Visuäly: Visualizing the Condition of Älynysse Bus

Arganka Yahya

University of Tampere
School of Information Sciences
Interactive Technology
M.Sc. Thesis
Supervisor: Harri Siirtola
May 2015

ABSTRACT

University of Tampere
School of Information Sciences
Interactive Technology
Arganka Yahya: Visuäly: Visualizing the Condition of Älynysse Bus
M.Sc. Thesis, 83 pages, 6 appendix pages
May 2015

We present Visuäly, a set of visualization techniques that enables users to explore historical data of bus conditions. We design and evaluate the prototype, then compare it with the existing system. It is meant to give another perspective and alternative to the system and to increase the value of the existing system environment. We will focus on the visualization technique itself. First, we performed a preliminary survey to assess the existing system. Then, we did four design iterations, each consisted of a moderated remote usability testing session. In addition, we held a survey to compare both systems. We found that participants understand and enjoy interacting with the proposed solution, and also prefer it to the existing system.

Keywords: Information visualization, remote usability testing, transportation, contextual information, design sprint.

PREFACE

Bismillāhirrahmānirrahīm. First, my warmest appreciation goes to my parents for their endless support. I also thank my supervisor Harri Siirtola who kindly gave many substantial advices to the visualization and my writing. I am grateful to have a supervisor who always give constructive feedback and raise challenging questions, so that I can explore and understand the topic more deeply. I thank Erkki Mäkinen who kindly review the text. I also thank all of the participants involved in this study. I thank Markku Turunen and the classmates on the Thesis Seminar Course. Without attending this course seminar, I might still have struggle in completing the thesis.

I thank Bimo Murti, Achmad Maulana, and Rut Christiani whom helped me to proofread the text. In addition, I thank boards and members of PPI Finlandia ry (Indonesian Student Association in Finland / Indonesialaisten Opiskelijoiden yhdistys) for making my stay in Finland a pleasant one.

Then, I thank GATE, an Erasmus Mundus mobility project, to fund my 2-years study at the University of Tampere. It opened up the opportunity for me to study and obtain practical research knowledge in Human-Computer Interaction.

Lastly, I thank the research communities, especially in information visualization. I am always fascinated with the potential of information visualization since the first day I learned this topic deeper in Harri's class. I have encountered countless interesting research journeys and results while completing this thesis. While this thesis only scratch the surface of the problem space, I hope it can benefit the reader in some way. For instance, by applying design principles and lessons learned in this research to form another research questions.

Tampere, 15 May 2015

Arganka Yahya

CONTENTS

TERMS AND DEFINITIONS

GHOA	Google Hangouts on Air
ITS	Intelligent Transportation System
NDA	Non-Disclosure Agreement
UX	User Experience

1. INTRODUCTION

Transportation system is one of the most important human needs. We rely on the transportation to move things between places, it can be goods or humans. Even in this century, where many breakthroughs in science and technology have happened, we are still craving for a good transportation system.

Transportation has become an integral part of city infrastructure. A good transportation system will play a great role on the future development of any city. One of the examples is the vision of integrated smart city solution, like Intelligent Transportation System (ITS) (Commission, 2013). A good ITS will not only support the integrated solution, but act as a backbone for mobility in it.

Mobility is important for residents, businesses, and visitors (Commission, 2013, 2014). A smooth mobility, with less congestion and fuel consumption, will make a city more attractive. Some key factors of transportation are accessibility, timetables, integrated infrastructures, and emissions. Failure to plan and manage these factors will introduce problems to mobility. This trend to address the urban mobility is not only an European but as a worldwide trend (Liu et al., 2013; Ming-wei and Jun, 2014; Mzee and Chen, 2010; Shah and Dal, 2007).

One challenge is how can we understand all of the data and information related to mobility, then turn them into insight for decision making? How can we find preferred methods to present the information to residents or municipalities?

Information Visualization (InfoVis) is one of the disciplines that can help to address these challenges. Researchers have tried to solve and help transportation planning and analysis using information visualization (Keim et al., 2008). It shows that information visualization can bring insight to local government as transportation service provider and public as customer (Anwar et al., 2014; Wang et al., 2014; Zeng et al., 2014).

Novel visualization techniques can be explored further with the advancements of ITS solutions, like the utilization of in-vehicle sensors. Sensors utilization can lead to different perspectives in seeing mobility data. In-vehicle sensors can transmit contextual data that can be useful when combined with spatial and temporal data such as time and location. Addition of contextual information helps to understand visualization (Masoodian et al., 2013).

As on ITS, a sensor that monitors a machine condition can set the path to the

unexplored information and insight for transportation manager and municipality. Seeing the same data from new perspectives will bring new ideas, that hopefully leads to better solutions. Example of sensor utilization in urban mobility can be found in Älynysse project (Wapice, 2013). It allows the engine condition and performance of a bus to be accessed by passengers.

Älynysse has many potential that can be improved and presented from a different perspective. Moreover, to our knowledge there are only few studies in transportation visualization that combine contextual data with spatial and temporal data. That led us to choose this project and theme as inspiration.

We present Visuäly, a set of visualization techniques that enables the user to explore historical data of bus conditions. As classified by Lam et al. (2012), we designed and evaluated the prototype to answer these questions:

- Is the proposed visualization easy to understand and learn?
- How does the proposed solution as perceived by human subjects response compared to the existing system?
- How can we implement Human-Centered Design process in interactive visualization development?

Our goal is to present and evaluate a set of novel visualization techniques, then compare them with existing visualization by subjective measurements. It is meant to give another perspective and alternative to the system. Thus, it can increase the value of the existing system environment. In this research, we will focus on the visualization techniques itself.

The discussion will continue in Chapter 2 with related works in transportation and contextual information visualization. Chapter 3 gives an overview of Visuäly design process and describes visualization tasks that are performed. We will discuss detailed methods and results for each design process in Chapter 4. To make the whole text more readable, we intentionally split methods and results for each iteration in sub chapters. Finally, we will present conclusions in Chapter 5.

2. RELATED WORK

In this chapter, we will discuss related work in the areas of information visualization and its application in transportation areas. In addition, we will also discuss the evaluation of information visualization and our contribution in this research.

Card et al. (1999) defined "visualization" as "the use of computer-supported, interactive visual representations of data to amplify cognition". In a simple term, to gain insight when interacting with visual representations. Another point of view is from Spence (2007) who described "visualization is solely a human cognitive activity and *has nothing to do with computers*". He added that the data representation is not limited to visual, it can be in any form. Spence described the information visualization activity as: data is transformed into pictures, then interpreted by a human being, and quite often causing an 'ah ha!' moment to a viewer. That moment, when a viewer gain insight or understanding, is one of the purposes of information visualization.

Therefore, it is important to not rashly jump into using technology in information visualization; but instead, to realize the power of traditional tools such as pen and paper. It is a good idea to remember that, many great examples of information visualization in early days were not computer-generated, but done by hand to deliver its values.

Fekete et al. (2008) described the values that information visualization can bring in detail, such as amplifying cognition and supporting perception. They pointed out examples of information visualization contribution from Napoleon's march drawn in 1869 by Minard to John Snow's map on London cholera epidemics. Notably, London Tube Map is one of the popular examples of visualization utilization in transportation. Even though it was introduced in 1933, the idea still survives and can be seen in many transportation maps in the world today (Garland, 1994).

2.1 Transportation Visualization

Information visualization is one of the disciplines that can address challenges in urban mobility. The next question is, what kind of data are available for transportation visualization?

Wang et al. (2014) categorized three major types of traffic data: event based, location based, and movement based. The first one is usually a log data that have

position, time, and a set of attributes. Location based data are usually collected by roadside detectors. Lastly, movement based data, which can be collected from GPS devices, records the trajectories of vehicles. In this research, we focus on the movement based data that have additional contextual data from the sensor.

Much research has been done in movement based traffic data. Andrienko et al. (2007) introduced a framework to help analyst to make sense of large sets of movement data that initially lacks semantics. They combined an interactive visual display with database operation and computation to complement each other. The computational techniques, aggregation and summarization, enable the visualization of large amount of data. These techniques will be useful when presenting the movement data on the map. For instance, aggregation and summarization can prevent a cluttered display being presented on the map when visualizing large amount of movement data.

Furthermore, Andrienko and Andrienko (2008) advanced with spatio-temporal aggregation, by considering two perspectives of movement: traffic-oriented and trajectory oriented. They defined three basic types of aggregation: spatial, temporal, and attributives. Although we will not discuss aggregation techniques, it is worth to mention that the design considerations of the prototype were inspired by those perspectives and techniques. Therefore, we prepared the prototype design to be able to support aggregation and summarization presentation for further development.

Du et al. (2013) demonstrated a spatio-temporal visualization for public transportation in MetroViz. Along with the geographical and bus route representation, they added a calendar representation to visualize ridership and adherence information. They argued that trajectories alone cannot effectively show data in those representations. Thus, they separated each representation to different level of visualization. Their work has inspired us to separate our representation to each module. However, our work differs in data and purpose from their implementation.

Chu et al. (2014) used the VATT System to transform geographic coordinates of taxi trajectory data to street names that reflects contextual information. It combined four levels of visualization: taxi topic maps, street clouds, parallel coordinate plot of streets over topic, and topic routes of temporal evolution. On the other hand, Krueger et al. (2014) allocated two views for geographical and temporal information to analyze movement data using semantic contextual information. They focused on uncertainty visualization and interaction techniques for uncertainty analysis. They proposed to utilized more contextual data such as weather information and traffic models; that is available from the sensors.

Chong and Kumar (2003) described the potential usage of sensors. One of the opportunities is to visualize contextual data that come from sensors. However, there are at least two challenges in visualizing sensor data (Kimani et al., 2013). First,

it is temporal in nature; thus, this data are similar to time-series data. Yet, their similarities also open the possibility of existing solutions in temporal visualization to address the challenge in sensor visualization. A thorough explanation in time-oriented visualization techniques was given by Aigner et al. (2011).

Second, sensor data has multidimensional characteristic and huge volume. One of the approach to address this issue is CircleView (Keim et al., 2004). CircleView combines hierarchical and circular visualization techniques to visualize multidimensional time-related data. Masoodian et al. (2013) proposed the idea of Time-pie; as the name suggests, a visualization that combines time-series and pie charts. Time-pie uses sensor data to provide contextual information in energy consumption. CircleView and Time-pie successfully show the potential and benefit of using and combining contextual information from sensors with temporal data. It is worth to mention that, while the sensor visualizations discussed by Kimani et al. (2013) and Masoodian et al. (2013) were more related to industrial activity, the main tasks, monitoring and control, are similar with transportation managerial activity.

Information visualization can be used to inform the dynamics of the city to residents and municipality. Urban visualization serves several purposes such as artistic, traffic monitoring, and pattern extraction from urban activity (Vaccari et al., 2010). Wood et al. (2014) also demonstrated the role of urban visualization in supporting the needs of local transport authority in London.

Another area that could benefit from transportation visualization is eco-driving, such as an EU funded project, ecoDriver. Hof et al. (2013) classified the usage of driving support system: pre-trip, in-trip, and post-trip. Pre-trip system is used before commuting; in-trip is used to assist the driver during the trip; and post-trip driving usually used to analyze the driving performance. Our research focus on the post-trip perspective, that is to analyze bus performance using historical data.

Tampere city transport is currently running a project to test and demonstrate the involvement of the community in urban transportation (Wapice, 2013). They put a sensor in a bus to monitor its condition and present all the data on the website. Examples of the data include speed, fuel consumption, engine temperature, RPM, and acceleration. They mostly have temporal characteristics and presented with line charts. Temporal visualization can help viewer to understand trends overtime. However, as Kimani et al. (2013) suggest, simple graphic representation like scatterplot or linechart have the problem of showing too much information. Thus, a combination or variation to present temporal information is worth exploring.

Our initial idea of combining contextual information with spatial and temporal information in transportation visualization resembles the discussion by Sun et al. (2014). They combined temporal visualization into map and presented several visual encodings. While the techniques performed well in user study, there might be some

problems when the road shape is curved and unusual. Therefore, we propose simpler visual encoding using color and width.

2.2 Designing and Evaluating Information Visualization

One of the purposes of information visualization is to facilitate data sensemaking process to gain insight. How can we measure insight and evaluate visualization? What is the preferable design process to create visualization?

Lam et al. (2012) demonstrated a set of scenario based looks to evaluate information visualization. They encouraged researchers to select "specific evaluation goals before considering methods, by organizing our guide by scenarios rather than by methods". They analyzed the evaluation scenarios of 850 papers (361 with evaluation) from 1995 until 2011 from four major information visualization publication venues. Then, they categorized the evaluation scenarios into two main categories: scenarios for understanding data analysis and for understanding visualization.

There are four scenarios for understanding data analysis such as *a*) understanding environments and work practices (UWP), *b*) evaluating visual data analysis and reasoning (VDAR), *c*) evaluating communication through visualization (CTV), and *d*) evaluating collaborative data analysis (CDA). On the other hand, there are three scenarios for understanding visualization *a*) evaluating user performance (UP), *b*) evaluating user experience (UE), and *c*) evaluating visualization algorithms (VA).

This research will focus on two scenarios: evaluating user performance (UP) and evaluating user experience (UE). UP scenario usually measures time completion rate and time. There are basically two questions that a UP scenario would address (Lam et al., 2012):

1. What are the limits of human visual perception and cognition for specific kinds of visual encoding or interaction techniques?
2. How does one visualization or interaction technique compare to another as measured by human performance?

We will address the second question in this research by comparing the existing solution in (Wapice, 2013) to our proposed solution. On the other hand, UE scenario commonly studies user's subjective feedback and opinions. In contrast with UP, "the goal of UE is to collect user reactions to the visualization to inform design" (Lam et al., 2012). The visualization can be in a form of paper, a design sketch, working prototype, or as a finished product. While the main purpose of UE is to understand how user think of the visualization, more specific questions can be addressed in this scenario (Lam et al., 2012):

1. Which features are seen as useful?

2. Which features are missing?
3. How can features be reworked to improve the supported work processes?
4. Are there limitations of the current system which would hinder its adoption?
5. Is the tool understandable and can it be learned?

We will focus on the third and the fifth questions, without neglecting the others. The last question is important since we introduced a set of interaction techniques to the participants and interested to see how they interact with it. The third question was selected because we implemented an interactive design process. Therefore, the work to find features or elements that can be improved on the next iteration is also important.

Our views on visualization will also have influence in designing and evaluating the visualization. For instance, if we see visualization from technological perspective, the visualization should be designed and evaluated so that it is effective and efficient. As described by van Wijk (2006), limiting our views of visualization only in technology and economy are not enough. He considered many views from technology, economics, art, design, and science. In addition, he encouraged a continuous user involvement and the use of mockup and prototype as early as possible. Our design philosophy is in line with his views, especially in art and design.

Ventures (2015a) has demonstrated the effective process of using prototype in product development called Design Sprint. It has the essence of iterative design process, such as design, prototyping, and testing (Ries, 2011). Design sprint enables the researcher to compress the iterative process into a five-day cycle. However, compressing the cycle into such short duration might not be very effective for a one-man design team. Therefore, we extended the cycle duration to be two weeks.

2.3 Contribution

Our main contributions in this research are *a*) a set of visualization techniques to monitor bus conditions that combines contextual, temporal, and spatial information in transport visualization; *b*) implementation of human-centered design process in the development of information visualization prototype; *c*) design study and qualitative evaluation that demonstrate the benefits and challenges of our proposed solution.

3. VISUÄLY

We will give a brief explanation of design iteration process in this chapter. In addition, we will describe the potential user of the proposed solution and the visualization tasks.

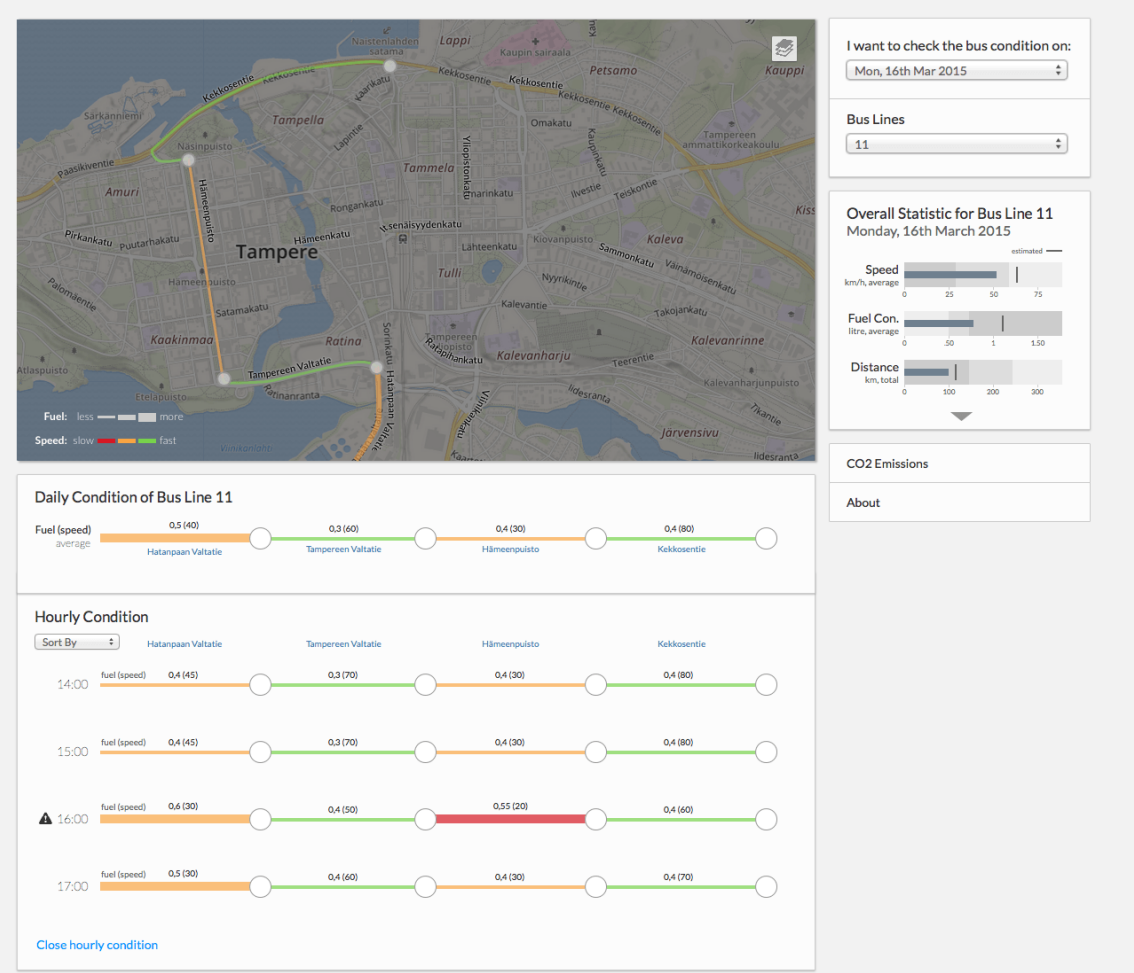


Figure 3.1: Dashboard Screen of Visuäly

We present Visuäly, a set of visualization techniques that enables users to explore historical data of bus conditions. We will first define the terms that will be used in this study: *screen* and *module*. The screen can be seen as a web page, while module can be considered as user interface elements on a web page. A screen can have more than one module. In addition, a module can contain several sub modules.

There are two main screens: landing page and dashboard. The purpose of landing

page screen is to give users a short description about the prototype and Älynysse, while the main functionality is executed on the dashboard screen.

On the landing page, we provide the bus picture and description of Älynysse. There is also a button that will take the user to the dashboard screen. There are three main modules on Visuäly dashboard (Figure 3.1): the map module, the dashboard control module, and the timeline module.

