, the page provides suggested detours, along with maps showing these routes, in order for the community to easily navigate the construction sites in a safe and accessible way. The data from this page showed us exactly where the hotspots of inaccessibility on campus related to construction are, as well as detours to avoid these areas. This data was useful for solutions involving mobility impairments, and is further discussed in section 5.2. (Construction + Detours, 2016).

Source: Map Application for People with Disabilities Using Smart Devices

This source is a study done by researchers Soo-Jin Lee and Yang-Won Lee, who develop a map application for a smart device that can be used by physically challenged people who experience difficulty interacting with a standard user interface for a map application. The application that they designed integrates voice commands and gestures into map software that allows users to interact with the software in an unconventional yet functional way. The study proved to provide individuals with upper limb disabilities such as hand tremors and amputations, with help in interacting with map software that is meant to improve accessibility. This study highlights the importance of including disabled people in the development of software that is meant to provide accessibility. (Lee & Lee, 2013)

Source: How 3D-Printed Maps Are Helping the Blind and Visually Impaired

This article describes how Students of Rutgers University look into developing 3D printed maps and discover its potential for the visually impaired. The map explicitly outlines the interior of a building and highlights the details necessary for the visually impaired. Such details include “uneven surfaces and hills to make the map more helpful during weather-related evacuations”. Further details consist of grid lines for scaling purposes, varied heights and textures corresponding to the different topography, and a marked corner to ensure proper orientation. The developed product demonstrates a viable solution for accessibility for the visually impaired. (Poon, 2016)

SECTION 3.0 CAMPUS ACCESSIBILITY ISSUES

The three main questions we considered when investigating this project are as follows:

- What are the key 'hot-spots; of (in)accessibility problems on campus?
- What are the most common accessibility problems being faced by students?
- What connections are missing currently on campus to promote accessibility more efficiently?

From the results of our survey, it was apparent that one of the main reasons certain locations were inaccessible, especially around the bus loop and Student Union Buildings, was due to the ongoing construction on campus. This issue is critical since it affects everyone on campus, especially those with disabilities, as they are forced to find an alternative routes.

For the physically disabled that have mobility impairments, these alternative routes often result in the duration of their trip around campus being increased which poses great difficulties since their mobility is already weakened due to their own handicap. Though walkways aren't always closed off due to construction, the work in progress means that walkways will have uneven terrain and changes in slope which they may find difficult to pass through.

In addition, the change in the environment caused by construction becomes a problem for the visually impaired. Visually impaired people must memorize detailed mapping of a location through somesthetic senses or they may rely on auditory senses to guide their path. Changing environments means that they will have to relearn and cope with the new adjustments. Loud noises made by constructions makes it troublesome for the visually impaired to listen to their surroundings and inconsistent road texture generates unfamiliarity which is detrimental to them.

Since construction occurs frequently, this imposes another issue regarding real-time updates of the ongoing construction. The implemented solution should be able to update or be maintained with as much ease as possible. Methods of retrieving this data on any structural changes on campus or if there is construction going on at a particular location is another issue we must look into.

The last issue that we looked into was the optimal platform for mapping. While a physical platform of the map is relatively simple to implement compared to a digital platform, a digital platform would reach a wider range of students, and its ability to update quickly with low cost is appealing when analyzing the triple bottom line of this solution. The two options will be compared through our solutions, and a conclusion as to what the best one is will be drawn.

SECTION 4.0 SOCIAL, ECONOMIC, AND ENVIRONMENTAL INDICATORS

The greatest method of measuring the social impact of our projects is through the surveying of students both before and after a solution is implemented. By basing some of our recommendations off the data collected in our survey, we were able to recognize that construction was a major issue for a lot of students, and as shall be seen, many of our solutions below target this specific issue. With this survey, we are able to gear our solutions to the needs of the students and faculty on campus, and so it is an effective way of estimating and measuring the social impact our solutions will have. Of course, to ultimately determine the true social effects each solution will have, students should be surveyed on each solution, both before and after its implementation.

