Enhancing Campus Transportation Monitoring

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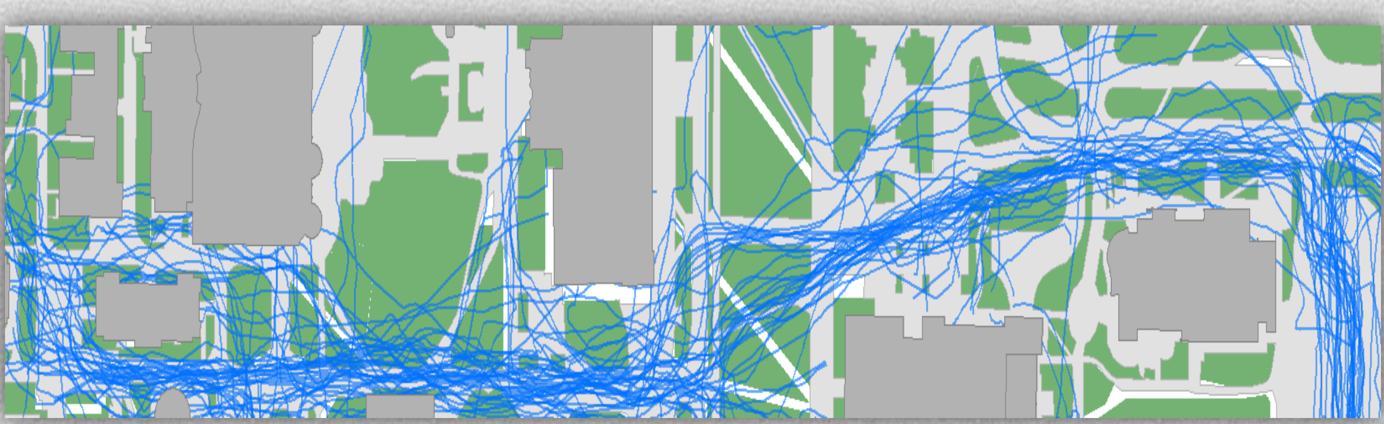
SEEDS Project by David Stonham

A study into the feasibility of using Global Positioning Satellite (GPS) technology to record fine scale human mobility patterns across the University of British Columbia's Vancouver Campus in an effort to inform the design of an on-campus transportation monitoring program.



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Executive Summary

The University of British Columbia (UBC) has been monitoring transportation to and from their Vancouver Point Grey campus since 1997. The data collected has been used to inform planning decisions such as land use and transportation planning decisions. [1]

In October 2014, UBC Campus and Community Planning published a new Transportation Plan for their Vancouver Campus to consolidate and update existing plans such as the 2005 Strategic Transportation Plan. The 2014 Transportation Plan identifies the need for, and commits to developing, a "comprehensive" on-campus transportation monitoring system. Until now, Campus and Community Planning has been reliant on surveys of the campus population to approximate on-campus mobility patterns.

Under the guidance of Campus and Community Planning, through the Social Environmental Economic Development Studies Program, and with funding from the Alma Mater Society's Sustainability Projects Fund, I conducted a pilot study using Global Positioning System (GPS) data loggers to monitor on-campus transportation patterns. By completing this pilot study, I am able to make recommendations to UBC Campus and Community Planning on the feasibility of using GPS technology for on-campus transportation monitoring.

The week-long pilot study, consisting of 10 participants, has collected sufficient data to show the positive and negative aspects of the technology. While I have not conducted the pilot study in a statistically representative manner, some abstractions can still be made from the data that I have collected.

This report concludes with a recommendation that GPS technology does indeed have a place in a comprehensive on-campus transportation monitoring system at UBC's Vancouver campus. I make several cautions as to the fine scale accuracy of the technology and the ease of working with the data, but show that the end product still has the level of detail necessary to inform planning decisions. Finally, I note that the implementation of an exciting new technology such as GPS catches people's attention, which in turn could lead to increased public engagement in sustainability and transportation planning, if the message is well presented.

[1] UBC Campus and Community Planning, (2014), Transportation Plan

Background

In April 2014, I attended the third open house in the public consultation process for the new University of British Columbia (UBC) Transportation Plan at UBC's Vancouver Campus. I talked with Chris Fay, Policy Analyst at UBC Campus and Community Planning, about the new plan. I wanted to know what it meant for the campus and for people who move about the campus on a daily basis. As a Geography student, studying urban sustainability, I was interested in how Campus and Community Planning were planning to justify future planning decisions on-campus, and measure their impact on the overall sustainability of operations at UBC. I was particularly intrigued by their target of promoting sustainable modes of transportation: walking, biking and transit.

Idealizing somewhat, I commented to Chris that it would be useful to have real-time, fine-scale information on where all members of the university community were at any given moment, plotted on some kind of marauders map. While this was perhaps unrealistic, I saw real potential for having fine-scale GPS tracks for a sample of the community over a given time, from which real planning decisions can be made, and from which changes to human mobility patterns and the resulting environmental impact on-campus can be recorded over time.

At a similar time, I became aware of the Social Ecological Economic Development Studies (SEEDS) Program at UBC and was looking to take on new projects that would complement my interests and my major. I had also recently heard about the Alma Mater Society's Sustainability Projects Fund, a source of funding for students carrying out initiatives pursuing sustainability-related projects. The following is a report on my student-initiated SEEDS project that followed.

Literature Review

Since 1997, UBC has measured campus mobility patterns including transit ridership, bicycle and pedestrian and vehicles. A range of methods have been used to collect this data, ranging from manual observation to employing automatic data counters. Measurements have been collected on an annual basis at similar time periods in order to enable appropriate year-to-year comparisons. The scope of data collected, however, has been limited primarily to commuters – how staff, faculty, students and visitors get to and from campus rather than focusing on how people move on-campus.[2]

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[2] UBC Campus and Community Planning, (2014), Transportation Plan

Campus and Community Planning have recently developed a new UBC Transportation Plan. During the Plan's development it became clear that there is limited data about on-campus transportation patterns and behaviours. As a result, the Transportation Plan commits to developing enhanced on-campus transportation monitoring. In particular, the current mode share behaviors are largely unknown regarding how campus community members and visitors move on-campus – whether this is to and from classrooms, workspaces, residences, amenities or recreation services.[3]

The Transportation Plan proposes the following actions for on-campus transportation monitoring:

> *Develop an on-campus transportation monitoring program to complement existing annual monitoring and reporting efforts. Monitoring will include:*
>
> - *Mode share at key locations across campus;*
> - *Speed, volume and mode share at key intersections and along major roads for all modes of transportation;*
> - *Heavy truck origin and destination data; and,*
> - *Transit, cycling and vehicle trip generation in neighbourhoods compared to standard ITE averages.*[4]

Collecting data will allow UBC to better understand campus circulation and mode share, to make targeted investments in its campus transportation network, and to improve campus livability for the entire UBC community.