Dashboard control module contains four sub modules: date and bus selection, overall statistic, CO_2 emissions, and description module. In addition, timeline module has two sub modules: daily condition and hourly condition module. We will describe the screens and modules in more detail at the end of this chapter.

3.1 Design Iteration Overview

There are three main phases of design iteration: insight generation, solution design, and comparison with existing evaluation. The first phase is done to get user feedback from the existing visualization. It is also done to generate more idea for designing the solution. There are four iterations on the second phase. Each iteration consisted of designing and evaluating a prototype with a remote usability testing. Finally, the result of the iteration, in form of a prototype, was compared with existing visualization. Table 3.1 presents the overview of all phases.

Table 3.1: Overview of all design phases

		Design process				Comparison	
	Insight	1st iteration	2nd iteration	3rd iteration	4th iteration	Static version	Existing vis.
Methods	survey, informal usability test	usability test, interview	usability test, interview	usability test, interview, questionnaire	usability test, interview, questionnaire	survey	survey
Participants	52 + 1	3	8	6	5	5	54
Data analysis	qualitative	qualitative, quantitative	qualitative, quantitative	qualitative, quantitative	qualitative, quantitative	qualitative	qualitative

3.1.1 Insight from Existing Visualization

We first examined the features and user feedback from the existing visualization. We conducted an online survey to get general pictures of what people thought of the website. It was done with online survey tool, Typeform (2014). We asked them whether they understood the purpose of the service and which machine condition parameters were important to them.

In addition, we held an informal usability session with a Human-Technology Interaction student in University of Tampere. It was done to get more qualitative data and more understanding of how the participant use the existing service.

Both results were analyzed and used as input for the next iteration. Based on the analysis, we can synchronize our assumption with participant thought and feedback of the current visualization. This can reduce biased standpoints when designing the proposed solution.

3.1.2 Designing the Solution

Following the insight generation phase, we moved to designing the solution. We modified and improved Design Sprint (Ventures, 2015a) according to our resources and needs. As described by Ventures (2015a), "The sprint is a five-day process for answering critical business questions through design, prototyping, and testing ideas with customers".

It is one of the great methods to test and validate a new idea in a short time, since it essentially skips build and learn phase on the usual lean methods in Software Development Life Cycle (Ries, 2011; Hart, 2012). However, it might not be so wise to directly implement any methods without considering our own research context and available resources.

Each sprint usually takes five days. In general, the first day is for idea generation and the last day is for user testing. Days in between are usually a design process to create a prototype that looks real. Ventures (2015a) recommends using a presentation application such as Keynote or PowerPoint to produce prototype that can be perceived as a working prototype. It is usually consisted of several images with transitions effect when the participant explore them.

While a design sprint is a great method to test the initial idea using static pictures and transitions, it is not that useful if we wanted to evaluate the interaction techniques. That is why we incorporated more prototype building activities and modified the sprint duration. It is modified to be ten days for each sprint due to the previous reason and constraint on resources. Nonetheless, we still hold on to its essential principles which is scheduling user study before each sprint.

We describe our modified methods for each iteration as follows. First, we sent out the invitation to join online usability testing by mail and social media. The invitation acted as a screening questionnaire, so that we can filter the participant by certain criteria.

Then, we defined set of personas, user flows, visualization tasks, and possible usage scenarios. They were used as a guidance when we started to design the prototype. After that, we sketched the idea on paper prototype to be self-evaluated. Along with this process, we also screened the participants and created a remote

usability testing appointment for them.

Among other methods and tools that exist, we continued the development of the prototype with Axure prototyping tools (Axure Software Solutions, 2002). It is indeed a challenge to find a balance between the functionality and the development effort. We chose Axure because its capability to help us create an interactive visualization without spending too much effort on technical requirements. Thus, we can focus our attention to the interaction techniques of the visualization itself.

After that, we did remote testing sessions at the end of the week. We used Google Hangouts on Air (GHOA) as a service. It helped us in terms of technical simplicity, because the session is automatically recorded and saved on to Youtube account. We designed the usability tasks beforehand, based on the visualization tasks and goals. In the usability session, we asked them to do several tasks while doing the thinking aloud method. Then, we requested them to fill in a questionnaire and answer questions on the closing interview. We used System Usability Scale (SUS) as the questionnaire (Brooke, 1996).

Finally, we analyzed results for all the sessions by measuring task completion rate and time. We also transcribed the conversation in the usability session and interview to capture more accurate user feedback and to help the analysis activity. The result was used as a recommendation for the next iteration.

We have done four iterations in this research. Each iteration differs with its own goal, task, and prototype. The first iteration was focused on the acceptance of the general idea, whether the participants understand the purpose and get the picture of the visualization or not. The second iteration resulted to almost complete prototype makeover from the previous iteration.

After two iterations, we started to get the understanding of which ideas are validated and which features are working. Therefore, we could do more exploration on the visualization techniques and collected more qualitative information. To achieve that, we slightly modified the tasks and interview questions. We also introduced SUS questionnaire starting from the third iteration.

The fourth iteration concluded the design process. Different from the previous iterations, the prototype was built based on the prototype on the third iteration. It enabled us to experiment with more detailed interaction techniques. We will elaborate our process in designing Visuäly on Chapter 4.

3.1.3 Comparison with Existing Visualization

We conducted an online survey to compare our proposed solution with the existing visualization. The procedure and method was generally the same as with the online survey in insight generation. However, there were some insertions and changes on the questionnaire. It was done because the proposed solution using a different

perspective than the existing visualization. Thus, giving the exact same question might be confusing or misleading to the participant. It was also done to gain more understanding about the participant feedback of the proposed solution.

To find whether the interactivity brings any additional value to the proposed solution, we also did a little experiment to compare the interactive version with static images. The experiment was done with the same participants as the fourth iteration.

3.2 Potential User and Visualization Task

The main goal of our visualization techniques is to present the historical data of bus condition. Thus, it is natural to think of the bus company and municipality as the main user groups. However, we also consider residents or public in general, in the spirit to increase public participation in urban ecosystem development (Commission, 2013). It is a challenging task to fulfill the needs of those two groups at the same time, since they may have different goals and purposes when interacting with the visualization. Therefore, we tried to find a balance when presenting the visualization. It has to provide general information that can be understood by residents in interesting format. At the same time, it provides the option for the experts to explore the information in details.

With that consideration, we defined the task that can be accomplished with our visualization techniques on the following sub section. A high-level task was used to describe the goal or activity in general. The goal can be accomplished with several alternatives. On the other hand, low-level task gave us more detailed user interaction specifications within the visualization. A high-level task could be completed by doing several of low-level tasks.

3.2.1 High-level Tasks

There are four high-level tasks that we would like to achieve using the proposed solution:

T1: Understand bus performance trends during a day (speed, fuel consumption, duration)

T2: Get the overview of overall statistic of bus performance

T3: Explore the performance details of certain bus line

T4: Switch between different views (such as by time line or by bus stop).

3.2.2 Low-level Tasks

The low-level tasks are presented for each high-level task:

T1:
- Present the user with bus line pattern (by color and width on the map)
- Put a legend on the map to describe the visual cue
- Show performance graphs on the 'time line module'
  - Based on time
  - Performance: speed, fuel consumption, and duration.

T2:
- Show the overall statistic on the side dashboard
  - Average daily data: speed, fuel consumption, duration, and distance traveled
- Provide visual cues of the statistic on the side dashboard
  - E.g., the meaning of 50 km/h average speed is fast, slow, or above estimated speed.

T3:
- Show label on the route when hovered
- Show tooltip on the route when clicked
  - More detailed few of the route
  - Speed and fuel consumption graphic
  - Option to see more detailed data.
- Give user a progressive disclosure feature on the 'time line module'
  - Ability to expand the 'Daily condition' into the 'Hourly condition'
- Provide more option on the side dashboard
  - See detailed technical data.

T4:
- Provide an option to manipulate the map layer
  - Show road name
  - Show base map layer.

3.2.3 Usability Testing Task Scenario

A task scenario can be designed based on the high and low-level tasks. The scenario can act as a guideline when designing the prototype. It was used to check which functionality and interaction should be developed during the iteration. After designing the scenario, the usability task description can be created.

Task 1
Given: link to the dashboard
Find: purpose of the page
Restriction: no mouse click, hover is acceptable.
Possible scenario:

1. On the map module
    - Hovering one by one on the route
    - Get the road name
    - See the legend on the corner of the map
    - Comparing legend with visual cues on the map.
2. On overall statistic module
    - See bus line number and the date
    - Get distance and fuel consumption comparison of all bus lines.

Task 2
Given: bus line and date.
Find: road section with the highest fuel consumption
Restriction: no mouse click, hover is acceptable.
Possible scenario:

1. Select date (e.g., Monday, 2nd March 2015)
2. Select bus line (e.g., 13)
3. On the map module
    - Hovering one by one on the route
    - Get the road name
    - See the legend on the corner of the map
    - Comparing legend with visual cues on the map.

Task 3
Given: bus line and date.
Find: distance traveled and fuel consumption on that day.
How:

1. Select date (e.g., Monday, 2nd March 2015)

2. Select bus line (e.g., 3)
3. On the overall statistic module
    - See bus line number and the date
    - Get distance and fuel consumption on that day.

Task 4
Given: bus line and date.
Find: conclusion of bus performance on that day.
How:

1. Select date (e.g., Monday, 2nd March 2015)
2. Select bus line (e.g., 11)
3. On the overall statistic module
    - See bus line number and the date
    - Get performance data on the module
    - Get the conclusion on the module.

Task 5
Given: bus line and date.
Find: detailed technical data of the bus performance that day.
How:

1. Select date (e.g., Monday, 2nd March 2015)
2. Select bus line (e.g., 11)
3. On the overall statistic module
    - See bus line number and the date
    - Get performance data on the module
    - See 'more data' icon
    - Click that icon
    - Get more detailed technical data on the module.

Task 6
Given: bus line, date, and road name.
Find: average fuel consumption in that road
How:

1. Select date (e.g., Monday, 2nd March 2015)
2. Select bus line (e.g., 3)
3. On the map module
    - Hovering one by one on the route to find the route
    - Click the road to see the tooltip
    - Get the road name, speed, fuel consumption, and operating hours on that route.
4. On the timeline module
    - Examine the trends based on speed and fuel consumption graphs
    - The values are written on top of the lines
    - User get the values
    - Clicking on the line will reveal the tooltip on the map module.

Task 7
Given: bus line, date, hours, and road name.
Find: bus speed on that road at certain time
How:

1. Select date (e.g., Monday, 2nd March 2015)
2. Select bus line (e.g., 3)
3. On the map module
    - Hovering one by one on the route to find the route
    - Click the road to see the tooltip
    - Get the average road name, speed, fuel consumption, and operating hours on that route.
4. On the timeline module
    - Examine the trends based on speed and fuel consumption graphs

- On the bottom of x axis: bus stop
- Hovering on the line will reveal its name
- User get the value above the line
- Clicking on the 'see hourly data' button will bring to hourly average module.

5. On the hourly average module
    - Several graphics are presented according to the operation hours
    - Search and match the operating hours
    - Get the value on the graphs.

3.3 Design Requirement, Screen, and Module

Based on the task analysis, the proposed solution should satisfy the following design requirements:

- it should be easy enough to use and understand, even for the general user group.
- it should facilitate user to compare information and detect the pattern.
- it should emphasize the general information first, while providing the possibility for expert user to explore further.
- it should have a visual consistency between the screens and modules; thus, the potential user should not have to form a new mental model and learn another graphical representation.

We designed two screens to accommodate these requirements, landing page screen and dashboard screen. The landing page provides the description of Älynysse with a bus picture and text. User can read a description and click a button to proceed to the dashboard screen. Meanwhile, dashboard screen is where most of the interactions are performed.

There are three main modules on dashboard screen: the map module, the dashboard control module, and the timeline module. Each module serves its own purpose. Map module combines contextual information and spatial information. This module represents information such as fuel consumption, speed, and bus trail with line width, color, and GPS position on the map. These same information are represented in a different way in the timeline module that presents the bus line sequence in a linear visualization.

Interactions in the map module are also linked to the timeline module. At default, the state of bus lines on the map and timeline are inactive. Then, the bus lines state will be switched when a user moves the mouse cursor on top of them (hover state). One hover action on bus line in one of the modules, map or timeline, will trigger the hover state for that bus line in both modules. The same linked interaction is also applicable in click action. When a user clicks on the bus line, a tooltip containing detailed information about that line will appear on the map. The tooltip will appear depending whether the user clicks the bus line from the map module or timeline module.

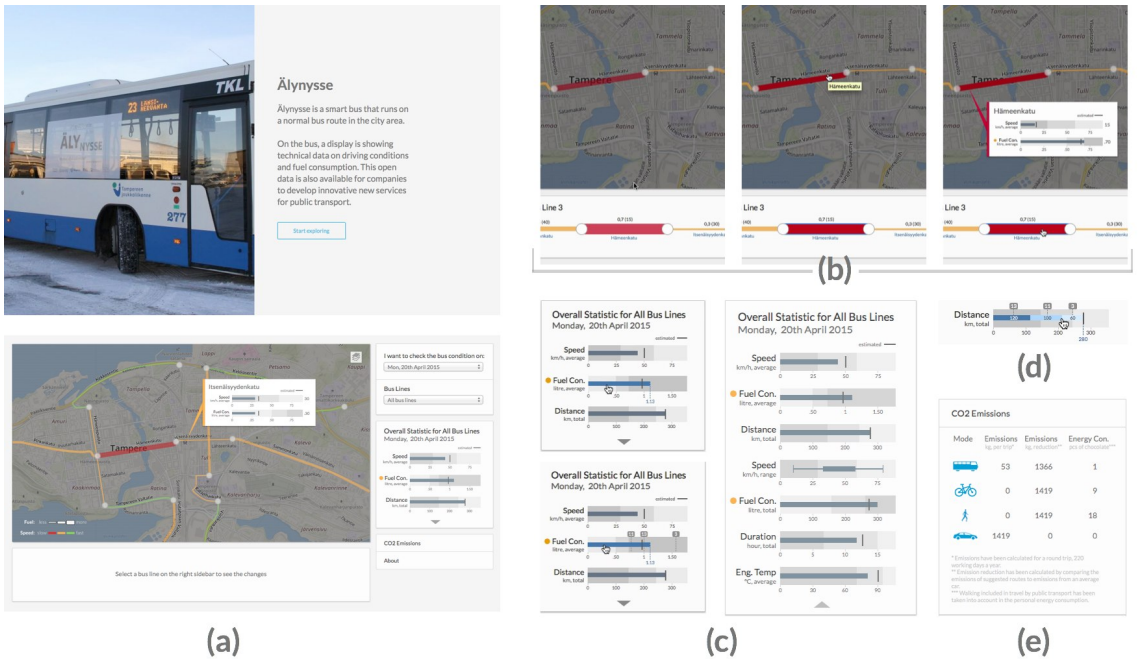


Figure 3.2: Visuäly screens and modules. (a) Landing page and dashboard screen. (b) Bus line states: inactive, hovered on the map module, hovered and clicked on the daily condition module. (c) Overall statistic module states: hovered and clicked. (d) Another variation of clicked state in overall statistic module, for the 'total' category. (e) Expanded state of CO_2 emissions module.

The tooltip on the map module contains detailed information of a certain road section such as the street name, speed, and fuel consumption. Speed and fuel consumption are being visualized with a non-interactive bullet graph (Few, 2013b). Bullet graph presents a single quantitative measure (e.g., speed) and relates the measure to its qualitative state (e.g., slow, medium, and fast). In addition, the graph is also able to provide other quantitative measures, such as estimated value. The technical specifications of the bullet graph are described by Few (2013a). We are also using a modified interactive version of the bullet graph on the overall statistic module.

Dashboard control module contains four sub modules: date and bus selection, overall statistic, CO_2 emissions, and description module. Date and bus selection module is used as a navigation on the dashboard screen. Although it was possible to use a date picker in a date selection, we chose to simplify our case study by limiting the date selection into five days. The selection is done with a dropdown menu. The same dropdown menu approach is also selected for the bus selection. Currently, only one bus has a sensor on the machine, since Älynysse is a special bus that acts as a moving lab. Everyday, the bus can run on two to four different routes. In this prototype, we provide three routes selection.

Overall statistic module presents seven pieces of information, each represented by an interactive bullet graph. Each bullet graph contains quantitative measurement, comparative measurement, and qualitative state. The comparative measurement is the estimated value of certain variable. Text labels for each bullet graphs are placed on the left side of the graphs. The label consists of the variable name (e.g., speed), unit (e.g., km/h), and measurement category (e.g., total, average, or range). In addition, an orange circle will appear on the left of the label if the measurement value exceed the comparative measurement. Finally, we provided a different active state for each measurement categories.

Timeline module simplifies the idea of the London Tube Map (Garland, 1994) and reconstructs the order of bus lines in a linear fashion, which can be seen in modern metro or tram maps. As mentioned previously, the interaction in timeline module is linked with the map module. At first, timeline module is inactive if 'All bus lines' was selected as the bus line option. It will present the visualization after a user selects one of the bus lines.

Timeline module has two sub modules: daily condition and hourly condition module. Daily condition presents the average information of the bus, while hourly condition provides more detailed information for each hour. Hourly condition module original state is hidden to create simpler display. This module can be revealed by clicking a 'See hourly condition' button on the daily condition module. The hourly condition module will appear and hide like an accordion menu. We use design principles and guidelines, such as animation, that are suggested by Haider et al. (2013). Daily and hourly condition modules use the same visual cue as map module to represent the speed and fuel consumption.

4. DESIGN ITERATION

We did four design iterations, each of them consisting of remote usability testing. In addition, before and after the whole design iteration process, we did an insight generation activity and compared the proposed solution with the existing visualization. We conducted a survey and informal usability testing in order to gain more understanding from public about the existing visualization. Hearing public feedback about the existing solution was also an effort to clarify our viewpoint on it, in order to prevent us from making a biased design decision. Then, we compared our proposed solution with existing visualization to see whether the solution provides any additional value for public.

On this research, design process is a continuous activity, which means that each iteration is usually built based on the result and recommendation of the previous one. However, each iteration has its own purpose and challenges, which make them unique. While there might be slight differences for each iteration, we summarized the overall process of each iteration as the following:

1. Create a screening questionnaire to invite participants for the remote testing. Then, promote the questionnaire on social media, mailing list, and personal email.

2. Screen the potential participants based on the selection criteria. If they are eligible and match the criteria, send a Non-Disclosure Agreement (NDA) to the participant (see Appendix B). If they are not eligible for that iteration, send them thank you notes.

3. If the participant agree with the NDA and the time appointed, plot them into time slot. NDA is used to protect the right of both parties (participant and researcher).

4. At the same time, gather ideas and, if available, combine them with analysis and recommendation from the previous iteration.

5. Define or refine visualization task based on the idea brainstorming. Check whether the visualization task on the previous iteration has already been validated, need improvement, or even has to change completely.

6. Create list of task based on the previous step. More often, we created the task even before started to sketch the idea on paper. It allowed us to concentrate on building things that will be measured and validated. Putting this step upfront will be useful to avoid design and develop unnecessary feature in later phase.

7. Sketch the idea on paper. We prefer to visualize the idea on paper before jump right in to the prototyping tools. It is fast and we can eliminate the risk of getting trapped in tools or application capabilities at the early stage (Buxton, 2007).

8. Design user interface elements if necessary. We used Sketch App (Coding, 2015) to design a particular element to be exported and used with Axure.

9. Create prototype in Axure based on the sketch. By using a prototyping tools, we could validate lot of ideas faster than developing the whole application.

10. Do a pilot testing if possible and send a reminder to participants. Pilot testing is one of the most important parts of the usability testing preparation. It helped us to find issues that we were not aware of until the pilot testing session was held.

11. Conduct the remote testing. We used and slightly modified the usability test script from Krug (2009) and Ventures (2015b). We will explain the procedure of each iteration in their own sub section. The remote testing script can be found in Appendix C.