The economic impact of our solutions will be measured through the cost of each solution. The budget UBC has to implement each recommendation depends largely on how beneficial the university sees each solution, with more funding often times being provided to the solutions that affect the most amount of people. With this in mind, it is ideal to keep our solutions cheap, while also affect as many people as possible to maximize the funding that can be acquired. The ratio of how many people can benefit from each solution to the cost of the solution will be a very strong mathematical way of measuring the economic success of our recommendations.

Finally, the environmental impact each solution has can be determined by looking at what products and resources it takes to make each solution, and the waste that may be generated from its use. As shall be seen in the solutions below, some recommendations have a strong economic impact in that they are cheap to implement, but suffer environmentally due to the waste they would produce. Thus, the balance between all of these indicators must be taken into account when designing each solution, and when picking the best option available.

SECTION 5.0 POTENTIAL SOLUTIONS

SECTION 5.1 SOLUTIONS FOR THE MOBILITY IMPAIRED

Traversing across campus is strenuous for the mobility impaired. Improperly cut curbs, uneven surface, cracks on walkways, and steepness of a path all makes it even more difficult for the mobility impaired to roam around. The following solutions are intended to mitigate these issues that the mobility impaired face on a day-to-day basis.

SECTION 5.1.1 Elevation Data Using Google Maps

When dealing with the problems people with mobility impairments have, it was important to find routes on campus that were both short and had very little elevation gain. The latter was especially important when dealing with wheelchair users, as even a minor incline for a long distance, or a major incline for a short distance, could prove to make their travel route significantly more challenging.

To solve this particular issue, we recommend the combination of data collected from Google Maps, seen in Figure 3, and the integration of software which calculates the minimum of the product of distance travelled and elevation changes experienced. Google will always provide the fastest route possible when picking a starting and ending point, which also takes into account the elevation changes the user would experience along this path. This elevation information is accessible when selecting the bicycle option when choosing your mode of transportation on Google maps. However, this information on the quickest route is calculated using the data from all users of the app, and thus shows the quickest path for the average user. Slight elevation changes affect people with no mobility impairments very little, and so Google is incapable of taking into account the quickest path for users that would struggle significantly from these minor elevation changes. Therefore, software should incorporate a program that mathematically determines the quickest path that takes into account both distance and elevation changes. This would specifically target and aid those with mobility impairments on campus.

Pros:

- Data is easily accessible and accurate through Google Maps
- As an application, many users can use it at once with very little cost to upkeep it
- Changes can be made instantaneously

Cons:

- Those who are less tech savvy may struggle with using the application
- The software must be developed before use

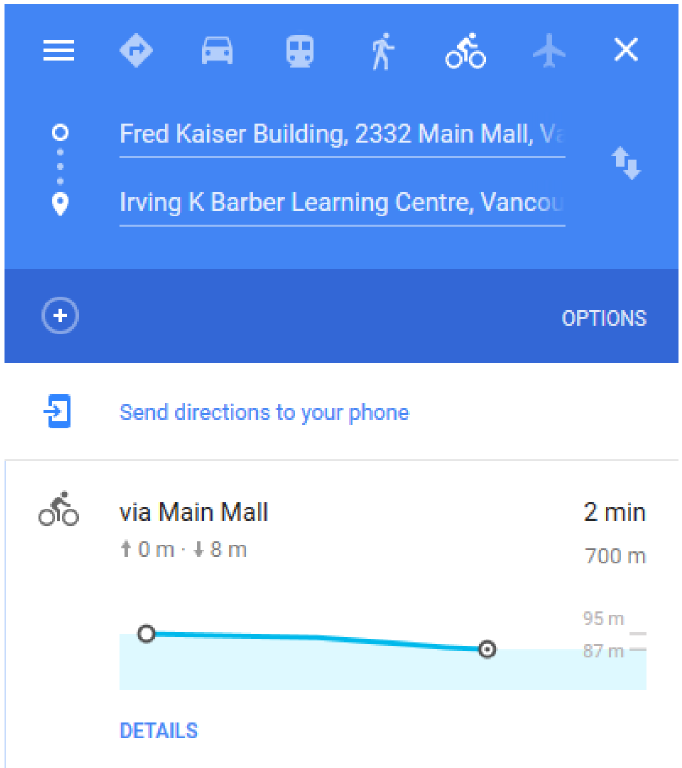

Figure 3: Elevation data seen in Google Maps.

