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## **Understanding Micro-Mobility Transport in New Zealand**

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### **Abstract**

The last decade has seen an explosion in the popularity of “micro mobility” transport services. In Wellington alone both JUMP and Flamingo have launched e-Scooter services since the commencement of this project in early 2019. There is a lot of data that is generated by these services, and understanding this data can help improve and enhance the services these vendors provide, and harmonise these services with a local or national overall infrastructure plan. *MicroVis* is a web application dashboard with multiple visualisation widgets developed for the specific purpose of assisting in analysing such micro mobility data, and developing insights into such data.



# Acknowledgements

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# Chapter 1

## Introduction

The transportation infrastructure is vital for any city, facilitating the movement of people and goods on a daily basis. Micro-mobility style services are an increasing part of the makeup of the national transport infrastructure, and is comparatively new part of how many people move.

### 1.1 Problem Statement

A recent phenomena in many cities is the introduction of micro-mobility services. With an increasingly urban population, there has been a resurgence in demand for such devices, with some companies that offer these services valued in the billions of dollars [17].

The term micro-mobility covers many different types of device, including bicycles, and electric scooters. Each of these types can have differing properties, and hence a different use case. Because of these differences, the way a user uses each of these devices is different. This makes investigating each specific service important to the vendors of such services.

Examples of such micro mobility include Onzo [22], Lime Scooters [16], and JUMP scooters and e-bikes [13]. Such services normally cover smaller distances than competing services such as taxi cabs, or purchasing modes of transport outright (for example the purchase of a car) [7]. These types of services can be seen in Figures 1.1 and 1.2.

Given the fact we now live in a “data rich” society, with an abundance of both open source and closed source data on how people interact with the world. With this changed data landscape, there is now more data than ever before about transportation, and micro-mobility in particular. A common theme from industry is a lack of knowledge on how to best represent this new abundance of data, and thereby gain useful insights out of the data.

For the past several years Victoria University of Wellington and Beca have collaborated on visualisation projects on transportation related data. This project forms part of this collaboration and was envisaged to encompass a visualisation in collaboration with service providers in order to derive insights into the services.



Figure 1.2: Micro mobility devices as used by customers in New Zealand

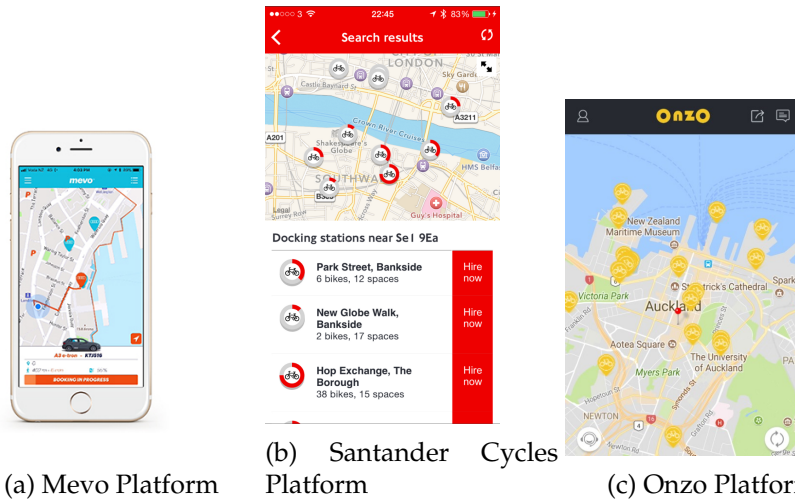


Figure 1.1: Mobile applications for various micro-mobility services

## 1.2 Description of Services

In these “micro-mobility” platforms each of these services offer a different value proposition to their users, and therefore can have radically different uses.

The term micromobility comes from a talk given by Dediu in a 2017 talk about micromobility at the TechFestival Conference in Copenhagen [19, 26]. Explaining the term to refer to vehicles under 500kg, commonly used for short distance trips.

These different uses can lead to a different “fingerprint” with each being used in different ways, at different times, by different people. These create different use cases for each of these services. Therefore it is important to create a generic platform that can be used to analyse data from different providers (such as the examples from Table 1.1).

Platform	mode	free floating?	payment method	Drive yourself?
<b>Mevo</b>	car	yes	Fixed + time	yes
<b>Uber</b>	car	yes	Fixed + time	no
<b>Onzo</b>	bicycle	yes	Time	yes
<b>Lime</b>	electric scooter	yes	Fixed + time	yes
<b>Santander Cycles</b>	bicycle	no	24hr pass + any time over 30 mins	yes

Table 1.1: Analysis of the characteristics of various “micro-mobility” platforms and differences

### 1.3 Research Questions

The research questions for this project are derived from meetings with members of industry, and what information they are interested in. Vendors, such as Onzo, were typically interested in where their services were being used. This was particularly of note for services that regularly relocate their assets overnight, as this could optimise such a relocation process. This could improve the experience for the end user, and provide better revenue for the service provider.

Government agencies, such as city councils, were typically more interested in how the service was being used, and whether the system was being used in conjunction with other services. These kind of agencies were interested in the “unique characteristics”, and how these services fit into a larger transportation strategy.

The research questions that this paper will explore are:

**RQ1** Where and when are micro mobility services being used in New Zealand?

**RQ2** What visualisation techniques are effective for understanding micro mobility data?

### 1.4 Outline

The remainder of this report is organised as follows:

<b>Chapter 2</b>	The background work, and related works to visualisation of micro mobility transport.
<b>Chapter 3</b>	The solution MicroVis offers and the design and implementation thereof
<b>Chapter 4</b>	The design of a user study to evaluate the efficacy of the solution
<b>Chapter 5</b>	The results, and evaluation thereof obtained from the user study
<b>Chapter 6</b>	Conclusion
<b>Appendix A</b>	Application for ethical approval lodged with the Victoria University Human Ethics Committee
<b>Appendix B</b>	Questionnaire for the user study associated with such an application





# Chapter 2

## Background

After reading numerous publications in the transport and visualisation domain it was concluded that there were not to the author's knowledge any existing systems with the same goal. However, there were many papers with similar features, and these papers provide an important reference for different aspects of the project. As such a selection of papers were examined to inform the design and implementation of this project. This discussion will first explore some existing transport visualisation systems, and will later refine to specific techniques and technologies.

### 2.1 Information Visualisation

Information Visualisation itself is a process that "transforms data, information, and knowledge into a visual form exploiting people's natural strengths in rapid visual pattern recognition"[9]. This pattern recognition allows for the expression and study of data in ways possible through no other medium, and can lead to users studying data in a more effective manner [9].

This kind of exploitation of natural strengths can often result in a system that begins with a more general overview of the dataset, and give the user the tools to filter down the data to a more manageable size, and view the details. This can be evidenced through Shneiderman's notion of the "Information Seeking Mantra", "Overview first, zoom and filter, then details-on-demand" [25].

One method of visualisation suggested by Shneiderman, is the idea of a customisable dashboard which he names as a "Dynamic Query" [24]. This visualisation method allows for exploration of complex datasets, and in particular data with unknown correlation between variables, such as economic markets, demographic data. Shneiderman also suggests that this "Dynamic query" system can replace keyword command language systems (such as a Database management system), and that humans can more intuitively view visual data than numeric, or otherwise raw data, and pithily cites Hamming as saying "The purpose of computing is insight, not numbers"

### 2.2 Visualisation Techniques

#### 2.2.1 Visualisation of Point to Point Movement

Nagel et al [21] have explored more dynamic visualisations, with a focus on interactivity looking at public transit systems. Nagel et al examined how to visualise interactive and accessible representations of the Singapore train system, this examined a combination of map,

time series, and an ‘arc’ visualisation (these can be seen in Figure 2.1), and created interactive graphics including filters, selections, and use of a multi-touch device. A series of user studies of the product were conducted, the results included that non-experts preferred more “concrete” representations of data (for example an overlay onto a known representation of a physical item such as a map), and experts preferred more “abstract” representations of data (i.e. the ‘arc’ and ‘time-series’ visualisations). Nagel et al posits that the reason for this is familiarity for non-experts, and experts prefer the abstract view to find more complex aspects to the data. This research is particularly relevant as it refines the types of visualisation that the project laid forth in this paper should take in order to appeal to the expert audience.

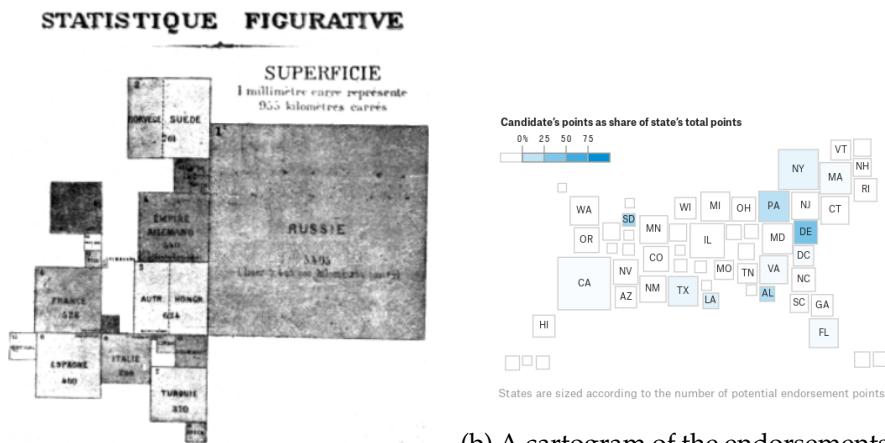


Figure 2.1: Multi touch table top with (a) Map, (b) Time Series, and (c) arc visualisation[21]

## 2.2.2 Visualisation of regional subareas

Rather than viewing activity as a series of distinct points, but rather areas, it is possible to view the traffic of an area using the area itself.

An example of this is called a cartogram. Cartograms are when a shape representing an area, such as a suburb in this case, is distorted in such a way that it is still recognisable, but its area corresponds to a value [27]. This kind of technique is hundreds of years old, and using computation it is possible to have a high level of distortion while maintaining a level of recognisability [14, 27]. Figure 2.2 examines the evolution of such techniques.



(a) A cartogram dated 1870 comparing the area of countries [27]

(b) A cartogram of the endorsements for Vice President Biden in the 2020 United States Democratic Party primary [6]

Figure 2.2: Examples of cartograms

Cruz et al. examined how to apply such techniques from a traffic visualisation perspective [8]. This found that when working with highly detailed maps, the algorithm to create a cartogram created a necessary trade-off between absolute accuracy, and maintaining the

original shape of the region being distorted. Their model created tension using spring forces proportional to the speed of vehicles along predetermined roads. This error was reported to be between 2% and 3%, with greater inaccuracy when their model showed more congestion, and hence less force, on the distortion effect. From this research it has shown that the co-efficients for such a diagram should be selected based upon striking a balance between identifiability, and proportionality.

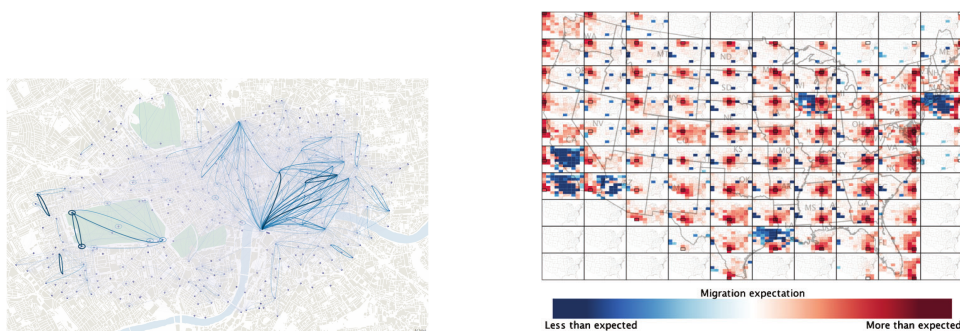
Another paper by Haenert and Sering examined how a “fish eye” view of detailed areas of interest can enhance readability in traffic visualisations [12], and in particular how to do that without such distortion. Of note is that this technique is not sufficiently optimised for real-time analysis.

### 2.2.3 Micro Mobility Transport Visualisations

Most visualisation techniques for micro mobility focuses on docked devices, such as the Santander Bicycles in London (also known as ‘Boris Bikes’).

Existing work focuses on aspects other than visualisation. Montero et al have explored modelling of changes to the adoption of micro mobility, and the consequential reduction of car usage, consequently creating OD Maps to display the generated results [20]. This study does not evaluate the efficacy of the visualisation, but demonstrates the application of OD-Maps in the context of micro mobility.

Wood et al. has previously worked on examining the London Cycle Hire Scheme (LCHS) and examined methods for visualising point-to-point travel. Wood et al [29] explores visualisation techniques, and in particular flow maps for display of point-to-point travelling. Wood et al analyses multiple approaches for visualising these trips, such as the aforementioned flow maps (see Figure 2.3a), spatial matrices, and hierarchical spatial matrices (‘Origin-Destination (OD) maps’) [28] (see Figure 2.3b). Wood et al finds that ‘OD maps’, and flow maps serve distinct, but complimentary purposes for the purposes of his paper, noting further development areas such as identifying seasonal trends better within the frameworks offered. It should be noted that the LCHS is a node-to-node system, that is based on docking the bicycles into defined spaces, and is not a floating system similar to some micro mobility offerings.



(a) A flow graph of the London Bike Share (Santander Cycles) System [29]

(b) An OD map of migration within the continental United States [28]

Figure 2.3: Some of the visualisation styles explored by Wood in [29].

## 2.3 Transportation Visualisation Technologies

One of the key features determined from previous studies was interactivity. The ability to interact and find specific insights was particularly important in understanding the data and

engaging the user [21].

One of the most common interactive visualisation frameworks is “Data Driven Documents” (D3) [3]. D3 is built in JavaScript and relies on the core Document Object Model (DOM) from HTML, which is present in all modern web pages, and browsers. The approach of D3 is to tie data to objects within the DOM. In combination with other technologies such as Scalable Vector Graphics (SVGs), and Cascading Style Sheets (CSS), D3 can be leveraged to create advanced, and interactive visualisations. An example of such a visualisation created in D3 and using SVGs can be found in Figure 2.4, where Bostock created a visualisation of drought severity.

This technology is particularly useful for this problem, as it provides a useful method of creating dynamic visualisations on a web platform. This makes the software operating system-agnostic, and usable on all platforms.

