Zero Waste Campus Project

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Abstract

Waste (i.e. paper, plastic, glass, metal, or food waste products) diversion has been a key focus for reducing the overall waste disposal as part of the Zero Waste Action Plan (2014). This requires efforts in both education and infrastructure. This research is interested in the infrastructure (i.e. locations of recycling stations) of waste sorting in the University of British Columbia (UBC) Vancouver campus, and how it may affect the rates of waste diversion and recycling. Currently, UBC has 117 traditional garbage bins that do not have any recycling option. This means the waste collected from these bins will not be recycled and reused for other purposes. Our client, Bud Fraser, plans to replace existing traditional garbage bins with new (Big Belly) recycling stations across the campus so the waste can be recycled properly. In turn, we aim to create a zero waste community. Due to the high costs of these recycling stations, it is essential to first determine the optimal locations for the installation of new recycling stations on campus, and to ensure that they are beneficial to the sustainability movement. This study evaluates potential locations using a set of criteria to identify suitable outdoor areas on campus. The criteria includes outdoor population density, waste generation (including garbage, recyclables and litter), proximity to food outlets, popular leisure and social gathering areas, frequently passed locations by students, and the recommendations by students and waste management staff. The six criteria were formulated based on the findings from previous studies (Wight et al. 2013, O'Connor et al. 2010, Clay, 2005) that look at potential factors that affect recycling. We also incorporated the advice from UBC's Social Ecological Economic Development Studies (SEEDS), specifically Bud Fraser's advice.

Primary data was gathered through appropriate research strategies such as mixed-mode survey, semi-structured interviews, and participant observation to analyze individual criteria. To

determine areas with high traffic, the participant observation method was used to evaluate the population and crowd flow of outdoor spaces (i.e. major roads and pathways), and to locate areas adjacent to food outlets. From the mixed-mode survey method, we determined areas that students frequently pass by and gather during their leisure time. The survey also allowed the participants (i.e. students) to take part in recommending where future recycling bins should be located. Furthermore, through the surveys we assembled knowledge about the students' perspectives and habits on recycling. By utilizing semi-structured interviews with UBC Waste Management staff, we were able to determine areas with a high proportion of litter and garbage disposal. Using Geographic Information System (GIS) analysis, we combined and analysed the data collected to produced a map that ranked our recommended bin locations into three categories: High priority areas, medium priority areas, and low priority areas (Appendix 1). The high priority areas are locations that encompass most of the criteria (i.e. five or six) in our list, and are important areas for recycling bins. The medium and low priority areas encompass fewer criterions in our list, but are potential locations for new recycling bins nonetheless. In conclusion, our team proposes to add fourteen recycling stations across campus to the existing nine recycling bins. The addition of these recycling stations will presumably contribute to the waste diversion efforts on campus.

Introduction

The University of British Columbia (UBC) has been actively promoting sustainable strategies in waste management which includes the implementation of the Zero Waste Action Plan (2014) on the Vancouver campus. The plan was first initiated in 2011 to increase regional waste diversification by 80% by 2020. Their long term goal is to transform UBC into a zero-waste community. UBC is interested in reducing the amount of garbage disposal sent to landfills, by actively promoting the sorting of different waste materials such as paper, food compost, and plastic, etc. (UBC Vancouver campus, 2014). Amongst various municipality considerations on basic waste management options, waste prevention and recycling are ranked the highest (first and second respectively) as they reduce the overall amount of 'residual' waste sent to landfills (Assamoi & Lawryshyn, 2012). To achieve both short term and long term goals of waste diversion, new outdoor recycling stations are to be installed to replace the existing 117 traditional garbage bins. The traditional garbage bins do not allow recycling of any waste, so the existence of these bins opposes the Zero Waste goal of the campus. The UBC Social Ecological Economic Development Studies (SEEDS) has identified the need for more outdoor recycling stations across the campus, together with our client, Bud Fraser. As part of a pilot project in the Zero Waste Action Plan (2010) and in partnership with UBC SEEDS, our team was tasked to determine the optimal locations for outdoor recycling stations, which will presumably yield the maximum rate of usage by the campus population. In our research, we will not be considering logistic and administrative matters such as the overall cost of the project. In the following sections, our team will review previous studies related to our research topic; in doing so, we will highlight and address the gaps in the state of knowledge.

Statement of problem

Bud Fraser plans to replace existing outdoor traditional garbage bins with new waste-sorting stations (plastic, glass, paper, compost etc.). However, the cost of installing a four-stream unit (Big Belly) recycling station is approximately $10,000, and it will be difficult to change the locations of the stations once they are grounded (Fraser, 2015). Therefore, it is essential to determine the optimal locations for their installation in order to reduce the cost of the project, and also to enhance the efficiency of the recycling stations. The replacement of existing traditional garbage bins with new recycling stations is also a focus of this study, as it will aid in the waste diversion movement and will provide the necessary infrastructure for sorting waste on campus. This study seeks to determine the potential areas or locations on campus that would benefit from the installation of a recycling station, by considering different factors that contribute to the rate of waste disposal. However, there are numerous factors that may affect the feasibility of a recycling station such as population density, accessibility of the location, and proximity to food outlets (Wight et al. 2013, O'Connor et al. 2010, Clay, 2005). Therefore, it is essential to determine which factors should be evaluated and considered for the purpose of this study. Furthermore, Bud Fraser and UBC SEEDS have provided us with some considerations such as visual appeal, event locations, easy installation and accessibility, and construction areas. Our group will use an analytical approach (GIS analysis) to evaluate different potential locations across the campus. We will recommend suitable locations accordingly, which will be presented in the form of a cartographic map (Appendix 1). We hope that the results from this study will provide valuable information for decision makers when planning for the installation of additional recycling stations on campus.

Literature Review

Our team reviewed a previous UBC undergraduate project by Jace Long (2009). In her research, Long utilized quantitative approaches to determine the best locations for the outdoor recycling stations. She relied on the UBC Building Utilization Data, and compared the indoor population density based on academic building occupancy rates on campus. Furthermore, she surveyed 23 participants from various faculties to find the busiest locations. Using this data, she created a thematic map showing the ideal locations for the recycling bins. Although her methodology provides a useful framework to help construct our research methods, the data she used is from 2009, which is outdated. The student population since 2009 has grown from 45,178 to 51,447 students in 2015, and UBC has gone through many construction projects since then (UBC, 2015). As a result, the population density and the infrastructure on campus has changed drastically. We decided that building occupancy rate was not particularly useful in our research because our study focuses on outdoor locations, and the majority of buildings on the UBC Vancouver campus already have recycling stations indoors. Similar to Long (2009), we conducted surveys on students to find the busiest outdoor locations and students recommendations for future recycle bins. To reduce bias in our sampling, however, we surveyed 124 students from a wide range of faculties (Appendix 2 and 3). Additionally, we used a participant observation method (instead of Long's building occupancy rates) to determine outdoor areas with high population and crowd flow. This is necessary as there is limited existing data on outdoor population density on campus. Although Long's (2009) study provided our team with potential methodology for our research, it lacks the depth of information that we are looking for.

In their research on recycling behavior, O'Connor et al. (2010) placed recycle bins around a public university in southeast Texas, and compared the proportion of plastic bottles in each bin to study students' recycling behaviors (O'Connor et al., 2010). Their findings suggested that participants recycled the most when the stations were closer to the "point of consumption", or where people consumed the most food (O'Connor et al., 2010). Their research highlights a major factor that was brought up by SEEDS, pertaining to the relationship between proximity of food outlets and waste production. This suggests that locations adjacent to food outlets have the capacity for higher waste generation, and thus the rates of recycling. The installation of recycling stations in these locations may be instrumental to the increase in waste diversion, and is desired in the case of our study. Information from the interviews we conducted with the UBC Waste Management staff also supports O'Connor et al.'s findings. They stressed that most areas with high waste generation are locations in close proximity to food service outlets. O'Connor et al.'s findings and our findings from the interviews highlight the importance of proximity to food outlets; therefore we included this factor into our final recommendations. Appendix 1 shows the location of the food outlets by star symbols.

Before we further analyze O'Connor and his colleagues' study, we would like to offer an explanation to distinguish recycling behavior and recycling culture. Recycling behavior, we believe, is the actual act of recycling; recycling culture, on the other hand, is the motivation behind the act of recycling. In this sense, recycling behavior depends on proximity to infrastructure, while recycling culture is focused on other parameters such as education and awareness. There are direct links between the two, and considering one without another would be inappropriate. On these grounds, comparison between the study from O'Connor et al. (2010) and the setting in UBC (our focus of study) would have to consider the difference in recycling culture

as well as behavior. Furthermore, their study was restricted to indoor recycling bins in university buildings, and focused on a single type of waste (plastic bottles) (O'Connor et al. , 2010). Other types of recyclables such as glass, paper and food scraps were not included in this research. The Zero Waste Action Plan (2014) focuses on reducing all types of waste, not only plastic. Thus, our study encompasses all recyclable materials (paper, plastic, metal, glass, compostables). The undergraduate and graduate student body accounts for 78% of the total UBC population (UBC, 2015). Therefore, it is effective to focus on the recycling behavior of UBC students for the purpose of this research.