SECTION 5.1.2 Campus Construction Map Smartphone Application

A fundamental factor in accessibility for people with mobility impairments is the familiarity which they have with their environment. It is essential for the mobility impaired to plan routes that they can be sure will be clear and easy to navigate, to ensure that their travel time will not be extended due to some unforeseen circumstance. The most common example of such a circumstance is construction, especially on a university campus such as UBC, where construction is constantly changing the landscape and interfering with students' navigation of the campus. Often, construction will cause students to take long detours around a site, or cause a previously clear path to become obstructed by uneven surfaces, equipment, or workers.

Solving this issue seems like a difficult task at first, as it would require documentation of every ongoing construction project on campus, as well as planning accurate detours around each project. However, UBC's Campus + Community Planning section of their website has all of this information available for the UBC community to use. The site has a map of ongoing construction projects that is updated weekly, and includes suggested pedestrian and cyclist detours. The site also has a construction schedule showing future construction projects and completion dates for current projects.

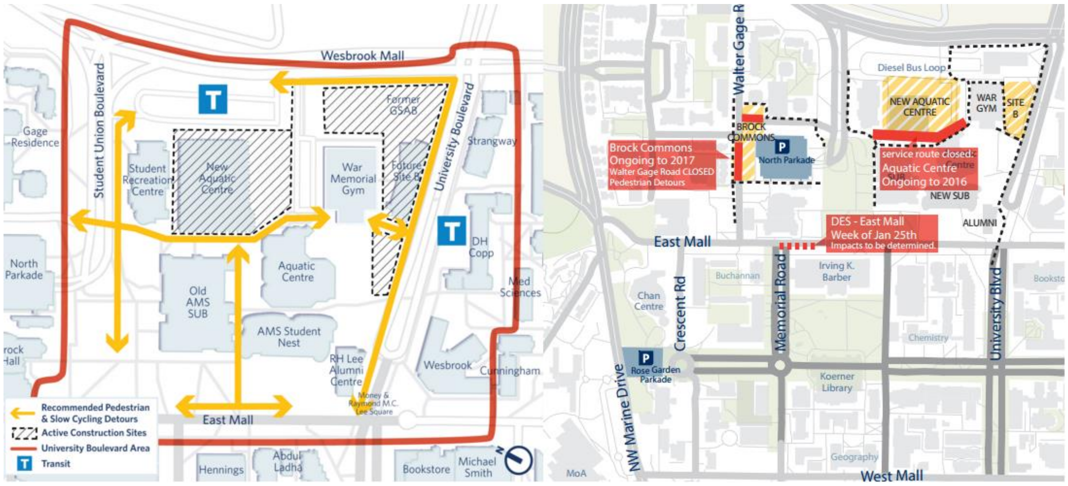

Figure 4: Detours (left) and Ongoing Construction Projects (right)

The first step in creating a solution for the issue of construction for the mobility impaired could be to integrate the data presented on UBC's website into a smartphone application that allows the user quick and easy access to see the obstructions that they will encounter on their route. The problem with the presentation of the data on UBC's website is that it is tedious to access, and does not organize the data in a way that is specific to a single person's route. For the phone application to be effective, it would have to be able to allow a user to input their route, and have the app tell the user exactly where they will encounter any planned construction, while showing any possible detours at the same time. This idea could also correlate to the inaccessibility hotspot map of data derived from the survey, to show all areas of accessibility on campus, and take them into account when planning a route. Furthermore, this idea could also include data from section 5.1.1, taking into account elevation and travel distance to provide the user with the fastest, most accessible route to any point on campus.