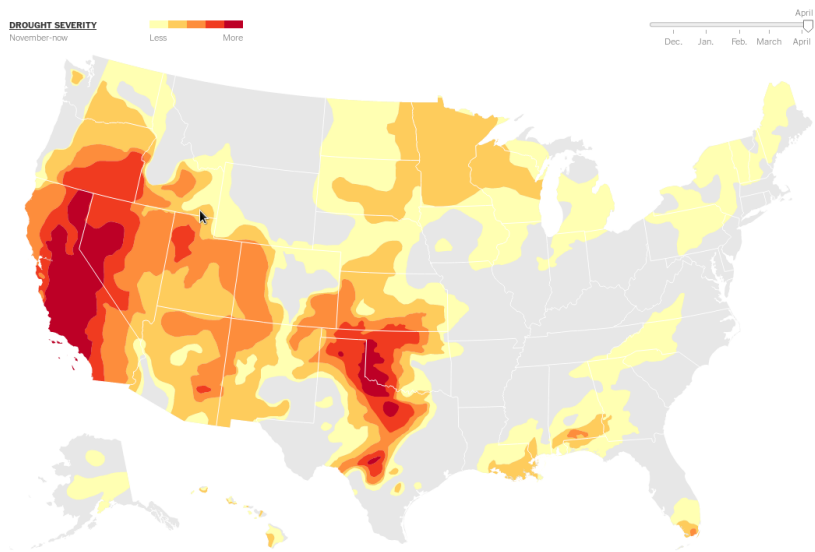


Figure 2.4: An example of a D3 interactive animation, a choropleth displaying drought in the United States at different times [4]

An alternative solution to this would be to use existing data visualisation tools such as R, a common statistical analysis language, that is used commonly in academia, and increasingly in business [1]. However, R and its common libraries are more difficult to provide an interactive environment to visualise data with.

## 2.4 Summary

## Chapter 3

# MicroVis

*MicroVis* (seen in Figure 3.1) is a proposed method to answer **RQ1** through visualisation techniques. It is made up of a dashboard like interface, with a series of visualisation widgets and filtering systems. The intended effect of this is to create a tool that works in a professional environment as a tool that works as a tool to assist in deriving insights about micro mobility transport data.

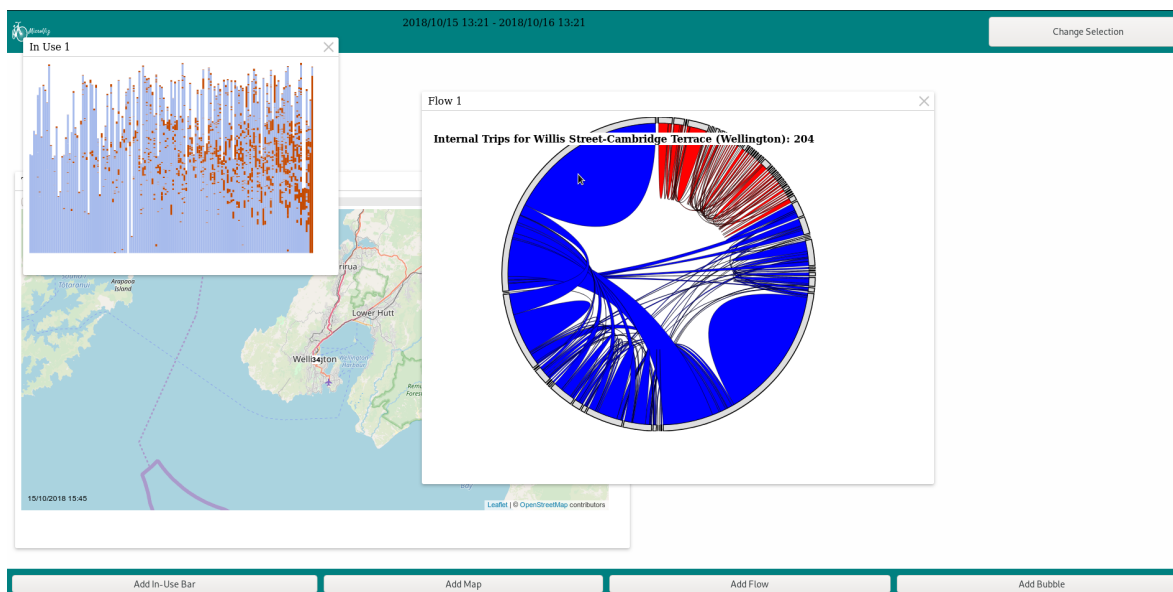


Figure 3.1: MicroVis, showing the In-Use Bar, Map, and Flow charts for a 24 hour period starting on the 15th of October 2018

### 3.1 Design

#### 3.1.1 Requirements

The design of the visualisations was guided by a number of functional and non-functional requirements. These requirements were derived from the research goals as stated in Section 1.3, research completed in Chapter 2.2 and in particular the findings of similar studies, and the limitations of the data provided.

These requirements were driven by the idea of creating an extensible and multi-platform system to visualise the data, and consultation with some members of the transportation industry.

The functional requirements were as follows:

- The application must be a web based visualisation
- The application must work on all modern web browsers
- The application must be real-time, or close to real-time in performance

The non-functional requirements were as follows:

- Usability — The application should be intuitive, such that minimal exposure to the application is needed to make full use of the program.
- Extensibility — The application should be easy to make modifications to.
- Accuracy — The application should not mislead the user about what the output shows.
- Security — The application should not reveal confidential or proprietary information.

### **3.1.2 Personas**

González demonstrated that in workplaces that use information visualisation tools, a typical user has a task prior to using the tool, rather than as an exploratory tool [10]. Subsequently is important to plan for the anticipated usages of the application.

As such a series of personas were created in order to simulate the anticipated users of the program and therefore the usages, rather than an ad-hoc development.

#### **Vendor Analyst**

The first persona would be for an analyst at a micro mobility vendor, who would be interested in more commercial aspects of the data.

Alfred Wessex is a young data analyst with a cycle hire company. He works on delivering data-driven insights into the business, and how he can contribute to the company. He has a strong history with Excel, and has experience with Tableau, which he uses to create visualisations to get a sense of the data. Alfred has strong experience with computers and can adapt to new interfaces easily.

#### **Regulator Analyst**

John Anjou is a middle age planner at the city council. He wants to find out where and when micro mobility is used, and use these technologies as part of the infrastructure plan for the city. John is competent in excel, and uses visualisations as part of his presentations, and to a lesser degree to spot patterns before using excel or another tool. John generally dislikes learning new interfaces, and will avoid learning new technologies if possible.

#### **Manager / Executive**

Jane Grey is a senior executive for a micro mobility company. She is focused on finding out ways to improve the adoption and use of the devices. Jane has little experience with excel, and prefers to view data visually. Jane is not technically savvy, and requires help on some basic computer functions.

### 3.1.3 Use Cases

This section shall describe a series of intended potential use cases for *MicroVis*

#### **Use Case 1: Find when micro mobility devices are most used during the day**

Alfred wants to know when devices are used during the day for planning purposes.

This could be useful for planning the redistribution efforts of the vendor.

1. Alfred finds the date range he is interested in.
2. Alfred selects the region(s) he is interested in.
3. Alfred clicks on the “In Use Bar” widget.
4. Alfred hovers over different periods to find out when each of these are more frequently used in.
5. Alfred calculates himself when these would be most used based on how he interprets the data.

#### **Use Case 2: Find where most trips are taking place**

Alfred wants to know which areas represent the greatest proportion of trips.

This is useful for measuring demand, and where to deploy these devices in the future.

1. Alfred selects the date range he is interested in.
2. Alfred selects whatever regions he is most interested in.
3. Alfred clicks on the “Flow” widget.
4. Alfred hovers over the largest arc segment(s).
5. Alfred notes the region(s) of interest.

#### **Use Case 3: Identify the unstable regions of the network**

Alfred wants to examine areas of the network, and find any where there are either surplus or a deficit of devices in that area over a specified period.

This is useful for Alfred, as it can help inform any redistributive efforts that the company may have.

1. Alfred selects regions that he believes are of interest.
2. Alfred chooses the timescale he is interested in.
3. Alfred clicks of the “Bubble” widget.
4. Alfred takes note of the items bottom left to top right diagonal.

#### Use Case 4: Compare the location of devices to where trips took place

Given the location of where each device was, compare that to the trips taken from various regions.

This would give information on the efficacy of introducing micro mobility to new areas, and whether adding a device into an area would be more used than where it is already.

All the personas would be interested in this

- Alfred would want to see where it is used the most, so he can redistribute items to more effective areas
- John wants to know areas which are under-served by public transport, and where existing infrastructure should be improved to increase use of more mobile devices.
- Jane wants to move the devices to places where they will be used more, to earn more money

1. The persona selects the timescale they believe are of interest
2. The persona views the flow graph and map side by side
3. The persona makes note of any observations they find interesting (e.g. there were 5 devices in region X, and they were never used)

### 3.2 Visualisations

As a visualisation platform, MicroVis has a series of visualisations that can provide insights from the provided data.

These visualisations are as follows:

Visualisation	What it depicts
Map	Physical locations of micro mobility devices at a single point in time.
In Use	When micro mobility devices were used during a range of time, and where each device were individually for those periods.
Flow	Where the trips taken came from, and went to.
Bubble Chart	The balance of incoming and outgoing journeys for each sub-region.

Table 3.1: Visualisations in *MicroVis*

#### 3.2.1 Map Widget

The Map widget displays a map of New Zealand, and displays micro mobility devices on it. This can be seen in Figure 3.2.

The user can navigate the map, using the mouse to both zoom and pan around, in order to view details of interest.

This visualisation shows the location of devices at a moment in time, and is animated over the time period selected by the user. This extrapolation is assuming that where devices ended their last trip is where they remain, at least roughly, and was acting under the assumption that they have not moved since then. If a device was currently in a trip, the algorithm applies a linear interpolation



Along the top control bar there is a play and pause button, and a control slider for the current time position, which can be dragged to change the time. This changes the positions, and whether the devices are visible, based on the information about each device at that point in time.

Due to the large number of devices, it is difficult to animate this at a high refresh rate. This is because of the resource intensive nature of mapping potentially hundreds of coordinate points, in fractions of a second timing. Because of this, and the lack of clarity in densely populated regions, a clustering algorithm is used. This condenses multiple device markers into a single marker to represent an area (as seen in Figure 3.2).

This is useful as it demonstrates where there is a lower turnover in the number of devices in the area, and therefore devices are not being used frequently in an area, or are being used to get to an area, but not from that specific area.

This satisfies, in part, **RQ1** (see section 1.3) by demonstrating areas where and when the devices are being used.

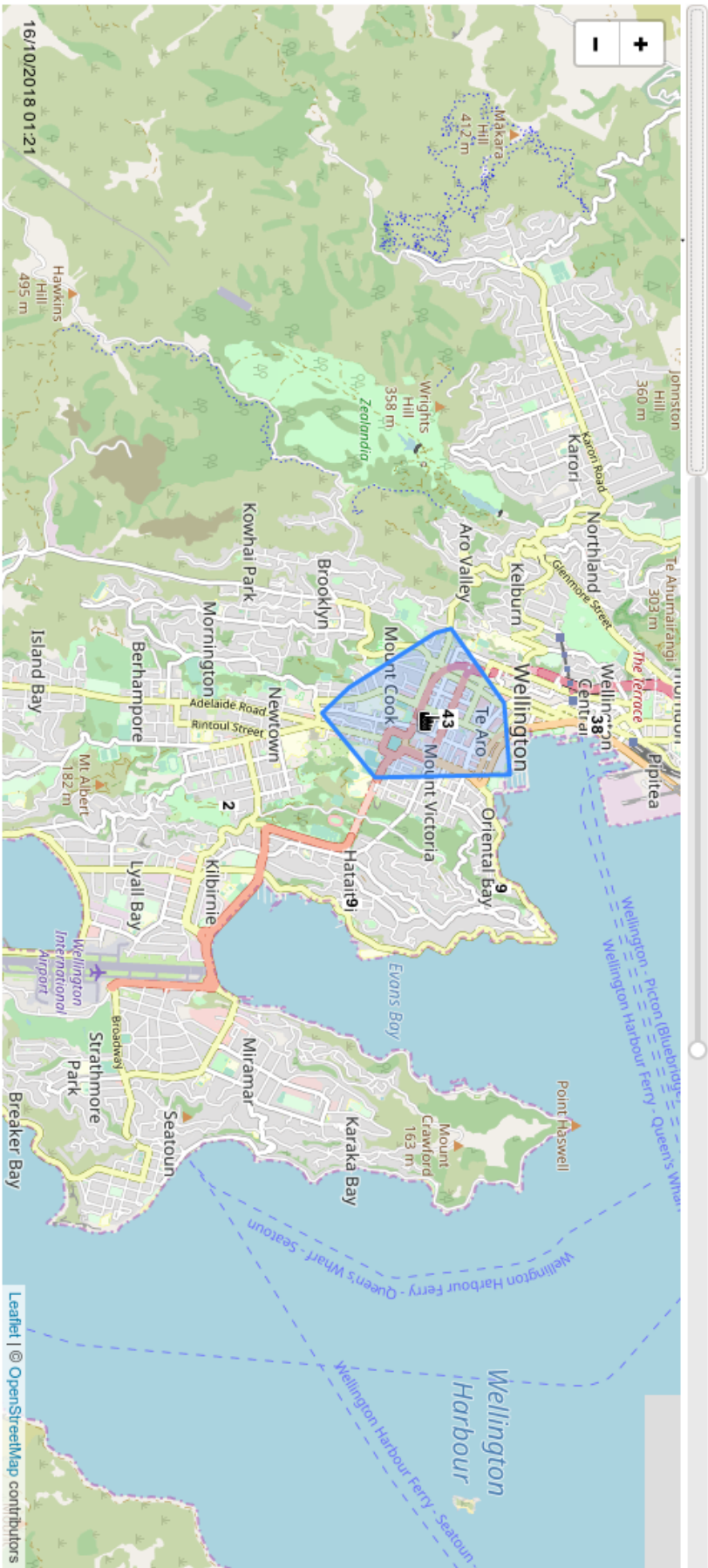


Figure 3.2: The Map visualisation showing where Onzo bikes are around the Wellington city region on the 19th of October 2019 at 6:23PM

### 3.2.2 In Use Bar Widget

The second visualisation shows the availability of the various micro mobility transport devices in the network.

The visualisation is composed of vertical columns, each representing a different device, and the colour changes along with time (along the  $y$  axis). A blue bar means that particular device is not in use, a red bar means that the device is in use. A white bar means data is unavailable for that period.