Another UBC study by Felder et al. (2001) audited the solid waste generated at the university, to determine the characteristics of residual waste, and to provide directions to reduce the waste. They recommended future researchers to integrate the audit data with campus regional planning data in GIS to create a waste generation pattern (Felder et al. 2001). Though this study presents a comprehensive methodology that is helpful for our research, it lacks users' participation. We will be using the Participatory Action Plan as the basis to our research as McPhee (2015) has recommended the use of utilizing the knowledge of our participants in our study is of importance. It is important to consider users' suggestions as they are directly related to the issue, and they are the most knowledgeable in terms of locating recycling bins at necessary locations for their day to day waste disposal. With the combination of recommendations and ideas from students, as well as knowledge we have as researchers, "it will be [more] powerful" than having data without participatory input (McPhee, 2015). Following this study, we used GIS to gather, organize, and analyse spatial data to recommend new outdoor recycling stations. As a result, we gathered our findings from our student survey, interviews with the UBC Waste Management, our own participant observation, and UBC SEEDS recommendations to create a

multi-layered map illustrating different factors that affect the location and the number of the recycling bins. We utilized this map to recommend the most efficient locations for the future recycling bins (Appendix 1).

A major challenge that we foresaw in our research project was determining the total number of necessary recycling bins. In other words, what were the practical challenges of placing too many or too few recycling bins? Gonzalez-Torre et al. (2003) compared the recycling collections of El Paso County (The United States) and Northern Spain. Their findings pointed out that although Spanish citizens recycled at a higher rate while having access to more bins, they were unhappy with the appearance of their city, the unpleasant smell and the inconvenient hours of collection from the bins (González-Torre et al. 2003). The issue of different cultures rises here again. While findings of previous studies suggested that the Spanish citizens are willing to participate in recycling, and understand the importance of recycling (Gallardo et al. , 2010), there is no evidence the people in El Paso have the same commitment and culture in recycling. Our studies suggest that the UBC community is very much like Spain, such that UBC students already value recycling. Therefore, if we recommend too many bins we will face the issues the Spanish community encountered. This is to say, since we have the culture of recycling implemented in our university, we should be careful not to propose too many locations. To do so we came up with a ranking system that divides the locations into high priority, medium priority and low priority (instead of recommending all the locations at once). Our ranking system is represented in our map on recommended locations of the future bins (Appendix 1).

Izagirre-Olaizola, et al. (2015) also presented that there is a higher rate of recycling in Spanish universities compared to American universities. They found that Spanish students were more intrinsically motivated to recycle and were provided with more infrastructures on their

campus. Izagirre-Olaizola et al.'s cross-cultural research gave us valuable insight when conducting our study in the locational context of UBC and Vancouver - the city of Vancouver places important emphasis on sustainability and waste reduction, which has manifested in a cultural practice of recycling. While implementing our survey, we inquired on the willingness to recycle, to gather insight on the intrinsic motivation to recycle. A careful consideration of consumer recycling behaviors and culture was required to produce an efficient plan for the placement of recycling stations across the UBC campus.

Moreover, Clay (2005) analyzed factors that influence the act of recycling among participants in the University of Leeds (UL) in the United Kingdom, but he took on a different approach. Through surveys, the study found that participants recycle more when bins were placed in the busiest areas in school due to social pressures (Clay, 2005). Clay (2005) suggested that people gain satisfaction and social status by being seen recycling. He also concluded that non-recyclers were more motivated to recycle when they saw their friends and colleagues recycle. This is to say, people tend to recycle more in high density areas (Clay, 2005). However, his research relied solely on surveys from only 40 student participations, resulting in some degree of bias and subjectivity. Similar to UBC, the University of Leeds has an active sustainability centre and recycling education culture (Sustainability.leeds.ac.uk, 2015). Due to the similarities between the culture of the UBC and the UL, we were able to further understand the behaviors of our participants. Considering Clay's research, we recommended high density areas for the recycling optimal locations, due to higher recycling outcomes and greater waste generation.

A similar research study by Wight et al. (2013) focused on the behavioral factors influencing recycling habits of students; they argued that convenience was the most important

factor in proper recycling. This study falls short in explaining the recycling culture of the university they focused on, which may have a different context as compared to UBC. It is difficult to compare UBC to their university. Although we speculate that convenience is an important factor, we did not consider it as criteria in our study. It is difficult to compare the students' recycling behaviors and culture between the two universities due to lack of background recycling information about Wighet et al.'s students. However, it is something to consider in future UBC studies.

Multiple scholarly articles have emphasized the importance of educating recycling bin users in creating a sustainable community. Olson, Arvai, and Thorp (2011), surveyed a sample of undergraduate, graduate students, as well as the faculty members of Michigan State University (MSU). They created a general mental model representing the subjects' understanding of the MSU concept of recycling (Olson, Arvai and Thorp, 2011). Their results demonstrated that consumer participation is the most significant factor in recycling rate, and educating the consumer promotes consumer participation. Pike et al. (2003) also argued that for a green sustainable campus, students must be educated on where recycling stations are and what can be recycled. The researchers focused on the university student residence at Francis Marion University in South Carolina, and concluded that students who received both the recycle bins and the recycling education had the highest rate of recycling. This study carefully considered the correlation between recycling behaviors and implementation of recycling culture through education.

Installing recycle bins without implementing the culture of recycling does not promise a sustainable campus. It is through combining education and real life practices that we can achieve the UBC's goal of waste reduction. We do, however, recognize that given the limited time frame,

we may not be able to address the issue of education in great detail. Therefore, the framework of our study will focus on tangible statistics gained through surveys and participant observation, such as identifying areas of high pedestrian traffic and locales of social gatherings. An aspect of our survey inquires into students' behavioural tendencies towards recycling - the higher emphasis that is placed on the importance of recycling, the more flexibility we will have when placing the new recycling stations further apart. We discussed the various factors and different approaches previous scholars have taken to tackle the issue of recycling and sustainability. In doing so, we aim to identify the strengths and weaknesses of previous research to set a framework for our project and to identify the existing gaps in current knowledge. Although we recognize the importance of the awareness and culture of recycling, our study will focus on the infrastructure aspects of this topic to recommend the best locations.

Methodology

For this project, our team used a combination of both quantitative and qualitative research approaches for our methodology to have a variety of sources to determine the recommended locations for new recycling bins on campus. The main goal of our research was to compile and analyse the data collected through our primary and secondary data sources, and to design a map using ArcGIS to illustrate a tier plan of the optimal locations to place several new outdoor recycling stations around the campus. We used a total of six criteria to determine the importance and necessity of recycling stations at specific locations on campus. Our preliminary research of previous studies, along with meetings with our client Bud Fraser from UBC SEEDS, and the interviews with waste management crew were key to developing the necessary criteria for the tier plan. The criteria includes outdoor population density, waste generation (including garbage, recyclables and litter), proximity to food outlets, popular leisure and social gathering areas, frequently passed locations by students, and the recommendations by students and waste management staffs. For example, from existing research by O'Connor et al. (2010), we recognize that information on food service outlets could be useful in determining 'points of consumption' on campus, and waste generation near food outlets. Furthermore, findings by Clay (2005) suggested that population density and peer pressure play a fundamental role in developing a culture of recycling on university campuses.

Bud Fraser provided us with some secondary data source such as the hard copy of a student survey previously done on campus, the spatial data of existing traditional garbage bins and food service outlets on campus (Appendix 4). The remaining of the secondary data were obtained through the UBC Geography department Database. They include relevant shapefiles like major roads, soft landscape, buildings, and other infrastructures for UBC Vancouver campus. A tier

plan was designed so that locations on campus that fulfilled the most of the aforementioned criteria were rated with the highest priority for new recycling bin placement. Highest priority locations fulfilled between five and six criteria, whereas medium priority locations had between three and four criteria, and low priority locations had between one and two criteria. In keeping in line with the Zero Waste Action Plan (2010), we not only wanted to find new locations recycling stations, we also wanted to replace existing traditional garbage bins with recycling stations on campus (Appendix 1). In our analysis, each criterion was weighted equally in determining the priority for new recycling bins in no any particular order.

Our preliminary research of previous literature sources helped us strategize our primary data collection methods. The research conducted by Vanniewenhuyze et al. (2013) suggests that mixed-mode surveys potentially reduce the number of non-responses from participants, the total cost of research, and may better represent the entire population of the study. In turn, we decided to develop a mixed-mode survey as one of our primary quantitative data sources. We designed the survey to be concise with only eight questions, first focusing on participant demographics, recycling behaviours, popular areas on campus, and finishing with recommended locations for new recycling bins. The average time for filling our survey was six minutes, according to the report our online survey generated. We developed and conducted the survey through the UBC online survey platform (FluidSurveys). The list of questions is provided under Appendix 5. Additionally, our team conducted several in-person surveys using a random sampling approach, targeting students in uncontrolled social gathering spaces on campus. This broadens the sample population by including participants outside of our social network. The target group for the mixed-mode survey was mainly undergraduate and graduate students, because they make up the largest proportion of individuals on campus (UBC, 2015). We also believe that success of

recycling on campus is mostly dependent on the participation of the student body. The survey responses were useful in providing us with spatial data of popular leisure locations on campus, frequently passed landmarks on campus, behavioural recycling trends, and recommended locations for new recycling stations by students.

We followed a similar methodology to Long (2009), using a survey as a quantitative approach, but aimed to include more qualitative sources in our approach to acquire data for areas on campus that generate more waste and litter (waste hotspots), have high outdoor population crowd flow, and recommendations of locations to install new recycling stations.