A somewhat similar smartphone application was designed by David Biddle, called LDN Access (Marcus, 2013), which stores routes, obstacles, and ramps around London that are accessible to individuals with mobility impairments. The system uses GPS for guidance, and the app designer highlights its ease of use which is simply icon touch based, making it ergonomic for a wide user base. This brings up another factor that is important when designing a smartphone application that is able to service users with disabilities - the interaction between the user and the application itself. Amputees or individuals who experience hand tremors have great difficulty interacting with map applications, essentially rendering the program inaccessible. In a 2013 study of map applications for people with disabilities, researchers developed an app that incorporated voice and gesture functions as a way to circumvent this issue (Lee & Lee, 2013). Such function would be an important consideration in the design of a campus construction map smartphone application.

Pros:

- Effective for disabled users who have to plan a route to class that is accessible and clear
- Useful for general users for planning routes on campus
- All necessary information is available on UBC website

Cons:

- Requires development of software that incorporates data from the UBC site
- Requires user familiarity with and ownership of a smartphone device
- Requires ability to operate a smartphone device

SECTION 5.2 SOLUTIONS FOR THE VISUALLY IMPAIRED

People that are visually impaired can have a difficult time self-navigating around campus. As a matter of fact, physical movement is one of their difficult challenges and so they are often accompanied by a friend or a family member to help navigate around unfamiliar environment. In addition, blind people must learn the details of their surroundings and so a changing environment poses further complications. They can still maneuver around by the change in texture of the surface they walk on; hence how they can tell if they reached a checkpoint prior to their destination. The following sections intend to help alleviate the problems that blind people face when moving around the campus.

SECTION 5.2.1 Tactile and Braille Campus Map

As blind people regularly rely on memorizing the details of their surroundings, the current campus accessibility map can be improved to take the visually impaired into consideration. Accessibility map around the campus can incorporate a 3D outline and braille printing. This allows a visually impaired person to interact with the map, helping them become more orientated of their environment and plan their routes. Current applications of this solution are already under development by universities such as Rutgers University (Poon, 2016). In addition, there exist Touch Mapper which focuses on the development of 3D printed maps for the visually impaired. A custom 3D printable map which can be obtained through google map will allow for easy setup if this solution is implemented.

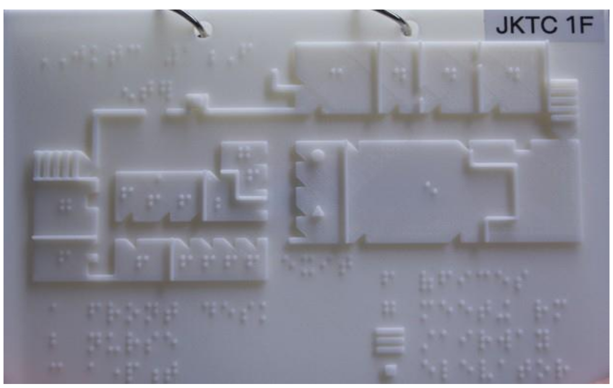

Figure 5: 3D printed map that outlines the interior of a building.

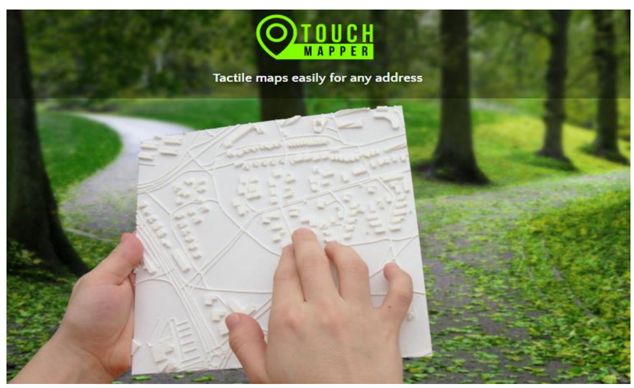

Figure 6: Touch Mappers allows one to input the desired address of a location which will output a 3D printable file.