12. Analyze the result, provide recommendations, and send the report. In early iterations we transcribed all the conversation, while later we only mark interesting events which can be referred to in analysis. Then, we identified and proposed the solution to the problem. It was complied as a short usability report that has been discussed with our supervisor.

Moderated remote usability test was selected as our main methodology in this research. A remote usability test enabled the participant and moderator to be on different places. It is possible because the interaction happened in online platform. It brings several benefits to the participant and researcher, such as open up greater number of participant, since they can participate anywhere. It also means that the researcher can save time and resources that is normally used to set up a dedicated test laboratory. On the other hand, Internet connection speed could introduce certain issues on the test, depending on where the participant and researcher located. Moreover, researcher is usually having a hard time to pick up visual cues from the participant (Lazar et al., 2010).

The first challenge is addressed by asking the potential participant's connection speed on the screening questionnaire. We asked them to rate the speed of their Internet connection in a five scale rating. Thus, the risk that related to slow Internet connection can be reduced by selecting participant with fast and stable connection.

The latter can be tolerated by using synchronous remote moderated test, which means the researcher and participant communicate and interact at the same time; either by video or sound. While the is participant doing a task, the researcher can pay more attention on how he/she interact with the prototype. It can be their mouse movement, humming, or silence. Researcher can also prompt a question when he assumes that the participant encounters a problem and is completely stuck. The latter challenge can also be viewed from different perspective, the participant also cannot see the researcher's body language. This helps them to "play dumb" when answering participant's questions and be less intimidating to them (Rubin et al., 2011).

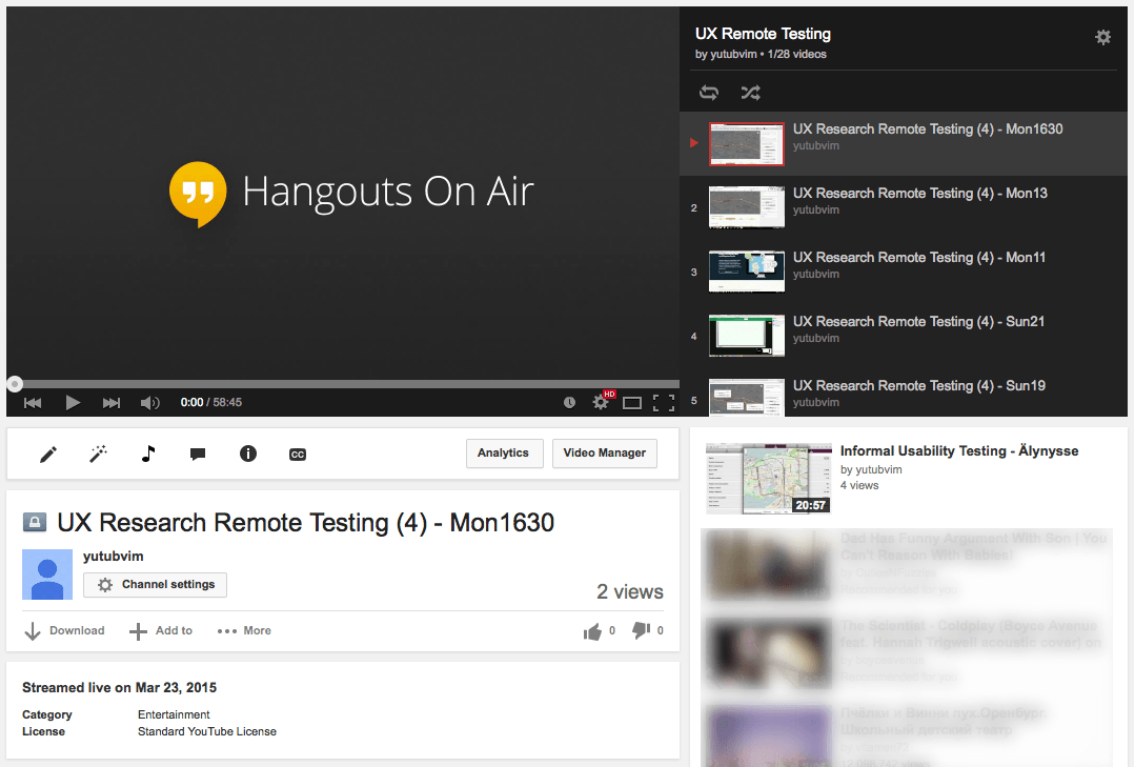


Figure 4.1: GHOA session will automatically stored to Youtube account

As mentioned, Google Hangouts On Air (GHOA) was chosen to be our platform to conduct moderated remote usability test. We have explored a collection by Ethnio (2015) that listed tools for doing remote usability and UX research. However, Typeform was the only one we found suitable for survey purpose. We had used Silverback 2 (Clearleft, 2015) to record a pilot test session. Unfortunately, the application could not record the voice if another software, such as Google Hangout or

Skype, was currently accessing the microphone. Without a recorded conversation, a remote testing might not be as useful as it should be. Doing the usual video conference while opening another screen recording application will also introduce the same issue, in addition to higher memory usage. Therefore, GHOA was used with its benefits: it is an easy to use online platform, a researcher can use a Google account to use the platform.

Different from a normal Google Hangouts, a GHOA session will be automatically saved in the moderator or session host account. Since Youtube is a service owned by Google, the researcher can also switch between another Google account and Youtube account with the same credential. The recorded session is unlisted by default, meaning that only those who have the link can access the video on Youtube. However, it can be changed to private in order to protect participant's privacy. Video collection can be downloaded later for convenient use. Thus, the space in the hard drive can also be freed, accordance to the researcher needs for analysis purpose.

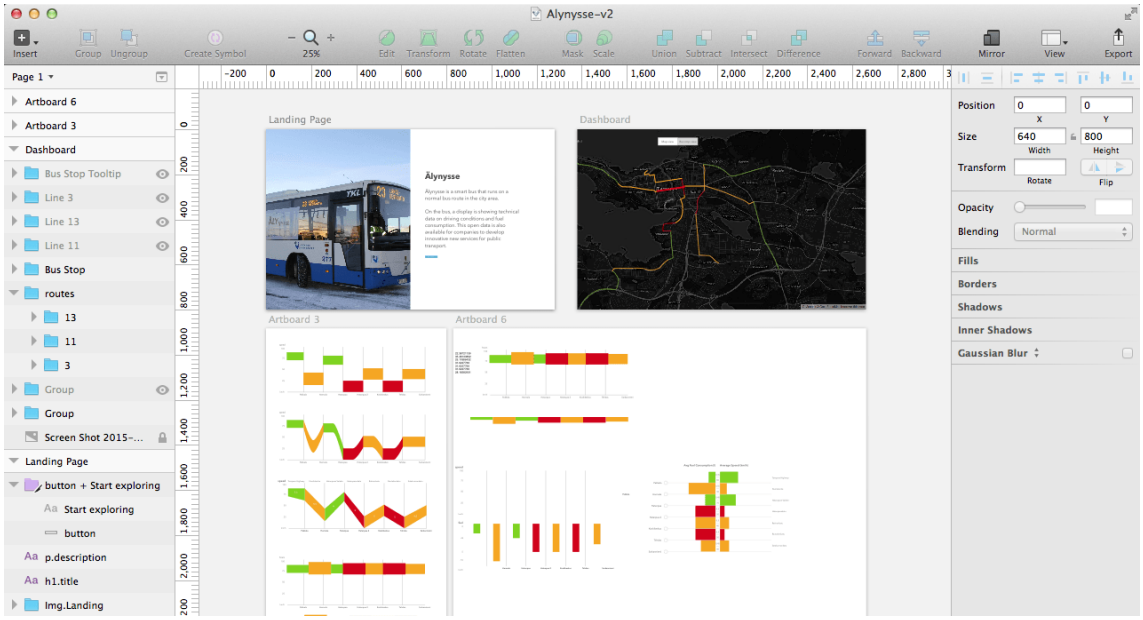


Figure 4.2: Sketch App let us explores range of possible design solutions. Screen shot from the 2nd iteration

Sketch App and Axure were used to speed up our UI design and prototyping process. The typical process was to generate many rough sketches on paper and convert them in Sketch. Sketch can be used to explore the user interface concept in more details and produced UI elements for later usage (Figure 4.2).

Then, the interaction of the prototype was designed in Axure. Figure 4.3 shows the work space of Axure. It has nice features such as layers, animation, conditional logic, and sharing capabilities. The latter is a handful features, because the prototype can be uploaded directly from local machine to Axure's server. By default, the

researcher did not have to allocate a particular web hosting and domain. Therefore, convinced us to select Sketch and Axure as tools for designing an interactive prototype.

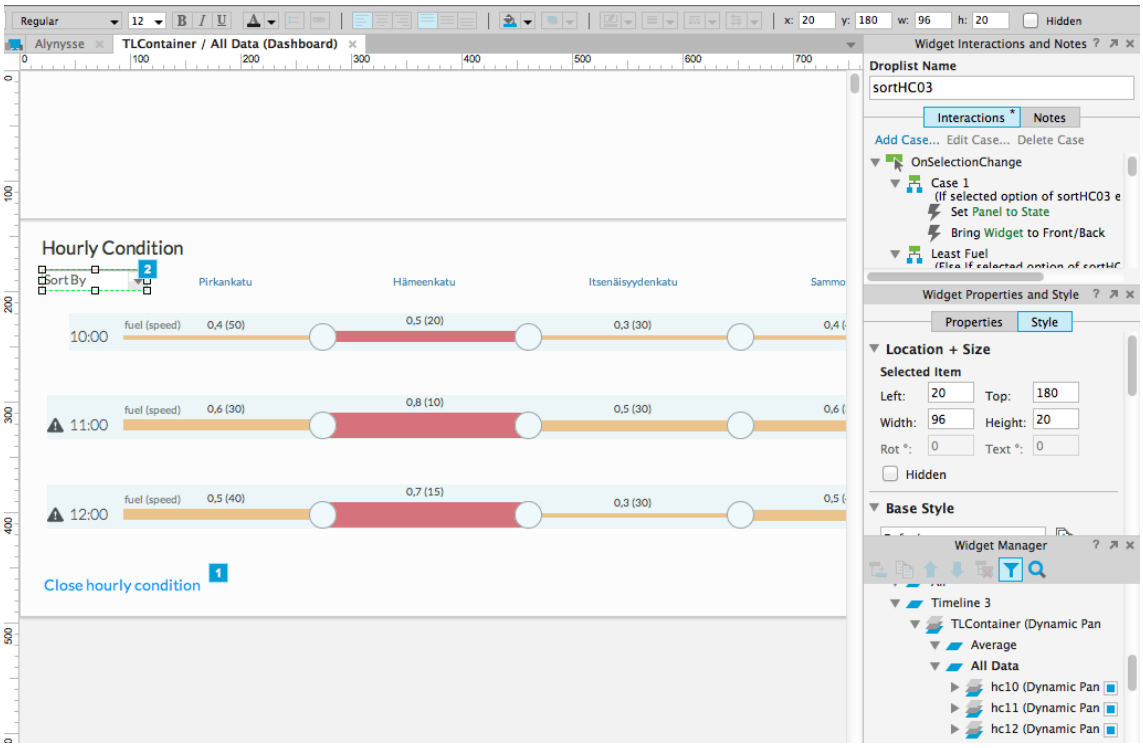


Figure 4.3: Axure work space with widget interaction on the sidebar. Example form the 4th iteration's prototype

Each iteration has its own purpose: the first and second iteration were done primarily to validate the general idea, whether it can be understood by the participants. They are also meant to test whether the prototype could convey the purpose of the visualization, without taking too much detail on the visualization techniques.

Along the way, after ideas and assumptions are validated, we started to shift our attention to the visualization techniques. Starting from the third iteration, we introduced a Simple Usability Scale (SUS) that was proposed by Brooke (1996). Based on the suggestions by Finstad (2006) and Jarrett (2011), we also slightly changed the question, such as changing the word "system" to "website" and "cumbersome" to "awkward". We measured task completion time and rate for each iteration, in addition to questionnaire and interview analysis. Participants comments were written down in paper while the session was held. Moreover, we also transcribed their comments and interview with a transcribing software, InqScribe (Figure 4.4). The transcription process was also helpful to pick a certain things that could be missed during the session.

We will discuss the process described in more detail for the rest of this chapter, starting from insight generation, design process, and comparison with existing

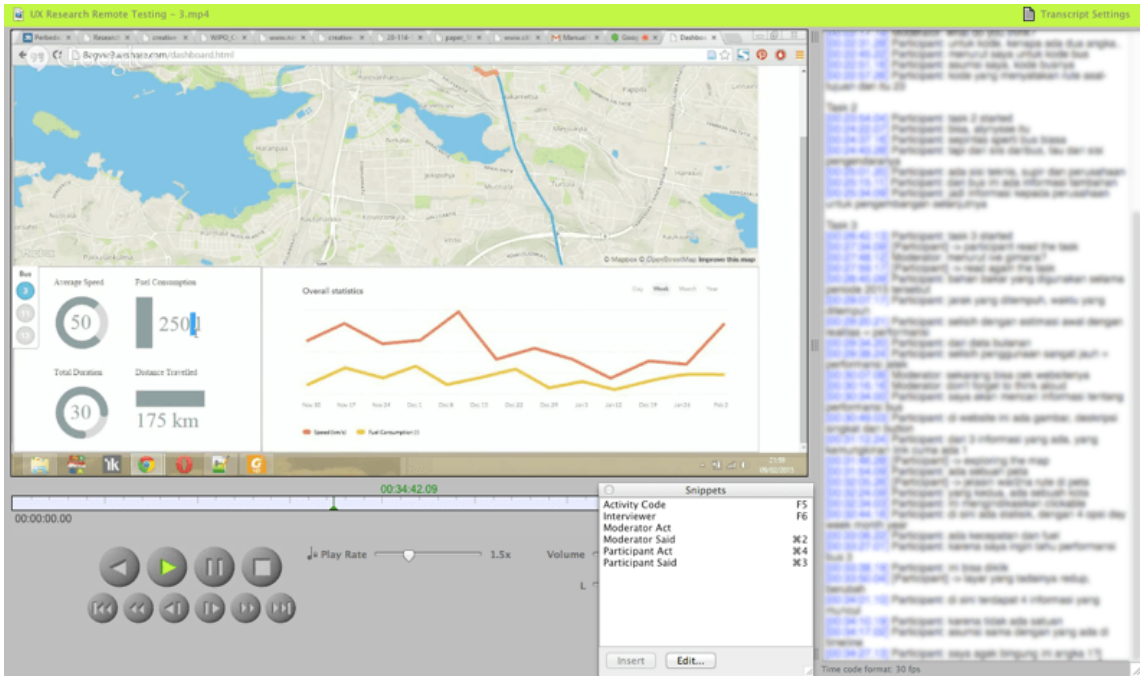


Figure 4.4: Transcription process on InqScribe. Example taken from the first iteration.

visualization.

4.1 Insight Generation

We started the iteration process by examining the current solution. We wanted to integrate our thought with feedback from the public, in order to avoid biased design decisions later on. There were two main characteristics that we were interested in to find out: general experience and specific data on the existing system.

The general experience consists of: *a*) Which features are working or not? *b*) What kind of information should be presented? *c*) Did the presented information and visualization match with user mental model? and *d*) Did the participants encountered any difficulties when interacting with the current visualization? While for the specific data, we wanted to find out *a*) Which machine condition parameter suits them best? *b*) Were they familiar with the existing visualization? *c*) How might they improved the current solution?

Survey and informal usability test were used to gather the required information. Based on the result of survey and informal usability test, we formed an initial storyboad, persona, and user story. They were not in the final state. This means, if necessary, that they were also updated while we are doing the iteration. The result of insight generation plays an important role on the whole design process.

4.1.1 Survey

We conducted a survey to get a general idea of what people think about the current visualization. On this survey, we gave the link to the visualization page and asked opinion from the participants. There were 52 respondents, most of them had not heard of the current Älynysse service. Speed, fuel consumption, and distance were the most interesting attributes. General rating was 3,33 on 5 scale in which 1 means not good and 5 means very good. However, there were different understanding from the participants about the visualization. The idea was clear for some of them, while the other participants had a hard time guessing the purpose of the visualization.

Purpose

To find out public opinion of the current visualization and get a clue of severe problems in it. To hear what are the most interesting attributes of machine condition from participant's point of view.

Participants

There were 52 respondents participated in this survey. Most of them came from Indonesia and Finland. The number of participants who hold Bachelor's and Master's degree were 24 and 19 respectively, while there were 7 PhDs and 2 high school graduates.

Procedure

The survey was done remotely with an online survey tool, Typeform (2014). We created the survey and distributed the link through email and social media such as Facebook and LinkedIn.

Electronic informed consent was provided at the beginning of the survey. It explained the risks and benefits, duration, participant rights, contact information for the research, and the consent itself. If they were agreed with those conditions, they could chose to continue. Otherwise, they could decline the participation without any consequences.

The questionnaires were presented to the participants after they read and agreed with the consent form. First, simple demographic questions such as age, location, and education were asked. We were also interested to find out whether they were familiar with information visualization and Älynysse. Before moving to the next part, we presented a short description to give a better understanding of Älynysse, in case they have not heard it before. Then, several questions about the service were posed to the participants. Links to the current web page was given to the participant and they could switch back and forth between that page and the survey form. In case the system was offline, there was also a video to demonstrate how

the system would functioned if it was online. We then asked which attributes that interest them the most. They were also required to rate the existing visualization. Finally, we asked their opinion on how to improve the current visualization.

Questionnaire

The questions were grouped into six sections. We will present the questions with the following notation: "(Question type) The question". For example, "(Short text) What is your name", is asking for a name with short text input. We used a (Statement) question type to give the participant a description, such as informed consent. All of the questions were required to be answered except the last question that asked their email. The questions consists of:

1. (Statement) Informed Consent
2. (Short text) What is your name?
3. (Question group) Hello, [Name]]! We will start by asking your background information.
   (a) (Number) How old are you?
   (b) (Multiple choice)Your highest education is...
      - Highschool
      - Bachelor
      - Master
      - PhD
   (c) (Dropdown) In which country do you live at the moment?
4. (Question group) Great! Now let's talk about Information Visualization and Älynysse a little bit.
   (a) (Multiple choice) How familiar are you with information visualization? (Choose as many as you like)
      i. I am a visualization researcher / professional
      ii. I took a visualization course in university / online course
      iii. I have read an article about it I saw visualization / infographic on the media
      iv. Info what? This is the first time I heard it.
   (b) (Multiple choice) Have you ever heard of Älynysse service?
      i. No, this is the first time I heard Älynysse.

ii. Yes, but I haven't used it yet.

iii. Yes, I have tried it.

5. (Statement) Imagine that we have a special bus that has sensor to monitor its machine conditions. It will send those data to Internet while the bus is moving. It will display the movement of the bus (GPS position).

   The sensor also monitors several machine conditions, such as temperature, speed, fuel consumption, and RPM.

6. (Question group) Now we will ask your opinion about the website. Remember, we are testing the website, not you. Therefore, there is no right or wrong answer. Feel free to switch between this form and the website while answering the questions.

   If somehow you are not familiar with the language; you can change it by clicking on Aloitus menu, then click on the Union Jack flag. Then, please click Data menu to come back.

   (a) (optional) You are welcome to watch the video, if the system status is 'Offline' when you visited the website.

   (b) (Long text) What do you think is the goal of visualization on that page?

   (c) (Long text) Is the current visualization gives a good picture of what's going on?

   (d) (Multiple choice) Which attributes interest you the most? (Choose as many as you like)

   - Temperature
   - Motor RPM
   - Speed
   - Throttle position
   - Fuel consumption
   - Distance

   (e) (Rating) What is your overall experience related to the visualization?

   (f) (Long text) How would you improve the visualization?