The first qualitative primary data source consisted of three separate semi-constructed interviews with the UBC Waste Management staff, in which we interviewed staff from different levels of operation. We conducted two in-person interviews (with Jarnail Sindhu, and Robert Mackenzie), and received one written response from Alana Marten, as she was away on the day of our interview. A list of questions asked in the interview is provided in Appendix 6. The interviews were done separately to assure that the information we received was not skewed by the other interviewee's responses. Each interview took about thirty minutes, and consisted of eight questions focusing on the job title and duties, waste hotspots, areas for improvement in waste management, and recommendations for new recycling bins. As mentioned before, this was a semi-constructed interview, meaning we allowed them to talk about the issues they thought were important to our study, and we used the questions to guide the overall conversation. We also provided Jarnail and Robert with two separate maps of recycling and traditional bins on the campus, and asked them to indicate the areas of high waste generation (Appendix 7 and 8). Interviewing different levels of operation gave us various perspectives of waste management at UBC, providing us with a clear overview of specific locations on campus to focus our research

on. It was very useful to receive key insights directly from waste collection staff, to understand the issues that we are facing from a ground-up perspective.

As an additional qualitative primary data source, we performed a participant observation method. The data our team collected from the mixed-mode survey focused for the most part on indoor spaces (i.e. buildings). We decided that a participant observation method would complement our findings from the interviews with the UBC Waste Management, and would be an effective way to measure outdoor population crowd flow of various locations on campus. Our team used a non-traditional observation method of visual imagery to estimate the number of people in the different outdoor locations on campus. Team members stationed themselves on the same day (5th Nov 2015) and at the same time (1.40 pm to 2.15pm), at more than 50 different locations across the campus. Appendix 9 shows the exact location of where we took our pictures.

We took 3 photos in different directions at each location, to get a complete view of the surroundings. Field notes were also taken at each location of observation to note the observation of the environment, people, and other relevant information (e.g. number of traditional bins/recycling bins, etc.) (Appendix 10). Our team then counted and compared the number of people in each photograph taken at the designated locations. The results were visually represented on a map, enabling us to contrast population densities and crowd flows of common walking routes on campus (more detail and visual representation will be provided in analysis section). The participant observation method served as an integral component of our qualitative primary data collection, as it provided us with concrete data of outdoor population crowd flows on campus, indicating areas with high density. This was an important criterion in determining the optimal locations for new recycling bins on campus.

Analysis

Survey Analysis

The findings from our survey gave us good insight into existing student recycling trends and outdoor population and traffic patterns on campus. Specifically, we focused on the results from the question, “where do you spend most of your leisure time on campus,” “what sites do you frequently pass on your daily routes on campus,” and “where would you like to see more outdoor recycling bins on campus” as these three questions provide direct insight into three of our factors of consideration for bins.

To gain more context regarding present recycling trends and rates on campus, we asked students how frequently they recycle various products, and our results can be seen in Figure 1.

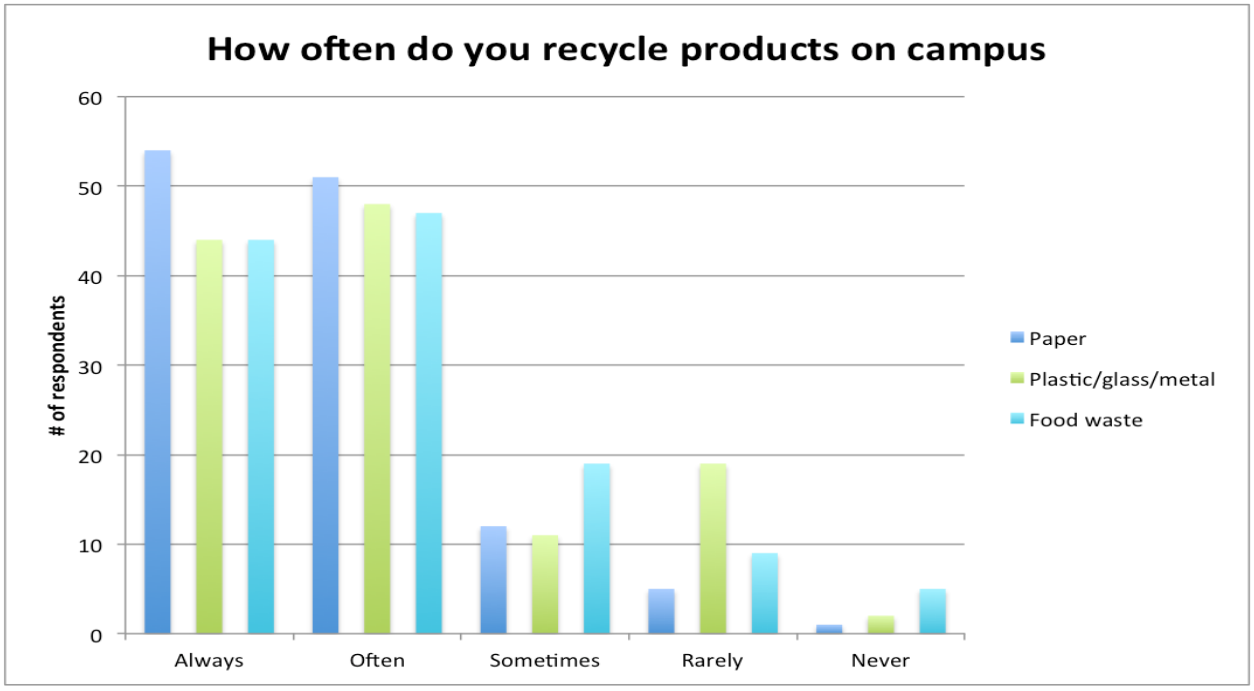

Figure .1 Willingness of UBC Students to Recycle (Culture of Recycling)

On a whole, most students reported that they either always or often recycling all their waste products on campus, which is what we expected due to the culture of recycling in Vancouver and at UBC. We can see that paper products have the highest amount of "always" respondents and lowest amount of "never" respondents, meaning paper is usually the easiest and most straightforward product to recycle. Whereas the number of "rarely' respondents was highest for paper/plastic/metals and "never" was highest for food waste products, indicating that students may face some barriers to recycling when it comes to these products. It also represents how committed they are to recycle on campus.

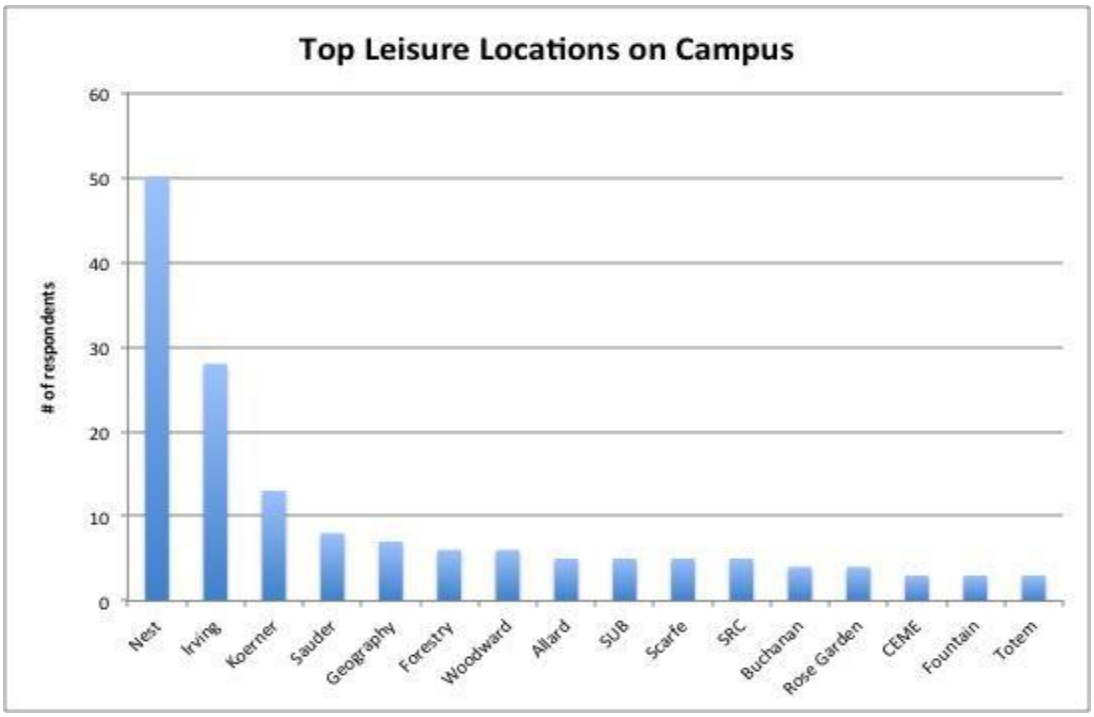

Figure 2. Top Leisure Locations on Campus Graph

Our survey results demonstrated that the most popular leisure location on campus by far is the Student Nest building, followed by Irving and Koerner libraries. However, as shown in Figure 2, no other buildings on campus are picked as much as Nest in terms of popularity.