This is because the data provided is only the trips each device took, not when it was put into service. This means it is impossible to determine when the device was first added, and impossible to tell when the device was recalled, or removed from the streets. It is therefore impossible to show the availability of the device between the addition of the device to the network and the first ride, and the last ride and removal from the network with currently provided data.

However, because this data only exists for devices between their first known trip, and their last known trip. This has the obvious issue where we don't know when a device was first added to the network, and when it was finally retired from the network. This interpolation also doesn't account for when the devices are moved around the network without a trip, as this data isn't recorded anywhere, and is impossible to accurately predict.

This visualisation is sorted by its percentage utilisation. That is, the proportion of the time a bike was in service, that it was in use. This is a simple sorting system that shows more used devices on the right.

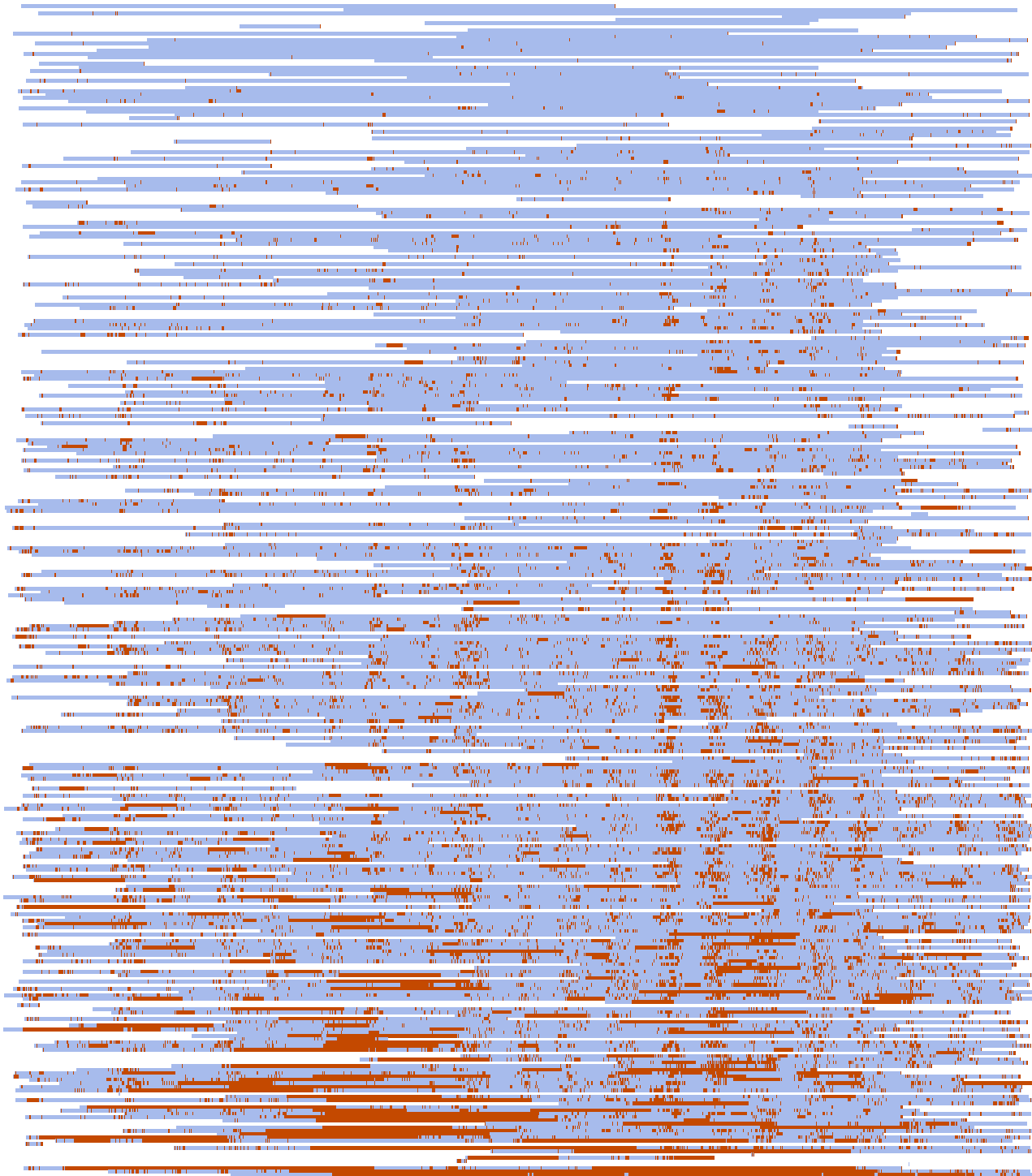


Figure 3.3: Availability Timeline Visualisation

### 3.2.3 Flow Widget

To meet the requirements for **RQ1**, there needs to be a method of viewing where trips were taken to and from. Given the large number of possible destinations, a more abstract view was used, and a chord diagram, similar to Anslow et al [2] was chosen in order to better represent this information, and can be seen in Figure 3.4.

This kind of diagram is useful to identify trip patterns, and common trip patterns. This is useful for planners, and vendors. For planners, this kind of information is useful to identify areas where these devices are being used, and the services that such a trip could be replacing. For vendors this information is key for business decisions such as where to place devices for maximum use.

This chord diagram represents the number of trips taken between the area units. Each arc length represents a different area unit, and the arc length represents the number of trips that leave the area. From each of these arcs are “chord”s, which represent each of the outgoing trips, and connect to the arc representing the area unit went to, and these “chords” size on each size represent how many left from the side which was connected to it (thus creating uneven chord sizes). It is also possible for a chord to loop back on itself (i.e. represent a trip with the destination be the same as an origin).

The colours of the chord diagram represent the city to which the trip belongs, with red trips showing Auckland based trips, and blue representing Wellington based trips.

Additionally, the use of hover-over interaction on each element of the graph. Hovering over an arc reveals which area the arc refers to, and hovering over a chord reveals how many trips were in each direction between the two areas the arcs refer to.

Critically the flow graph also reduces the visual complexity, as it does not encode much geographical information.

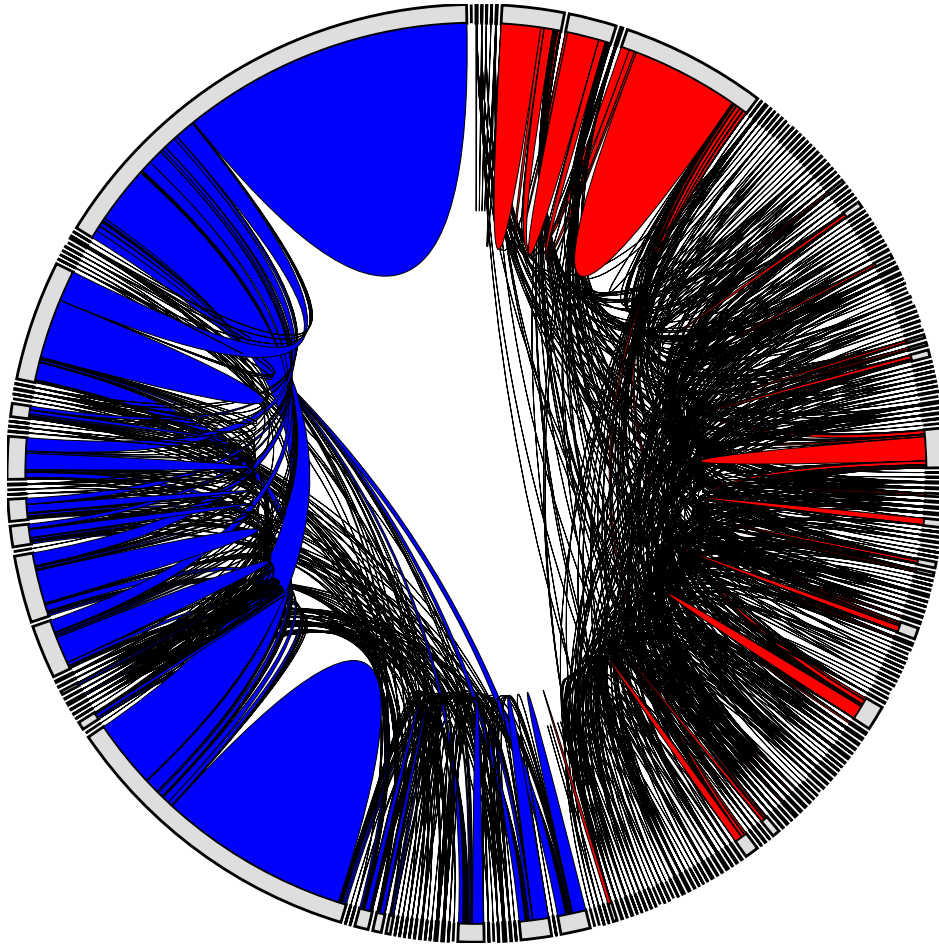


Figure 3.4: Flow Graph, representing all trips between the 15th October and 5th November 2018

### 3.2.4 Bubble Chart Widget

In order to view the balance of devices in regions (as in Use Case 3), there needs to be a method comparing the incoming and outgoing traffic. This is what the bubble chart does.

The purpose of this diagram is to identify areas where there is an imbalance in the incoming and outgoing trips. This has a significant impact for vendors, such as Onzo, which undertake device relocation at night, moving these devices from areas of low utilisation, to ones of high utilisation.

It was designed to be a simple and immediately readable graph, and a scatter plot or bubble chart is a simple method to convey this kind of information.

Each of the circles on this chart represents a region, the larger the circle represents more trips that involve that region (i.e. travel to and/or from the region). The  $x$  axis represents the number of devices that started in that region, and the  $y$  axis represents the number of devices that ended in the region.

The scale for both axes is the same, this means that if the circle is off the bottom left-top right line, there is an imbalance in the number of devices, and that might warrant further inspection.

The circles are hollow to allow the user to see all the data points and their placement.

Due to the large difference in values possible (see Figure 3.5), a Voronoi diagram is used by the implementation around each of the points to make highlighting each data point eas-

ier. By having these invisible Voronoi cells, this allows for easier selection of smaller items. On hover over each of these Voronoi cells, a tool tip reports the highlighted regions incoming and outgoing trips.

Moreover, there is zooming functionality for this diagram. This assists in viewing closely clustered data (for example: the bottom left data points in Figure 3.5)

What can be understood through analysis of Figure 3.5 is that generally there aren't regions with large imbalances, and that some regions require a little rebalancing (for example fourth from the right data point, which is "Thorndon-Tinakori Drive").

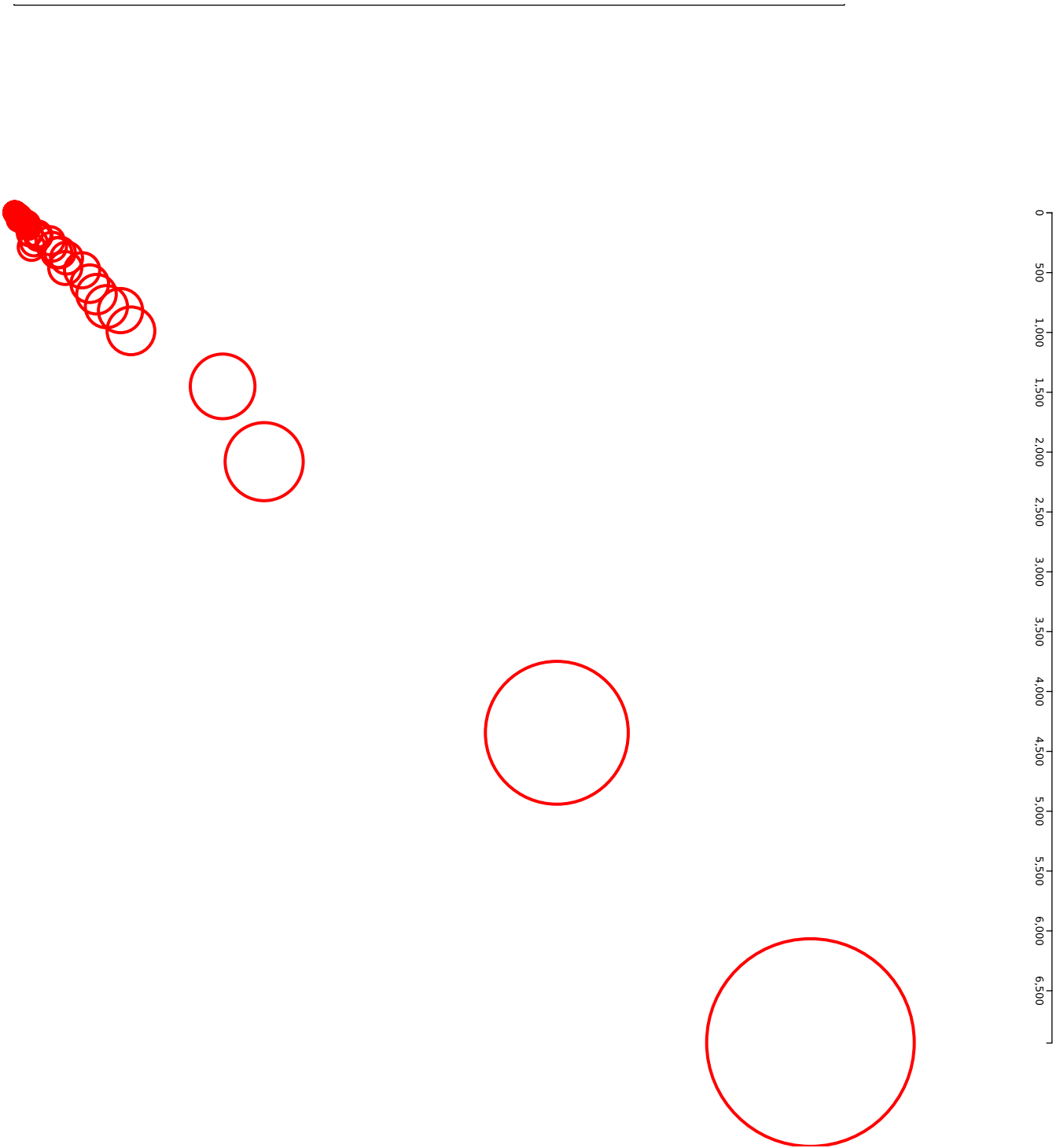


Figure 3.5: Bubble Chart showing all Mevo trips from the 15th October to the 5th November 2018



### 3.3 User Interface

One of the features that is most needed to solve the diverse needs of the target audience is flexibility. Experts interrogating the data may come across unexpected or unforeseen use cases. Only a subset of visualisation tools are relevant to an individual problem. A dashboard allows for an extensible tool, and empowers its users to decide which visualisations to use their own judgement to decide which visualisations are important for the given problem.