Within the broader geographical context of Metro Vancouver, there have been several attempts to study human mobility; none, however, have used GPS technology. TransLink, Metro Vancouver's transportation authority, conducted their Trip Diary Survey in 2008 and in 2011. In total, 22,848 households completed the survey providing detailed information such as the time, start and end location, mode and purpose of their trips over a 24 hour, weekday period. One of the goals of the Trip Diary Survey was to "collect statistically reliable data for the purpose of current and future regional transportation and land use planning."[5]

More recently the City of Vancouver implemented a Transportation Panel, a longer term study into the mobility patterns of a cohort of individuals across the city. According to

[3] UBC Campus and Community Planning, (2014), Transportation Plan, p.11
[4] UBC Campus and Community Planning, (2014), Transportation Plan, p.40
[5] Ipsos Reid, for TransLink BC, (2012), 2011 Metro Vancouver Regional Trip Diary Survey – Methodology Report

Steve Brown, former Project Manager for the Transportation 2040 Plan at City of Vancouver, the Transportation Panel had its first round in 2013. The goal of this study is to assess mobility patterns with an emphasis on long-term change over time; for example, whether a person makes more or fewer trips during particular stages of their life.

Transportation monitoring is an important aspect of transportation planning at UBC and in the wider community. The findings can be used to make informed decisions in the use of public space. In spite of this, however, there have only been a handful of human mobility studies conducted primarily using Global Positioning System (GPS) technology. GPS provides extremely accurate location data that, when recorded in conjunction with time, can be used to track changes in location, or movement.

In April 2013, a report was published on a study which used GPS Data Loggers to track the fine-scale (within city) mobility patterns of 582 residents from two neighborhoods from the city of Iquitos, Peru. The primary motive for this study was analysis of infectious disease propagation amongst resource-poor neighbourhoods in Peru. GPS tracking was not simultaneous for all participants, a 15-day tracking period was deemed "sufficient to characterize participant's short-term spatial routine" and participants were mainly tracked "within a 1-year period."[6]

Intention and Scope

The intention of this pilot study is to provide Campus and Community Planning with meaningful comments and recommendations as to the feasibility of using GPS to track fine-scale human mobility on UBC's Vancouver Campus. The main focus will be on the processes of designing the study, collecting the data, and transforming it into usable information. A series of recommendations will assist Campus and Community Planning in the design of further iterations of the study.

While this SEEDs project will also attempt to provide some meaningful data to Campus and Community Planning, the scale of the study and some of the survey methodology utilised may compromise the scientific validity of the data. Campus and Community Planning should use the resulting data and visualizations at their own discretion, taking into consideration any bias introduced. The data will be most useful for designing future monitoring programs.

[6] Vazquez-Prokopec, G.M., et al, (2013) Using GPS Technology to Quantify Human Mobility, Dynamic Contacts and Infectious Disease Dynamics in a Resource-Poor Urban Environment, *Plos One,* volume 8, issue 4, p.4.

Study Design

In order to keep the operational costs for the pilot study low, a small number of participants were recruited. The 10 participants were selected using a convenience sampling method to reduce the time and cost associated with recruiting a scientifically representative random sample.

The pilot study was conducted during mid-October, the same period in which Campus and Community Planning usually conduct their existing annual transportation survey of the UBC campus. This time of year was chosen in order to align with existing methodology and so that the results of the pilot study could be compared and combined with the information already gathered by UBC for a deeper indication of the transportation patterns on-campus.

The length of the pilot study was five days, running from Monday 27th to Friday 31st October 2014. Weekend transportation patterns on-campus are significantly different, as students are not attending classes and many staff members are not working. A longer period would have been preferred and may be achievable in the future if the process for receiving and analysing the information gathered is automated.

Technology Selection

There are several different technologies that could be used to collect GPS location data of the participants in this study, the two most viable options in this circumstance being a cell phone application (App) and a purpose-built GPS Data Logger. The advantages and disadvantages of these two options are significant and must be considered when designing the study: a brief explanation of the two options will follow along with anticipated advantages and disadvantages of each method.

The first approach utilizes purpose-built GPS Data Loggers, standalone devices used for receiving a GPS signal and storing information about the location of the device over time. The devices would be handed out at the start of the study. The participants activate their device and it would remain active throughout the day, or until it is turned off. At the end of the study the devices would be collected and the data downloaded from the internal memory of the device.

Advantages	Disadvantages
The devices will have been purpose-built for the function required in this study	There is a large cost associated with purchasing GPS Data Loggers
The device should be easy to operate and remain functional throughout each day	There is the potential for some devices to become lost or stolen by the participants

The GPS devices represent a capital investment and can be used in a variety of subsequent monitoring applications	Some devices are engineered for more advanced applications such as hiking and route planning
It is clear to the participants that information recorded while the device is on their person will be handed over at the end of the study	Participants may forget to carry the device with them for the duration of the study resulting in a loss of potential data

Table 1: Advantages and Disadvantages of GPS Data Logger Method

A 2nd approach would involve utilising GPS receivers built into most modern smartphone models to gather location data. An application would provide an interface between the user and the technology. Participants would use their own smartphone devices and download an application, either designed specifically for the study or pre-existing from a 3rd party. The application would be launched at the commencement of collecting data and the participant would send their GPS tracks wirelessly via email to a designated email address for collecting the results of the study.

Advantages	Disadvantages
GPS is already built into a device that the participant owns, avoiding the need to hand out expensive equipment	Not all randomly selected participants will have access to a GPS-enabled smartphone compatible with the developed application
The application could be customised and updated to suit the ongoing needs of this and future studies	The application may need to be running and active on the device to properly record GPS location data
Participants could submit their information at intervals throughout the study assisting with prompt analysis	There may be an issue of privacy over when and where the application is recording the location of the participants in the study
The cost of scaling the study once an application has been developed will be small	Some users may forget that they need to actively submit their GPS data files by email

Table 2: Advantages and Disadvantages of Cell Phone Application Method

A 3rd method of collecting location based data is through the use of a web based application utilizing an online mapping software, however this falls outside the scope of this study, to test the use of GPS technology.

The GPS Data Logger technology fulfilled the purpose of this pilot study: to analyse the feasibility of GPS technology. The purchase of purpose-built devices was, in the short term, easier and cheaper than the development of a mobile application, even though it is the more expensive option to scale up. A purpose-built device that remains on throughout the duration of the day is much more reliable than asking the participants to power up the app each time they begin to move about and will therefore yield better results for the purposes of analysing the feasibility of the technology. A further study looking at the feasibility of implementing a web or mobile app is critical to ensure the best methodology is selected.

Limitations

Following the literature review and discussions with Campus and Community Planning, it is evident that knowing what mode of transportation people are using and also the purpose of people's trips is important for planning purposes. In order to address this challenge I intended to analyse the speed recorded for each of the points. Given the speed of individuals at any given location, along with contextual information from the points around, an inference can be made to their mode of travel. This turned out not be a particularly accurate method of collecting mode share. Recommendations follow as to a more efficient incorporation of a 'mode share' element into future iterations of the study.