7. (Email) That's it. Fill in your email if you are interested to get the updates and see your impacts of the study. (Optional)

Results

Almost all of the participants had not heard of Älynysse service before (48 of 52 participants). More than half of the participants had seen visualization or infographic on the media. On the other hand, 13 percent had never seen visualization before.

The existing visualization was rated as 3.3 on 5 point scale in which 1 means bad and 5 means very good. However, there were different opinions among the participants, whether they were correctly understood the visualization purpose or not. Understanding the purpose of a service or application is important for the interaction. With that understanding, the user can decide whether to leave or explore the service. Different understanding of the purpose can also lead to dysfunction of the service or application because their functionality might not match user expectation.

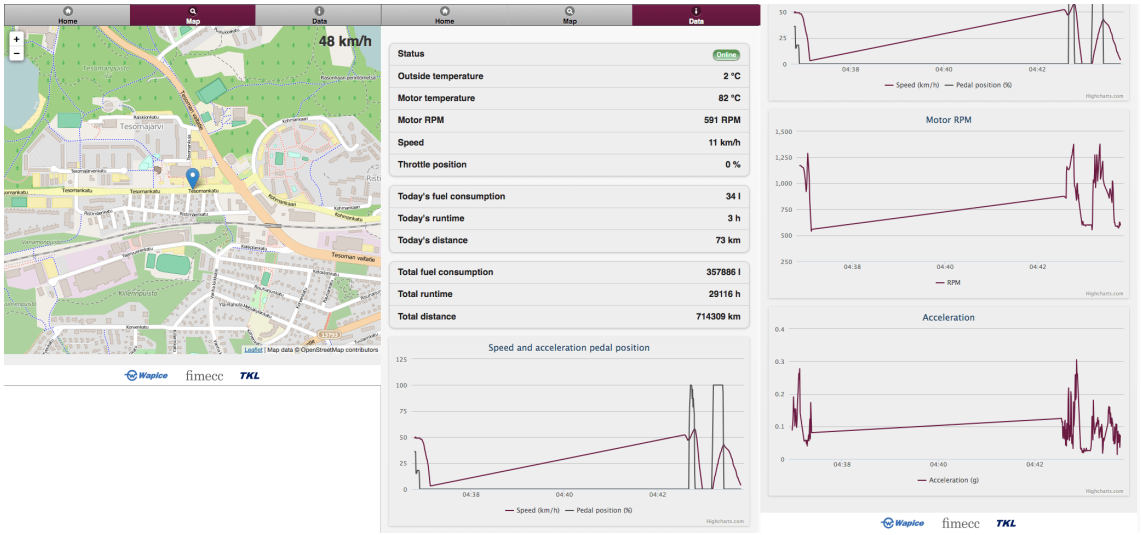


Figure 4.5: Screenshot of existing solution, taken from Wapice (2013)

Attributes that interested them the most were speed (35 votes), fuel consumption (32 votes), and distance (28 votes). Remember that the participants were able to choose as many options as they wanted. Meanwhile, the other options such as temperature, motor RPM, and throttle position only got 17, 10, and 6 votes, respectively. This finding is in line with our initial thought, that the provided information on existing visualization was 'too technical' for general user group such as residents. It might be useful if the system emphasized the general information first, while provided the possibility for expert user to explore further. We will present their feedback from the open ended questions below.

What do you think is the goal of visualization on that page?

We found that almost all participants understand the goal of the existing visualization.

P1: "Inform the condition of the bus to the user (the user might be the police who monitors the bus speed, or people who takes care of the bus machine). In the homepage, it is stated that Älynysse has participatory functions for passengers, but I have no idea what the benefits are for passengers."

P9: "The information that is included on that page seems to be used to find out the efficiency of one bus. The information could also be used to see if the bus driver drives the bus efficiently."

However, some of them were still confused about its purpose.

P34: "In the beginning you say that alynysse provides the passenger with the opportunity to make buses and public transports meet the passenger needs. But then I don't have idea on the data that present on website related to the goal."

P8: "... and on the "Kartta" page I see a map and a moving dot, the moving vehicle (a bus?) I guess. Goal of the visualization is unclear to me, depends to whom it is targeted at."

P25: "What I didn't understand is that, what is the whole purpose of visualising the data..what need of people is it fulfilling? To monitor fuel consumption?"

P26: "Perhaps just to make it look modern and interesting."

One of the participant pointed out an interesting idea.

P23: "This data would be helpful in the case of an accident where you would need to evaluate what caused the system failure. This information would help rectify that error and prevent such cases in the future. Also the information provided would give an idea of the fuel usage and when and where the drivers are speeding etc."

Is the current visualization gives a good picture of what's going on?
We got various feedback from participants. While some of them thought the visualization was good, there were many participants who felt that the current visualization has many aspects that could be improved. We analyzed and classified their answer on the following themes:
The visualization is not representative enough.

P19: "Maybe yes for expert, but for me not, it looks a little bit complicated"

P28: "Not really, if you ask about the engine and many hard things of that bus, that's awesome. But if you ask about the condition inside bus, I thought it was not visualized."

P39: "Not bad. The webpage looks like a rough version. The visualization ..... No, I didn't get a good picture, maybe just from my own point of view."

P50: "almost, when the chart is shown.. it doesn't explicitly show "what's going on"

Issues related to User Interface and User Experience

P10: "For the visualization, it does decent job, but the UX needs work."

P23: "I think it does. Maybe you would need some getting used to. But it is not visually appealing at the moment."

P26: "It does. But no such highlight of primary or secondary information. Is it that all the information depicted contain same relevance?"

P8: "...hard to guess what drivers get out of that. When I click the moving dot, I would expect to get some info on that car."

P44: "Judging from a laptop, with the browser fully open, the two columns of information are too far apart. I have to look left and then right. I think it would be nicer to diminish the distance between them."

Should the map be separated from the visualization page or not.

P3: "it is, separating general information and detailed one is a good idea!"

P6: "Partially, yes. But, I think it's better if the map and data visualization displayed in one page like a dashboard. You can make that complex number into better visualization form such as speed made like speedometer or something else."

P29: "No. actually, it is better to put all of the current information on the map pages. So, you do not need to switch page if you want to see the info beside the velocity. I would say that the page data should contain just the analysis of the data, for the current condition, put it in the map page."

P37: "To be honest, no. User need to switch tab (from map to data) to see details."

Usage of real time data and its representation issues

P5: "No. The data interval of the graphs are restricted and only show data from some seconds ago. The data in the table is just plain text and hard to compare if their values are high or low. It is hard to extract knowledge from the data."

P45: "Quite good. One thing that disturbs me is that the graphs show on about 20 seconds time period."

The meaning of information is demanded

P9: "In my opinion, the current visualization is quite complete. However, it still gives raw data to the reader. For example, what does 'Today's fuel consumption = 48 L' mean? Is it efficient enough?"

P15: "Yes, but some terms are difficult to understand like 'Throttle' and also i was little disturbed by visualization are made separately like 'motor RPM' (by status and curve)"

P30: "Probably not for me, may be you can add the resume or the conclusion of that graphic such as this bus too fast / this bus broke. So that we can understand what is the meaning / purpose."

P34: "I don't think so. The page shows the graphic of speed, acceleration, motor RPM, etc. You provide number and the unit for every data depicted, but I think that data can't be information without indicator for common person like me. Example : Average motor RPM is 1200 rpm. What does it mean? Is that ideal condition or not?"

Lastly, about user groups and their needs.

P12: "yes... at least quite understandable. by seeing the 'data' page, it shows basic information about the engine performance. the 'map' page is helpful if we want to monitor the current location of the bus. although, I still don't understand (yet) who would get benefit from this information system."

P27: "Well, I don't know. I'm not sure who needs all that information. And is it really needed. I mean is all the information about the bus and the trip important. Why I need to know this?"

P47: "I'm not so sure. I don't know who is it for ? If it is for passengers then I can't think of any real usefulness of the visualization, except for fun"

How would you improve the visualization?

We also classified their responses into several themes. The first one is improvement on the visualization itself.

P52: "Not all is visual. There are also only numbers. Maybe to visualise them as well."

P6: "Maybe, I would make that complicated data into simple visualization."

P13: "as I said a module which shows the current speed/temperature/etc. I dont want to interpret the graphs"

P18: "It should give alert like red color background on a data that suppose to be above normal. I'm a little bit confused about the way it visualizes data."

P30: "For the speed, you can visualize it as speedometer and fuel using bar chart."

P36: "We need to apply some contrast colors for each graph, because I found that speed and pedal position graph colors almost looked the same."

P39: "The visualization is not "beautiful" yet. I am not sure how much customization every user can do with current webpage?"

P45: "To make it easy to see visualizations for longer time periods."

Then, they also demanded improvement on the whole design in general.

P5: "Interactive graphs, better visualization of the data shown as text (for example, as gauges or graphs). Include new data (knowledge) generated from these values with some visualization."

P23: "A suggestion I would give is to show the graphs in smaller widgets on the front page(above the fold) itself, rather than the text. Also to make the webpage look more modern."

P37: "Remove the tabs. Build (only) one single dashboard to show summary of the bus condition (including map, speed, motor rpm, time, etc.) No need to switch tab from map to data, and switch back to map again."

P44: "I would center both columns and right-align the left column, and left-align the right column so that information can be visually consumed reading vertically down the middle, rather than shifting my eyes right, left, next line, right, left, etc."

P51: "The values corresponding to the same class, should be organized under one heading like the mechanical readings should be given some headings also. The readings for different items are written too far away, so a normal user can be distracted by that ending up to note wrong readings. Therefore the distance should be cut to half at least."

Lastly, provide meaningful information.

P19: "Give a good (simple) resume for the result"

P34: "please provide the information or indicator not only the data. I really don't know what I can conclude after reading that data. For example beside the data of speed there is indicator : maximum speed of bus on the road should be 50km/hour."

P35: "Give summary for the graphic data"

P38: "By adding a tab that provides status of some other important features of car as well "

P42: "I will improve the visualization with added information about driver bus condition"

P32: "Maybe you can add some critical action and highlight it, for example like when the bus try to increase the speed, it has some effect to the RPM too, and also to the acceleration. Try to resume when the bus in the highest speed (maybe in highway, i dont know, :)), it will become more interesting."

4.1.2 Informal Usability Testing

We did a 20 minutes informal usability session with one participant to gain more understanding how the participant perceive and interact with the existing solution. The participant was one of the respondents from the previous survey, he is a Human-Technology Interaction Master's student at the University of Tampere. We found that the purpose of the website was roughly understood by the participant. However, it seems that the participant was not sure if public needs all of the machine condition data. There were also considerations about design elements such as icon on the map and line chart on the data page.

The test was held in a discussion room in University of Tampere Library. A laptop was used to open the existing website. We recorded the conversation with a voice recorder and screen captured the laptop screen to see how participant interact with the website. Different from the usual usability testing, this informal usability testing did not have a set of defined tasks. The participant was allowed to freely explore the website and give his comment while thinking aloud.

The procedure is described as follows. First, the participant was greeted and introduced to the test scenario. Then, we gave a short explanation about existing Älynysse service. Participant was given an informed consent to be read and signed before proceeding to the actual test. After that, the test was started with participant exploring the website. He can stop and ask question if necessary. Moderator was demanded to not give direct answers to his questions and "play dumb" (Rubin et al., 2011). For example, give a stimulating question such as "what do you think?" or "what would you suggest?". We also provided a video, to prevent if the system was offline and the participant could not see the visualization running. After the test, we performed a semi-structured interview with open ended questions. The exact question was not defined, rather defined from a template and improved along the way while the participant doing the task.

We found that the participant was confused with the map page on the existing system, especially with the marker icon. The participant thought the marker was represent a building, which in reality it represents the Älynysse bus itself. Using the similar marker as Tampere Public Transport service would be a good idea, according to participant's suggestion. The next discussion was about user groups, participant was not sure if public or residents will get a lot of benefit from the information on the website. The participant said, "These data, from a bus passenger perspective, are not really interesting". As a passenger, however, participant stated that speed and outside temperature might be interesting. Participant also mentioned about the issue on the time line or line chart; then suggested if we could 'zoom out' the time range to around ten minutes. This is due to the limitation of using real time data. Adding average data is one of the idea to overcome this issue. The participant also mentioned about the possibility to combine the data in Data page with the map, if the information can be presented without taking too much space.

4.1.3 Initial Personas and User Stories

Personas and user stories were created based on the analysis from the previous survey and informal usability testing. They were used as a guideline to help us to set the requirements in designing the proposed solution. We divided the target users as two main user groups: general users and expert domain. General users consisted of residents or potential visitor of the city, while expert domain ranged from municipalities to the management and the drivers of the bus company. Although it is natural to jump in and focus solely on the expert domain, we wanted to find out whether the idea can also be understood by the general user group.

Cooper (2004) defined personas as a hypothetical archetypes of actual users. They are not the real people, but they represent them throughout the design process. They have specific attributes such as name, activities, roles, and goals. As noted by Goodwin and Cooper (2011), the benefit of using personas as an archetypes is that they use people rather than abstract idea as the presentation. Thus, they help us to be more involved and see the archetype in intellectual and emotional way.

Initially, we created two personas for the general user group. First, we defined their name and detailed description. The description consisted of their relevant characteristic and behavior, such as job or activities. Then, we described their goals: the reason why they will use the solution, how will they use it, and what benefit that the solution will bring to them.

The first persona was Mäkinen, a resident of Tampere. Mäkinen works as a librarian in Tampere City Library. He is 40 years old, graduated from the University of Tampere with Social Science Degree. He has been living here since his childhood. He usually goes to his office by bus since he lives 6 km from the office. As a frequent

bus user, sometimes he wonders why this bus takes a longer route when there seems to be a shorter one? He also wonders the fuel efficiency of the bus. He heard that there is a certain bus, number 277, that has sensor in it. He opened the web service only to found that he is now more confused about the visualization. He would use the site to find the driving behavior of the bus on certain road section, like speed and fuel consumption. He would also like to explore the site based on time range he intended.

The second persona was a potential visitor user named Keiko. She is an environmental engineering student from Japan. She loves to travel around the world, especially by plane. However, she had only traveled in Asia. Her last trip was to Indonesia. Since she has an engineering background, details and plans are very important for her. That is the reason she always creates a plan before traveling. She is planning to visit Europe and meet her friend in Tampere this winter and want to check the transportation beforehand. She wonders how can she commute in that city? How much should she spend her money? Keiko will use the website to find basic information of the buses. In addition, the site will give more information of local policies. It will show her, for example, how far can she go in an hour and how much will it cost.

The personas served as the foundation to build user stories. Their attributes, especially goals, can be used to discover the stories. User story describes the functionality that will be valuable to potential users (Cohn, 2004). It will help the designer to formulate and present the requirements from the user perspective. Thus, it will also help to set the priority of the design decisions in prototype building process. Cohn (2004) also propose formula to create a user story:

As (role) I want (something) so that (benefit).

It is already noticeable that the values in parentheses are corresponding with the attributes from personas. We can create a user story based on the persona's identity, goal, and possible benefit when using the proposed solution.

Before creating the story, we explored the personas to define their characteristic in more detail. A resident is certainly more familiar with the city than the potential visitor. The locals have probably used the service from the local transportation service, while the visitor may have not. Resident's previous experiences could caused them to have certain opinion about the current service, whether positive or negative.

On the other hand, the visitor could bring a new perspective or current expectation based on their experience with their own transportation service. Resident might not be able to switch to different perspective and produce a breakthrough innovation ideas in mind, because they have already adapted with the problem and possible solution. In contrast, the visitor with different thing and experience might lead to a solution that was previously unnoticeable from the resident point of view.

Then we created high level user stories and defined possible task for one of the personas. The user stories for both personas are presented as the following. First, as a (resident), I want (a comprehensive visualization) so that (I can get more understanding of the transportation in my city). Second, as a (visitor), I want (a simple interactive website) so that (I can learn and explore about the city transportation).

Possible tasks were defined to facilitate the user story. For instance, to give the resident more understanding of transportation of their city, we created a set of general tasks, such as giving them the information about bus driving behavior that consists of speed and fuel consumption. Resident can also be presented with bus lifetime, how many kilometers it has traveled today or this year. Functionality to check the bus condition on certain time would also facilitate the user story. They will be also able to check, filter, and sort the information based on certain criteria such as time, routes, minimum, and maximum value. These personas, tasks, and user stories were used as the basis when sketching and developing the first prototype.

4.2 First Iteration

The first iteration was intended to gain more understanding of needs and requirements from the participants. We also tried to validate which idea will be accepted and understood by them. Therefore, in this iteration we spent more time generating and presenting the idea on the surface level, while not providing sophisticated interaction techniques to the participants. This allowed us to explore more idea by sketching rather than spent more time on Axure.

The first test was done in GHOA to evaluate the initial idea of the whole prototype. On this test, we measured the task completion time and rate. Participants were asked interview questions related to their experience after doing all the tasks. Task performance and satisfaction results from the interview were analyzed to provide recommendations for the next iteration.

4.2.1 Evaluation Goals

We redefined tasks that have been created on insight generation phase and created small features that can be implemented on the prototype. Based on the user stories, we wrote each of them on post-it notes and put them on the wall (Figure 4.6). There are 14 features that will be implemented for the whole iteration. However, the first iteration only covered some of them. It was because we were more interested in finding out whether the main idea and the sketch could be accepted and understood by the participants, rather than test the functionality and performance on the early stage. Nevertheless, we shifted our focus to the functionality and more detailed interaction when the ideas had been validated on later iterations.

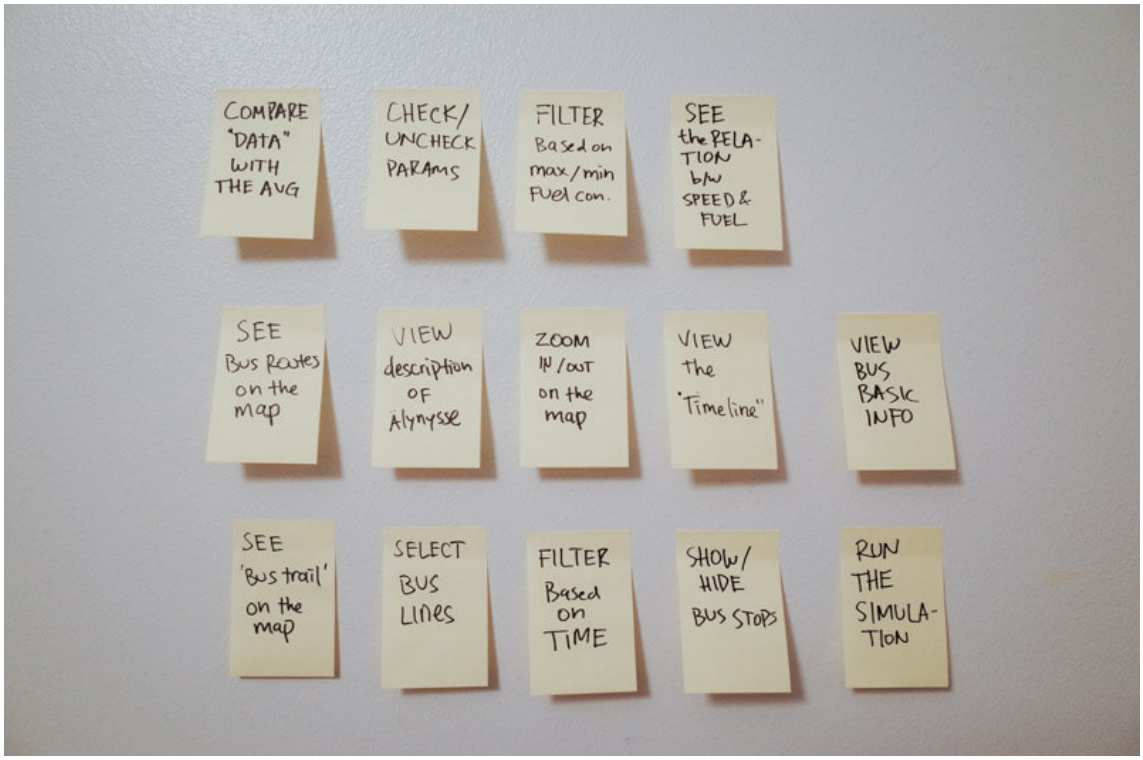


Figure 4.6: List of detailed features that built from user stories

After possible features were listed, we created a user flows diagram consisted of rough layout sketches, contents, and actions for each potential screen or module. Since we were planning to implement the prototype on the web platform, the screen can be seen as a web page. On the other hand, modules can be considered as user interface elements on a web page. A screen can have more than one module.