Pros:

- Enhances details of an environment, benefiting those that are visually impaired
- Exterior locations can easily be 3D mapped with Touch Mapper
- Durable compared to digital mapping

Cons:

- Requires additional cost to update or renovate the existing maps around campus
- Interior locations (i.e buildings) will require one to custom design the map of the interior

SECTION 5.2.2 Portable Braille Map

Following a similar idea to the previous subsection 5.2.1, maps can be reduced in size to fit in the hands of a person. Essentially, a specifically designed braille maps that uses similar materials as braille books will be implemented; allowing the user to interact by feeling the texture pattern of braille. This idea promotes portability in which the user can easily carry around the campus and refer back to it anytime.

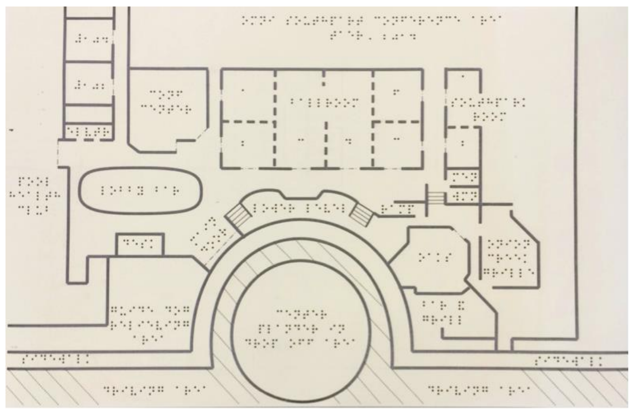

Figure 7: Braille mapping of an interior.

Pros:

- Portable and convenient
- Durable compared to digital mapping
- Will not be as costly to update map due to changing environment compared to static campus map

Cons:

- Contributes to environmental waste
- Only targets the visually impaired audience

It is important to note that the cost of implementing this solution is dependent on the amount of visually impaired people that may prefer to have a portable map on hand.

SECTION 5.3 QUICK FIXES FOR TRIPPING HAZARDS

Accessibility maps provide a general guideline of which route a person can take depending on their mobility preferences, however even the most ideal route can have a couple of small hazards along the way which could not have foreseen on a map. One hazard which affects many people, whether they are impaired or not, is a tripping hazard; this hazard is due to a sudden uneven elevation between adjacent concrete slab or pavement. The following outlines several methods to mitigate the dangers of tripping hazards in order to manage an accessible and safe public sidewalk for all pedestrians.

Figure 8: A pedestrian warning sign near the main entrance of the UBC hospital

SECTION 5.3.1 Ramping and Patching

Ramping and Patching is a technique where a concrete or asphalt material is used to build a ramp from the low slab to the high slab; this helps smoothen the transition between pavements and reduces the likelihood of tripping. This technique is cheaper and faster than replacing the sideway pavements. Often, this is done in a short amount of time when the sidewalk are not occupied (i.e during class sessions, or weekends) to avoid additional obstruction for pedestrians. The main drawback of this technique is the lifespan as this technique is not meant to be a permanent fix; the materials will crumble away over a few months.

Figure 9: An asphalt patch applied to help smooth out the uneven pavements

SECTION 5.3.2 Mudjacking

Another technique is mudjacking which involves drilling a hole through the lower slab and pumping a concrete mixture under pressure below it until it is elevated to the same level of the other slabs. Mudjacking is ideal for stairways and extremely large slabs, usually 20 inch by 20 inch. The cost of mudjacking will depend on the density of the material underneath the lower slab. It can be difficult to bring the elevated slab to exact level. In addition, the hole drilled will crack and crumble over time and the overall process can be labour intensive.