One of the critical features for a dashboard, or widget based system is that it must allow for items to be added. Both Microsoft Windows, and Apple Macintosh computers have application launch menus along the bottom of the screen. For familiarity, the decision was made to emulate this layout. Along the bottom of the screen were buttons to add visualisations to the display. This can be seen in Figure 3.6



Figure 3.6: Visualisation Launch Bar, showing the buttons to launch each of the visualisation widgets for *MicroVis*

#### 3.3.1 Selection

Similar to adequate selection of visualisations, it is important that users are able to select the correct data to visualise, and that these visualisations reflect the selected data.

In order to achieve this a selection tool bar was created at the top of the interface, as seen in Figure 3.7. This provides information on the currently selected time period, and provides a method of changing the filters used in the selection.

By default, the selection of the application is over a one day period in the data to provide a simple measure of time without too much information in the dataset. This gives the freedom to examine areas of interest, and expand the selection to find any seasonal patterns.

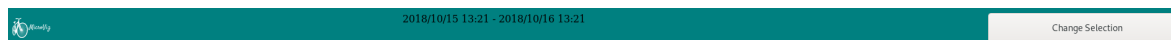


Figure 3.7: *MicroVis* Selection Bar, this depicts the logo on the left, the date and time selection in the centre, and the selection change button on the right

#### Date and Time

The application can only show data between two points in time. A method of navigating the time selection is crucial to being able to understand details within the dataset. These time controls are a start and end time selection. Figure 3.8 shows the individual date-time selection system. This includes a date selection calendar system, this allows for quick navigation

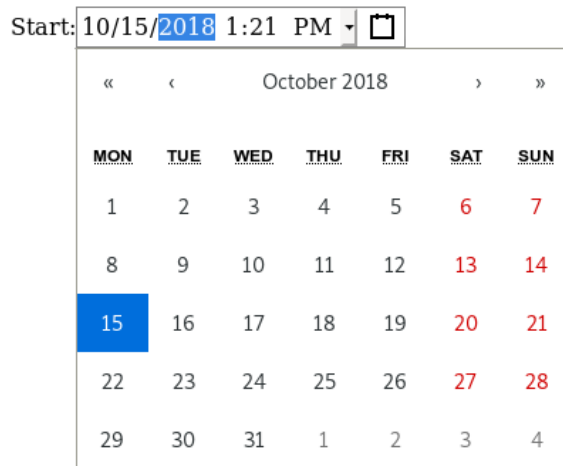


Figure 3.8: Date Time Selection

### Hierarchical Region Select

There are circumstances where the areas of interest comprise only a small portion of the dataset, and can therefore be difficult to understand this information. Cities can be geographically dispersed places, of which only a handful could be of interest in any particular user, however a macro view of a city or region can be also important at times.

Given that a city can have hundreds of subregions, such as the Auckland “Super City”, it can make sense to create methods of selecting large groups of regions at once, thereby allowing for more easy selection of larger units such as cities.

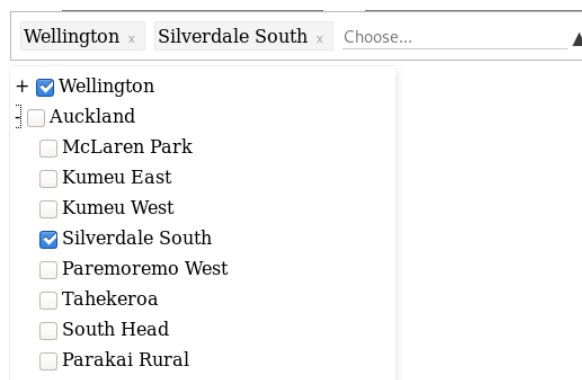


Figure 3.9: Hierarchical Region Selection System

## 3.4 Discussion

A number of alternative designs were considered for each of the visualisations

### 3.4.1 Map

The primary alternative to the map system was a heat map for where each of the devices had stopped or started across the network during the given time period.

This has the benefit of abstracting concrete numbers further away, and providing a more intuitive and instinctive graphic that is more understandable, however this was ultimately

not selected due to the fact when zooming into data at a relatively high level the overall heat map can be compromised, with everything being light except for a few dots of indistinguishable colour for the exact spots these bikes were dropped off at. This issue with the consistency of the experience from a more zoomed out experience to a more zoomed in experience led to this idea being less favoured than the final implementation.

### 3.4.2 In Use Bar

Originally conceived as an alternative to the In Use Bar, was the idea of a heat map representing how many trips were in 15 minute intervals, in a similar fashion to the GitHub contributions graph (as seen in Figure 3.10).

A style such as this allows for easily comparing across multiple days at the same time, and provides a more aggregated method to display the data, providing less visual elements within the visualisation.

This system was not chosen ultimately due to this aggregation. This kind of aggregation stripped data about which devices were being used away from the user, which is potentially of interest to the vendor personas for maintenance purposes.

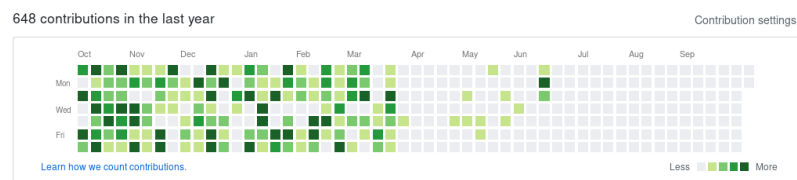


Figure 3.10: A github contribution graph for Jacob Beal, showing when more commits were done through colour intensity

### 3.4.3 Flow

Initially instead of a chord diagram, a forced directed diagram was selected as the preferred method of showing the relations between regions. Forced directed diagrams are a method of visualising a network of data, and its properties. However, these diagrams can be unpredictable, and with large amounts of disparity in the data can create very unstable datasets that are difficult to read.

Due to this disparity, the initial plan to use these was rejected, as experimentally it was found that some data selections had a large difference in number of trips, and hence tended to drift out of the map. Moreover, the distance that would be encoded representing the common routes would be difficult to judge how accurately this represents the information, and how internal trips (trips to and from the same location) would be represented made the visualisation less viable compared to a chord diagram layout.

### 3.4.4 Bubble

The bubble diagram is a method of visualising the incoming and outgoing traffic on nodes, and comparing these values to establish any deficit or surplus of devices on the network. An idea that was considered for representing this information was through the use of a cartogram (such as what was explored in Cruz et al. [8]). This cartogram, as explained earlier, scales the size of regions based on a numbering system, and these scaled values can preserve the original shape of areas to a certain degree.

However, similar to the shortcomings of the force-directed graph, there were problems in the size of the dataset being tested. Most of the trips took place within a small subset of the cities at any particular time, the effect on this was rendering the map unreadable in general, with entire suburbs removed from the map, or shrunk to an unrecognisable size. This cartogram system was found to create too foreign maps, and comparing two regions was difficult because of non-uniform regions (e.g. comparing the large square of Willis Street-Cambridge Terrace, to the curved and long Lambton region).

## 3.5 Architecture

### 3.5.1 Data

Vendors and stakeholders in the micro mobility market, such as Mevo, JUMP, Uber, Onzo, and Lime have been contacted by the author. Getting these stakeholders involved is vital to ensuring the product works on multiple data sets, and provides useful information.

With Onzo, a local bike sharing micro-mobility company, the authors have formed a partnership to work with the data collected and analyse the results. As part of this Onzo has also indicated its willingness to take part of user study evaluations of the end-product. Onzo provided data in the form described in Table 3.2

id	start_time	end_time	amount	person_id
example	1539948147	1539948217	100	example
bike_num	distance	status	is_deleted	is_display
31223144	2	2	0	1
start_axis	end_axis		calorie	
"174.780909,36.848985"	"174.857678,36.453983"		0	

Table 3.2: An example row of data, and header, in the format provided by Onzo (linewrapped for readability)

In partnership with Hutt City Council, the authors have obtained data for review from the trial of Lime Scooters within the Hutt Valley region, and expressed willingness to participate in a user study of the end-product of this paper. An example of data provided from the city council can be found in Table 3.3.

trip_id	start_time	completed_time	distance_meters
99999999	01010101010	101010101010101	99999
start_latitude	start_longitude	end_latitude	end_longitude
-41.3353	174.97632	-41.3468	176.012

Table 3.3: An example row of data from the Hutt Cities Lime Scooter Trial

Furthermore, continuing from work over the summer, Beca Group Ltd. continued to work with the authors. Beca Group was able to provide valuable contributions on the effectiveness of visualisations, and has expressed willingness to work with the authors on a user study.

### 3.5.2 Data cleaning

As part of the process of obtaining useful data, the data seen in Table 3.2, and Table 3.3 needed to be converted into a format that can be more easily used by the designed visualisation programs.

As part of this, the data is converted into JavaScript Object Notation Data Interchange Format (JSON), which is a format that represents an object in JavaScript [5]. As a part of this format, the data has been characterised into different objects for each device, and each “rest period”, between each of the trips to reduce algorithmic complexity.

JSON was chosen for its interoperability with JavaScript code, and its relatively small filesize. This was chosen over a database because of the unchanging and relatively small size of the data. Additionally this reduced the complexity of the code would allow for more easily debugging the code during development.

Part of the data cleaning involved categorisation of the start and end points. This was achieved by using the 2018 area units from Stats NZ, these area units provide distinct recognisable boundaries that are used for statistical purposes such as the census. This categorisation of location was done during the data cleaning process. This reduced run-time complexity and increased performance of the visualisations.

The chosen file format is shown in Listing 3.1

Listing 3.1: Reformatted JSON Data

```
{
  "81000923": {
    "id": "81000923", //bike ID is repeated for ease of access.
    "available": [
      {
        "status": "occupied", //is this time frame in use?
        "bike": "81000923", //bike ID
        "start": 19000919, // start time as a UNIX
          timestamp
        "end": 19200023, // end time as UNIX timestamp
        "startloc": { //location as an object of WGS84
          latitude
          //and longitude
          lat:,
          lng:,
          area:,
        },
        //similar to startloc
        "endloc": { ... }
      },
    ],
    {
      "status": "available",
      "bike": "81000923", //bike ID
      "start": 19000919, // start time as a UNIX
        timestamp
      "end": 19200023, // end time as UNIX timestamp
      "loc": { ... }, // same as above locations
      "area": "Auckland_Central_West" // name of Area
        Unit (i.e. suburb) that the bike is in
    }
  }
}
```

```

    ]
  }
}

```

---

### 3.5.3 Architecture

The architecture of MicroVis is broadly dependent on the Flux programming style and the React JavaScript framework, and the overall architecture can be seen in Figure 3.11.

The first major design decision was not to use a database management system, and instead employ the use of a JavaScript Object Notation (JSON) data file, which was built into the system. This decision was made to reduce the dependencies and cost-to-setup for the application. This was because the nature of the data given is historical, and therefore, given the size of the data store was relatively low, it was decided that simply including the data within the built application would be the most effective method of delivery.

Another key decision that was made, was to use the react JavaScript framework. React is a component development library that is widely adopted amongst industry, and has a large library eco-system attached to it, that would assist in further development.

The data itself is stored within the redux library. Redux is a “flow”/“flux” data management system, which allows components throughout the application to both view, and provide update commands to the central data storage system. This was used to great effect in building the visualisation system, and the data selection system.

The windowing system of the application is built using a library called react-cristal, which allows subcomponents to be displayed as floating “windows” akin to a typical desktop manager on Windows or Mac OS X. react-cristal was chosen over other libraries due to its simpler design, and more in-depth configuration system.

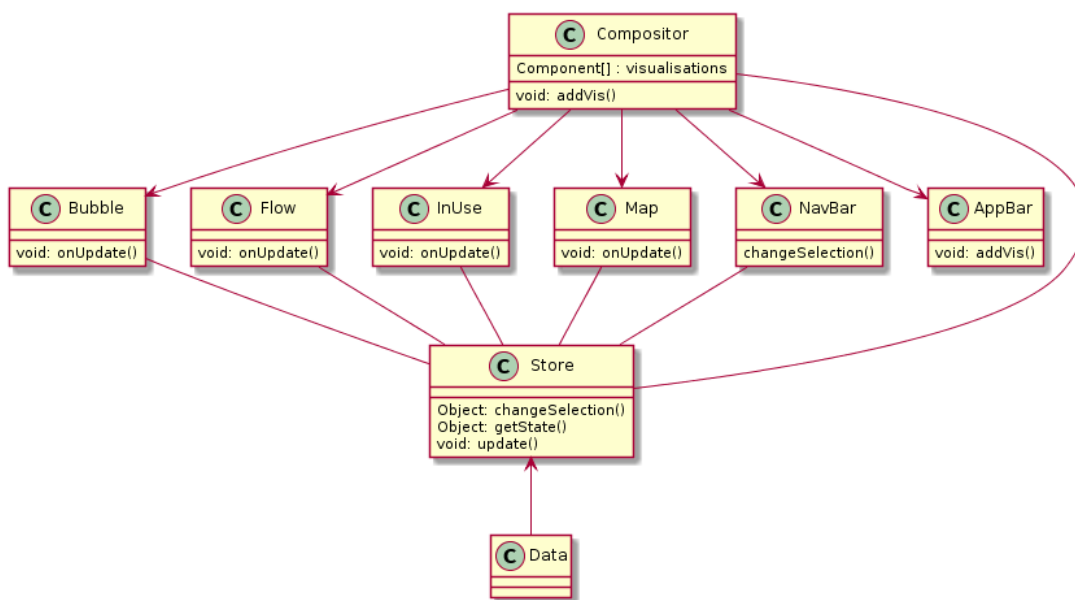


Figure 3.11: Architecture of MicroVis

## 3.6 Summary

*MicroVis* is a proposed tool which would assist in the analysis of micro mobility transport data for users in industry.

Its features such as a dashboard layout provide flexibility in creating insights into the data. The visualisation widgets provide complementary views into different aspects of the data, which is real industry data.





## Chapter 4

# User Study Design

In order to effectively determine the efficacy of *MicroVis*, as explained in Chapter 3, a user study was carried out. As a part of this the user study would comprise of two aspects, the correctness of results, and the subjective rating of *MicroVis*, and how fit for use *MicroVis* is. This was undertaken, in part, to fulfill the research question **RQ2**.