The benefit of using user flows diagram early on the process is that we can use our persona's perspective. This means that we can list the possible contents and actions that will be performed, without specifying detailed design for a screen. We can iterate faster while using the persona's perspective such as "What would Mäkinen do?" or "What would attract Keiko on the first place in this screen". It allowed us to generate several design solutions to accomplish an action. For instance, to describe the purpose of Älynysse on the main screen, the researcher could present the information with text, picture, video, or combination of them. Each option has its own benefits and challenges that we might be able to identify on the test. By listing design options, we reduced the risk of being stuck on one design solution.

The sketches were created on paper then transferred on Sketch App (see Appendix). After that, we use Axure to built the interactive prototype. In this iteration, there are two screens: landing page and dashboard. The purpose of landing page is to give participant a short description about the prototype and Älynysse. While the dashboard held the main functionality. On the landing page, we present

a picture of the Tampereen Kaupunkiliikenne Liikelaitos (TKL) bus and description of Älynysse. There is also a button that will took the participant to the dashboard page.

The dashboard page have three modules: map, timeline, and bus selection. We initially used an interactive map rather than static map picture, to add polished touch to the prototype. The participants can interact with the map just like any other interactive map. In addition, we added another layer on top of the map. The layer was consisted of bus lines with different color coding. The line will reveal its detail on a tooltip if it was clicked by the participant. Timeline module presented the trend performance of the bus by daily, weekly, monthly, and yearly time interval. We used a static picture with some hover and click interaction on this module.

There were two sub-modules on the bus selection module: bus route selection and bus performance graphs. To simplify the scenario, we were using three bus routes on the iterations. The participants can select one or more bus routes and see the changes on the performance graphs. If more than one route is selected, the graphs will present the sum or average of the selected routes. The performance graphs consists of average speed, fuel consumption, total duration and distance traveled (Figure 4.7).

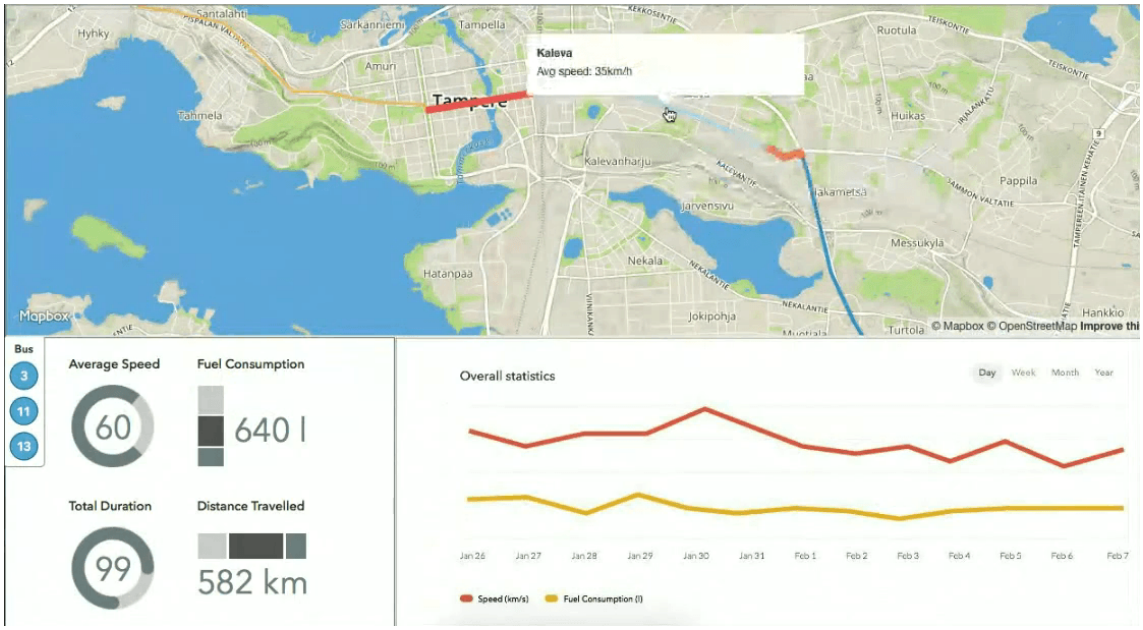


Figure 4.7: Dashboard screen of the first iteration. Map, timeline, and bus selection module in clockwise order from the top

Overall, we were interested to find out whether the participants:

- understand the general idea of the prototype
- get the picture of dashboard modules (map, timeline, and bus selection)

- can find the road with the least fuel consumption
- can find out how long the bus has been operated
- see the bus performance trends
- get the average data of each bus line.

4.2.2 Test Procedure

The first usability test was done remotely with GHOA. It was a moderated remote testing, meaning that the researcher and the participant were seeing and speaking with online conference tool. Both of them shared their screens, the participant was seeing the task, while the researcher seeing the participant screen.

One week before the test we sent out the invitation as a screening form through social media and email. The purpose of a screening form is to filter the participants based on the certain criteria. However, for the first iteration we did not put too much restriction for the participants. The priority was based on the participant time availability, background knowledge or occupation that might related to visualization, and how they usually check a transportation schedule.

Then, Non-Disclosure Agreements along with the appointed time slot were sent to the eligible participants. If a participant agreed with the NDA and the proposed time, a time slot was scheduled for his/her. The participants were reminded to join the session one day before the test.

On the test day, moderator set up the GHOA session and invited the participant. Then, the moderator introduced participant with the test procedure according to the script. The session started with explanation of the prototype and purpose of the test. The participants were also reminded about important points from the NDA. Background questions were asked before moving to the task. We wanted to find out how familiar the participants were with visualization, UX, and transportation system.

After that, the moderator sent the link to the prototype to start the task. Participant was asked to share their screen, so that the moderator can see how they interact with the prototype. The moderator also shared the screen to present the task. For each task, we started counting the time when the participant read the task description; and stopped the counter when the participant finish each task. Finally, we asked several questions to the participant on the interview. There were ready made questions and follow up questions. A follow up question usually asked about the participant's specific or unusual behavior.

After the whole test was conducted, we downloaded the videos from Youtube and transcribed all of the conversation. We also measured the task completion rate and

the time for all of the participants. Afterwards, we analyzed the interview session and provided recommendations for the next iteration.

4.2.3 Participants

They were three participants involved on the first iteration. Two of them were Master's degree students in software engineering related areas. One of the participant was a professional UX designer.

4.2.4 Tasks

There were eight tasks in total, with one practice task and one 'free' task to get the participant adapted with thinking aloud:

- Practice Task "Imagine yourself as a student in Tampere region who wants to check the price of a single bus ticket. How do you find it?"
  The purpose of this task is to practice thinking aloud and the test procedure in general. The task is not related to the evaluated system.

- Task 0 (t0) "From the website homepage, can you guess what is the bus number of Älynysse". The purpose of this task is to make the participant relax and more adapted to thinking aloud.

- Task 1 (t1) "Your friends ask you what is Älynysse is all about. How do you explain them?"
  The purpose of this task is to find out if the landing page is descriptive enough.

- Task 2 (t2) "Now you know a thing or two about it. Help me to explain bus number 3 performance on January 2015."
  We wanted to find out if the dashboard and control placement is on the right place. Also, if the bus button and timeline filter is easy to be identified.

- Task 3 (t3) "How do you find the most 'fuel efficient' road section?"
  The purpose of this task is to find out if route coloring in map is effective enough.

- Task 4 (t4) "How might you know the bus operation time on 2014?"
  The purpose of this task is to find out if timeline filtering is good enough (especially year). Also, if dashboard section (average, total) is easy to understand.

- Task 5 (t5) "Which bus line has the least fuel consumption?"
  The purpose of this task is to find out if the buttons and the graphs are understandable.

- Task 6 (t6) "You want to know how much is the speed and fuel consumption of the bus on February 5th, 2015."
  The purpose of this task is to find out whether the correlation between speed and fuel can be found easily.

4.2.5 Result and Recommendation

Two tasks were failed to be solved by the participants (t3 and t4). On the other hand, the other tasks were successfully done by all the participants with various time interval (Table 4.1). P3 was faster than the other participants in most tasks. Meanwhile, p2 was found to be notably slower than the other participants. The longer time was due to p2's tendency to describe things in systematic and detailed manner. Normally, it is recommended to interrupt the participants if they spent more time than the estimation for particular task. Then, the particular task can be considered failed for the participant. However, in this iteration we were interested to see how the participant interact with the prototype. This might allow them to reveal unexpected findings or ideas. Allowing the participant freely explore the prototype lead to considerable time completion differences. The other reason might be the questions on several tasks were unclear. For instance, in t3, the participants have different understanding of what 'fuel efficient' means.

Table 4.1: Task (t) completion times in minutes

Participant	t0	t1	t2	t3	t4	t5	t6
p1	0:49	1:54	2:45	2:16	2:07	4:24	0:48
p2	0:58	1:40	10:12	6:00	3:51	1:56	2:38
p3	0:16	0:46	2:11	1:33	1:41	2:14	1:33
Min	0:16	0:46	2:11	1:33	1:41	1:56	0:48
Max	0:58	1:54	10:12	6:00	3:51	4:24	2:38
Avg	0:41	1:27	5:03	3:16	2:33	2:51	1:40
Failed	0	0	0	2	1	0	0

All the participants shared the same understanding for the purpose of the prototype. From the interview question "Based on this session, what do you think about the content of the page?", their answers were leading to similar conclusion. P1 said "It's about bus monitoring system and such...". P2 summarized the purpose very well with "...present information about data usage from a vehicle, such as fuel consumption, speed, distance traveled, and duration".

The same goes for the most important thing on the prototype. All participants agreed that bus line selection and graphics on that module are important. However,

bus selection module still need a lot of refinement. This might be due to misplacement of the bus routes button or lack of emphasis of its design; as p3 said "it took a while for me to realize that option".

They also had the same view about the potential user group of the proposed solution, despite that none of them having an educational or professional background that were related to transportation management. They all agreed that municipality or bus company will benefit from the prototype idea. P3 mentioned that the prototype might not be targeted for general user group, however "the data is important for the company".

The initial idea was validated. Moreover, participants encouraged us to go further even though only using a prototype, with some of the module merely using static images. It shows that participant already understood the value behind the prototype and demanded more functionality. P1 commented "I like the idea ... because of smart bus, the data is interesting". P3 added "...because it's still a prototype, there's no problem. However, if we have more things to do, it might be interesting".

We have learned valuable lessons and possible things that could be improved on the next iteration. First, although the initial idea was validated, there were still some issues with the user flows. We were planning to take a step back and redesign the user flows, so that it will flows smoothly. Another lesson was related to the task questions. It is always a good idea to check the question clarity on the pilot test. Therefore, we can avoid ambiguous questions that might confused the participant.

The encouragement from the participant can also be viewed as a green light to explore more features on the prototype. We will introduce more complex interaction techniques and visualization on the next iteration. In addition, there will be complete redesign on the layout, module position, and the navigation. Lastly, we consider changing the interactive map to a static map picture after seeing it being utilized in this iteration. There might be also increase in technical effort on the map along with the prototype's improvement if we stick with the interactive map layer. This will contradict the main philosophy of the design sprint, which concentrate on the idea testing and spend less time on the development. The result and recommendation will be taken into consideration to improve the second version of the prototype.

4.3 Second Iteration

We revisited and redesigned the user flows which resulted in major changes of the whole prototype. Along with that, we changed the visualization tasks to test the changes that have been made. The usability test for the second iteration was done by video conferencing software to test several features on Älynysse prototype. On this test, we measured the task completion time and rate. Two tasks have low completion

rate (4 of 8 and 2 of 8), which indicates that the elements to accomplished the task should be given more priority on the next iteration.

4.3.1 Evaluation Goals

We have completely redesigned the prototype on this iteration by changing the layout, adding new screen, and implementing more sophisticated interaction and design. These changes were based upon the redesigned user flows. Therefore, we are interested in evaluating the change and finding out whether the participants can

- Understand the description in Landing page
- Understand the color cue on the road section
- Using the right navigation easily
- Get the conclusion from the overall statistic module
- Get the information displayed in tooltip (on the map module)
- Understand the visualization in Bus Stop View screen.

4.3.2 Improvements from Previous Iteration

We created a new solution from scratch based on the result and recommendation from the first iteration. In this iteration, we wanted to prioritize on visual elements and interaction techniques on the map. Thus, we replaced the interactive map with map picture of Tampere. Use of the static picture allowed us to concentrate on the possible interaction that can be built on Axure, rather than spending time programming on the interactive base map. Keep in mind that, only the base layer of the map that is a static picture. Then, we put interactive layers on top of the map layer. We also did whole new layout design on this prototype. The changes were surely changed how the participant interact with the prototype while doing the task, inline with the user flows design.

We designed a new user flow diagram with contents and actions as additions. Based on the user flows, we can create a plan of how the participant will accomplished a certain task, what screen they will encounter, and what actions will be provided to them. We are still using the same term: screen to mention a web page; and module to describe a user interface element on a page.

The first screen is the landing page. The purpose of this screen is to introduce participant to the prototype. This screen was performed well on the first iteration. Therefore, only a small refinement on the button was made to the screen. The second screen is the overall view screen that consists of three modules: map, timeline, and

dashboard control. The dashboard control module has several sub modules: bus line and date selection module; and overall statistic module. The third screen is bus stop view, which presented a new visualization on speed and fuel consumption between bus stops.

Overall view screen can be seen as a dashboard where most of the interaction happen. Map module will contain information such as a map, overlaid bus lines layer, zoom in/out button, legends, and settings button. It will allow the user to zoom and pan around the map; hover and click the bus lines; examine the legends; and change the map setting by clicking settings button. Note, however, that zoom and pan action were not implemented yet since we are currently using a static map. Dashboard control and its sub modules have a bus and date selection functionality; and bus performance information. The participant can update the view on the map and timeline modules by changing the selection on the dashboard control, either by selecting a certain bus route or changing the date. They can also notice how the changes affect the overall statistic on the same module.

On the other hand, timeline module presents more detailed visualization based on the map view. On this iteration, we only used map and dashboard control modules. Meanwhile, the information that should be presented on the timeline module will be placed on the bus stop view screen.

To accommodate the new screens and modules, we changed the placement of the navigation from lower left to top right of the screen. We used bus selection module as the navigation, similar with the previous iteration. However, this time, it resides one layer above the map modules. It was moved so that the participants can instantly locate the navigation since the eyes will generally search from left to right, although it might be perceived differently by people with different reading habit.

We also changed the way bus route selection worked. Previously, we used buttons that can be activated by a click. In this prototype, the participants simply chose the routes from a drop-down menu. In addition, we provided date selection as another filtering parameter. Participants could have more specific information about bus performance by selecting route and date. A specific route and date have made a detailed study case easier, for instance, by examining the performance per day.

The placement of the overall statistic module is changed to be below the bus and date line selection module. Previously, they were designed to give the impression that those elements were actually in one design group. However, in this improvement, we split those modules because of their different functionality. Overall statistic module now contains three information: average speed, total fuel consumption, and total duration. In contrast with the previous iteration, the information on overall statistic module were presented as texts rather than graphics. We ignored the visualization elements on this module on this iteration because we wanted to prioritize

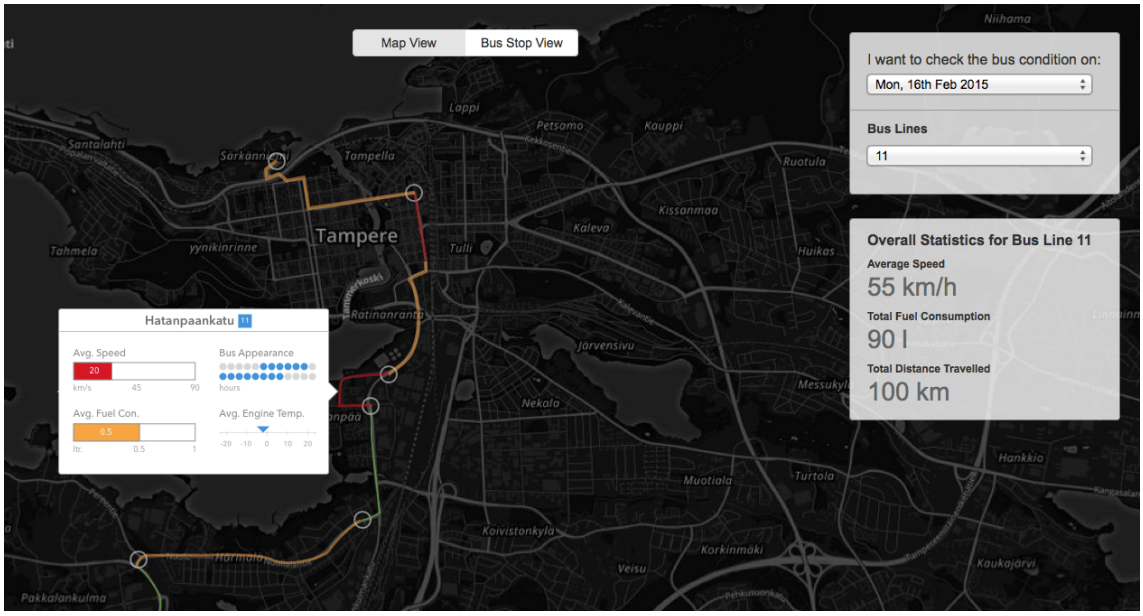


Figure 4.8: Dashboard screen of the second iteration. Map layer was changed to black theme and navigation was moved to the right side of the page

on the visualization of the map module. Nevertheless, we introduce the visualization techniques on this module on the fourth iteration.

Based on the recommendation from the participants, we made some adjustments to map module. The participants said that they could not see the bus lines clearly on the map. In respond to this issue, we were using a dark theme on this iteration. Bus routes can be clearly recognized with a dark base layer map. There are three color coding to indicate the average speed of the bus: green, orange, and red; meaning fast, medium, and slow, respectively. Bus stops are represented as a white circle that connects the bus route lines.

As mentioned, we also replaced the interactive map with a static map picture. This replacement allowed us to implement more interaction techniques on top of the map layer. There will be a change of state if a route line or a bus stop is hovered by the mouse. For instance, the bus line will change its opacity to 100% when hovered. In addition, if its clicked, it will reveal a tooltip that presents bus performance on the route (Figure 4.8). There are six information on the tooltip: road name, bus line number, average speed, average fuel consumption, bus schedule, and average engine temperature.

Bus stop view screen was introduced in this iteration. This screen consisted of a static visualization to show the relation between fuel and speed between bus stops. We experimented with a two-way bar chart, on the far left there were bus stops, while the road name were placed on the opposite. Values of the average fuel consumption and speed were placed as a stack on the middle of the visualization.