Trip purpose is another important factor that transportation studies try to gather. Since this pilot study is focussing on the GPS technology, the purpose of an individual's trip was not recorded. This is a limitation of the technology, and collecting this information was beyond the scope of this study. I have, however, made some suggestions for how to incorporate a 'purpose' element into future studies.

The pilot study was geographically limited to the boundary of the campus as defined by the Campus and Community Planning Land Use Plan. In the interests of privacy, GPS data that was provided outside this area was clipped to the campus boundary. In the future the geographical scope of the GPS Study could be expanded, depending on resources available.

In order to reduce the time and cost of recruiting a random sample of participants the majority of them were students recruited through announcements made in classes in the Geography Department. It was thought that those students with an interest in the technology would be more willing to participate and would have an interest in the outcome of the study. This method, however, will have inevitably introduced some bias into the study both in the assessment of the user's experience with the devices and their patterns of mobility around the campus.

Ethical Considerations

In order to protect the privacy of the individuals participating, precautions have been taken to ensure that the data gathered is not used maliciously. Throughout the study design, every effort has been made in order to ensure the privacy of participants. In addition, participants were required to consent to providing data that could be interpreted as being sensitive.

In order to protect the participants from malicious use of the data, the study the results were aggregated and anonymized prior to any visualisations being made public. After the study is completed the data collected will be stored anonymously in a secure location for future reference. The consent of the participants will also be retained. The data collected in this study is ultimately being collected on behalf of the office of Campus and Community Planning at the University of British Columbia and it is their responsibility to protect the privacy of the participants in the study throughout the lifespan of the data collected.

GPS Testing

Prior to the GPS study, a pre-test was carried out with a GPS device. This pre-test assisted with the device selection and also pre-empted issues that might have arisen in the pilot study. I carried a Garmin GPS device with me for one week, recording tracks as I moved between different buildings during my daily routine.

Overall, the GPS test was promising: The signal was distorted amongst the tall towers in downtown Vancouver, but remained accurate amongst the comparatively open residential district of Kitsilano and on the UBC campus. The GPS files, converted to .kml format, were easily displayed on a map, shown below. An element of translucency in the line colour helps to highlight the most frequented routes around the city.

Whilst conducting this trial it also became evident that the device given to the study participants must be very simple to use. The Garmin GPS, designed for the purpose of navigation whilst hiking. While it had a large LCD display shows the current track, additional features of the device made it confusing to set up. It also needed to be manually started at the beginning of each trip as the battery life was too short to leave it on.

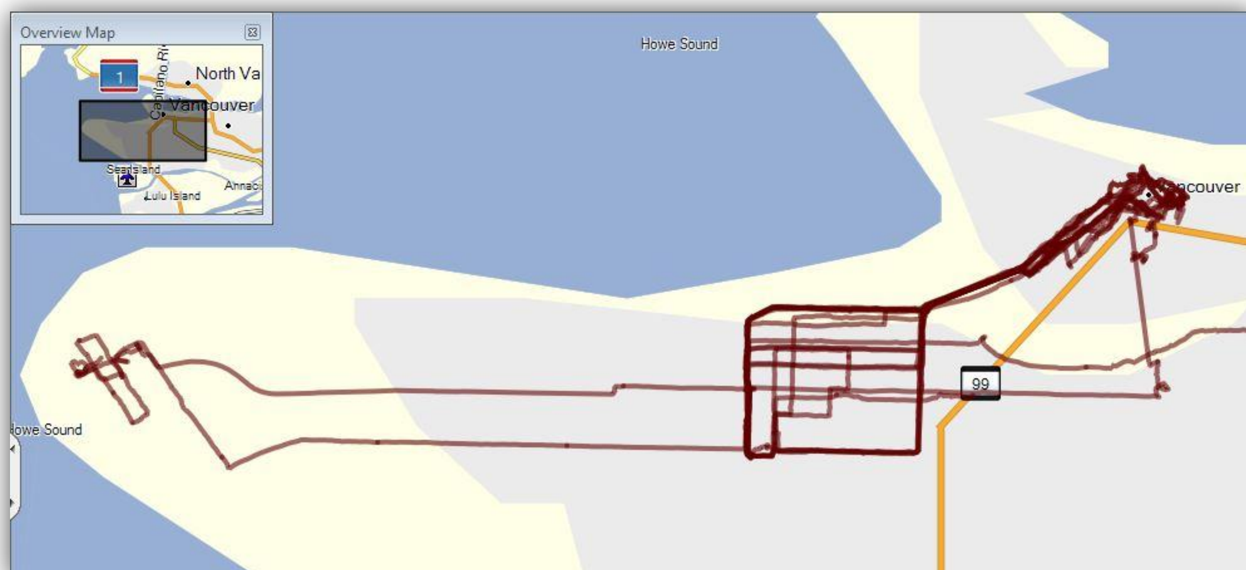


Figure 1: Trial GPS Tracks in Vancouver

Device Selection

Figure 2: Columbus v990 GPS Data Logger

After a thorough online search, I chose the Columbus v990 Data Logger for the study. Its simple design and innovative features set it apart from other devices on the market. The device is intuitive to use with few buttons. There are lights and sounds which provide the user with necessary information without overwhelming them with superfluous controls.

The v990 has a built in G-sensor used to detect whether the device is in motion. If the device is stationary for 5 minutes it will switch to a standby mode to conserve battery life. Once motion is detected again it will power up and continue to record location data on the same track. This feature simplifies the participant's active role in the study. Since participants can easily activate the device and are able to leave the device on throughout each day, their movements should be recorded with minimal interference. The device is then easily turned off and charged if necessary at the end of each day.

The Columbus v990 also features a point of interest button, which, subject to further testing, could be used for an additional feature designed into the study. This point of interest can also be annotated using a voice tag, recorded at the touch of a button using the built-in microphone. Costing just less than $100 per device, this option is most suited to the small scale pilot study I am conducting to test the application of GPS technology to human mobility tracking.

The following graph shows how this might not be the cheapest method to scale to a larger study. Using GPS Data Loggers, each participant requires the use of a device for the duration of the study, therefore a sufficient number of devices must be bought to accommodate each of the participants. The cost can be reduced by dividing the participants into groups and staggering their study periods. Fewer devices would need to be purchased as they can be used by multiple participants throughout the study.

A mobile or web based application has a fixed development cost which varies only according to the complexity desired. At a small scale, such as the 10 participant pilot study, it is not economically feasible to develop, however the cost to scale up an app based study once it has been developed is minimal. This is something that should be considered by Campus and Community Planning upon evaluation of this pilot study and further research as the feasibility of implementing an application-based study should be undertaken.