### 4.1 Ethics Approval

This study was approved by the Victoria University Human Ethics Committee on the 2nd of August, 2019, and was an amendment of a pre-existing approved study. The completed Human Ethics application may be found in Appendix A, and the Questionnaire, information sheet, and Consent Form can be found in Appendix B

### 4.2 Pilot Study

A pilot study is a study conducted prior to the intended user study, where a small sample of participants complete the study, with the intent on identifying easily rectifiable issues prior to the main evaluation.

A pilot study was conducted on five participants, who study technical degrees at the University of Auckland. The results of these studies lead to changes in the design of the application in order to create more usable applications, such as the use of a hierarchical selection system as opposed to a large number of selections across multiple regions.

### 4.3 Participants

The target user of the *MicroVis* application are data analysts in particular, specifically those within the transportation sector. It follows, therefore, that the ideal candidates for study participants are transport analysts, with experience in using data analytic tools such as excel and tableau.

Of the 12 participants, 10 were transport analysts, planners, or otherwise involved in the transport industry, such that they were ideal candidates, however, these were not in sufficient numbers to draw statistically significant conclusions, and hence were supplemented by fourth year students.

Participants were recruited from the Greater Wellington Regional Council (GWRC), Beca Group, and Victoria University of Wellington (VUW). Participants from GWRC and Beca

were asked by email for availability to carry out testing, and VUW participants were drawn from analytical degrees (such as Information Systems, Engineering, and Computer Science).

It is important to note that there was a large variation in the technical literacy of some participants in the pool of professional participants, and this is reflected in the overall results of the study.

## 4.4 Procedure

In order to maintain consistent results the same methodology was employed on each participant in the study.

It was important for the study that each participant had a similar exposure to the tool, as such participants were selected such that they had no experience with MicroVis before, and were given the same introduction to the tool. Participants were given the option to explore the tool for a period, or if comfortable, to begin the survey immediately.

The evaluation also made use of audio recording technology, and cognitive walk-through protocols, in order to capture more qualitative data on how participants found aspects, and which aspects were liked the most, and which were found most frustrating, and of particular note was areas of improvement.

### 4.4.1 Apparatus

To perform an evaluation on the system, consistent hardware and software was used to create a replicable and consistent experience across all candidates.

Each candidate was seated in front of a 13 inch Dell Latitude laptop, provided by the School of Engineering and Computer Science, and used only the trackpad, and keyboard built into the device. This ensured a consistent input method, and was selected as a portable method that could be tested on-site for participants.

For each participant, they viewed the application through the Chrome Web browser, running a consistent version. This is important due to minor ways in which different browsers can render the same input inconsistently, and can have differing adherence to the HTML and ECMAScript (javascript) standards.

## 4.5 Tasks

The questionnaire, as shown in Appendix B, consists of a series of tasks to evaluate the efficacy of the application. These tasks are based on the use cases identified in subsection 3.1.3.

- T1** Open the program and find which suburb had the most micro mobility devices within it on Sunday 11th November at approximately 9am
- T2** Open the program and identify which was the most used device on the 13th of November in Wellington
- T3** Open the program and find whether more devices entered or left Lambton Quay on November 12th
- T4** Open the program and identify how many services left the airport region on November 15th

Table 4.1: Tasks used in both the pilot and user study

Following each of these scales Likert scales were used to evaluate the efficacy of the tool to perform that task.

Likert scales are a standard psychometric scale, whereby a participant is given a five (or seven) point scale to answer a question on a spectrum of responses, typically from 'Strongly Agree' to 'Strongly Disagree', with a neutral response [18]. Likert scales are often effective tools due to their familiarity with participants, considering their ubiquity in most preferential surveys. The results from these can be analysed by viewing the distribution and measures of the resulting response values.

## 4.6 Questionnaire

In addition to the tasks, the questionnaire obtains a self-selecting proficiency scale, similarly ranked on a Likert scale.

Following the tasks, there is a post-survey, that asks for a holistic evaluation of the tool. By including this in a post-questionnaire section, it allows for an informed response to how useful and usable each visualisation was. This meant that the response was more reflective of the overall experience with the tool.

In addition to the Likert scales, a NASA Task Load Index (TLX) evaluation, and System Usability Score evaluation methods were employed. These scoring systems represent the ease of use for the software in a standardised, and comparable way to other systems, and provide a consistent result.

The System Usability Score was chosen due to its suitability as a system to compare the usability of a system [23]. This allows for future usability testing to evaluate the efficacy of any changes made, and develop an improved solution.

## 4.7 Data Collection & Analysis

Data was collected through two means, through an online questionnaire, which recorded respondents quantitative responses, and the use of audio recording and the use of cognitive walk through protocols to obtain qualitative responses and comments on MicroVis.

The use of a questionnaire provides a single coherent structure, and a series of tasks for participants to complete. Given the preferred recruitment criteria, this sequencing of tasks and data entry is intended to provide a familiar and organised structure to the user study.

The use of an audio recorder allows for precise capture of qualitative discussion about MicroVis that may not be encapsulated by the questionnaire form. The use of a cognitive walk through protocol allows the user study observer to understand how the participant experts an application to behave, and how they intuitively interact with MicroVis.



# Chapter 5

## Results

### 5.1 Evaluation of Tasks

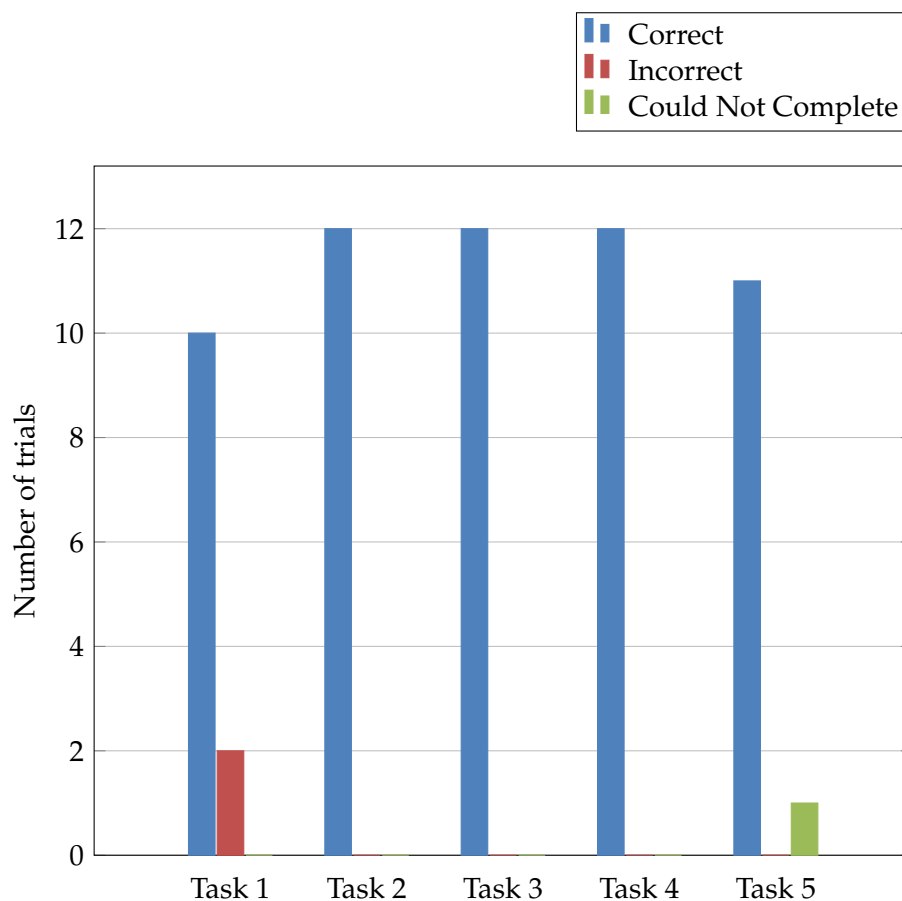


Figure 5.1: Number of correct answers for each task within the user study

Examining the correctness rate for all five tasks in Figure 5.1, there was a failure rate of  $\frac{3}{60} \approx 5\%$ , for all tasks. These results indicate that, in general, the data was successfully translated graphically, as otherwise incorrect answers would have been given.

Task 1 had two incorrect answers. Observations from these tasks show that the participants had in one instance panned away from the correct answer, leaving it off screen. Another had failed to zoom in sufficiently and had answered “Wellington City”, as a region in and of itself.

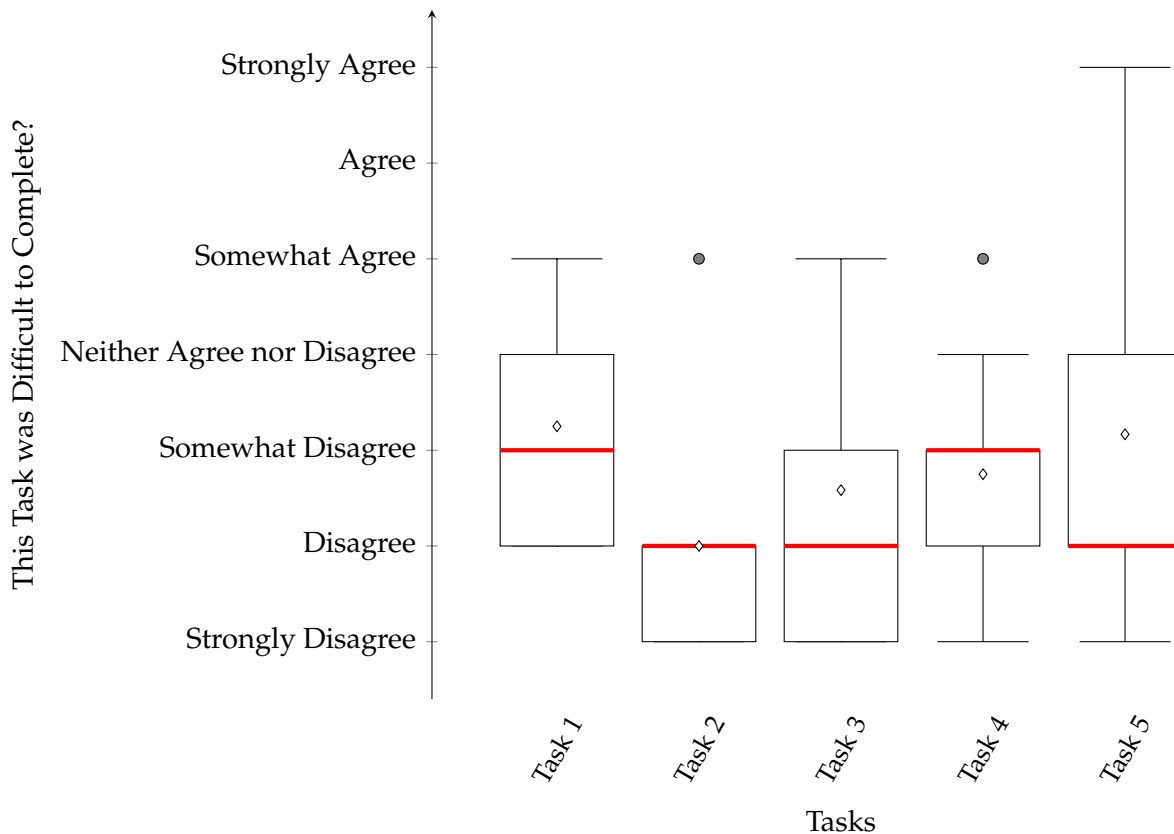


Figure 5.2: The difficulty of each task to complete: “This task was hard to complete. How strongly do you agree to the statement”

Task 5 had the only response where the respondent did not feel they could answer a question, specifically the respondent felt that they could not understand the flow widget.

Looking at the tasks difficulty to complete in Figure 5.2, Task 2 was found to be the easiest by far, with Tasks 1 and 5 being found the hardest.

Task 4 is a modified version of task 3, with added complexity, so an increase in difficulty was to be expected, especially as it is the first, and only, task that requires the use of filters. These factors indicate a reasonable explanation for the increase between the two. Of interest is the fact that the range of values for Task 4 had less people believe it was hard to complete.

Also of interest is the fact that no average score stated it was hard to complete any of the tasks. This suggests that the tool was well suited for each of the tasks.

## 5.2 Evaluation of Visualisations

Participants were asked to provide a rating using a 7 point Likert scale for how effective they found each visualisation. This 7 point scale ranged from “Strongly Dissatisfied” to “Strongly Satisfied”, with a neutral option. The results of this can be found in Figure 5.3. A seven point scale was chosen over a 5-point scale to provide greater fidelity in the answers provided. This was because together the visualisations are key to any interaction with *MicroVis*, whereas all of the tasks does not encompass all possible usecases for *MicroVis*

These results show that, although they had the same median value of satisfaction, In use, followed by bubble were the most well received, while Flow was the least preferred. However, it should be noted that all, bar Flow, had no dissatisfaction with the efficacy. This

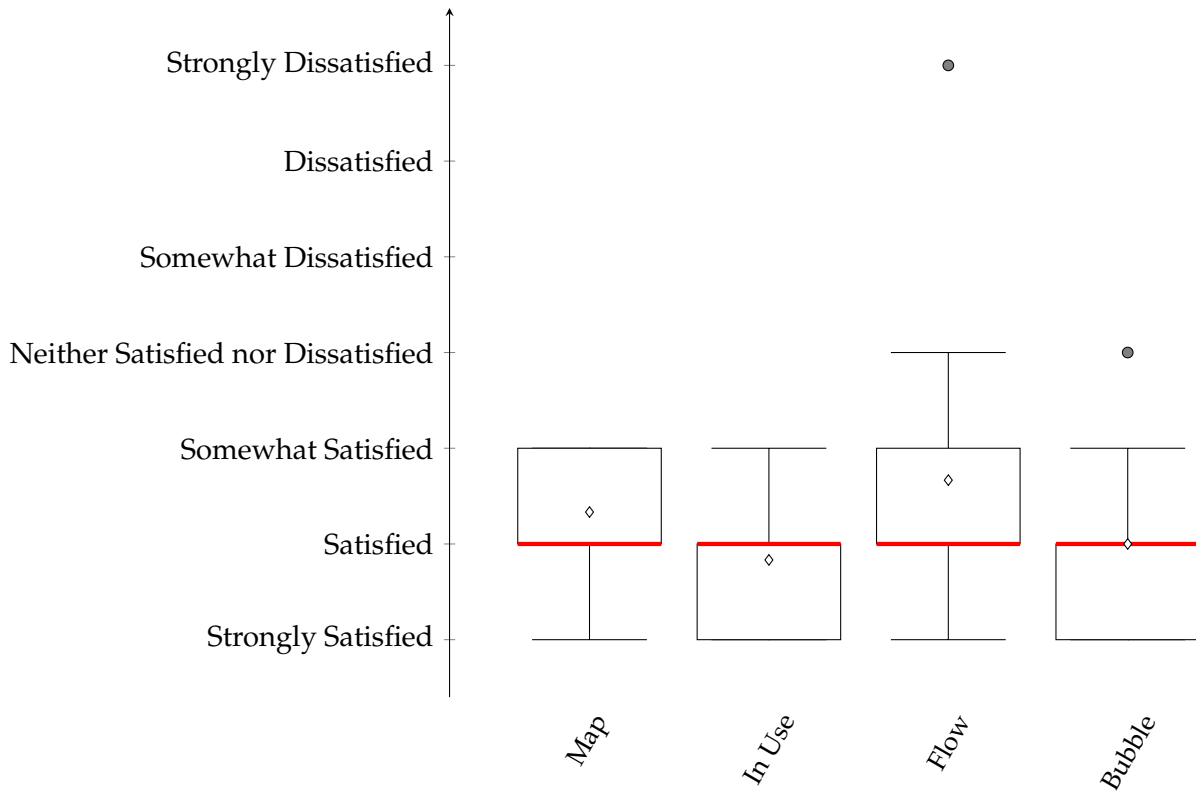


Figure 5.3: The self-reported satisfaction of each part of the product. “Effectiveness of Visualisation”

clearly shows that the participants found that the visualisations offered were effective at showing the provided data.