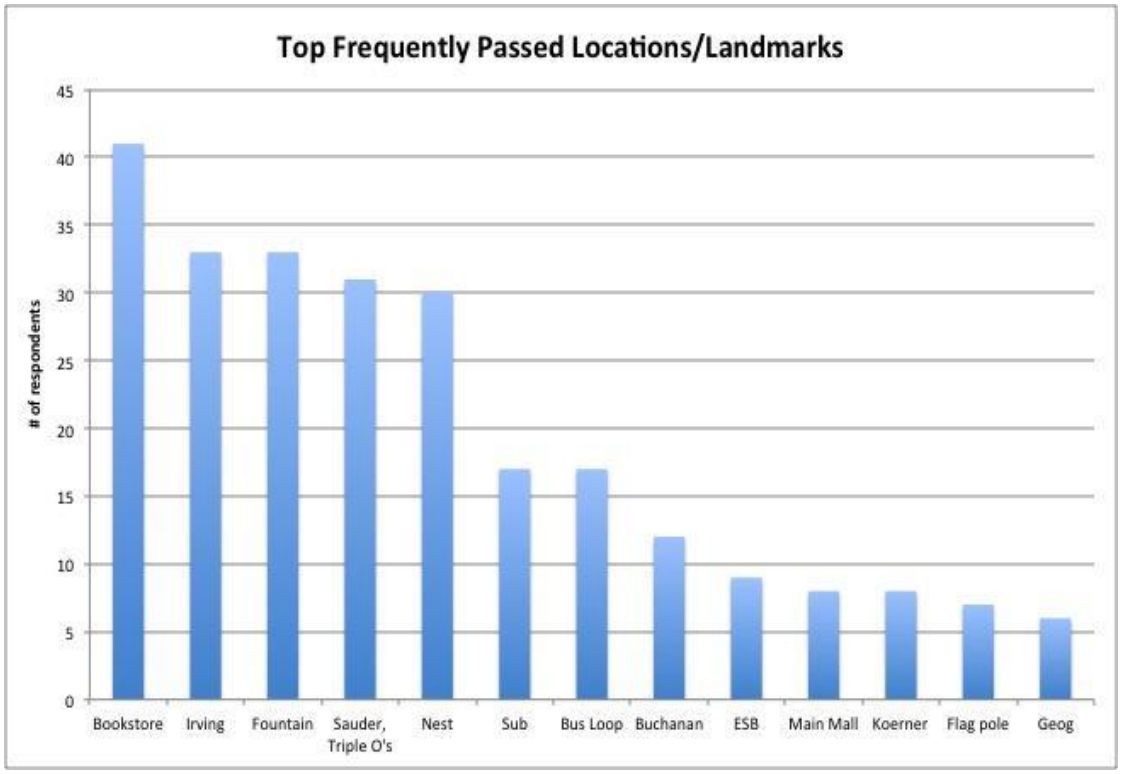

Figure 3. Top Frequently Passed Locations/Landmarks

When looking at our results for "What sites do you frequently pass on your daily routes on campus?" We can see a more even distribution of participants in each category.

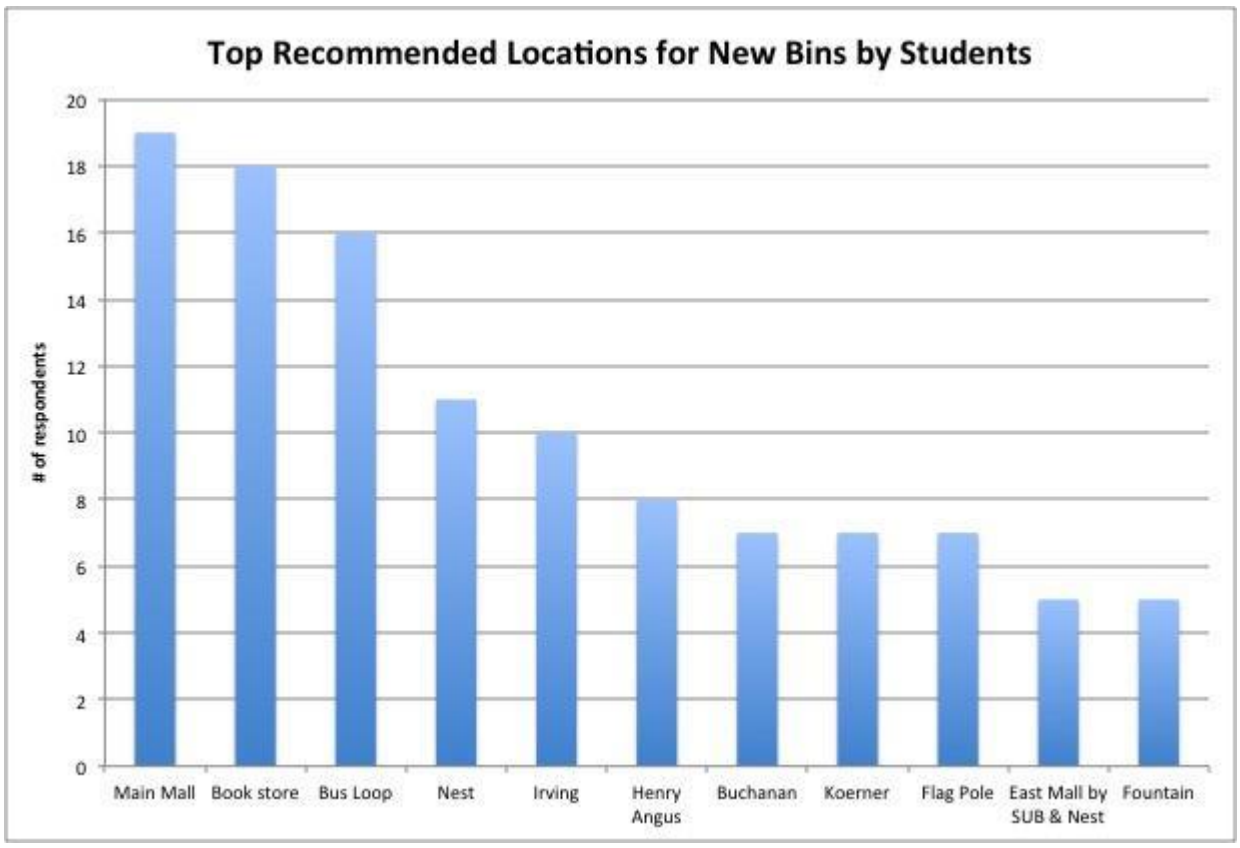

Figure 4. Top Recommended Locations for new bins by Students

The graph for the top recommended locations looks much more similar to the frequently passed locations than the top leisure locations. When comparing Figure 3 and 4 we can observe the distribution is quite similar, and upon further inspection we can see great overlap in the results.

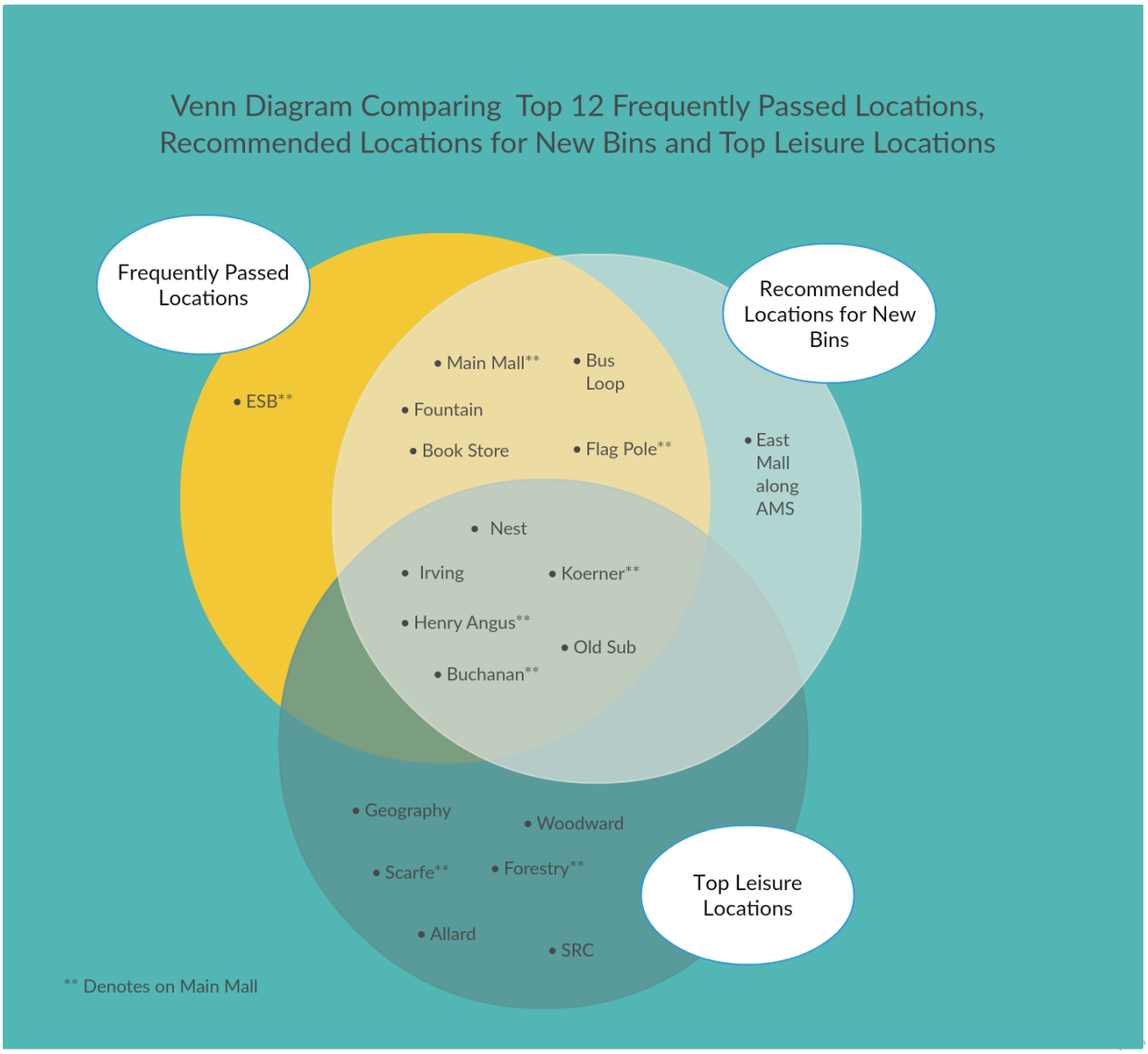

Figure 5. Comparisons of Survey Data

After looking at the general trends in each individual data set, we can begin to compare the three to find trends and commonalities. It is interesting to note that within the top twelve for each data set, there is an eleven out of twelve overlap between the frequently passed spots and the top recommended spots, yet only five out of twelve overlap for the leisure time locations as indicated in Figure 5. The only locations that do not overlap between frequently passed and