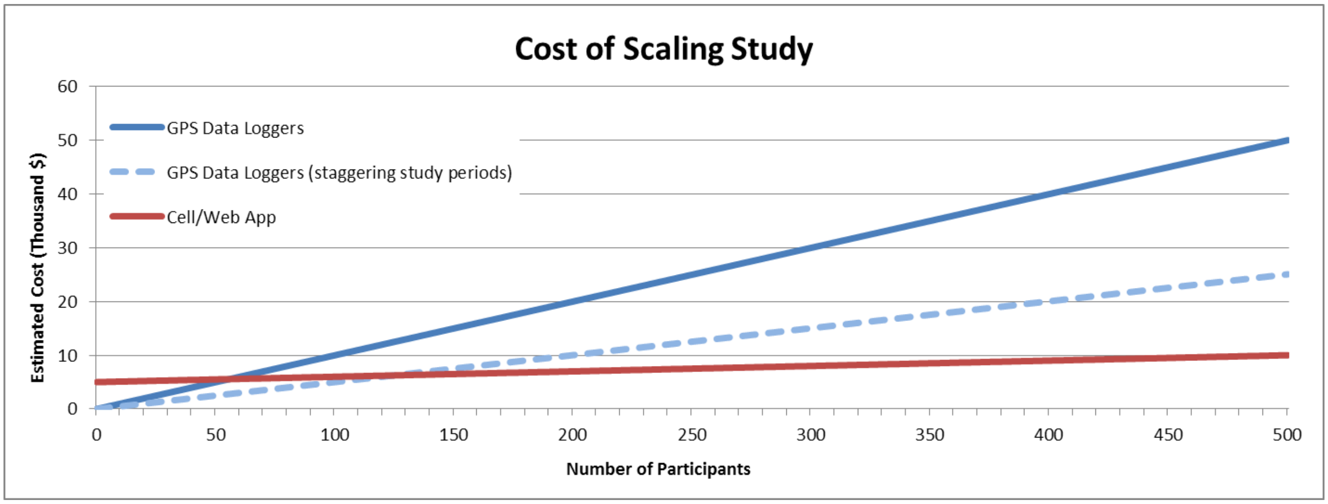


Figure 3: Estimated cost associated with scaling the study

Results

Although the data gathered over the course of five days was not scientifically representative, it was sufficient to test the technology and to draw some important conclusions as to how GPS could be used to inform planning decisions on-campus. The following map shows the tracks collected and contextualizes them using existing transportation monitoring data carried out at the screenlines, or access points, of the campus.

Campus wide, the GPS tracks uncover spatial patterns of mobility which will assist with planning decisions that cover the campus, for example planning a network of bicycle routes, or identification of the highest traffic routes for placement of recycling stations. A similar result may be achieved by asking participants to draw their routes on a map, however people are not likely to remember the precise route taken over the course of a day. Traditionally, transportation surveys such as the Translink Trip Diary ask the start and end location of a trip but are not able to study the route taken by the participants.

The high locational accuracy of GPS also facilitates analysis of the tracks closer up also reveals patterns which can be used to inform public realm improvements. In the case of this study, one example of a trend that emerged was outside the Student Union Building (highlighted in the inset map below). Approximately half of the tracks in this location show people following a major paved path, turning at an intersection. The other half of the tracks utilise a smaller uneven path that passes amongst trees in the area. The use of GPS technology has brought to light a nuance in the route people will take and identifies this path as a candidate for public realm infrastructure improvements.

Final Map

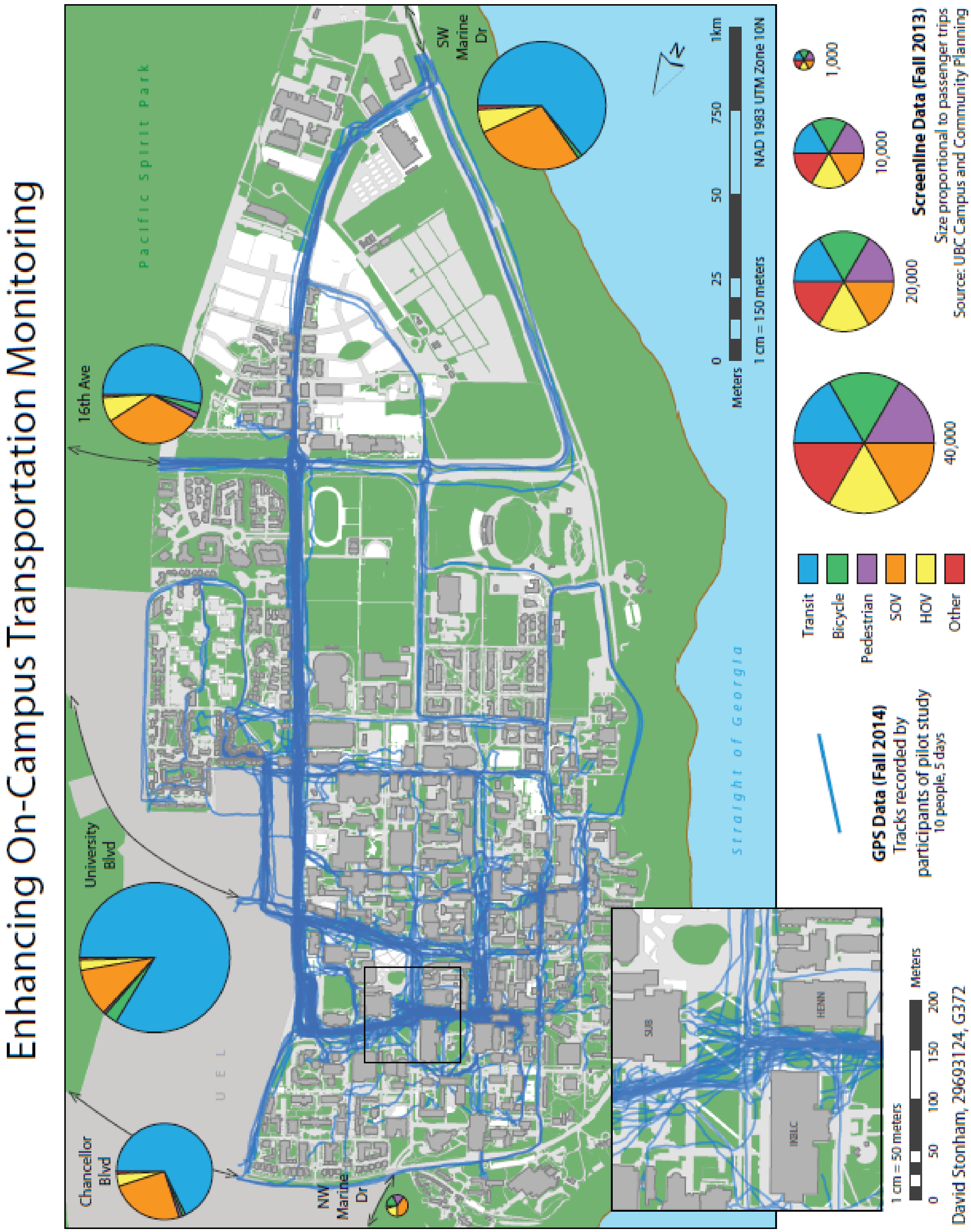


Figure 4: Final Visualization of GPS Tracks

Please note this map has been submitted for academic credit in Geography 372, November 2014

Data Analysis

In total, 76 separate .csv files were collected; each had to be processed individually in order to create the final visualisation. Below I have indicated the process undertaken to display the data on the pre-prepared base map to highlight its complexity.