The satisfaction of the map was received generally less favorably in comments than the likert scale reporting. Part of this was due to issues that arose during testing, whereby expanding the map started to render regions of the map unusable. The clustering algorithm was generally poorly received, while many acknowledged that it may become unreadable with a lot of data points, they found that the numbers were hard to spot, and didn’t always show clustering that aligned with the area units found in other areas of the program. However, many did find that they enjoyed the familiarity of a map, and that it was generally relatively easy to manipulate. A few comments noted that the progress of the animation was generally not useful for observation, and that perhaps an iconic representation of the micro mobility transit devices would have been more useful.

The In Use bar was generally found to have favourable comments. Comments generally appreciated the ordering of the bars by utilisation, and noted the patterns of use were interesting. There was generally confusion about the areas that were white, indicating that a device had not entered the network yet, or had left the network, in a future revision it was suggested adding a third colour to the diagrams to represent this state. A few had tried to click on sections of the graph, expecting some visualisation of that trip to be displayed.

In retrospect, the relative failure of the flow visualisation was foreseeable. The chord-diagram system is not an immediately obvious relationship, and can easily be misinterpreted and confusing due to its more alien nature compared to more traditional charts. Comments generally recommended labels for large arcs of the chord diagram, and the use of more different colours within each of the cities, and that the arcs should be sorted by size rather than name. Given the colours difference compared to other diagrams, they felt that

instinctively the colours did not provide a meaningful enough distinction, and that the data from multiple cities could be represented by two adjacent diagrams.

The bubble diagram was especially favoured by people with greater Excel skills, generally they noted that they found this diagram comfortable to interpret. Many participants noted that the purpose of this graph was not clearly obvious, and the lack of axis labelling increased confusion. A few participants wanted a method of examining specific nodes more easily through being able to filter on click.

### 5.3 Evaluation of Dashboard Management & Filtering Systems

Each participant of the user study provided an evaluation on some overall aspects of the tool using Likert scales. These results can be found in Figure 5.4.

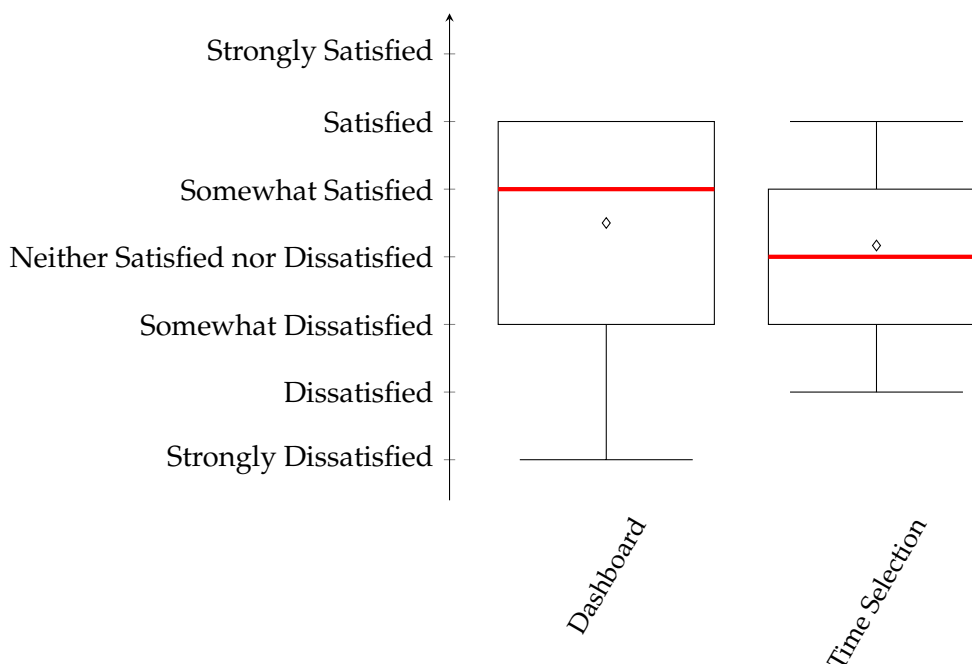


Figure 5.4: The self-reported satisfaction with overall aspects of the tool

Though not reported, due to the fact it was added after the pilot study, the comments provided for region selection was generally positive. Participants noted the hierarchical structure was intuitive and useful. Some expressed confusion at the notion of exclusive and inclusive search parameters, the labelling of the system was at times confusing, although once explained they felt comfortable and saw its utility.

Overall, the dashboard system was marked as having a median response of “Somewhat Satisfied.” The dashboard was commonly noted as being clunky, and at times unresponsive. The visualisation buttons were noted as forgetful, and not intuitive. Generally the filtering system was well received, and was appreciated for its clear demarcation by some participants, and some noted they didn’t like the windowing system and the fact they could lose a window behind another by mis-clicking.

The existence and necessity of the dashboard received mixed reviews. Some participants liked the ability to drag their views around, and to display visualisations of their choice, while others didn’t see much utility. One participant believed the system would be more effective as isolated applications, and allow the user to manage browser tabs as they saw



fit, while another advocated a tiling window system, similar to that of i3 on GNU/Linux to prevent hiding windows and optimisation of space.

The time selection system was received slightly negatively under the Likert Scale, but was disliked more within comments. Comments generally noted that the bounding of the data was unclear at best, and did not notify the user when these values were changed. The date format was unfamiliar (i.e. using the US date format system rather than ISO8601, or the conventional format in New Zealand dd/mm/yyyy), and the text input was “finicky”.

## 5.4 System Usability Score

The results of the System Usability Scale 10 questions can be seen in both Figure 5.5 and Figure 5.6.

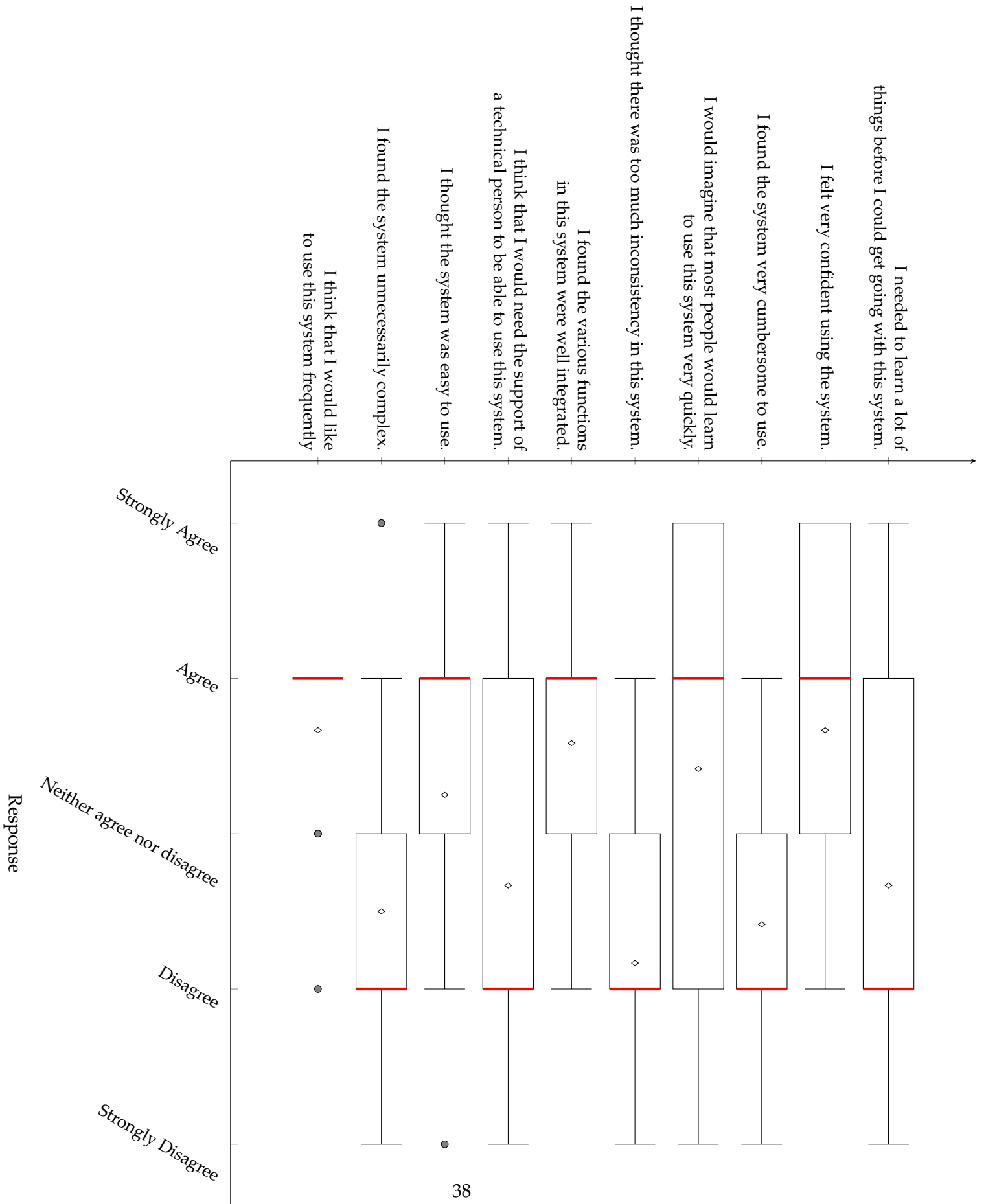
Overall Figure 5.5 show generally positive answers to each question in the question battery.

Examining the overall System Usability Score (SUS) gives an indexed score of approximately 66 points. This is around the score of the “average” System Usability Score from the Sauro-Lewis CGS table of 68 points [15]. This indicates that there is considerable work to do, considering that this same table considers that an above-average experience is approximately 80 points, which is a required improvement of  $\approx 30\%$  to create an above-average interface.

This score reflects a generally sound user interface, with a significant issue with bugs throughout the user testing process. Additionally many participants stated that they believed they would need to learn a significant amount in order to work effectively with it, and before recommending it to others.

In particular participants noted that they were generally dissatisfied with the time selection system, and found it particularly unsuited, and that there were follow on effects from its poor suitability.

### SUS Questions



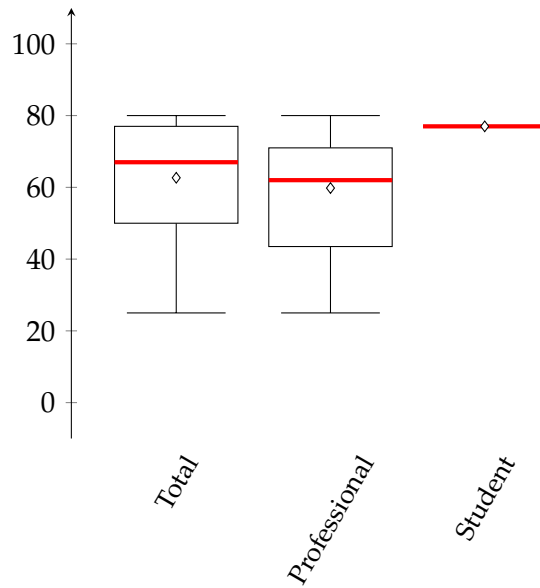


Figure 5.6: System Usability Scale Score Distribution for MicroVis, across multiple user groups

## 5.5 NASA Task Load Index Evaluation

The NASA Task Load Index is a tool used to evaluate the difficulty of tasks, both cognitively and physically. An evaluation on MicroVis was completed as part of the user study. The overall rawTLX scores can be seen in Figure 5.7, and the breakdown thereof in Figure 5.8.

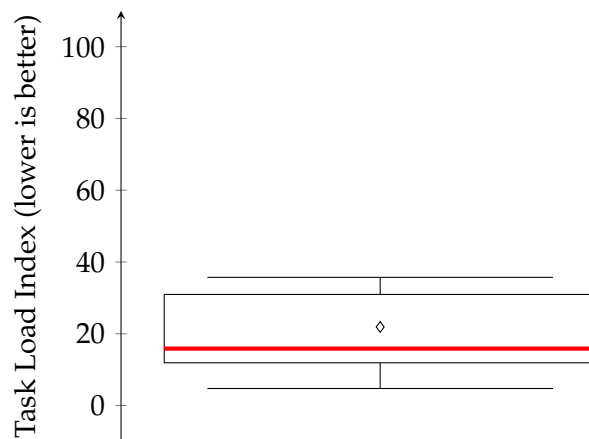


Figure 5.7: rawTLX Index Scores given by participants

It is important to note that TLX scores are not benchmarked [11], and therefore is difficult to determine whether the task was difficult compared to an average task.

These results show that the most demanding aspect of MicroVis is mental. This represents the overall mental energy the participant had to put into the tasks. Given that MicroVis is an analytics tool, this is unsurprising.

Physical demand and Effort were both low scores, representing the fact that it is a desktop based experience. There is an obvious outlier for physical demand, and there was no comment provided explaining this anomalous value.