recommended spots are the Earth Sciences Building (ESB) and East Mall along AMS. However, upon further inspection we can observe that ESB is located along Main Mall, which placed #1 on the top recommended locations and #11 on the frequently passed locations. "East Mall" along AMS is essentially synonymous with the Nest, so due to the overlap we can say that the top 12 frequently passed location and recommended locations essentially go hand in hand. Students are clearly conscientious about what locations they frequent on campus and that these locations would be the most convenient and conducive to recycling. The data from the top leisure time locations do not appear to demonstrate any trends analogous to the frequently passed and top recommended locations. This could be due to the nature of the question posed – "spending leisure time" entails staying stationary at a location, which is why we see several department/faculty specific buildings listed that are not listed in the other two categories. It is also important to observe that all top 12 locations for leisure time are physical buildings that all already have recycling stations inside them. However, it is interesting to observe that within the total data sets, more people listed a location along east mall as a frequently passed location (147) than people who listed a location along Main Mall (117), despite Main Mall being explicitly stated as a location that is both frequently passed and is recommended to have new bins.

Interview Analysis

The aim of these interviews was to gather information on where current garbage hotspots, recyclable hotspots, and litter hotspots were, and to recommend new strategic placement of outdoor recycling stations on campus. The purpose of the first and second question (Appendix 6) was to ensure that our team was aware of the locations and the workings of the UBC waste system. Jarnail has worked for the UBC Waste Management for 19 years and has recently been

promoted to the Acting Head of the department. Robert and Alana are both experienced UBC waste drivers for more than 15 years. This information assured us that the data we gathered was from an experienced crew and was valid for our research.

Question 5 and 6 informed our team about the routine of the UBC waste management crew. It showed how often recycling bins are emptied and which recycling bins on campus are emptied the most. They are in charge of emptying all outside campus recycling bins and every type of waste (cans, paper, garbage, glass, metal, and etc.). However, through our interviews with the employees, it was impossible to find an accurate answer for this question. Robert explained that "everyone has their own routine" in terms of when the workers empty their recycling bins, and workers do not record when or which bins are emptied every day. For them, it was a matter of subjectivity and depended heavily on their experience. For example, Jarnail said that the waste management crew "generally empty [bins] once a week," while Alana responded that they emptied the bins "everyday [from] Monday to Friday." Due to the variety of the answers we received, our team decided to not add the findings for this part of interview to the general analysis. We believe, if the waste management records this data future research on high waste generation will be done more accurately.

Figure 6 shows the consolidated results for questions 3, 4, and 8 from all three of the interviewees in a Venn diagram. Question 3 asked the interviewees about the current busiest traditional bins and recycling bins on campus. These areas are under "Garbage and Recyclables Hotspots" in Figure 6. Question 4 pinpoints the areas that generate the most litter on campus. They are listed under "Litter Hotspots" in the same figure. Question 8 asked the interviewees to recommend new strategic placement of outdoor recycling stations on campus to help us decide

which locations to include in our recommendations. These areas are listed under “Recommended Areas” in the diagram.

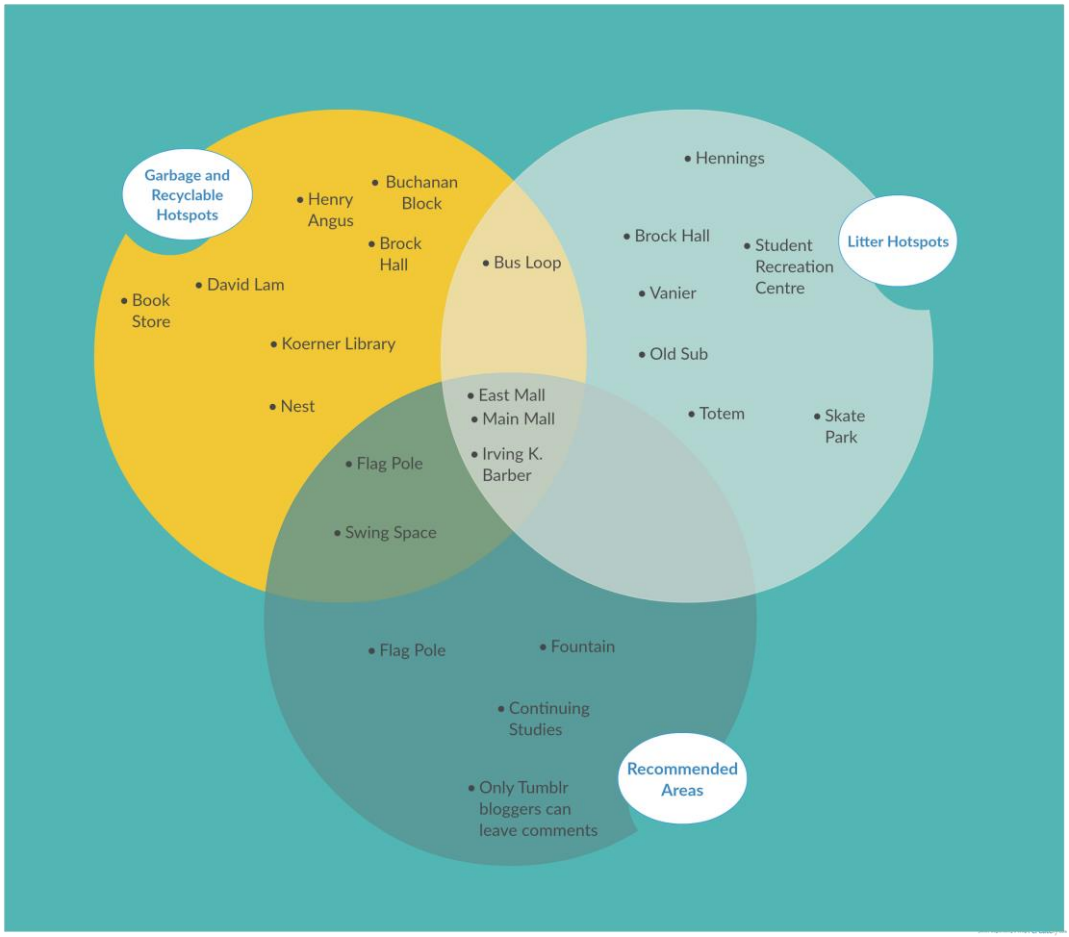

Figure 6. Diagram Representing The Overlap of Questions 3,4, and 8 in our Survey

The overlapping areas from all three questions were East Mall, Main Mall, and Irving K Barber. The Flag Pole, Swing Building Space, and the Bus Loop overlapped in two categories. Though all the areas listed on the Venn diagram are potential hotspots for the new implementation of the recycling bins, the overlapping areas are significant because more than one interviewee believed these areas are problem spots.

Figure 7 represents our findings on a thematic map. The circles represent the current traditional bins' locations and the recycling bins are represented by triangles. The symbols that are coloured red represent areas that Waste Management categorized as garbage and recyclables hotspots. The red hachured areas are categorized as litter hotspots. After analysing the information on litter and waste production, we were able to determine areas that overlapped, indicating a high amount of waste generation on the map (see Figure 7). These areas represent top potential spots for the implementation of our new recycling bins. Furthermore, the map shows that currently we have only 44 out of 117 traditional bins (37.6%) in the hotspot locations, which is not enough to withstand the daily waste generations. Most of the recycling bins (6 out of 9) are situated in the hotspot area which signals the need for more recycling bins. By implementing more recycling bins in hotspots and decreasing the number of traditional bins, we are advancing towards goal of having zero waste on campus.