1. Transfer the .csv file from the MicroSD card in the GPS Device to a hard drive on the computer
2. Open the file and resave it (this fixed an error where null characters were stopping the file from being imported to ArcMap)
3. Import the file into ArcMap, selecting the correct geographic coordinate system, WGS 1983, and the fields containing the latitude and longitude coordinates recorded
4. Convert the file into a .shp (point data) file
5. Project the file into the correct projected coordinate system to align with the base map (in this case NAD 1983 UTM Zone 10)
6. Convert the point data file into a line file
7. Apply the correct symbology (line colour/thickness/transparency)
8. Clip the line to the campus boundary (in some instances entire files were recorded off campus, in this case the whole file was discarded)
9. Manually clean up errors in the data collection (details below)

Errors and debugging

Several technical glitches occurred which I manually corrected when processing the data into tracks for the final visualization. I will briefly describe the errors and explain how I overcame them.

Figure 5.1: Errors – Glitch

This track had a simple technical glitch, the GPS device picked up two or three additional points scattering the signal but quickly regained correct signals and continued on the original path. This might have been caused by atmospheric or magnetic interference. I manually re-connected the points on either side of the error to form a continuous line.

In this track the GPS device lost its signal before reconnecting a few minutes later. This appears as a jump from one location on the map to the next. While I can be fairly confident of the route taken in this instance, this error occasionally appeared on a much larger scale , potentially caused by the satellite moving out of view, rendering the section of track unusable.

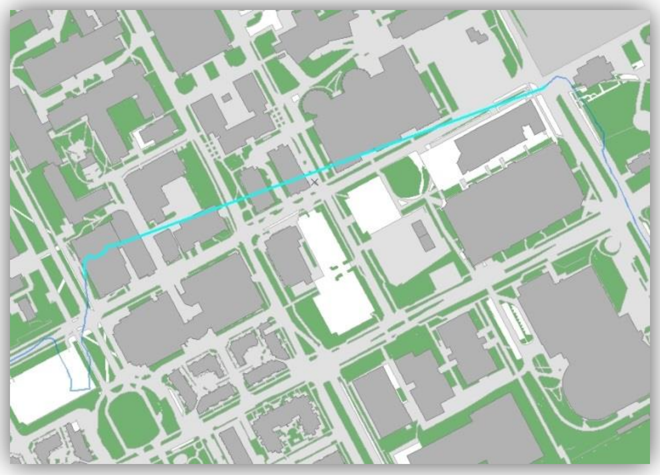


Figure 5.2: Errors – Jump

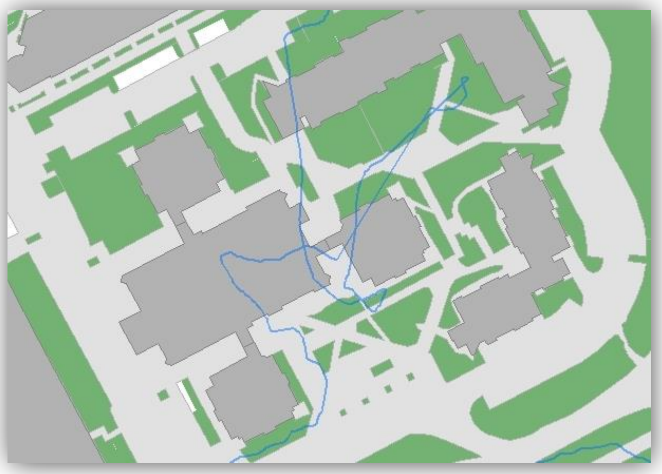


Figure 5.3: Errors – Illogical

This image shows a participant entering from the bottom and going inside a building. After this the track wanders around the nearby buildings and courtyard. Unfortunately the majority of the track after the first intersection with the building is unusable because it is illogical to assume the participant travelled the route shown.

A participant in this example enters a building. The signal is scattered by materials in the roof and walls causing a large cluster of noise. This is a small example; some created a lot more noise. This was fixed by clipping the track at the entry and exit points of the building, usually fairly obvious, and deleting the scattered points on the line between.

Figure 5.4: Errors – Noise

Mode Share Analysis

Mode share was not as easy to estimate as I had initially thought. The intention was to translate the speed recorded at each point, and the spatial context where needed, into a 'best guess' of the mode of transportation being used. While the data to perform this calculation was recorded by the GPS Data Logger, processing this information is technically complicated.

The issue lies in the range of speeds capable by each mode of transportation. In metropolitan areas of Canada, such as Vancouver, BC, unless otherwise posted, the speed limit is 50 km/h; cars and busses can easily reach these speeds. Even a moderately athletic cyclist can reach these speeds on flat, even terrain.

Cyclists will usually move at 10-20 km/h and will reduce their speed when sharing the right of way with pedestrians, a common occurrence on-campus. A pedestrian's speed will likely remain below 10 km/h unless they begin to jog. An average walking speed is 3-5 km/h, but there is no way of determining whether this range is reached all of the time.

As we can see, normal speeds for each of the four modes of transportation described here overlap, making it hard to determine the mode being used at any given point by the participants. In addition, all four modes of transportation are capable of moving at very low speeds (0-5 km/h), meaning a GPS signal showing a low speed could have been created by a participant using any mode.

Adding to the complexity further, speeds for each mode of transportation fluctuate over time at varying rates. For example, a pedestrian will maintain a low, but constant speed for the duration of a trip, but a participant using transit will remain stationary while waiting for the bus, accelerate, and then return to a standstill between each subsequent transit stop.