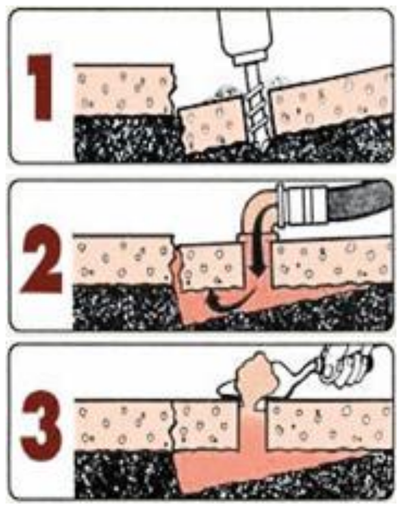

Figure 10: A brief demonstration of mudjacking

SECTION 5.3.3 Grinding and Chipping

Instead of trying to fix the lower slab by raising it, the edge of the higher slab could be chipped away or grinded down. Grinding involves using a specific tool called a grinder, which internally consist of a rotating pounder that can chip and crack away at concrete. It is ideal for small elevation difference between the slabs, usually between ¼ and 1 inch.

The main drawback of grinding is that it consequently weakens the strength and shorten the lifespan of the concrete. Grinding will leave a noticeable scar on the slabs, which may be an aesthetic concern for some. It is also difficult to make the elevation the higher slab exactly the same as the lower slab through grinding. Finally, a replacement teeth for the grinder can be very expensive.

SECTION 5.3.4 Saw Cutting

A favoured approach for dealing with tripping hazards under 2.5 inch is to minimize concrete damage by cutting, rather than grinding or pounding, away the higher elevated slab. Saw cutting is a technique where workers can make a horizontal flush cut on higher slab to remove uneven elevation between concrete without jeopardizing its strength and lifespan.

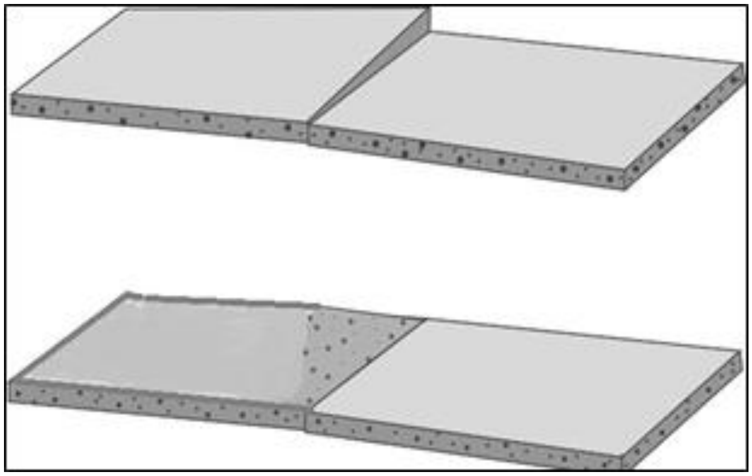

Figure 11: An image overview of saw cutting

Saw cutting is often inexpensive and can be complete within an average of 15 minutes. In addition it the repair can be long lasting for over 6+ years unlike other previous methods. It is also still cost effective when compare to a complete replacement of the sideway. The main drawback is with regards to the scar the butt will leave on the higher pavement.

SECTION 5.3.5 Sidewalk Replacement

When dealing with an elevation difference greater than 2.5 inch it is financially viable to consider a complete replacement. The previous techniques discussed are not suitable for a very high displacement when considering in the cost associated with them. The benefit of a complete sidewalk replacement, aside from having a brand new sidewalk on campus, is the opportunity to allow for the pruning of roots or other potential problems which may have caused the mis-elevation problem in the first place. This technique is the most expensive option out of all, it will be disruptive to pedestrian as they will have to take another route as the sidewalk is being replaced over a long period of time.