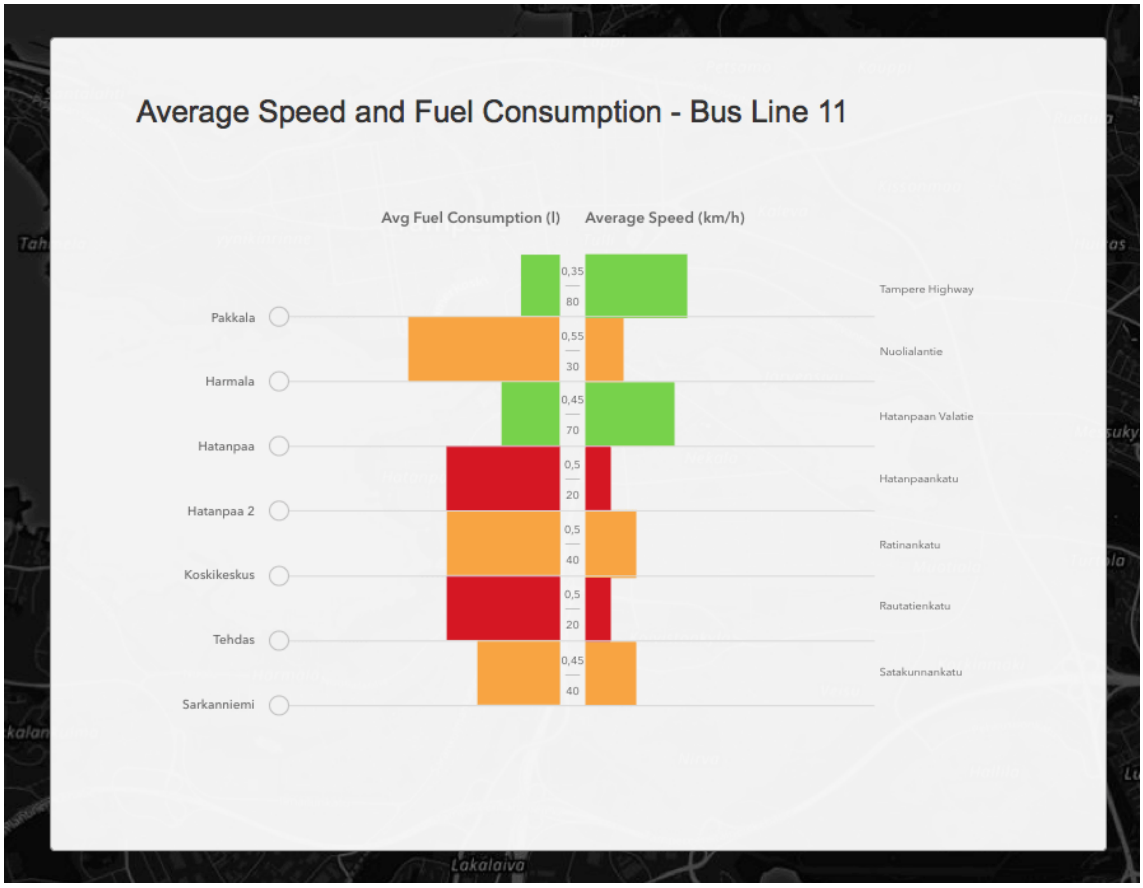


Figure 4.9: Visualization of the bus stop screen

4.3.3 Test Procedure

The same procedure as the first iteration was done in this iteration. The moderated test was done with GHOA while both the participant and the researcher sharing their screen. The participant was asked to do certain tasks while thinking aloud. Finally, an interview was conducted to gain more insight from the participant. Overall, the main difference between this iteration with the previous one was the usability task.

4.3.4 Participants

They were eight participants: five Master's degree students in Information Technology-related area, a UX designer, an interaction designer, and a front-end web developer.

4.3.5 Tasks

There are eight tasks in total, including a task to practice thinking aloud:

- Practice task "Imagine that you will be traveling to Tampere next month. You want to find how much is the Tourist Ticket cost? How do you find it?"

- Task 1 (t1) "Your friends ask you what is Älynysse is all about. How do you explain them?"
- Task 2 (t2) "What do you think is the purpose of this page? You can scroll and move your mouse. But, don't click anything yet."
- Task 3 (t3) "Please find a road name with the most fuel consumption, at bus line 11, on 16th February 2015."
- Task 4 (t4) "Please find average speed and fuel consumption on 'Kalevanpuistotie' road, at bus line 13, on 16th February 2015."
- Task 5 (t5) "Please find the time when bus 3 across 'Sammonkatu' road, on 16th February 2015."
- Task 6 (t6) "Please find the distance traveled and fuel consumed at bus line 13 on 16th February 2015."
- Task 7 (t7) "Which bus line operated the longest on 16th February 2015?"

4.3.6 Problems Found

The colours of the bus lines confused most of the participants, especially at first glance. Some of the participants thought they were indicating the bus speed, while others thought they were the fuel consumption. Some of the information was not presented well enough or too technically, such as bus appearance and temperature. Visualization in Bus Stop View needed a lot of refinement.

4.3.7 Result and Recommendation

Four tasks (t1, t2, t6, and t7) were successfully done by all the participants, while four of the eight participants completed t3. Only two participants were able to complete t5. For t4, seven out of the eight participants finished this task. N/a value means there was a technical problem while doing the task, so the exact time is not available. Most of the task average timings were faster than the estimated time on the task plan.

Interestingly, p8 only used Bus Stop View for t2-t5, while the other participants were using Map View. P8 seemed to be confused to do the task only by looking at the graphs. P8 didn't click the route lines on the Map View, but instead went to the Bus Stop View and tried to come up with a math formula to do the task. The click function on bus line was unnoticeable only in p8's session, until it was explained on the interview session.

Table 4.2: Task (t) completion times in minutes

Participant	t1	t2	t3	t4	t5	t6	t7
p1	n/a	0:56	2:39	0:58	2:21	0:48	2:07
p2	0:33	2:27	1:27	0:47	2:40	0:37	1:12
p3	1:13	0:45	4:38	3:10	1:59	0:34	1:20
p4	0:38	1:39	1:59	0:59	3:07	0:36	1:26
p5	0:48	0:52	2:33	0:21	2:02	0:22	0:31
p6	n/a	1:05	2:22	3:45	1:06	0:25	0:30
p7	0:49	0:52	2:18	1:16	2:11	0:20	0:52
p8	1:04	2:03	4:03	3:07	2:47	0:28	3:24
Min	0:33	0:45	1:27	0:21	1:06	0:20	0:30
Max	1:13	2:27	4:38	3:45	3:07	0:48	3:24
Avg	0:51	1:20	2:45	1:48	2:17	0:31	1:25
Failed	0	0	4	1	6	0	0

To improve the prototype for the next iteration, the following needed to be taken care of *a*) Coloring of the routes (t2 and t3), like mentioned above; *b*) A better option to show the road name, especially for the participant who's not familiar with Tampere region; and *c*) Visualization for the bus timetable (t5) and the Bus Stop View. It can be improved by putting a legend on the map and on the Bus Stop View.

4.4 Third Iteration

We changed major screens and modules of the prototype from the previous iteration. In addition, we implemented a new timeline module. The usability testing was done on video conference service to test several features on Älynysse prototype. In this test, we measured the task completion time and rate. One task had two possible correct actions, due to the lack of proper question. Additionally, a questionnaire was given after the participant completing the tasks. Overall, the visualization was understood by all of the participants. However, there were several minor usability problems that needed to be fixed.

4.4.1 Evaluation Goals

We completely redesigned the prototype in this iteration, which means that three different prototypes have been produced so far. We removed the bus stop view screen and added a new module on the overall view screen. These improvements were based on the previous iterations result and analysis. Thus, we were interested to find out whether the participant:

- Get the description in Landing page
- Understand the visual cue differences in bus line route coloring
- Able to use and understand the right navigation (bus line selection)
- Understand the information provided on overall statistic module
- Information display in tooltip (on the map module)
- Understand the visualization in Daily Average Module
- Understand the visualization in Hourly Average Module.

4.4.2 Improvements from Previous Iteration

Based on the previous iteration recommendations, we improved the prototype on the following areas:

- Change the map size and theme
- Give legends on the map
- Refine the visualization on the map with line color and weight
- Simplify the data shown on the tooltip on the map.
- Introduce a new visualization on Daily Average module
- Provide hourly detail in Hourly Average module
- Link the elements between map and Daily Average module
- Put more data on the Overall Statistic module
- Refine the overall design, layout, and typography.

We have done major improvements in this iteration, while still keeping the user flows diagram as design reference. First, we changed the map module size, theme, and position in z-axis. Previously, it was a full screen map which positioned behind the dashboard control module. In this iteration, the map was positioned at the same layer with dashboard control module. Moreover, the color theme of the map was changed to be lighter than the previous one, based on the participant feedback about its dark theme. Legend was also introduced in this iteration, it shows two information: speed and fuel consumption. color and thickness are used to represent speed and fuel consumption respectively. Green, orange, and red corresponds to fast,

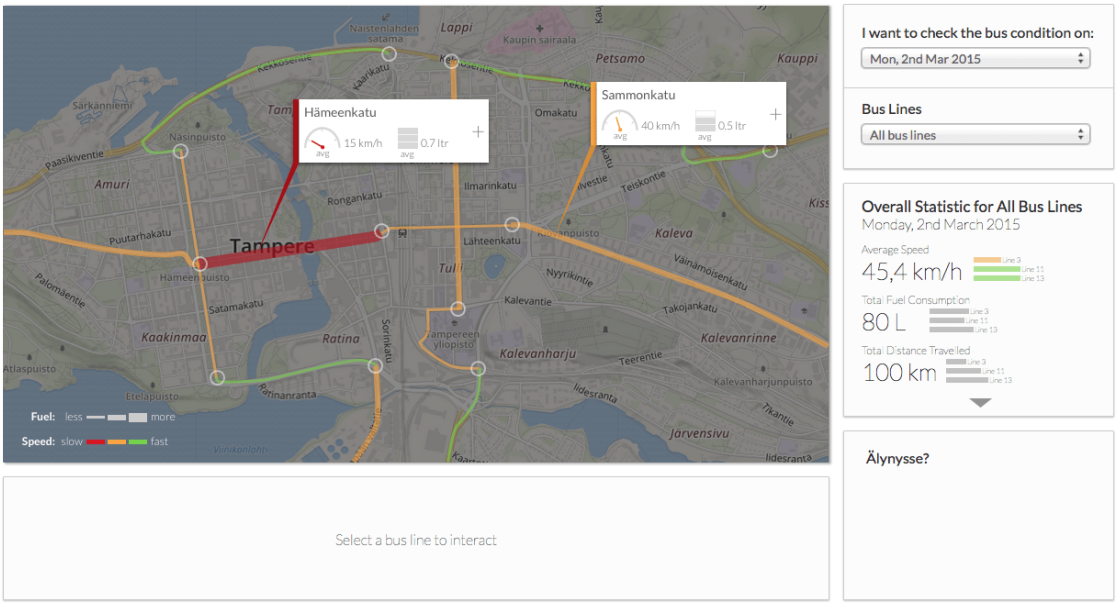


Figure 4.10: Major changes have done in the third iteration. Map module is changed to lighter theme and separated from the control. A new, daily average module is also introduced

medium, and slow speed; while the thicker the line, the more fuel are consumed on the line.

The same representation was used on the bus line routes in the map module. We refined the visualization on the map module by using more distinct line thickness to differentiate the fuel consumption values on each line. Bus line routes color were still distinguishable, although we used a lighter color theme as a baseline map. In addition, we simplified the visualization on the tooltip, there were only three pieces of information compared to six on the previous iteration. These were street name, speed which was represented by a gauge graphic, and fuel consumption which was represented with a vertical bar chart. The tooltip tail and its left border color were the same as the bus line routes. Therefore, it created another visual cue, in addition to speed text and gauge meter.

Timeline module was implemented in this iteration, although we changed its name to daily average module to make it easier to be referred to. However, it still showed more detailed information from the map module in temporal representation. With the implementation of daily average module, we removed the bus stop view screen. Therefore, the implementation has created simpler design using only one screen. The default state of this module was inactive until the participant select one of the bus line from the dashboard control module. If it was inactive, it prints the text "Select a bus line to interact".

After the participant select one of the bus line, the module will show the visualization. When activated, it will present the daily average performance of the line similar to modern metro maps. It consists of bus stop, the road, line number, and the value of speed and fuel consumption. Color and thickness were also used on this module in order to make comparison easier. For instance, to find out which route has the highest fuel consumption. We also provided a functionality for the participant to explore more detailed daily data by clicking "see hourly average link". It will reveal the same data representation with hourly average. The participant can examine and see the hourly trends during that day.

We also linked the interaction on the map module and daily average module. For instance, if the participant clicks a particular route on the map module, a tooltip that correspond to the route will appear. We designed the interaction so that the tooltip also appeared when a participant click the corresponding line on the daily average module. Hovering on a particular line on the daily average module also created the same hover effect on the map module, and vice versa.

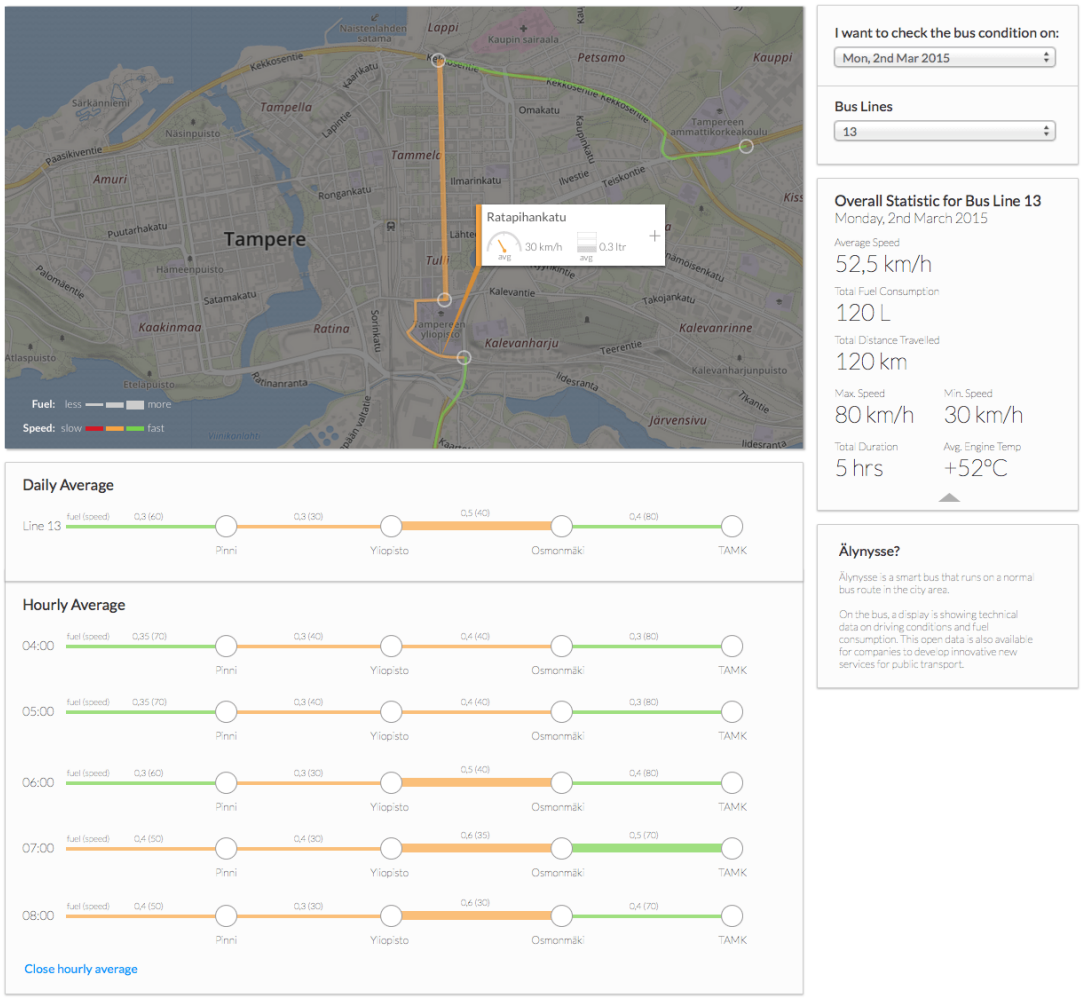


Figure 4.11: Daily average module and hourly average module on bus line 13

More information were added to the overall statistic module. Previously, there were only three pieces of information. In this iteration four new information were added such as maximum speed, minimum speed, total duration, and engine temperature. We also implemented the progressive disclosure techniques to hide the newly added information, and only showed them when the participant clicked the down arrow button. This was done to keep the simplicity and hide the potentially irrelevant information from the general user, while giving a possibility for the expert user to explore more information.

Finally, we refined the overall design by changing the border radius, shadows, and the color of module containers. We also worked out on small details such as typography of the prototype.

4.4.3 Test Procedure

The same procedure as the previous iteration was used in this iteration. The moderated test was done with GHOA while both the participant and the researcher sharing their own screen. The participant was asked to do certain tasks while thinking aloud. Finally, an interview was conducted to gain more insight from the participant about the prototype.

However, the main difference between this iteration with the previous one was the usability task. In addition, we started to ask the SUS questionnaire to the participants.

4.4.4 Participants

There were six participants: three Master's degree students in Information Technology-related area, a UX designer, an Intelligent Transportation System researcher, and a mobile developer.

4.4.5 Tasks

There were nine tasks in total, two tasks (Practice task and t0) were for the practice purpose and to get the participant adapted with thinking aloud behavior:

- Practice task "Imagine that you will be travelling to Tampere next month. You want to find how much is the Tourist Ticket cost for the local bus? How do you find it?"
- Task 0 (t0) "Your friends ask you what is Älynysse is all about. How do you explain them?"
- Task 1 (t1) "What do you think is the purpose of this page? You can scroll and move your mouse. But, don't click anything yet."

- Task 2 (t2) “Still without clicking. Can you point out which road has the slowest speed?”
- Task 3 (t3) “(You can click now) Please find the distance travelled and fuel consumed at bus line 3 on 2nd March 2015.”
- Task 4 (t4) “Can you describe, in a human way, how was the performance of all bus lines on that day?”
- Task 5 (t5) “How do you find the fastest and slowest speed of a bus?”
- Task 6 (t6) “How much is the average speed and fuel consumption on Tampereen Valtatie road on Bus Line 11, on 2nd March 2015?”
- Task 7 (t7) “What time did Bus Line 13 has the most fuel consumption on 2nd March 2015?”

4.4.6 SUS Questionnaire

A modified version of SUS was used during the test. The word ‘cumbersome’ in question number eight on the original questionnaire was replaced with ‘awkward’. ‘The system’ was also replaced with ‘the website’ on all of its appearance. The answer provided as a scale option to the following questions:

1. I think that I would like to use this website frequently.
2. I found the website unnecessarily complex.
3. I thought the website was easy to use.
4. I think that I would need the support of a technical person to be able to use this website.
5. I found the various functions in this website were well integrated.
6. I thought there was too much inconsistency in this website.
7. I would imagine that most people would learn to use this website very quickly.
8. I found the website very awkward to use.
9. I felt very confident using the website.
10. I needed to learn a lot of things before I could get going with this website.

There are five options to be selected for each question:

1. Strongly disagree

2. Disagree
3. I don't know
4. Agree
5. Strongly Agree.

In addition to SUS questions, two five scales and two open ended questions were added:

11. Which grade would you give to the usability of the service?
12. Which overall grade would you give to the web service?
13. In your opinion, what was good about the web service?
14. In your opinion, what was bad about the web service?

Table 4.3: SUS score calculation

Participant	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	SUS Score
p1	4	1	4	2	5	1	4	1	4	2	85.0
p2	4	2	4	2	4	2	5	2	5	1	82.5
p3	4	2	5	1	4	2	5	3	4	2	80.0
p4	4	4	2	4	4	2	5	2	4	1	65.0
p5	4	3	4	1	5	3	5	2	4	2	77.5
p6	3	4	5	3	4	2	4	4	4	2	62.5
										Mean	75.4

4.4.7 Problems Found

1. While the visualization on Daily and Hourly Average module can be understood in general, its value was hard to read by some of the participants.