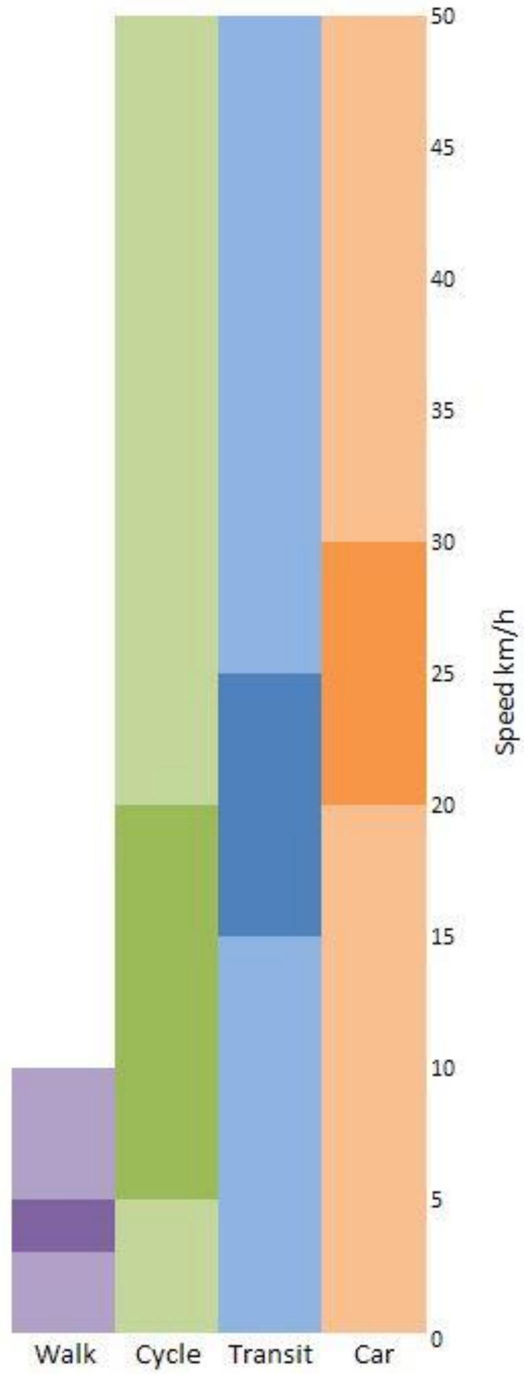


Figure 6 – Mode speed range s

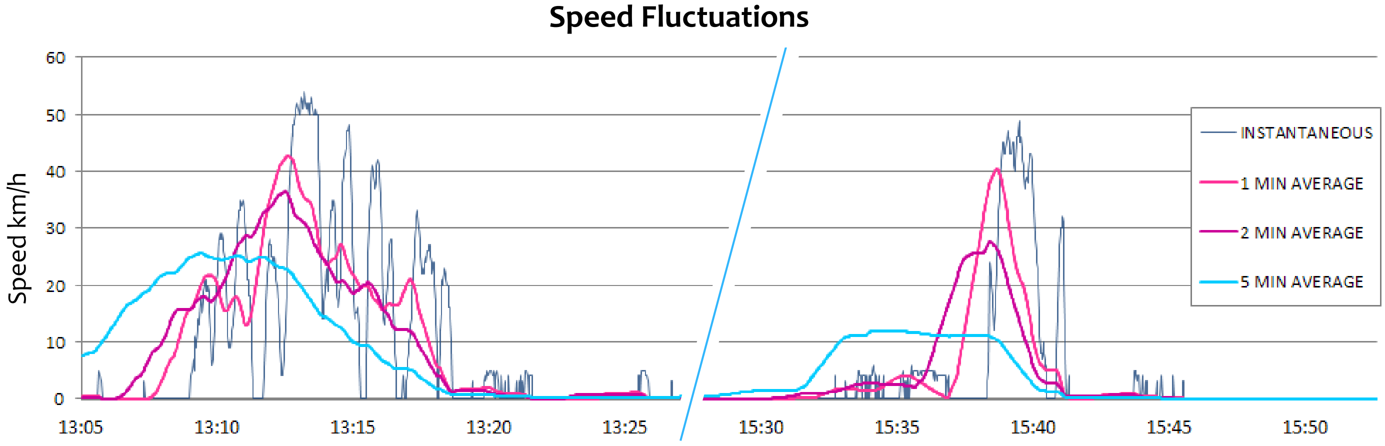


Figure 7 – Participant speed fluctuations

As shown in the chart above, these fluctuations in a participants real time speed can be averaged over various temporal scales. However, since each mode of transport has different temporal scale of fluctuations, this does not assist in determining which of the (somewhat unclear) speed ranges, and thus transport modes, the participant falls into, even when the variables are narrowed down with the mode share survey implemented in this pilot study (Appendix 2).

Further investigation into a more precise method of recording participant mode share needs to be undertaken. It would be ideal to collect this information automatically, in order to reduce the burden on the participants, though in practice this might not be feasible. Not only has this been identified as a requirement in the Transportation Plan, but it is clear that this information will enhance the utility of this study in a number of ways.

Trip Purpose

It is important to know the purpose of a trip in order to better plan for future growth. It was beyond the scope of this study to determine the purpose for each of the trips; this is not something that can be easily embedded into the GPS technology that was the subject of this pilot study. That being said, I can make a couple of recommendations for areas where further feasibility testing might yield results.

Consider the final visualization (above) as a base map with each participant's recorded trips as layers overlain on top. If one wanted to know the pattern of trips created by participant 1, they could simply hide all the layers attributed to participants 2-10. Now let's imagine a scenario where each trip has appended a further attribute, the purpose. This would allow the data analyst to create layers made up of trips with the same purpose. In this scenario, turning off all layers but one, the trip purpose in question now has its own visualization.

In theory, attaching the "purpose" attribute to each point on the database is simple, it is, however, the means by which this information is collected and stored within the database which is more complex. Further exploration of this issue is necessary to inform future study designs.

Participant Experience

An important factor in study design is the participant experience. I conducted a participant experience survey (Appendix 3) in order to gauge participant engagement in the study and to help inform methodological changes in future iterations of the study.

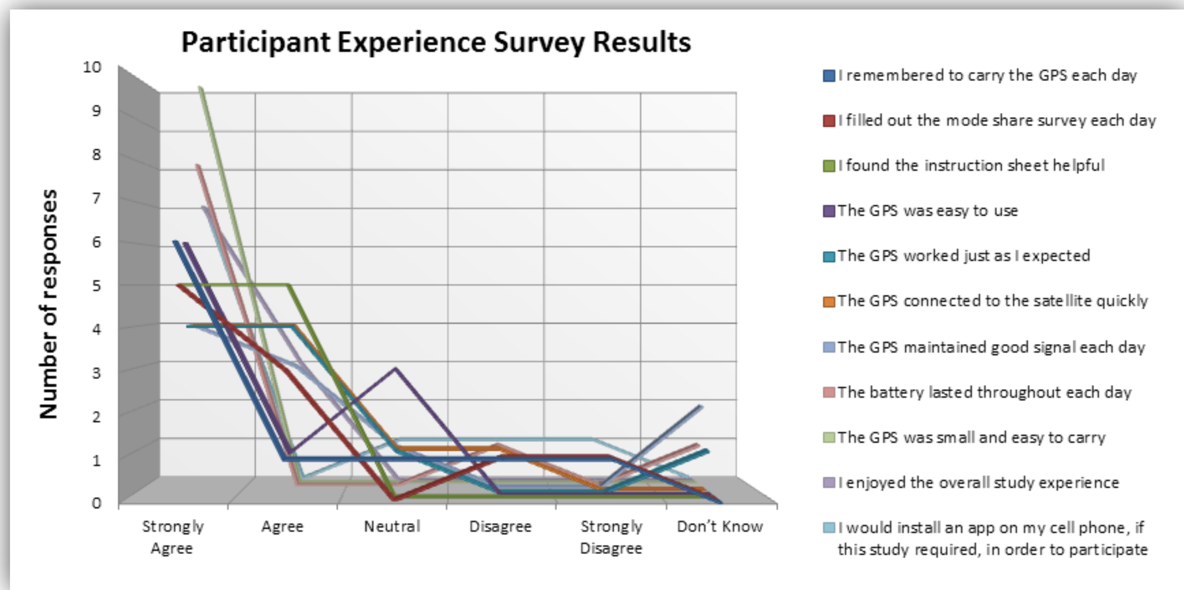


Figure 8 – Participant experience survey results

The results show a generally positive experience. All 10 participants agreed that they "enjoyed the overall study experience", (7 of 10 strongly agreed). Although only 6 participants strongly agreed that they "remembered to carry the GPS each day" of the study, and 2 disagreed with this claim.