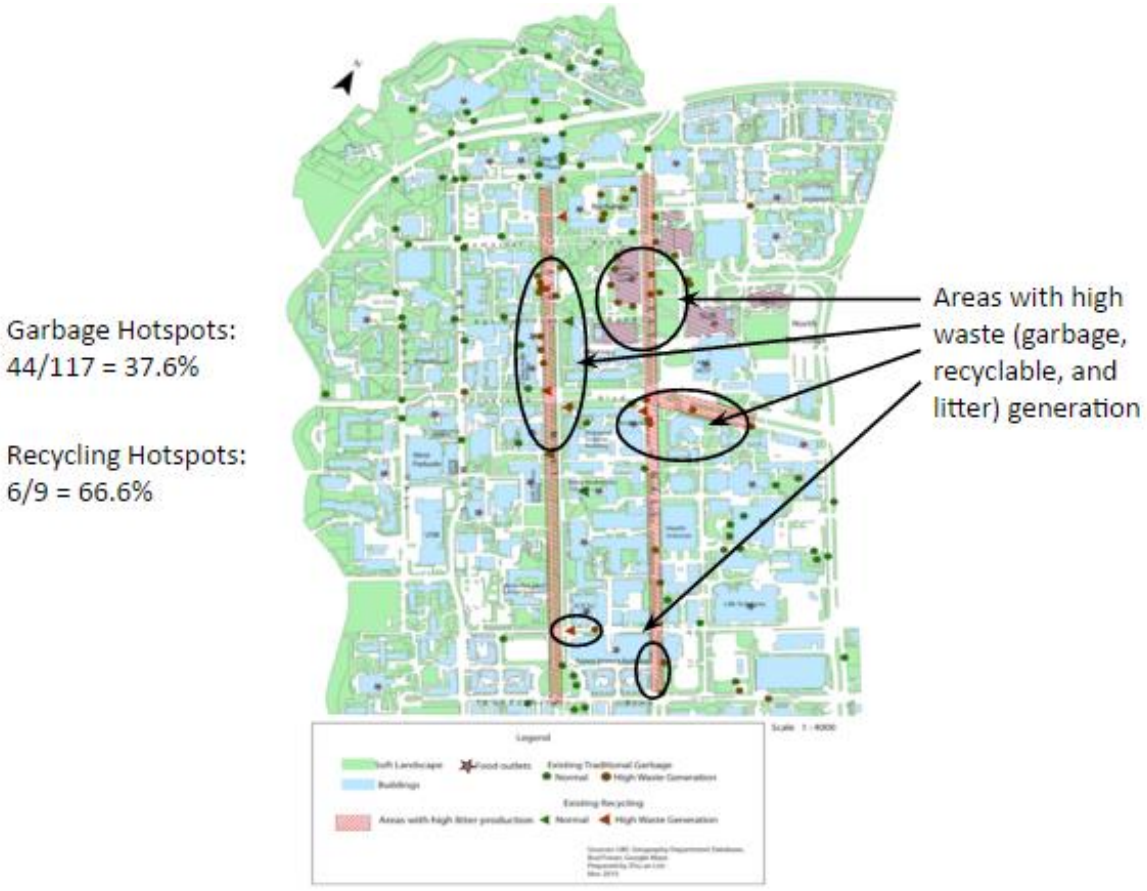

Figure 7. Waste Hotspots, Based on Results from Interview with UBC Waste Management

Participant Observation Analysis

We identified a few major trends in our participant observation. We noted that very few people were sitting down on benches, and we believed cold weather may have influenced this. We expect to have more people sitting outdoor during the warmer months as the weather is better. We also noted that some of the current recycling bins were very hard to locate (even though we already knew their locations from the map provided to us); this was especially true during the pilot test observation. In our meeting with Bud Fraser on November 6th, he mentioned

that planners intentionally chose locations for aesthetic reasons. However, for practical reasons we highly recommend making the bins as visible as possible. We speculate that if students do not see the bins easily, they are less likely to recycle. In terms of population flow, Main Mall was the busiest area. East Mall came up second; and West Mall, with the exception of Swing Space, was the least crowded road. Based on our findings, we created a population flow map (Figure 8), and used it as a layer in our final map to recommend potential locations for future bins. There appears to be some correlation between the areas with high population density and waste hotspots, indicating the need for a recycling station at areas with high outdoor population.

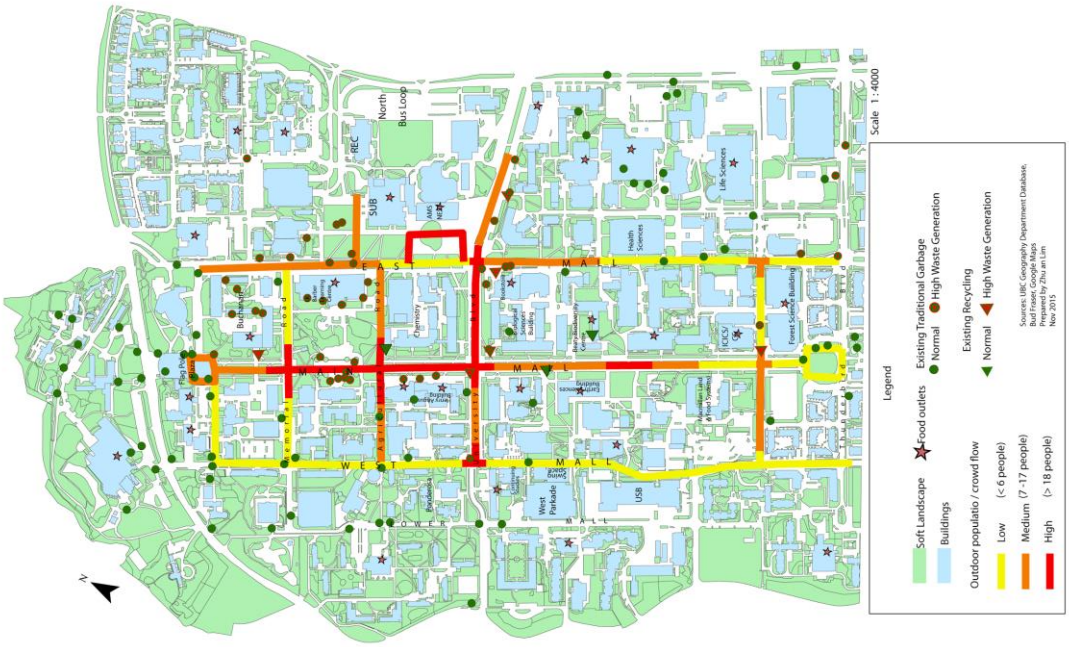

Figure 8. Outdoor population density on campus, based on participant observation results

Significance of Research Study

In conclusion, our team has proposed 14 new locations for the installation of recycling stations across the UBC campus, which we have represented on a cartographic map (Appendix 1). These locations are chosen based on the six formulated criteria in the research, and they will provide an overview of suggestions and recommendations for the installation of new recycling stations. The data collected from our primary research (participant observation, interviews, surveys) were analysed using the Geographic Information System (GIS) as different layers of considerations for the study. By overlapping different layers of spatial data, we were able to see which locations on campus satisfied the majority of the proposed criteria and were suitable for the implementation of new recycling stations. Our research illustrates some patterns and relationships between the different factors, such as the correlation between areas with high outdoor population and high waste generation. By analysing these patterns and trends, we picked the top areas that are in need of new recycling stations. Areas that were considered to be high priority reflected high waste production and a large outdoor population, which suggests that the probability for the use of recycling stations is much higher in these areas. They are also considered to be closer to points of consumption (i.e. food outlets), which suggest a better chance for recycling based on a previous study by O'Connor et al. (2010). This study also considers popular leisure and social gathering locations, as the effects of peer pressure may increase efforts in recycling and thus the use of these recycling stations (Clay, 2005).

The findings from our research are crucial as it contributes to the decision making process for the installation of new recycling stations on campus. Our study evaluated individual locations and determined the feasibility of installing a new recycling station at these locations. Using both quantitative and qualitative analysis, our research provides decision makers with the data and information needed to determine which areas on campus require more recycling stations

or which areas to replace existing traditional bins. By using a scientific, analytical approach, we can justify our recommendations and claims to our client and partners. Because the cost of implementing a recycling station is much higher than a traditional garbage bin, is it important to first ensure that the chosen potential locations will promote the sorting of waste and reduce the amount of garbage. As mentioned in the first sections of this report, the recycling stations (Big Belly) which will be installed at outdoor areas will also be grounded, meaning there will be additional costs to move recycling stations once they have been installed. The results from the study are also important to the Zero Waste Action Plan (2011), which aims to reduce the amount of garbage waste and increase the rate of waste diversion through recycling. Therefore, by determining the optimal locations for installing more recycling stations, we hope that it will promote the recycling movement and propel the UBC community into a zero waste campus in the near future.

Future Research Directions

Although our research offers important information to aid in the decision making process of recycling bin installation, there are still many relevant factors which may affect the efficiency of these stations that our research did not take into consideration. For example, we did not consider or differentiate between the types of waste (e.g. plastic, food compost, etc.) that are found across the campus and how that might affect the rates of use of recycling stations at different locations. Future studies might look into data of contamination rates in traditional garbage bins and recycling bins across the campus, and use that data as an additional layer of information when considering potential locations (Felder et al. 2001). This may reveal trends in waste disposal behaviors around campus and show which areas require more sorting stations

rather than traditional bins to promote the recycling movement. It would also provide the necessary infrastructure in strategic locations to enable users to recycle their waste rather than disposing it into a garbage bin. Some areas might have higher contamination levels as they are closer to food outlets such as Starbucks or Tim Hortons (Sandhu, 2015). Waste with more than 5% contamination is diverted to garbage, which defeats the purpose of a sorting station (Mackenzie, 2015). Therefore, further studies might also look into education and awareness of contamination rates, and the importance of sorting waste correctly.