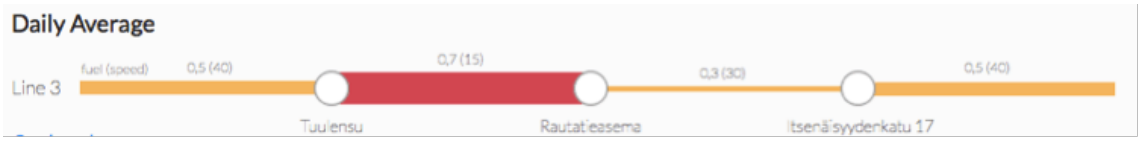


Figure 4.12: Daily average module

2. It's hard to find the road name, especially for the participant who is not a Tampere residence.
3. While the overall condition of a bus can be found, its meaning was still poorly understood by most of the participant

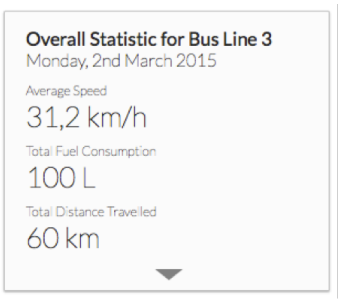


Figure 4.13: Overall statistic module

4.4.8 Result and Recommendation

All tasks were successfully done by all the participants with variability on completion time. Landing and Dashboard page are understood correctly by all of the participants (t0 and t1) with the average time 1:01 and 1:15. Visual cues and legends on the map certainly brought an improvement, as a result t2 average time is 0:24.

The participants did t4 in different ways. However, all of them mentioned the overall statistic module, which is in line with the task design. For t5, all of the participants used map view to do the task, except p6 who identified 'maximum and minimum speed' on the overall statistics module.

There was a completion time variation on t6. P1, p3, p4, and p5 found the solution under 1 minute, while p2 and p6 took more than 2 minutes. One of the possible cause was that the road names were not presented directly on the map. Participant had to hover on the routes, or lines on the daily average module, to see the road name. The fact that p2 and p6 were not familiar with Tampere region supports the idea that it is hard to find the road names without hovering the mouse on the routes.

For the last task (t7), p1, p3, and p5 completed it faster than the average. It is probably because they had clicked and accessed the hourly average view while doing the previous task. Most of the participant mentioned the text on the visualization, either to small or quite hard to be interpreted for the first time. However, after several moments, they realized the meaning of the text. Nevertheless, they understood the visualization because the line color and weight on the module are consistent with the other on the map.

One of the participant, p1, was considerably faster on the completion time than the others. While the other participants had a similar time, p6 used almost 15 minutes.

Based on the task performances, interview, and questionnaire we decided to improve on these areas:

1. Improve the design and typography on the visualization's label. There is the

possibility that fonts are rendered differently between local machine and the server. (Lato is used as a webfont, while the local machine use an installed Lato font)

2. Provide an option to change the base map layer (e.g., show with the street names and another attributes)

3. Give more meaning to technical data for general user, such as the meaning of 100 l fuel consumption on a day, is it above or below average? The CO_2 emissions data is also possible.

Table 4.4: participant (p) and completion time (t)

Task	Description	p1	p2	p3	p4	p5	p6	Avg
t0	Your friends ask you what is Älynysse is all about. How do you explain them?	0:21	0:30	1:08	0:47	2:18	1:05	1:01
t1	What do you think is the purpose of this page? You can scroll and move your mouse. But, don't click anything yet.	0:34	0:45	1:55	1:25	0:55	1:54	1:15
t2	Still without clicking. Can you point out which road has the slowest speed?	0:16	0:26	0:23	0:28	0:29	0:24	0:24
t3	(You can click now) Please find the distance travelled and fuel consumed at bus line 3 on 2nd March 2015	0:21	0:45	0:43	0:58	0:15	0:37	0:36
t4	Can you describe, in a human way, how was the performance of all bus lines on that day?	0:23	0:53	0:51	1:57	0:34	4:41	1:33
t5	How do you find the fastest and slowest speed of a bus?	0:19	1:50	1:00	2:44	0:55	0:43	1:15
t6	How much is the average speed and fuel consumption on Tampereen Valtatie road on Bus Line 11, on 2nd March 2015?	0:38	3:03	0:52	1:05	0:52	2:29	1:30
t7	What time did Bus Line 13 has the most fuel consumption on 2nd March 2015?	0:46	2:14	1:32	2:26	1:03	3:01	1:50
	Total	3:38	10:26	8:24	11:50	7:20	14:54	

4.4.9 Feedback from Interview

The participant did like

- The user interface and design

  p1: "The design is compact, all-in-one, great!"

p3: "I like the design, it's clean."

p4: "The label is obvious, such as 'I want to check the bus condition on:'"

- Ability to check the bus condition on the overall statistics

  p4: "I think, they are (pointing to the overall statistic module and bus selection) important functionality of this system"

  p6: "...with this (pointing to the overall statistic module), I know the overall picture of bus condition without having to check the details."

- Views on the map

  p5: "The map is important for me..."

  p5: "...colors on the map are intuitive. I immediately know what it means"

  p6: "I like the map, because I'm a visual person"

The participant wished the following improvements:

- Provide more data

  p1: "...slippery condition would be good, especially for Finnish winter. I don't know where to get the data though."

  p6: "I believe this (pointing to avg. engine temperature) is very valuable for some people. However, I don't really understand, because I'm a business minded person"

- Make data more meaningful

  p4: "You can put a visual cue in here (pointing to the overall statistics value) like color for speed. It's already good, but it will help me a lot to interpret the value"

  p6: "...for example, a warning if the fuel consumption exceed the weekly or monthly average. Or if the speed exceed the speed limit on a certain road"

- Another way to find the road name

  p4: "...road name comparison, I shouldn't hover them one by one..."

  p5: "I wish I could search the road name"

  p6: "I have to click one by one to find the road name"

4.5 Fourth Iteration

Different from all of the previous iterations, the prototype on the fourth iteration was built based on the previous iteration. New visualization techniques on the dashboard module were introduced. We also refined the design and functionality on map and daily average modules.

The fourth iteration of usability testing was done on video conference service to test several features on Älynysse prototype. On this test, we measured the task completion time and rate. We modified the task questions to be more open ended to gain more insight from the participants. In addition, a questionnaire was given after the participant completing the task. Overall, the visualization was understood by all of the participants.

4.5.1 Evaluation Goals

Based on participant satisfaction and performance on the third iteration, we shifted our attention to more sophisticated visualization and interaction techniques. Therefore, we wanted to find out whether the participants are able to:

- Understand the description in Landing page.
- Get the visual cue in bus line route coloring.
- Using the right navigation (bus line selection).
- Understand and use the visualization on overall statistic module.
- Understand the information displayed in tooltip (on the map module).
- Interact with the visualization in Daily Average Module
- Interact with the visualization in Hourly Average Module.

4.5.2 Improvements from Previous Iteration

Based on the previous iteration recommendation, we improved the prototype on the following areas:

- Give ability to show/hide the base map and road name.
- Simplify the data shown on the tooltip on the map.
- Change the Overall Statistic module representation from text to graphics.
- Put a new module, CO_2 Emissions below the Overall Statistic module.

- Put a description module below the CO_2 emissions.
- Provide a sort feature in Hourly Average module.
- Refine the overall design, layout, and typography.
- Change several tasks to be more open ended to gain more insight about the prototype.

The improvements were built on the prototype from the third iteration, unlike the previous iterations which the prototypes were always built from scratch. First, we introduced a new visualization to present information on the overall statistic module. The visualization presents seven information with a bullet chart for each of them. In each bullet chart there are the name of parameter, such as speed; then its measurement, for instance km/h and average; and a bar graph that presented qualitative and quantitative information at the same time. The main part of the graph represent the quantitative value. While the rectangles on the background represent the qualitative values, for example three rectangles on the speed bullet chart represent slow, medium, and fast. By using bullet chart participants were able to get a glimpse of the actual value and which category does it belong at the same time.

There were also improvements on the map module such as the option to adjust map layer and simplification of the tooltip. In this prototype, the participants were able to hide or show the base map layer and road name layer from the settings button. The button was positioned at the right top of the map, it will reveal a map layer settings module when the button is clicked. The layer settings module contains two checkboxes: base map and road name.

We also simplified the visualization on the tooltip using the bullet chart for speed and fuel consumption. This decision created a visual consistency on the map modules and the overall statistic module; thus, the participant or potential user did not have to form a new mental model and learn another graphical representation.

CO_2 emissions and description modules were added below the overall statistic module. Both of them are presented as an accordion menu, a rectangle that will show its content after it has been clicked. We chose the accordion to avoid these two modules to become a distraction for the participant, since they are a secondary information. As a recommendation from the previous iteration, CO_2 emissions module present an emission comparison between several modes of transportation: bus, bicycle, walk, and car. It presents how much emission they produced per trip, their emission reduction, and energy consumed. We followed an example from the Helsinki Reittiopas. The description module contains the same information with the landing page screen.

Lastly, we refined the overall design such as giving more detailed attention on the interaction techniques of the linking between map modules and daily average modules. In this version, the hover and active state of the bus line routes are more obvious. We also fixed issues related to the clarity on the font. In addition, there are a new sort feature on the hourly condition module.

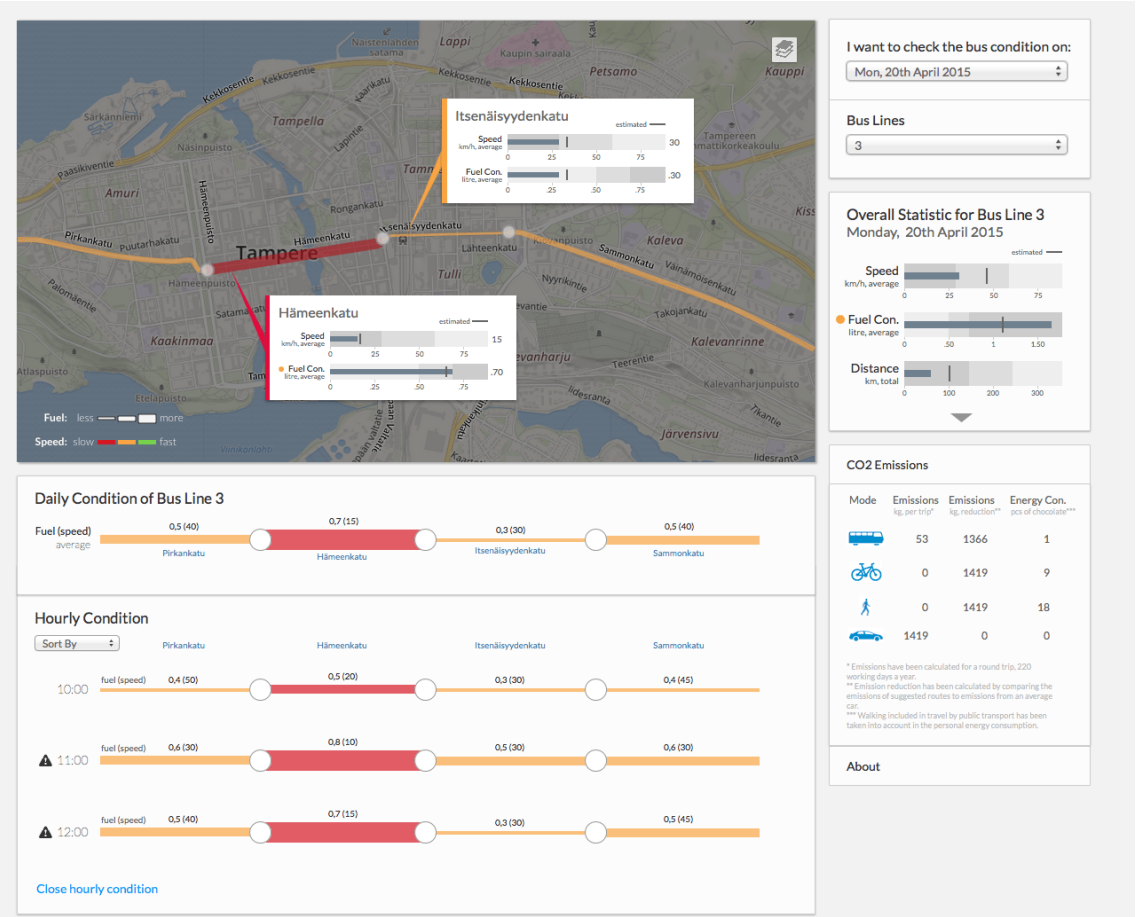


Figure 4.14: The prototype was built based on the third iteration. Overall statistic module was improved with graphics. Two new modules are also positioned below that module.

4.5.3 Test Procedure

The same procedure as in the third iteration was done with some adjustments to gain more insight.

The improvement between this iteration and the previous one was that the tasks were modified to have open and descriptive answer, such as "Can you describe..." and "How do you...?". Moreover, the moderator frequently prompted the participant to find alternative answers or describe more things like asking "Is there another way do that?" or "Do you want to add another things?". They are meant to gain

more insight about their thoughts about the process and the prototype; in addition to the completion rate.

4.5.4 Participants

There were five participants: four Master's degree students or graduates in Information Technology-related area and a professional on telecommunication field.

4.5.5 Tasks

There were ten tasks in total, two tasks (Practice task and t0) were for the practice purpose and get the participant adapted with thinking aloud behavior. Several tasks had open ended questions that led to explanatory answer from participants.

- Practice task "Imagine that you will be traveling to Tampere next month. You want to find how much is the Tourist Ticket cost for the local bus? How do you find it?"
- Task 0 (t0) "Your friends ask you what is Älynysse is all about. How do you explain them?"
- Task 1 (t1) "What do you think is the purpose of this page? You can scroll and move your mouse. But, don't click anything yet."
- Task 2 (t2) "Still without clicking. Can you point out which road has the most fuel consumption?"
- Task 3 (t3) "(You can click now) How do you compare the condition of all bus lines?"
- Task 4 (t4) "Please describe the condition of Bus Line 3, on Monday 16th March."
- Task 5 (t5) "How much emissions can you reduce by taking another transportation modes?"
- Task 6 (t6) "How do you find the fastest and slowest speed of a bus? (e.g., Bus Line 11)"
- Task 7 (t7) "How much is the average speed and fuel consumption on Ratapihankatu road, on 16th March 2015?"
- Task 8 (t8) "How do you find the time, when that bus is having unusual condition? Why?"

4.5.6 SUS Questionnaire

The same questionnaire as in the previous iteration was used. The results are shown in Table 4.5.

Table 4.5: SUS score calculation

Participant	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	SUS Score
p1	5	4	4	2	4	2	4	1	4	2	75.0
p2	4	2	4	1	4	3	4	2	3	2	72.5
p3	4	1	5	2	4	3	4	2	4	4	72.5
p4	4	4	5	5	5	2	2	1	5	2	67.5
p5	3	2	4	3	4	2	4	1	4	2	72.5
										Mean	72.0

4.5.7 Problems Found

1. Two participants had misunderstood the meaning of width in the legend due to the same color with the road on the map (Figure 4.15).

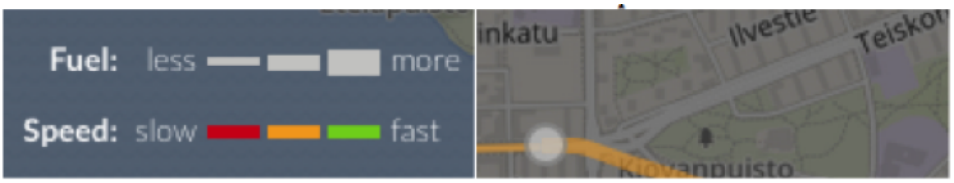


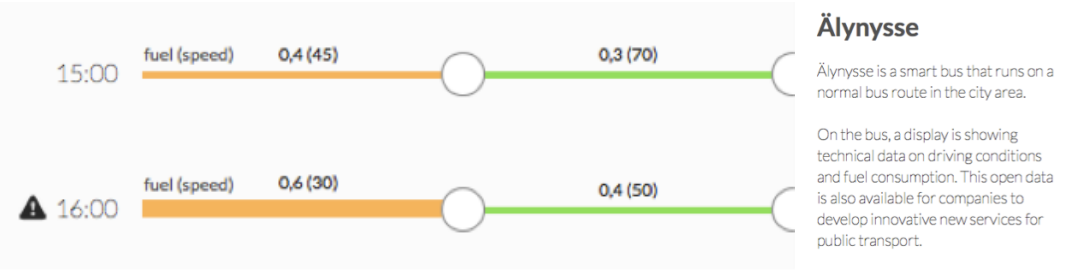
Figure 4.15: Colors on fuel's width are similar to road's color

2. While the improved version on Hourly Condition module is functioned better than the previous iteration, several participant had a different understanding with one of the (!) sign (see Figure 4.16(a)).

3. Some participants had a problem reading several texts, due to the use of webfont that is not rendered in the same way as on the development machine (see Figure 4.16(b)).

4.5.8 Result and Recommendation

All tasks were successfully done by all the participants with variability on completion time. Landing and Dashboard page were understood correctly by all of the participants (t0 and t1) with the average time 1:22 and 1:45. We found that a legend for vehicle speed was clear for all of the participant. However, for the fuel



(a) (b)

Figure 4.16: (a) The (!) sign was understood as a warning by the participants. (b) The font are not legible enough

consumption, two participants, p1 and p5, associated the width color on the legend (gray) with the color on the map (gray). Average time for t2 is 1:26 with p1 failed to accomplished the task, by guessing the wrong road name. Later on, p1 realized the right association.

Each participant has their own way to explain the prototype while doing the t3. In general, most of the participant get the idea on how to compare all of the bus line condition. P1 was very detailed and explored almost all of the functionality, while p2, p4, and p5 spent more time explaining the overall statistic module. P3 is uniquely explored and explained tooltips on the map, while changing the bus lines from the right sidebar. These different ways of explaining things resulted to average time of 5:56 for t3.

The same condition happened with t4, where each participant described their findings with their own ways. However, they were all using daily condition module to explain and shared the same conclusion. Average time for this task was 4:12.

Unlike the previous tasks, t5 was asking for a certain value, resulted in similar ways for the participant to find the answer. All of the participants used and understood the emissions module easily, with average time for t5 was 1:41.

Almost all of the participants used a combination of map and daily condition module to accomplished t6, with 1:39 average time. They mentioned the color was a helpful cue to find the slowest and fastest speed. The only exception was p2, where p2 found the answer on the overall statistic module. There were also a speed range on the overall statistic module contains minimum, median, and maximum speed.

There were two possible ways to find the information required by t7. One way is by accessing the tooltip after clicking the routes on the map, done by p1, p2, p3, and p4. The other way was by looking its value on the daily condition module, which was done by p5. The first option was a fruit of the improvement from the previous iteration. They were able to find the road name instantly on the map. Average time for t7 was 1:20.

T8 was successfully done by all of the participants with 1:36 average time. The participants were all able to find the time when the bus is having unusual condition. They shared different perspectives regarding to the meaning of (! Sign). However, they all agreed that it means something unusual or problem that needs an attention.

Table 4.6: Participant (p) and completion time (t)

Task	Description	p1	p2	p3	p4	p5	Avg
t0	Your friends ask you what is Älynysse is all about. How do you explain them?	2:06	1:03	1:58	0:56	0:46	1:22
t1	What do you think is the purpose of this page? You can scroll and move your mouse. But, don't click anything yet.	1:44	1:04	1:26	2:45	1:44	1:45
t2	Still without clicking. Can you point out which road has the most fuel consumption?	2:04	0:24	1:44	1:07	1:53	1:26
t3	(You can click now) How do you compare the condition of all bus lines?	10:35	3:01	5:11	5:30	5:24	5:56
t4	Please describe the condition of Bus Line 3, on Monday 16th March.	6:20	2:15	4:24	4:43	3:20	4:12
t5	How much emissions can you reduce by taking another transportation modes?	2:30	1:18	2:06	0:41	1:51	1:41
t6	How do you find the fastest and slowest speed of a bus? (e.g. Bus Line 11)	0:31	0:37	2:52	2:54	1:23	1:39
t7	How much is the average speed and fuel consumption on Ratapihankatu road, on 16th March 2015?	2:03	1:10	0:41	1:15	1:29	1:20
t8	How do you find the time, when that bus is having unusual condition? Why?	2:36	1:11	2:05	1:01	1:07	1:36
	Total	30:29	12:03	22:27	20:52	18:58	

One of the participant, p1, was considerably slow on the completion time compared to the others, while the other participants are having a similar time, except p2 with only 12 minutes. It is probably due to the nature of p1 ability to describe certain things in detail and complete manner; and p2 who is a straight to the point person.