When asked about the GPS Data Logger, 80% of responses were positive, whilst 20% were neutral, negative or unsure. All 10 participants strongly agreed that the Columbus V990 was "small and easy to carry", though they were less sure of the technical functionality of the device. 8 out of 10 participants agreed that the device "worked just as [they] expected", even though all 10 participants agreed that "the instruction sheet was helpful".

My final question to the participants, designed to inform further assessment of an application-based survey design, yielded 70% strongly agreeing that they would "install an application on their phone, if the study required, in order to participate". A further 1 participant was neutral, and only 2 participants would be opposed. In light of this overwhelmingly positive response to an application based study, I recommend further investigation into an application-based study, followed by an evaluation of the benefit and drawbacks of each methodology.

Recommendations

Based on my research and the outcomes of this pilot study I make the following recommendations for consideration by UBC Campus and Community Planning when developing an on-campus transportation monitoring strategy:

Overall:

1. There is undoubtedly an additional value to mapping mobility patterns rather than simply collecting data in the form of numbers in tables.
   i. Patterns become evident ***at all scales*** which are not obvious without mapping.
   ii. Maps are a valuable asset and talking point for community engagement in the planning process.

Technology:

2. The use of GPS Data Loggers has proven to be viable method of collecting spatial data that can be translated onto a map, however further research is required in order to fulfil the requirements of the study and enhance the utility of the data gathered
   i. Explore the feasibility of two additional means of creating spatial data which were not within the scope of this project.
      a) An interactive web-app using embedded mapping software (see Appendix 4).
      b) A mobile app for creating and storing GPS tracks on participant's smartphones.
   ii. Explore additional means of accurately and efficiently collecting participant's mode share and trip purpose and attribute this to the GPS tracks displayed on a map.
      a) Collection of these factors should be as unobtrusive as possible to the participants.

3. The Columbus V990 GPS Data Logger performed as, or better than, expected and should be sufficient for future use. Further devices may be useful if GPS Data Loggers are being used by more participants.
    i. Aside from a few lost signals and clusters of additional noise, the V990 performed the basic task of collecting data well.
    ii. It boasts features that trump other models on the market at the same price for this purpose.
    iii. Participants of the study found it easy to use, small and light to carry and found that the battery lasted for reasonable lengths of time.

Methodology:

4. Design a study that can be adapted over time to facilitate exploration of specific research questions. Consider the involvement of students with research questions.
    i. Throughout this project, and on numerous occasions, fellow student showed a genuine interest in the study's methodology and results.

5. Design for a longitudinal study, collecting data across several years, whilst allowing for shorter periods of more intense data collection.
    i. Enables trend analysis over time, and across the dynamic academic seasons.

6. Group participants into cohorts and stagger their study periods in order to reduce capital investment in data loggers.

Analysis:

7. Explore means of automating the data processing and visualisation steps
    i. Even with ten participants and five days the amount of data collected took several hours to process manually.
    ii. This will afford the luxury of scaling up the study whilst limiting additional capital cost.

8. Where feasible, within the constraints of practicality and privacy, make the process transparent and the data gathered available to the public.
    i. People with an interest in the study should be given the opportunity to make their own observations and conclusions.

Appendix 1 – Participant Instructions

MOBILITY STUDY INSTRUCTIONS

BEFORE THE STUDY - Familiarize yourself with the GPS Data Logger.

The **ON/OFF** button is on the top right. Long press it to turn the device on and off.

The **ORANGE** light indicates writing to the memory card it should be on and flash occasionally during operation, otherwise it is not important for the study.

The front **GREEN** light is the most important it shows you the status of the device.

- OFF means the device is off – turn it on or charge it up.
- STEADY means it is trying to get the GPS signal. Hold the device still and ensure there is a clear view of the sky. This can take up to 30 seconds.
- FLASHING means the device has locked onto the GPS signal. Put the device in the protective cover and continue with your normal routine.

The **WHITE** light indicates the status of the motion sensor. This device has a function which makes it go into standby mode when still for more than 5 minutes. When you move again it will wake up, regain the GPS signal, and continue recording your track. If the light is on it means the motion sensor mode is active.

Your movement tracks are recorded onto the memory card plugged into the bottom of the device. Each time you turn the device on or off a new track is created on the memory card.

In the top left corner there is a battery status indicator. It should be **GREEN** indicating full charge. If it is **RED**, the battery level is low. Charge up the device using the cable provided when you can.

DURING THE STUDY

ATTACH the device to your person, or a purse that you will carry with you during the day, using the hand strap on the device. The device is easy to lose, and expensive to replace.

As you leave your place of residence each morning please turn on the GPS device. We are only analysing patterns of on campus transportation, so your data will be clipped to the campus boundaries, but if you turn it on as you begin your journey in the morning you are less likely to forget to turn it on as you arrive on campus

Go about your usual routine. We are interested in learning what factors influence your normal mobility, so try, as much as possible, to forget about the device during the day.

When you leave campus, or get back home, turn off the device. **CHARGE** the device using the USB cable provided to ensure the battery that lasts for the whole of the next day. **COMPLETE** the accompanying survey to provide information on the modes of transportation you used during the day.

AFTER THE STUDY

Please **RETURN** your device, along with the charging cable and information that you have recorded to Chris Fay (chris.fay@ubc.ca) via the UBC Campus and Community Planning Office, 2210 West Mall.

Appendix 2 – Mode Share Survey

MOBILITY STUDY SURVEY Participant___

In order to understand how you move around the campus, it helps us to know what modes of transport you are using on each day of the study. Please check all of the modes of transportation you used on each day.