Another issue is the difficulty in obtaining accurate data for outdoor locations on campus, as there is limited existing data which reflects the population density in outdoor locations. It is therefore essential to come up with innovative ways to gather primary data in terms of outdoor population and crowd flow. In this instance, the use of a participant observation may be a good representation, but it incorporates some degree of subjectivity when it comes to the data collection process. There could be some degree of bias during the collection process such as the time chosen to take the observations, the number of locations observed, and the method of counting the number of people as well. The presentation of discrete data as a continuous layer on the thematic map may also display some degree of misrepresentation. Future studies might include more creative ways in obtaining more accurate data for outdoor locations, such as aerial photography with the use of drones, remote sensing, or even by tracking the movement of students via Wi-Fi usage on campus.

This study did not rank the individual criteria when considering the potential locations, thus each criteria or factor is considered to be equally important. Future studies might develop some form of ranking amongst criteria to determine which are more important and have a bigger

influence on the efficiency of recycling stations on campus. The different importance of factors might affect the optimal location for new recycling stations. For example, if proximity to food outlets is considered to be more important than popular leisure spots, the consideration for locations adjacent to food outlets will be of a higher priority than the latter. A trial and error method of installation would be a good way to gauge the importance of each factor, by installing a number of recycling stations across the campus to test their efficiency. However, this method would require more resources (money, manpower, etc.) and time to achieve.

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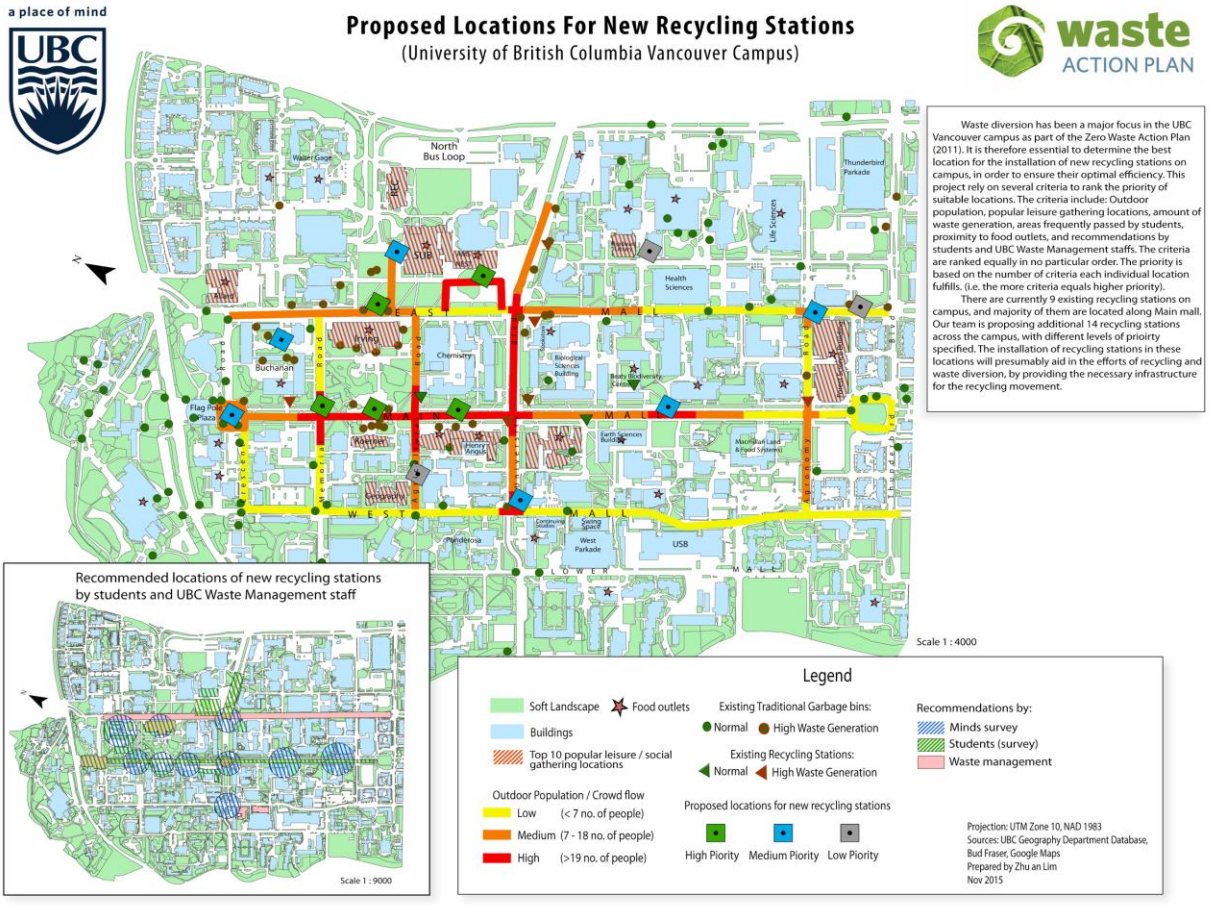
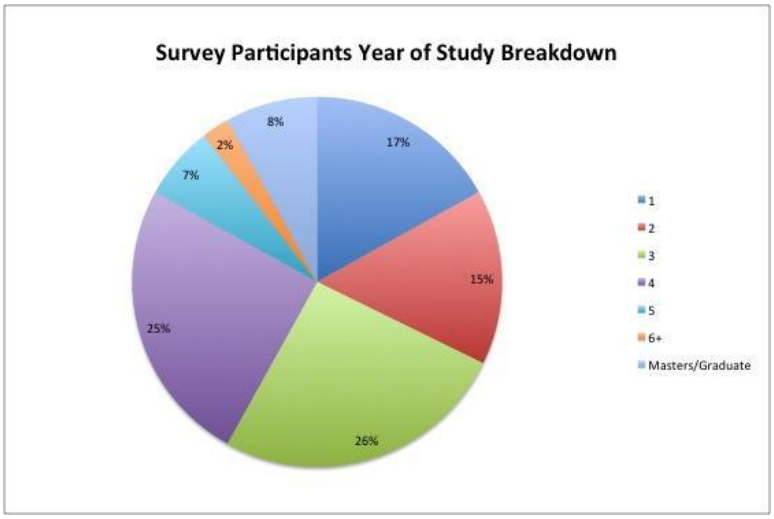
Appendix

Appendix 1 - Our Recommended Locations of Future Recycling Bins



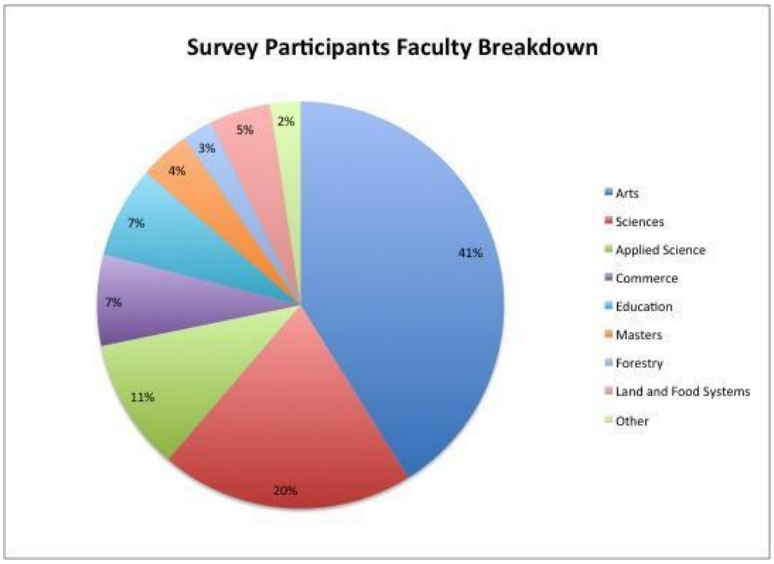
The locations of recycling bins are recommended considering six important factors. These areas are prioritized by colored squares (green, blue, grey) on this map.