The provided frustration index score was the most varied result. This range represents

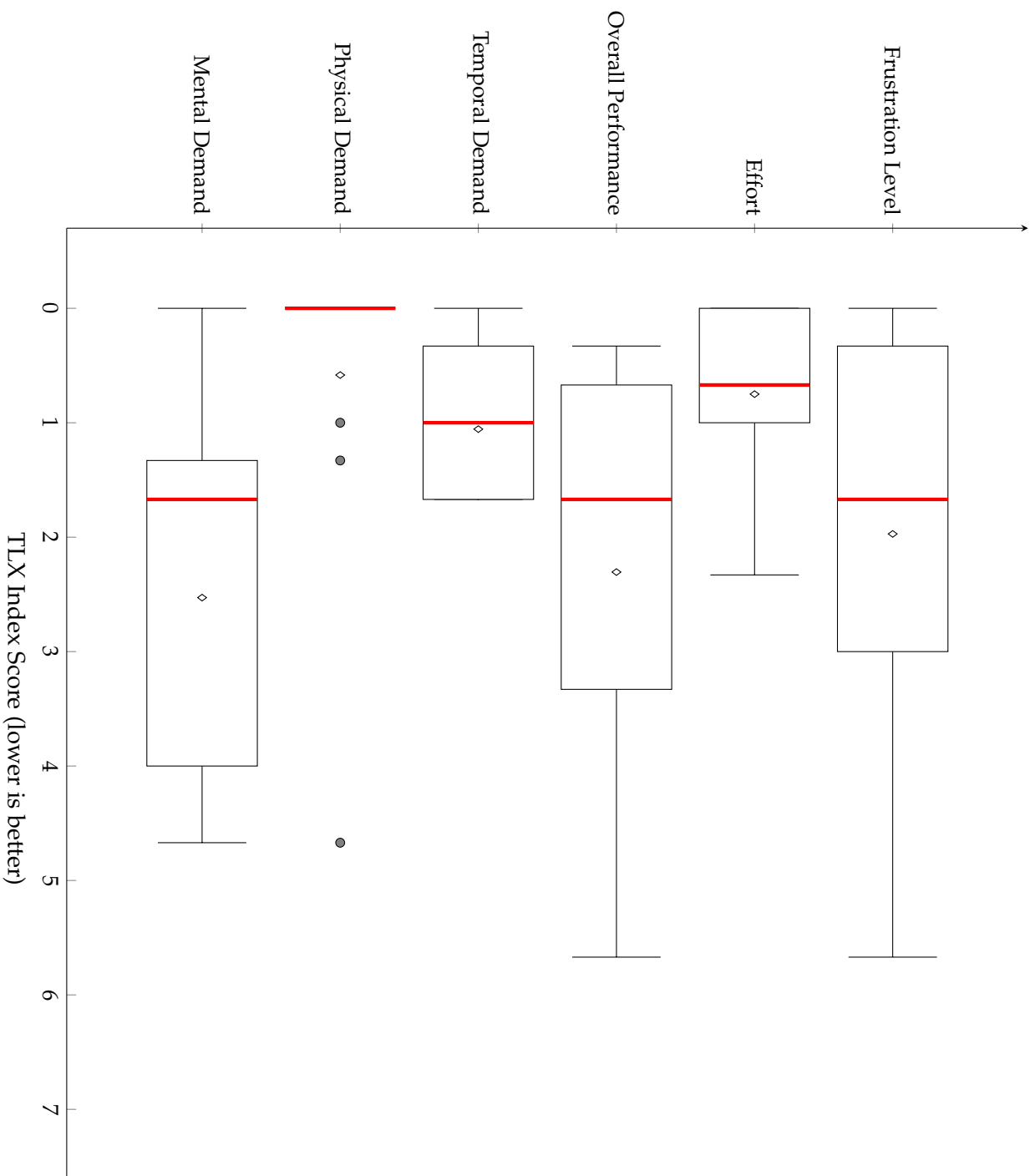


Figure 5.8: The breakdown of the NASA Task Load Evaluation Index Components

times where bugs in MicroVis has made it frustrating and difficult to complete the tasks, and how it can impede the work flow of participants.

## 5.6 Discussion

Overall the study demonstrated that the tool was effective at visualising the data, however there were significant user interface issues that are still to be overcome.

The overall dashboard concept was often deemed unnecessary, but individual visualisations were generally viewed positively.

### 5.6.1 Threats to Validity

Because of the nature of participant recruitment, there were no participants that worked directly, or focused solely on micro mobility transport. As a result, some of the findings of the user study may have found information that was “useful”, to be considered less so by users with more domain expertise. However, considering the limited number of transportation experts in New Zealand in general, and the limited engagement received from micro mobility companies there was not much further that could have been accomplished.

Additionally, many users found that the instruction to Task 5 too vague, and requested clarification from the observer. As a result, the difficulty for Task 5 was marked as more difficult by some participants based on the more obscure task intent, rather than the inherent difficulty of *MicroVis*.



# Chapter 6

## Conclusions

### 6.1 Future Work

Evaluations of MicroVis have exposed several areas for improvement, fixing these areas may yield improvements to usability, and provide further insights into the dataset, and hence improve MicroVis' efficacy.

The following changes could be implemented to improve usability in the MicroVis application:

- Change the Date system to use a more natural date format, more familiar to the intended users (either ISO-8601 format, or DD MM YYYY).
- Remove the clock graphic from the date time selection, or make it interactive.
- Add a clear-all button to the region selector.
- provide more axis labelling to visualisations.
- provide graphical icons for the launchers for various visualisations
- Use either a tiling layout system, replacing `react-cristal` with a system like `react-mosaic`, or separate the visualisations more generally, perhaps using pop ups.
- Fix the time selection system bounding system, making it more transparent.
- Fix the map visualisation to properly handle resizing.
- Provide a mechanism to save or load dashboards, and a set of default visualisations

The following changes could be implemented, which may improve the efficacy of the MicroVis application

- Provide a visualisation of how close trips were to transport hubs, would be useful for town planners.
- Provide a point to point trip visualiser on the map.
- Allow for the selection of discontinuous regions of time (e.g. every Monday, or every Weekday between 9 to 5).
- provide a mechanism to upload your own data to the visualisation system, rather than having to rebuild the application for each dataset.
- Providing the In-Use Bar with a method to highlight subsection

## 6.2 Contributions

The aim of MicroVis was to both design, and implement a system for visualising micro mobility data that would allow expert interrogation of the dataset.

The MicroVis project was built, with a customisable dashboard system, providing methods to filter the provided data and a number of visualisations which can be displayed:

- A map visualisation, showing the physical location of micro mobility devices at given time intervals.
- A “In Use Bar” visualisation, showing when devices were in use in a given time frame.
- A “Flow” visualisation, showing the flow of trips between different subregions.
- A “Bubble Chart” visualisation, showing the balance of incoming and outgoing traffic for each subregion.



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## Appendix A

# Ethics Application



## **Human Ethics Application**

Application ID : 0000026264  
Application Title : TrafficVis: Visualizing data of the New Zealand State Highway Network  
Date of Submission : N/A  
Primary Investigator : Jacob George Beal; Principal Investigator  
Other Personnel : Dr Stuart Marshall; Head of School (or delegate)  
Dr Craig Anslow; Supervisor  
Jonathan Carr; Associate Investigator  
Hamish Bernard Clark; Associate Investigator

## Research Form

### Application Type

1.

**IMPORTANT: Please select type of research below and click on 'Save' to access the rest of the form.**

\*

Research

### Application Details

Category

B

3. Application ID

0000026264

5. Title of project

(Click the ? icon for more info)\*

TrafficVis: Visualizing data of the New Zealand State Highway Network

6. School or research centre\*

Engineering and Computer Science

7. Personnel\*

1	Given Name	Jonathan
	Surname	Carr
	Full Name	Jonathan Carr
	AOU	
	Position	Associate Investigator
	Primary?	No
2	Given Name	Jacob
	Surname	Beal
	Full Name	Jacob George Beal
	AOU	Engineering and Computer Science
	Position	Principal Investigator
	Primary?	Yes
3	Given Name	Hamish
	Surname	Clark
	Full Name	Hamish Bernard Clark
	AOU	Engineering and Computer Science
	Position	Associate Investigator
	Primary?	No

8. Are any of the researchers from outside Victoria?\*

Yes

No

9. Is the principal investigator a student?\*

Yes

No

### Student Research

9a. What is your course code (e.g. ANTH 690)?\*

ENGR 489

9b. Supervisor\*

1	Given Name	Craig
	Surname	Anslow
	Full Name	Dr Craig Anslow
	AOU	Engineering and Computer Science
	Position	Supervisor

9c. What is your email address? (this is needed in case the committee needs to contact you about this application)\*

carrjona@ecs.vuw.ac.nz

**Project Details**

10. The following question is meant to help applicants consider their research application and any protocols that should be uploaded and to help committee members review the application. Please check the box if your research:

- Is an anonymous questionnaire
- Uses tertiary students as participants
- Is a health or disability research project
- Includes Māori participants, or otherwise has an impact on Māori
- Includes participants from another significant cultural group, or has an impact on that group
- Uses highly sensitive information (see Policy for definition)
- Collects or uses human tissue, including blood, saliva and genetic material
- Uses noninvasive physiological procedures (e.g., EEG, heart rate monitor)
- Uses equipment (e.g., TMS) that may temporarily alter mental function
- Administers substances (e.g., food, alcohol, placebo pill) to be ingested by participants

11. Does this application relate to any previous applications submitted to an ethics committee?\*

- Yes
- No

12. Describe the aims and objectives of the project

*Provide a brief summary in plain language of the purpose, research questions/hypothesis, and objectives of your project. \**

The purpose of this research is to investigate how a web app can be produced that can intuitively visualise data from the New Zealand State Highway network, with a focus on the capability of identifying network resiliency issues. A resiliency issue is when the road network would be unable to perform under unexpected circumstances (such as an increase in traffic or a road closure).

This research involves the development of a web application, which is to be evaluated via participation in a trial app, followed by a questionnaire.

The two main research questions are:  
 - How can traffic volume data be visualized to identify and compare traffic behaviour and trends?  
 - How can data visualization techniques be used to identify network resiliency issues?

This research is being completed under external supervision of Beca Group Ltd. Beca Group Ltd will not have access to any of the data collected during user studies; they will receive only the Honours report and software produced.

An early prototype of the web application is accessible from [homepages.ecs.vuw.ac.nz/~carrjona](http://homepages.ecs.vuw.ac.nz/~carrjona)

13. Describe the benefits and scholarly value of the project

*Briefly place the project in perspective, explaining its significance and worthwhile outcomes. Include how this project will build on relevant literature, including references if appropriate.\**

This research project will produce a web application that is capable of analysing large amounts of data from the New Zealand State Highway network. There is currently no application designed for this purpose, so the TrafficVis web application may be of significant value to data and traffic analysts looking to identify and understand New Zealand traffic trends.

In particular, the ability to investigate the effects of abnormal traffic behaviour in order to identify resiliency issues could help guide future spending on New Zealand infrastructure by identifying which areas of the network require further analysis or development.

14. Explain any ethical issues your research raises for participants, yourself as the researcher, or wider communities and institutions, and how you will address these. This is an opportunity to present what you think the key risks are in your project and show how you have taken them into account.\*

I do not think there are any significant ethical issues involved in the research itself, other than the ethical considerations for completing an observational study outlined in the remainder of this application.

**Key Dates**

If approved, this application will cover this research project from the date of approval

15. Proposed start date for data collection\*

01/09/2018

16. Proposed end date for data collection\*

30/09/2018

17. Proposed end date for research project\*

17/11/2018

### Proposed source of funding and other ethical considerations

18. Indicate any sources of funding, including self-funding (tick all that apply)

*Internally: by a University grant, such as the University Research Fund*

*Externally: funding from an external organisation for this project, or a scholarship awarded by an external organisation*

*Self-funded: paying for research costs such as travel, postage etc. from your own funds*

- Internally funded  
 Externally funded  
 Self-funded

*This question is not answered.*

19. Is any professional code of ethics to be followed?\*

- Yes  
 No

20. Do you require ethical approval from any other organisation, such as another tertiary institution in New Zealand or overseas, or a District Health Board?\*

- Yes  
 No

### Data Collection and Recruitment

21. Please select all forms of data collection you will use in your project\*

- Interviews  
 Focus groups  
 Questionnaires  
 Observation  
 Other

22. Provide an explanation of the sampling rationale for your study.

*E.g. representative sampling of a particular population, purposive sampling, convenience sampling. Include here your eligibility criteria for potential participants -- will there be particular criteria for participants to be included in your study, or criteria that will exclude them? \**

Ideally, the study will involve participants that have experience as data analysts or traffic analysts. This is a limited population of possible participants so anyone that is willing to participate and meets this criteria is likely to be selected. This is an example of convenience sampling.

If I am unable to complete user studies with participants with data analysis experience, studies will be completed using third-year and fourth-year tertiary students from the School of Engineering and Computer Science. Students that are willing to participate in the study are likely to be selected, unless the a mutually agreed time cannot be arranged, or if the student has prior experience using my web prototype.

23. How many participants will be involved in your research?

*If there will be several different groups of participants, please specify how many groups and how many participants in each group. \**

It is likely to be difficult to gain participants with the required background for this project; up to 5 participants will be involved.

If students are used as study participants, greater numbers of participants will be possible. 10 - 15 students may be involved.

24. What are the characteristics of the people you will be recruiting?\*

The study will involve participants that have experience as data analysts or traffic analysts. This is the target demographic of the TrafficVis Web Application so will provide the most value as user study participants.

If students are to be used as study participants, as students from the School of Engineering and Computer Science they are likely to have some experience using data analysis tools.

25. Outline in detail the method(s) of recruitment you will use for participants in your study. *Include here how potential participants will be identified, who will contact them and how. Please include copies of all advertisements, online posts or recruitment emails in the 'Documents' section. \**

This project is being completed in part with an external supervisor, Chris Vallyon of Beca Group Ltd. Chris may be able to help me get in contact with data/traffic analysts so that I can explain the project and ask if any are interested in participating in a user study. At this point in time it is looking to be extremely unlikely that I will have the opportunity to recruit any experienced data/traffic analysts.

If students are to be used as test participants, students will be recruited primarily via asking for participants at relevant research group meetings (i.e., the Human-Computer Interaction research group meetings).

My recruitment speech (for both groups) will be similar to the following:

"I am completing an Honours project which involves the development of a web application for analysing traffic data from the New Zealand State Highway network. The application provides a customizable dashboard which incorporates machine learning techniques, and a number of visualizations and tools that can be used to explore the data.