MONDAY

- ☐ Walk
- ☐ Run
- ☐ Cycle
- ☐ Roller-skate
- ☐ Skateboard
- ☐ Bus
- ☐ Car (driver)
- ☐ Car (passenger)
- ☐ Taxi
- ☐ Other_____________
- ☐ Other_____________
- ☐ Other_____________

TUESDAY

- ☐ Walk
- ☐ Run
- ☐ Cycle
- ☐ Roller-skate
- ☐ Skateboard
- ☐ Bus
- ☐ Car (driver)
- ☐ Car (passenger)
- ☐ Taxi
- ☐ Other_____________
- ☐ Other_____________
- ☐ Other_____________

WEDNESDAY

- ☐ Walk
- ☐ Run
- ☐ Cycle
- ☐ Roller-skate
- ☐ Skateboard
- ☐ Bus
- ☐ Car (driver)
- ☐ Car (passenger)
- ☐ Taxi
- ☐ Other_____________
- ☐ Other_____________
- ☐ Other_____________

THURSDAY

- ☐ Walk
- ☐ Run
- ☐ Cycle
- ☐ Roller-skate
- ☐ Skateboard
- ☐ Bus
- ☐ Car (driver)
- ☐ Car (passenger)
- ☐ Taxi
- ☐ Other_____________
- ☐ Other_____________
- ☐ Other_____________

FRIDAY

- ☐ Walk
- ☐ Run
- ☐ Cycle
- ☐ Roller-skate
- ☐ Skateboard
- ☐ Bus
- ☐ Car (driver)
- ☐ Car (passenger)
- ☐ Taxi
- ☐ Other_____________
- ☐ Other_____________
- ☐ Other_____________

Appendix 3 – Participant Experience Survey

Participant Experience Survey

The GPS Mobility Study in which you participated was designed by David Stonham, an undergraduate geography student, through the SEEDS program. As part of the evaluation of the technology, David would like to understand more about your experience participating in the study and using the GPS technology.

Your feedback is important as it will help David to evaluate this pilot study and make recommendations to Campus and Community Planning regarding how this GPS technology can be used for the purpose of monitoring human mobility at UBC.

Finally, as a thank you for your participation in the study and for your time providing feedback through this short survey, we would like to offer you a $5 gift card to for UBC Food Services courtesy of the SEEDS program.

I am a:

- ☐ Student
- ☐ Faculty Member
- ☐ Staff Member
- ☐ Other ___________

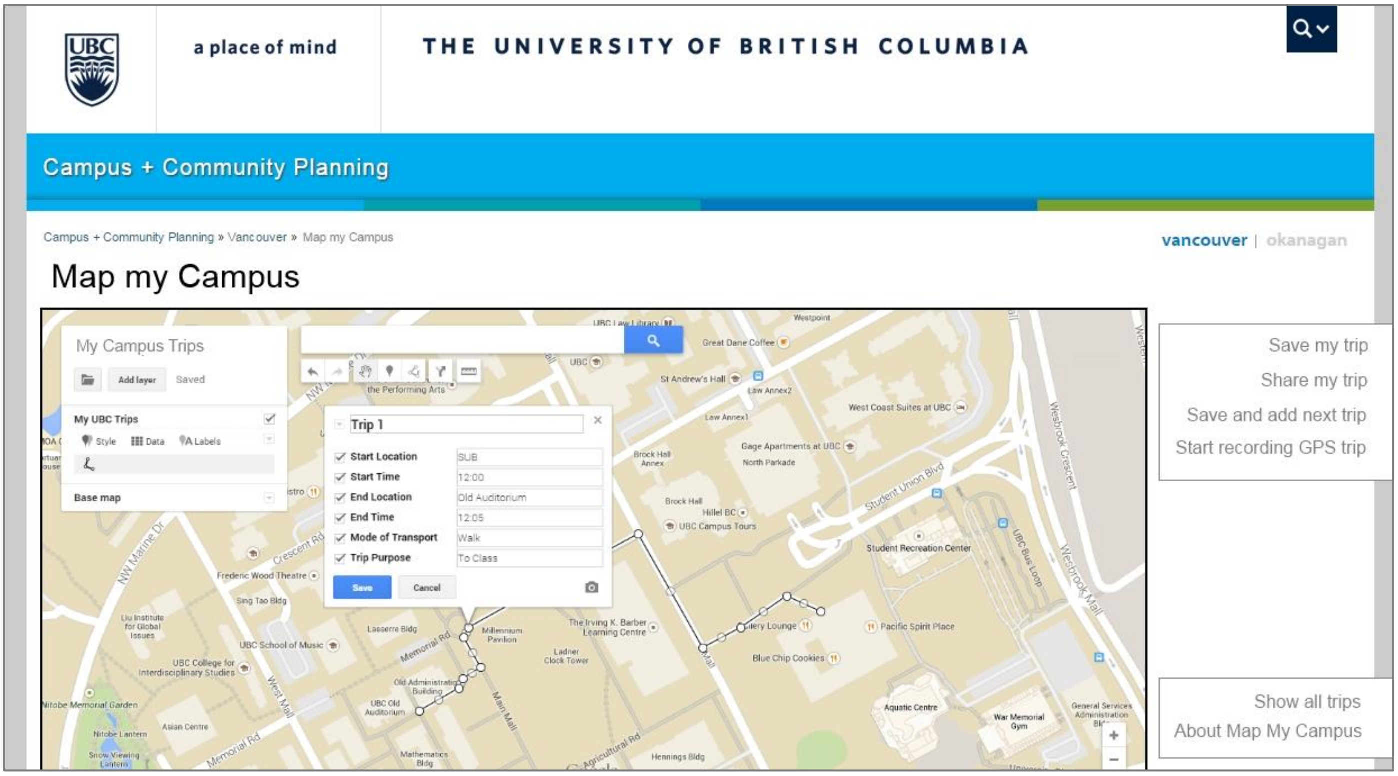
I live:

- ☐ On Campus
- ☐ Off Campus
- ☐ Other ___________

Please evaluate the following statements:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
I remembered to carry the GPS each day	☐	☐	☐	☐	☐	☐
I filled out the mode share survey each day	☐	☐	☐	☐	☐	☐
I found the instruction sheet helpful	☐	☐	☐	☐	☐	☐
The GPS was easy to use	☐	☐	☐	☐	☐	☐
The GPS worked just as I expected	☐	☐	☐	☐	☐	☐
The GPS connected to the satellite quickly	☐	☐	☐	☐	☐	☐
The GPS maintained good signal each day	☐	☐	☐	☐	☐	☐
The battery lasted throughout each day	☐	☐	☐	☐	☐	☐
The GPS was small and easy to carry	☐	☐	☐	☐	☐	☐
I enjoyed the overall study experience	☐	☐	☐	☐	☐	☐
I would install an app on my cell phone, if this study required, in order to participate	☐	☐	☐	☐	☐	☐

Appendix 4 – "Map My Campus" – Web-app Proposal



Above I have depicted a web based application (also accessible on mobile device) which allows participants to record their own trips to, from, and around campus. This is similar to the approach taken by the City of Vancouver in their Travel Diary survey.

This application could be used as a platform for conducting statistically representative sampling as part of a comprehensive transportation monitoring program at UBC Vancouver, by recruiting participants and providing links to the webpage. Alternatively, Campus and Community Planning could make the web application available to anybody wishing to log their trips at UBC and allow each user to decide whether or not their information can be included in the ongoing transportation study.

The web app should allow participants to manually trace their trips and assign attributes to the lines, such as start and end times, mode and purpose, but should also allow users to record or upload GPS tracks. Google Maps Engine, used to create the above image, is an application that functions well in this manner and should be considered.