Pros:

- These solutions are simple and can make a significant difference in how easy it is for those with mobility impairments traverse
- These solutions target specific, small areas, and so the cost can be kept quite low

Cons:

- With UBC's ever-changing landscape, in may not be worth it to fix certain areas that may change very soon
- Requires tools and expertise in each method to accomplish the task

SECTION 6.0 CONCLUSIONS AND RECOMMENDATIONS

All of the solutions outlined in section 5.0 provide realistic and tangible benefits to the UBC community, and are of worth to consider to improve the accessibility of the UBC campus. However, after taking into account all social, economic, and environmental indicators, the most reasonable and effective solution that UBC could implement is a phone map application for accessibility on campus.

There are several features that are essential for an accessibility map application for the UBC campus to be successful. First and foremost, the app must be able provide GPS tracking and route planning as a basic function, making this application useful for a wide audience of users (not just those with a disability). Second, the app must map ongoing construction projects as well as detours around these projects (Section 5.1.2). Third, the app must be able to provide elevation data regarding the chosen route, in order to ensure that an individual with a mobility impairment will not be taken through a path that they find difficult, or are unable to travel (Section 5.1.1). Finally, the map application should be developed in a manner that makes the user interface accessible to individuals with upper limb disabilities, in order for the solution to truly be accessible to all users.

The social impacts of a smartphone map application for the university campus could be immense. The user base would not be limited to just disabled individuals on campus, as it would be equally as useful for all members of the UBC community, as well as visitors to the UBC campus. By providing construction, detour, elevation, and distance data, users would not only be able to calculate the shortest path to their destination, but also the most accessible. The number of individuals that own a smartphone, and thus would be able to use such a map application, is a strong indicator that this idea could greatly increase accessibility on campus. The economic side of this idea is another indicator that shows it would provide benefits to a large percent of the UBC community without costing the university very much at all. Besides the initial investment of developing the application, the only other cost associated with an app is the necessary updating that it must receive in order to accurately provide route data with the completion of ongoing construction and the addition of new construction projects. Compared with fixing tripping hazards and creation of physical maps for the visually impaired, creating a smartphone application has a much lower ratio of cost to number of individuals that may potentially benefit. Finally, the environmental impact of this application would be essentially zero, as it is entirely software based, and would only expend the energy from the battery of a user’s smartphone.

While an accessibility map can provide a general guideline of which route to take, the actual path could present some unforeseen hazards, such as tripping hazards caused by an uneven elevation difference between two or more concrete slabs. Tripping hazards can endanger a wide range of pedestrians, whether or not they have mobility impairment, as well as resulting in legal actions towards the campus for failure to deal with these hazards. There are several techniques that can be used to resolve tripping hazards on sidewalks, the main one being saw cutting where a horizontal flush cut is made on the high slab to remove its height difference. Saw cutting is ideal for displacements of up to 2.5 inches, before the cost of it becomes comparable with a complete replacement of the sidewalk instead.

REFERENCES

Beneduci, G. (2010, January). How to Remove Sidewalk Trip Hazards on Tight Budgets [PDF]. Los Angeles: Precision Concrete Cutting.

Construction + Detours. (2016). In *Campus + Community Planning.* Retrieved March 25, 2016, from http://planning.ubc.ca/vancouver/transportation/construction-detours

Fulk, T. (n.d.). Trip & Fall Hazards: Remove the Liability of Uneven Walkways [PPT]. Georgia Safe Sidewalks.

Google Surveys. (2016). Accessibility at UBC. Retrieved from: https://docs.google.com/forms/d/18Bzc42UQgamJVYGe7xAjcp MJGYXfmJ811EMc0oSZbk/edit?usp=drive_web

Lee, Soo-Jin, & Lee, Yang-Won (2013). Map Application for People with Disabilities Using Smart Devices. *Proceedings of the World Congress on Engineering and Computer Science, Vol I, 2325.*

Marcus, A., & SpringerLink (Online service). (2013). *Design, User Experience, and Usability. Health, Learning, Playing, Cultural, and Cross-Cultural User Experience: Second International Conference, DUXU 2013, Held as Part of HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013, Proceedings, Part II*. Berlin, Heidelberg: Springer Berlin Heidelberg.