Appendix 2 - Survey Participants (Students) Year of Study Breakdown



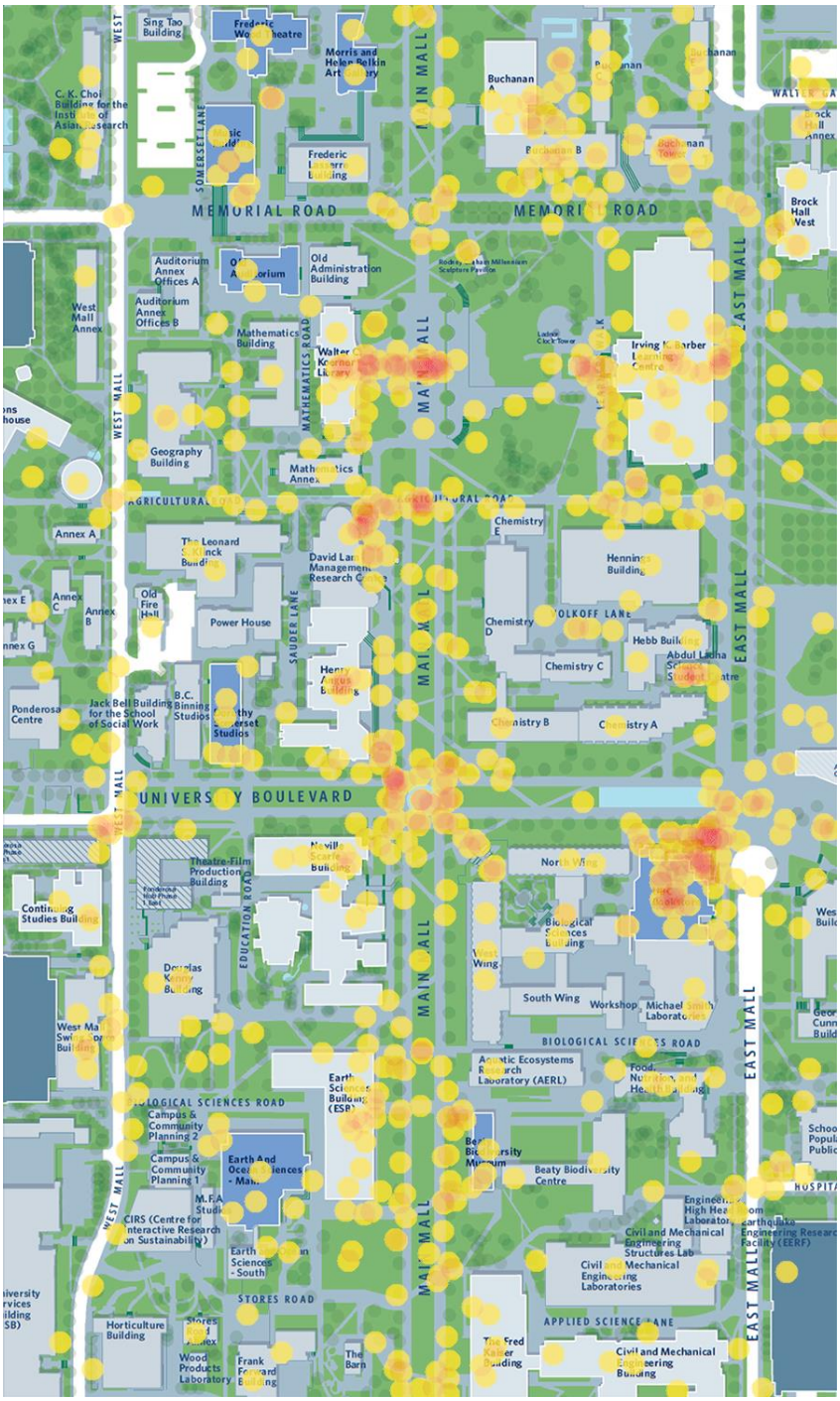
This graph represents the diverse range of students that were surveyed. Out of 163 students surveyed, 124 fully completed the survey and were considered in our study.

Appendix 3 - Survey Participants Faculty Breakdown



This graph represents the diverse range of students that were surveyed. Out of 163 students surveyed, 124 fully completed the survey and were considered in our study.

Appendix 4 - Minds Survey Map from Bud Fraser



Minds Survey Map provided by Bud Fraser, showing student recommendations for new recycling bin locations.

Appendix 5 - Survey Questions

What is your year of study?

What is your major of study?

Where do you spend most of your leisure time on campus?

What sites do you frequently pass on your daily routes on campus?

How high of a priority should campus sustainability be to UBC students?

How often do you recycle paper products on campus?

How often do you recycle plastic/glass/metal products on campus?

How often do you recycle food waste products campus?

Are you willing to go out of your way to recycle a product on campus?

If yes, how long (in minutes) are you willing to travel to properly recycle your waste on campus?

If no, what do you do with your waste on campus?

Where would you like to see more outdoor recycling bins on campus?

Appendix 6 - Interview Questions

How long have you worked for UBC Waste Management?

What is your position? What are your responsibilities?

Name the top areas that generate the most *waste* on campus.

Which areas generate the most *litter* on campus?

How do you determine when and how often to empty the recycling bins?

How often are the bins emptied?

How do you think waste management can be better improved in UBC?

Which areas do you recommend for more recycling bins?

Appendix 7 - Participant Observation, Locations of Data Collection

This map represents the exact location we took our pictures during our visual participant observation.

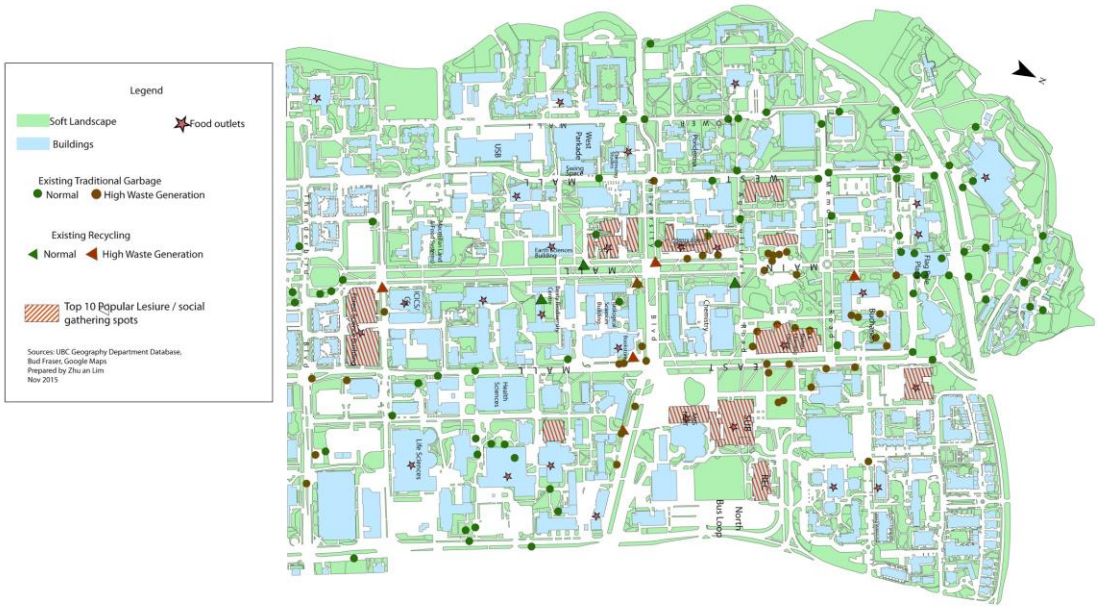
Appendix 8 - Participant Observations Table

Location	# of People	Observation	Time
A1	10	people going to and from between classes	1:46
A2	16	not many sitting areas, just outside the law building, most of the people are there	1:47
A3	17	a few people on benches and walking to and from	1:49
A4	3	not really any people, also not really any sitting space	1:49
A5	2	quite empty	1;51
A6	2	appears to be busier on west mall as it gets further from the periphery	1:52
A7	19	very busy! some people sitting on benches eating, but its cold so less people than normal	1:54
A8	19	some people walking around	1:55
A9	4	some people sitting on the benches	1:56
A10	15	Mostly people walking around	1:57
A11	5	mostly walking people	1:58
Z1	6	Very few people, mostly passing by	1:47
Z2	17	quite a few people passing by between main and west mall	1:50
Z3	30	crowded intersection, only one recycling bin outside Triple Os	1:53
Z4	36	many passerbies, also people sitting on the benches	1:56
Z5	10	one outdoor fod outlet behind irving, few ppl walking by	1:59
Z6AMS	28	more people outside AMS at the open space	2:02
Z6Road	5	more people outside AMS at the open space	2:02
Z7	6	quite a few people passing by	2:05
Z8	12	I expected more people by the old sub. Probably because it is not peak hours.	2:07
M1	8	Near bus loop, Nobody is sitting everyone is walking to class	1:49
M2	11	N/A	1:51
M3	30	One of the busiest places, New bookstore, AMS, 2 food trucks, ppl sitting	1:53
M4	20	2 food trucks, people sitting down, no visible recycle bins	1:58
M5	16	N/A	2:01
M6	25	N/A	2:04
M7	4	N/A	2:07
M8	21	Quite a lot of people, no one sitting down, no visible recycle bins	1:56
M9	10	more quiet places, no bus, people passing by	2:06
Y1	9	sidewalk half closed, construction, people hang out by public health building	1:40
Y2	5	6-7 ppl walking with food, ppl using recyclable bottles, bench nearby	1:42
Y3	4	1 garbage bin, people walking by, no sitting area	1:47
Y4	0	construction, people are concentrated by the starbucks down the road, walkway closed	1:49
Y5	14	busy intersection,no one is sitting, 2 garbage bins 1 meter apart, no recycle bins visible	1:50
Y6	6	Sort it Out Bins, not many ppl at the corner, benches along agronomy	1:53
Y7	14	residential area, construction	1:56
Y8	20	people walking with starbucks cups, a starbucks nearby	1:59
Y9	15	more pedestrians and bikers, ppl sitting at the open area outside earth and sciences	2:03
Y10	2	few people	2:06
Y11	3	one person sitting on a bench very few walking by	2:08
Y12	1	not many people	2:11
Y13	0	residential area, construction, sidewalk closed	2:13
Y14	4	few people, residential area	2:15
D1	4	Very Few people, 2 traditional bins	1:50
D2	3	very few people, space for social gathering	1:53
D3	2	few people large recycling	1:56
D4	5	large social gathering space, food truck	2:09
D5	2	few people	2:03
D6	15	more pedestrian traffic, no social gathering spaces	1:59

Details on our findings from participant observations shows some major trends

Appendix 9 - Top 10 Leisure Spots

Top 10 Leisure Locations on Campus



Appendix 10 - Top 10 Frequently Passed Locations