I am looking for participants to take place in an observational study in which you will use the application to complete a number of tasks, and then complete a short survey on your experience. The both the screen and your voice will be recorded for the duration of the study.

[If I am able to offer supermarket vouchers, I will state so here]

This project is being completed under external supervision of Beca Group Ltd. However, Beca will not be involved in the user study or analysis of resulting data."

26. Explain the details of the method of data collection. For example, describe the location of your research procedures, if appropriate (e.g. where your interviews will take place). If necessary, upload a research protocol in the 'Documents' section.\*

User Studies will take place in Cotton 241. The participants monitor will and voice will be recorded. The participant will complete a number of tasks using the web application prototype and then complete a questionnaire.

27. Will your research project take place overseas?\*

Yes

No

28. Does the research involve any other situation which may put the researcher at risk of harm (e.g. gathering data in private homes)?\*

Yes

No

## Participants and Informed Consent

29. Does your research target members of a vulnerable population?

*This includes, but is not limited to, children under the age of 16, people with significant mental illness, people with serious intellectual disability, prisoners, employees and students of a researcher, and people whose health, employment, citizenship or housing status is compromised. Vulnerability is a broad category and encompasses people who may lack the ability to consent freely or may be particularly susceptible to harm.\**

Yes

No

30. Have you undertaken any consultation with the groups from which you will be recruiting, regarding your method of recruitment, data collection, or your project more widely?\*

Yes

No

31. Will your participants receive any gifts/koha in return for participating?\*

Yes

No

32. Will your participants receive any compensation for participation (for instance, meals, transport, or reimbursement of expenses)?\*

Yes

No

32a. Give details of the compensation participants will receive.\*

Students will receive supermarket vouchers in return for their participation.

33. How will informed consent be obtained? (tick all that apply to the research you are describing in this application)\*

Informed consent will be implied through voluntary participation (anonymous research only)

Informed consent will be obtained through a signed consent form

Informed consent will be obtained by some other method

## Treaty of Waitangi

How does your research conform to the University's Treaty of Waitangi Statute? (you can access the statute from Victoria's [Treaty of Waitangi page](#))\*



Victoria's Treaty of Waitangi Statute has been read and understood. This research project does not need to take into account the Principle of Government, Principle of Self-Management, the Rangatiratanga Principle, Principle of Reasonable Cooperation or the Principle of Equality.

4.1

No actors in this research are acting under the delegated authority of the council.

4.2

No actors in this research commit to Māori research excellence, building Māori staff capability, or the contribution of Matauranga Māori or Te Reo Māori and Tikanga Māori to the culture of Victoria.

4.3

No actors in this research are acting under delegated authority of the council.

4.4

The protection of Taonga is not relevant to this research.

### Minimisation of Harm

34. Is it possible that participants may experience any physical discomfort as a result of the research?\*

- Yes  
 No

35. Is it possible that participants may experience any emotional or psychological discomfort as a result of the research? (E.g. asking participants to recall upsetting events, viewing disturbing imagery.)\*

- Yes  
 No

36. Will your participants experience any deception as a result of the research?\*

- Yes  
 No

37. Is any third party likely to experience any special hazard/risk including breach of privacy or release of commercially sensitive information? This may occur in the instance participants are asked to discuss identifiable third parties in the research.\*

- Yes  
 No

38. Do you have any professional, personal, or financial relationship with prospective research participants? \*

- Yes  
 No

39. What opportunity will participants have to review the information they provide? (tick all that apply)\*

- Will be given a full transcript of their interview and given an opportunity to provide comments  
 Will be given a full transcript of their interview and NOT given an opportunity to provide comments  
 Will be given a summary of their interview  
 Other opportunity  
 Will not have an opportunity to review the information they provide

### Confidentiality and Anonymity

40. Will participation in the research be anonymous?

*'Anonymous' means that the identity of the research participant is not known to anyone involved in the research, including researchers themselves. It is not possible for the researchers to identify whether the person took part in the research, or to subsequently identify people who took part (e.g., by recognising them in different settings by their appearance, or being able to identify them retrospectively by their appearance, or because of the distinctiveness of the information they were asked to provide).\**

- Yes  
 No

41. Will participation in the research be confidential?

*Confidential means that those involved in the research are able to identify the participants but will not reveal their identity to anyone outside the research team. Researchers will also take reasonable precautions to ensure that participants' identities cannot be linked to their responses in the future.\**

- Yes  
 No

41a. How will confidentiality be maintained in terms of access to the identifiable research data? (tick all that apply)\*

- Access to the research will be restricted to the investigator
- Access to the research will be restricted to the investigator and their supervisor
- Focus groups will have confidentiality ground rules
- Transcribers will sign confidentiality forms
- Other

41b. How will confidentiality be maintained in terms of reporting of the data? (tick all that apply)\*

- Pseudonyms will be used
- Data will be aggregated
- Participants will be referred to by role rather than by name
- Other

42. Will participation in the research be neither confidential nor anonymous, and participants will be identifiable in any outputs or publications relating to the research? \*

- Yes
- No

### Access, storage, use, and disposal of data

43. Which of the following best describes the form in which data generated in your study will be stored during the study?

*See help text for guidance on these terms. Further info available on human ethics website\**

- Identifiable
- Potentially identifiable
- Partially de-identified
- De-identified
- Anonymous
- Other

44. Which of the following best describes the form in which data generated in your study will be stored after the study is completed?

*See help text for guidance on these terms. Further info available on human ethics website\**

- Identifiable
- Potentially identifiable
- Partially de-identified
- De-identified
- Anonymous
- Other

45a. Proposed date for destruction of identifiable research data (i.e. the date when data will be de-identified and personal information on participants destroyed)

\*

31/08/2018

45b. Proposed date for destruction of de-identified research data, including anonymous data

\*

17/11/2018

46. Will any research data will be kept for longer than 5 years after the conclusion of the research?\*

- Yes
- No

47. Who will have access to identifiable, de-identified or anonymous data, both during and at the conclusion of the research?\*

- Access restricted to the researcher only (whoever is named as PI)
- Access restricted to researcher and their supervisor
- Access restricted to researcher and immediate research team, e.g. co-investigators, assistants
- Other

48. Are there any plans to re-use either identifiable, de-identified or anonymous data?\*

- Yes
- No

49. What procedures will be in place for the storage of, access to and disposal of data, both during and at the conclusion of the research? (Check all that apply)

*Information regarding appropriate data storage is available on the human ethics website. Note that storing research data on USB drives is strongly discouraged for security reasons. \**

- All hard copy material will be stored securely e.g. in a locked filing cabinet
- All electronic material will be held securely, e.g. only on University servers, password protected
- All hard copy material will be appropriately destroyed (e.g. shredded) on the dates given above
- All electronic data will be deleted on the dates given (ITS should be consulted on proper method)

## Dissemination

50. How will you provide feedback to participants?\*

The user studies will be conducted in person so immediate feedback will be possible when necessary. Participants will have the option of receiving a transcript of their user study. Participants will have the option of receiving a summary of their user study. Participants will have the option of receiving a copy of the Honours report when it is completed.

51. How will results be reported and published? Indicate which of the following are appropriate. The proposed form of publications should be indicated to participants on the information sheet and/or consent form\*

- Publication in academic or professional journals
- Dissemination at academic or professional conferences
- Availability of the research paper or thesis in the University Library and Institutional Repository
- Other

51a. Describe how the results will be disseminated\*

Results will not be published in any journals or available via the University Library.

52. Is it likely that this research will generate commercialisable intellectual property?

(Click the ? icon for more info)\*

- Yes
- No

## Documents

53. Please upload any documents relating to this application. Sample documents are available on the [Human Ethics web page](#).

Please ensure that your files are small enough to upload easily, and in formats which reviewers can easily download and review. To replace a document, click the tick in the column to the right of the document title. A green arrow will appear - click this arrow to upload a new document. To add a new document click on 'Add New Document', at top right of the documents window. Then enter the document name in the box that appears and click the green tick. A green arrow will appear to the right of the file name which allows you to upload the new file.

**Please also collate all your documents into one PDF or Word file, and upload as a new document. This should be labelled as 'Combined Documents'.**\*

Description	Reference	Soft copy	Hard copy
Participant information sheet(s)	information-sheet.pdf	✓	
Participant consent form(s)	consent-form.pdf	✓	
amended documents 25 July 2019	CombinedDocuments.pdf	✓	
Combined Documents	consent-form.pdf	✓	

## Amendment or extension request (available only for approved applications)

43. Are you applying for an extension, an amendment, or both?\*

- Extension
- Amendment
- Both an extension and an amendment

43a. Please give details of the changes you would like to make, and the length of extension you are seeking\*

We are requesting an extension through the end of 2020 (Dec 31 2020) to continue with ongoing research for ENGR489 in the transportation visualisation space, with new principal investigators under the same supervisor.

The projects have two different questionnaires and tools being tested, but both remain within the transportation visualisation space of the original project, with investigation and evaluation methods remaining fundamentally identical.

43b. Please enter the date you are submitting this request\*

25/07/2019

Please check that you have answered all mandatory questions and have saved the application before submitting your form. Any new or amended documents (e.g. Participant Information Sheet) to be added to your application should be emailed to [ethicsadmin@vuw.ac.nz](mailto:ethicsadmin@vuw.ac.nz) before submission. To submit your form, click on the Action tab and then click on Submit for review

44. Do you have a second amendment/extension request to make?

- Yes  
 No

*This question is not answered.*

45. Do you have a third amendment/extension request to make?

- Yes  
 No

*This question is not answered.*

46. Do you have a fourth amendment/extension request to make?

- Yes  
 No

*This question is not answered.*

## Incident Reporting

Research teams must immediately advise the Human Ethics Committee if an adverse incident occurs in the course of their research project.

**Adverse incidents are instances of potential or actual physical harm to participants or researchers; emotional harm or distress to participants or researchers; and any other unforeseen events that raise ethical issues.**

A full incident report must be completed and emailed to [ethicsadmin@vuw.ac.nz](mailto:ethicsadmin@vuw.ac.nz). You can download this form here (link to be added). After you have emailed the form, please complete the questions below, then click on the **Action** tab and click **Report Incident**

Do you have an incident to report?

- Yes

*This question is not answered.*

Please go to the **Action** tab and click on **Report Incident** to complete the process.

## **Appendix B**

# **User Study Survey**

English

## Informed Consent

Hi!

The purpose of this study to evaluate the micromobility visualisation prototype. This is a web application for the visualisation and analysis of data gathered about micromobility services.

This is being developed as an Honours project by myself, Jacob Beal, at Victoria University of Wellington. This project is being completed under supervision of Dr. Craig Anslow of Victoria University, Dr. Ramesh Rayudu of Victoria University, and Chris Vallyon of Beca Group Ltd.

If you agree to take part in this study, you will complete the following for sections of this study:

1. Consent Form
2. Pre-Study Questionnaire (~10 minutes)
3. 5 Tasks to Attempt (~20 minutes)
4. Post-Study Questionnaire (~10 minutes)

But first, we have some formalities to cover:

This research has been approved by the Victoria University of Wellington Human Ethics Committee, Application Number: 0000026264.

This research is confidential. This means that the researchers named above will be aware of your identity but the research data will be combined and your identity will not be revealed in any reports, presentations, or public documentation.

The information produced by this study will be used in my Honours report, and will contribute to the development of the web application.

You do not have to accept this invitation if you do not want to. If you do

### Further Communication

- I would like to receive a copy of my survey responses and have added my email address below.
- I would like to receive a copy of the final report and have added my email address below.

Email (optional)

### Pre-Study

## Pre-Study Questionnaire

Which of the following best describes you?

- Student
- Academic
- Data or Traffic Analyst
- Other / I'd rather not say



How would you rank your experience with data analytics tools? (e.g. PowerBI, Excel, Tableau, etc...)

No Experience    Poor    Below-Average    Average    Above Average    Excellent

How would you rank your experience with data analytics tools? (e.g. PowerBI, Excel, Tableau, etc...)

### Task 1

Open the program and find which suburb had the most micromobility devices within it on Sunday 11th November at approximately 9am

	Strongly Disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	S
I found this task difficult to complete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

**Task 2**

Open the program and identify which was the most used device on the 13th of November in Wellington

	Strongly Disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	S
I found this task difficult to complete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

**Task 3**

Open the program and find whether more devices entered or left Lambton on November 12th

- More Entered
- More Left
- About the same

	Strongly Disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	S
I found this task difficult to complete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

**Task 4**

Open the program and identify how many services left Lyall Bay-Airport-Moa Point on November 15th

	Strongly Disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	S
I found this task difficult to complete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

**Task 5**

Open the program and identify which region had the most trips with Lambton

	Strongly Disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	S
I found this task difficult to complete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

## Post-Evaluation Survey

### Post Survey Questionnaire

Thanks for completing the tasks! Please fill out this brief questionnaire on your experience using the tool

You are welcome to further explore the prototype before answering these questions if you'd like.

If you wish to expand more on any of your ratings, there is room for extra comments at the bottom of this page.

	Strongly Disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree
I found it easy to create dashboards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I found it easy to navigate through different time periods in the dataset	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Effectiveness of each visualisation

	Extremely satisfied	Moderately satisfied	Slightly satisfied	Neither satisfied nor dissatisfied	Slightly dissatisfied	Moderately dissatisfied
Map	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In Use Bar	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flow Graph	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Bubble Chart	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Task Load Index Evaluation

Very Low

Very High

0 0.3367 1.3367 2.3367 3.3367 4.3367 5.3367 6.3367

Mental Demand  
(how mentally  
demanding was the  
task?)

Physical Demand  
(how physically  
demanding was the  
task?)

Temporal Demand  
(How hurried or  
rushed was the pace  
of your task?)

Effort (How hard did  
you have to work to  
accomplish your  
level of  
performance?)

Frustration (How  
insecure,  
discouraged,  
irritated, stressed,  
and annoyed were  
you?)

Perfect Failure  
0 0.3367 1.3367 2.3367 3.3367 4.3367 5.3367 6.3367

Performance (How successful were you in accomplishing what you were asked to do?)



## System Usability Scale Evaluation

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I think that I would like to use this system frequently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I found the system unnecessarily complex.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I thought the system was easy to use.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think that I would need the support of a technical person to be able to use this system.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I found the various functions in this system were well integrated.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I thought there was too much inconsistency in this system.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would imagine that most people would learn to use this system very quickly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I found the system very cumbersome to use.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Any further feedback or comments?

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