There were three recommendations that can be implemented immediately, such as *a*) Differentiate width color on the legend with road's color. *b*) Provide a tooltip to give more detail or explanation of the (! Mark) *c*) Change the font on the text that is hard to read.

4.5.9 Interview Questions

"Which parts of this page are most or least important to you?"

- Overall statistics

  p1: "Overall statistics. I can see the overall condition of the bus. If it's okay (pointing to the overall statistics module), I don't have to explore the daily condition. However, if I see a warning here, then I'll explore the detail here (moving the mouse to daily condition)"

  p3: "...and the most important, overall stats and the map"

- Map view and its color

  p2: "...the colors! I know where the bus is running slow or fast..."

  p4: "The map and the information on it are important, then daily condition about bus lines"

- Graphic elements

  p5: "All the graphics are important. Because they have their own functionality. The least important? Hmm.. I think they are all important"

"What do you think this graphic might do? (point to the overall stats graphic)"

- Most of the participant understood the function of overall stats graphic

  p3: "... if we hover our mouse, the value will reveal itself. There's the estimation (pointing to the vertical line), however the actual value was only this much. It means it didn't reach the target"

  p2: "... when we hover, there is a 'fall down' animation, it's great (while demonstrating)"

  p4: "...the average condition on each parameter (speed, fuel consumption, distance). This statistic show the habit of the bus each day and compare the statistic with the estimated data."

"Under what circumstances would you use this? Why?"

- They all agreed that this idea would be valuable to municipalities or transportation manager

  p1: "If my work related to transportation manager. Each day I will check my bus condition and performance."

  p1: "...then If I were in a municipality, my perspective is on the road. I wouldn't check each day, maybe once a month, to help me determine policies."

  p3: "If I have my own bus company... check the fuel consumption report."

  p4: "This information is needed to analyze all bus average speed, fuel consumption, and distance and this information can help bus company to predict total operational cost on each day, week or month."

- One participant also mentioned an interesting usage of the prototype

p2: "... when I want to go somewhere, I will check the route with the most green lines. If there are a lot of red lines, I will find another route."

"What do you like or dislike about this?"

- The participants did like the user interface and how the information were presented.

  p5: "There are a lot of information, but the presentation is uncluttered... not confusing."

  p2: "I like the whole interface, colors and width variations on the routes. The graphics are also interesting."

  p3: "What I like, I can get a lot of information with a simple interface... informative."

  p4: "I like the simple information about technical data of bus in each day based on the estimated data."

  p1: "It's fun to use, simple yet communicative."

- The participants had trouble with the fonts and the meaning of the warning sign)

  p2: "The text looks small in my screen and I had a bit of difficulty in reading some of the text."

  p5: "I need to zoom in and out between the maps and tables; some words look too small for me (I use netbook just in case)... still a question for me, what was the warning sign refers to?"

  p3: "What I didn't like, some fonts were too small..."

"If you had three wishes to make this better for you, what would you wish for? Why?"

- p2: "... better legibility of the fonts"
- p3: "... some alert, or some way to support decision making process. Maybe like a recommendation, what should I do when the fuel consumption is high?"
- p1: "If I were in the position of transportation manager, I think is sufficient enough... maybe the meaning of that warning sign"
- p5: "more color contrast on the fonts"
- p4: "... the FAQ button"

4.6 Comparison

In addition to remote usability testing, we compared the prototype with the existing visualization to collect participants opinion and their satisfaction. On the other hand, we also compared the proposed solution with its static image from. This was done to find out whether the interactivity brings any value to the visualization. We found that the prototype performed better compared to the existing visualization, in term of user satisfaction. Interactive version of the prototype was also preferred by the participants.

4.6.1 Proposed Solution and Existing Visualization

After the fourth iteration, we held a survey that was similar to the survey on the insight generation phase. Some descriptions were modified according to the prototype description. It was done to compare satisfaction rate and find feedback about the proposed solution.

Participants

Totally 54 participants responded to this study. Most of them came from Indonesia and Finland, with 31 Bachelor's and 21 Master's degree holders. 57% of the participants had not heard about Älynysse, while 24% had heard and tried Älynysse, either from the previous survey or from the participation of remote usability testing. The remaining 19% of the participant had heard, but had not tried Älynysse.

Procedure

The same procedure as the survey on insight generation phase was used on this survey with little adjustment. The main differences were the prototype itself and text description about the project. The survey was done remotely using Typeform (2014). We created the survey and distributed the link through email and social media such as Facebook and LinkedIn.

Electronic informed consent was provided at the beginning of the survey. The consent explained the risks and benefits, duration, participant rights, contact information for the research and the consent itself. If they agreed with those conditions, they can chose to continue. Otherwise, they can decline the participation without any consequences.

The questionnaires were presented to the participant after they read and agreed with the consent form. First, simple demographic questions such as age, location, and education were asked to the participant. We were also interested in finding out whether they are familiar with information visualization and Älynysse. Before moving to the next part, we presented a short description for the participant to get

a better understanding of the proposed solution. Then, several questions about the solution were provided to the participant. Links to the current web page was given to the participant and they can be switch back and forth between that page and the survey form. They were also required to rate the proposed visualization. Finally, their opinion about how to improve it was asked.

Questionnaire

In line with the first survey, we presented the question with the following notation: (Question type) The question. For example (Short text) What is your name, is asking for a name with short text input. We used (Statement) question type to give the participant a description, such as informed consent. All of the questions are required to be answered except the last question that asked their email. The questions consists of:

1. (Statement) Informed Consent
2. (Short text) What is your name?
3. (Question group) Hello, [Name]]! We will start by asking your background information.
   (a) (Number) How old are you?
   (b) (Multiple choice)Your highest education is...
      - Highschool
      - Bachelor
      - Master
      - PhD
   (c) (Dropdown) What country do you live in?
4. (Question group) Great! Now let's talk about Information Visualization and Älynysse a little bit.
   (a) (Multiple choice) How familiar are you with information visualization? (Choose as many as you like)
      i. I am a visualization researcher / professional
      ii. I took a visualization course in university / online course
      iii. I have read an article about it I saw visualization / infographic on the media
      iv. Info what? This is the first time I heard it.
   (b) (Multiple choice) Have you ever heard of Älynysse service?

i. No, this is the first time I heard Älynysse.

ii. Yes, but I haven't used it yet.

iii. Yes, I have tried it.

5. (Statement) Imagine that you are a transportation manager or municipality that have a system to monitor your bus performance.

   You can see the speed, fuel consumption, and other information visualized on the website.

6. (Question group) Now we will ask your opinion about the prototype.

   Remember, we are testing the website, not you. Therefore, there is no right or wrong answer. Feel free to switch between this form and the website while answering the questions.

   (a) (Statement) READ ME FIRST. Before we start, there are some things that we need to point out: 1. Imagine yourself as a transportation manager or municipality that can see your bus fleet condition everyday. 2. It is just a prototype. That means some links, buttons, or functions are not working properly 3. Only Monday, 20th April 2015 is currently working for this survey purpose

   (b) (Long text) What do you think is the purpose of this page?

   (c) (Long text) Is the current visualization gives a good picture of what's going on?

   (d) (Rating) What is your overall experience related to the visualization?

   (e) (Long text) How would you improve the visualization?

7. (Email) That's it. Fill in your email if you are interested to get the updates and see your impacts of the study. (Optional)

Results

More than half of the participants (31 from 54) had not heard of Älynysse before. Thirteen participants had tried Älynysse, whether tried the existing visualization, did the previous survey, or participated on the remote usability test. Meanwhile, ten participants had heard, but had not tried Älynysse.

The proposed solution was rated 3.83 on 5 point scale in which 1 means bad and 5 means very good. The rating is higher from the result of the existing visualization. However, it is worth to mention that only one participant rated 1, and one participant rated 2. Different from the existing visualization result which two participants rated 2 and six participants rated 1.

What do you think is the goal of visualization on that page?
The majority of the participants understood the purpose of the proposed solution.

- P5: "To give overview of the fleet and gives options in relation to a more LEAN business. I know this system (even we called it something else) from my work. I worked with the systems Coalition Force Tracker and Blue Force Tracker"

- P37: "To show a better picture of the overall performance of the buses going on Monday, 20th April 2015. This helps me as a manager to define, develop and/or create a new business strategies to maximize the performance of the buses."

- P52: "To visualize commuting data from daily bus lines in Tampere (generally). From transportation manager POV, to obtain relevant data that are used to design and calculate bus routes efficiently."

- P54: "I think this prototype is incredibly awesome. Of course, If I were the transportation manager, I would get help by this program. I would say it is pretty detail in giving the information about the speed and fuel consumption in general."

On the other hand, only one respond indicated that the purpose was not clear enough. P35: "Simple but no clear enough"

Is the current visualization gives a good picture of what's going on?
Most of the participants understood how the proposed visualization works.

P18: "I would say so. First, it has maps with lines that indicate where the bus go fast or slow. Furthermore, the different size and color of lines are easy to understand. Second, the graphs on the right hand side are easy to read as well."

P35: "It's awesome, it's also informative by giving the sign of the rush hour so we can compare bus condition properly. But it would be great if this website provide quick information / recommendation regarding the bus condition."

P42: "This is much better than that in the first(original) version. I can quickly understand what are being displayed on the map. The interactivity is simple, yet enough to explain the details."

P50: "Yes. Colors and thickness/bolding show nicely different properties. I also noticed estimations after a short look to the UI."

Some participants asked for more explanation. However, it is worth to mention that, in the experiment we sent a direct link to the dashboard screen, where the complete description is in the landing page screen.

P11: "yep, even though it takes sometimes to understand what is the meaning of legends in the map. Maybe some short description could help.."

P22: "Yeah quite good. Better to give first explanation to the website, what to do in the website"

How would you improve the visualization?
Ability to perform more analytic task

P35: "It would be great if this website provide quick information or recommendation regarding the bus condition. So as a transportation manager we can manage our bus fleet more quickly and more efficiently."

P37: "Adding more charts, graphs and KPI. Just like in typical Business Intelligence or Google Analytics dashboards."

P43: "Add more flexible reporting system, so user can freely do analysis based on what they are thinking."

A short explanation about the page

P3: "Everything looks good. It is quite simple and easy to understand. Yet, a simple training is still needed in the beginning to clarify some possible misunderstandings."

P22: "give the explanation about things to do in this website, its like tutorial"

P25: "...A short-quick tutorial about the page would be great."

Some participants asked for more functionality in date selection module. However, we are aware of possible improvements on the date selection. In this stage, we deliberately use a simple dropdown menu.

P7: "The date, maybe I can select the bus history in one month ago or else."

P29: "Maybe Date-picker could be provided for picking the bus condition date."

P45: "Selection of dates could be in calendar format."

4.6.2 Interactive and Static Version of the Proposed Solution

We have done a follow-up survey to compare the interactive prototype with its static picture. On this survey, we presented the static version of the interactive prototype and ask the participant to compare them. The same task as the remote testing on the fourth iteration was used with little adjustment.

We measured their preferences and their thought of the interactive elements for each task. We found that for most of the tasks, participants preferred using the interactive version. While as a whole system, all participants preferred to use the interactive version than static pictures. Moreover, the participants rated the interactive version better than the static pictures (4.4 on 5 rating scale).

Purpose

The purpose was to find out whether the interactivity brings a value to the visualization, compared to the static picture.

Participants

The same participants as in the fourth iteration were recruited. They are five participants: four Master's degree students or graduates in Information Technology-related area and a professional on telecommunication field.

Test Procedure

The survey was done remotely with an online survey service, Typeform. We sent the invitation link to the participant and asked them to answer the survey.

We divided the survey in two general sections: comparison for each task and comparison as a whole. For each task, we presented them with a static version of the prototype and asked them to do the task by answering the question on a text box. As a precaution, we also included a link to access the full size image on each task. Then, we asked them to compare it with the interactive version. Finally, they gave a rating scale on the helpfulness and the importance of interactive visualization regarding each tasks.

After doing all the tasks, we asked their preference to visualize the information as their overall experience. We also asked their opinion about the quality of interactive prototype, compared to the static version. Finally, we asked them to fill a rating scale on its overall quality, performance, design, and their overall experience.

Tasks

There were eight tasks in total. They were similar with the task on remote testing with following difference: removal of practice task and t0 and adjustment to umoderated survey for t1, t2, and t3. Several tasks had open ended questions that led to

open answer from participants.

We were also interested in their satisfaction and asked them the following questions:

- After doing all the tasks, which one do you prefer to visualize the information?
- Please explain why do you prefer [Depend on the previous answer]?
- How would you compare the quality of interactive visualization to static image? (5 scale)
- How would you rate the interactive visualization overall quality?
- How would you rate its performance?
- How would you rate its design?
- Overall, how satisfied are you with the visualization experience?

Result

As a whole system, all of the participants preferred using the interactive version to static picture. They also rated the quality of interactive system better than a static picture. Each of overall quality and performance got a 4.4 rating in one to five scale. While the design got 4.6 rating, the satisfaction rate was 4.2 (Figure 4.18).

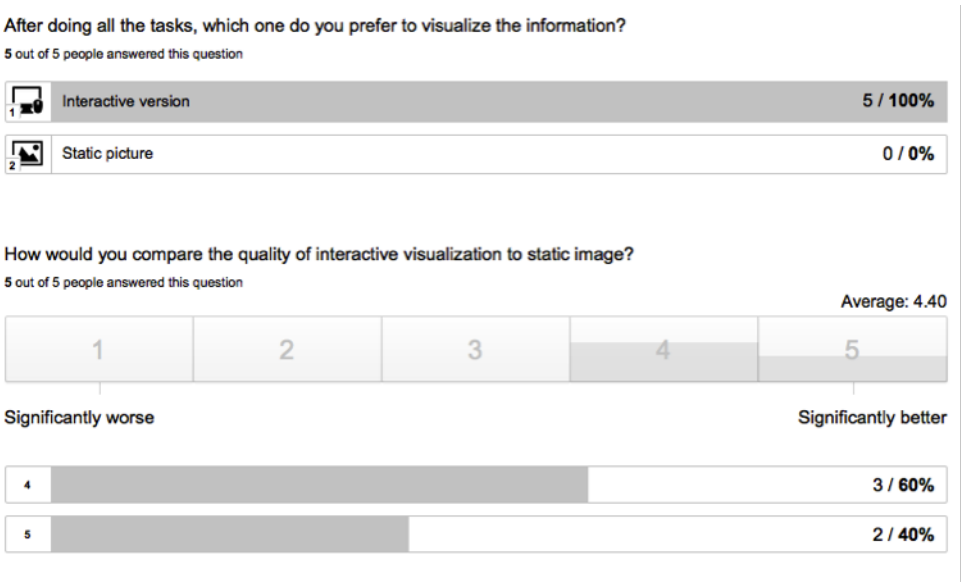


Figure 4.17: Breakdown of The Overall Preferences

For the comparison by each task, only on t5 participants seemed preferred static picture to the interactive version, with 2:3 ratio. 2 refers to the interactive version

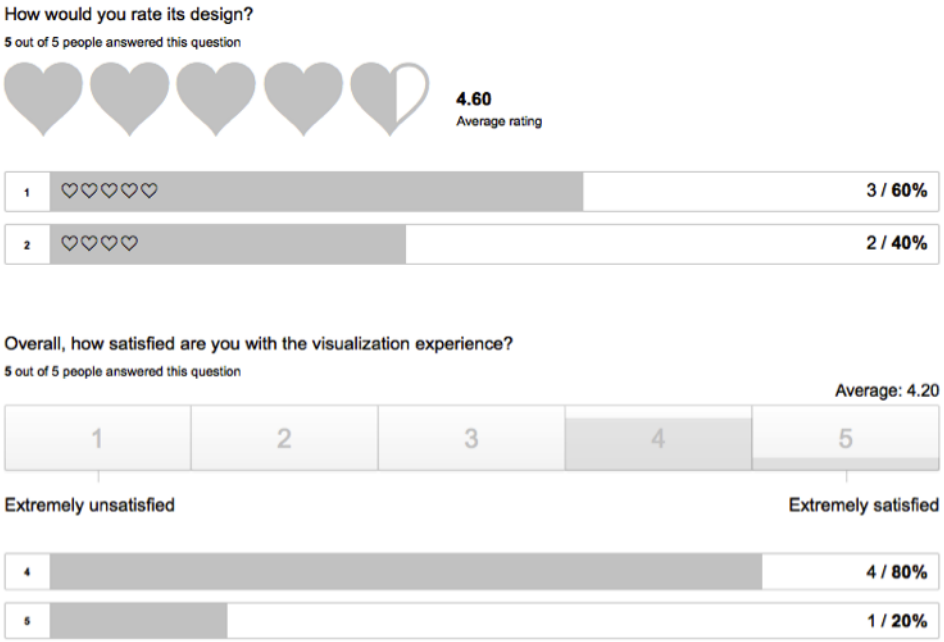


Figure 4.18: Overall Satisfaction Result

and 3 refers to the static picture. Note that, t5 tested an additional feature of the prototype and not the main functionality.

All of the participants preferred to use the interactive version on t1 and t3. While four of five participants preferred to use them on t2, t4, t6, and t7. With t8, three participants preferred interactive version to static picture.

Table 4.7 presents the comparison result. The answer of "Which one is more helpful for you?" is put on x column on the table. There are two options for the answer: static picture (S) or interactive version (I). While y refers to the answer of "What do you think of the interactiveness to accomplished the task?". The answer to this question is a 5 scale, with 1 is not necessary and 5 is absolutely necessary.

Then, the sum of each I and S are counted for each task. While the average is measured on the scale.

Why do they prefer interactive version?

Based on their answer on the question "After doing all the tasks, which one do you prefer to visualize the information?", we asked them why they chose either static or interactive version:

P1 (interactive): "It's more fun, not boring, and I can re-do what I previously did. Some texts would only be shown in the interactive version (on hover), which is good because it is somewhat disturbing to be shown without mouse 'hover'."

Table 4.7: Comparison for each task

Participant	t1		t2		t3		t4		t5		t6		t7		t8	
	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y
p1	I	5	I	4	I	4	I	4	I	4	I	4	I	4	I	4
p2	I	5	S	3	I	5	I	5	S	1	I	5	I	3	I	5
p3	I	4	I	5	I	5	I	4	S	1	I	5	S	1	S	2
p4	I	5	I	4	I	5	S	4	S	4	S	5	I	5	S	4
p5	I	5	I	5	I	5	I	5	I	3	I	5	I	5	I	4
Prefer Interactive	5	-	4	-	5	-	4	-	2	-	4	-	4	-	3	-
Prefer Static	0	-	1	-	0	-	1	-	3	-	1	-	1	-	2	-
Interactiveness scale avg.	-	5	-	4	-	5	-	4	-	3	-	5	-	4	-	4

P2 (interactive): "It gives me what information that I need to know in a clear and simple way. I think static or interactive are about how pleasure its users think when they use the website. I feel it is exciting. It gives me chances to know many information, without being wasteful. This website allows me to get them in ease, without takes of my time to look around and nervously searching the menu buttons."

P3 (interactive): "So I can explore the system and be more confidence in answering the task. And also, there is task that require me to find the maximum speed and it is easier to answer that task if I can sort the information in the interactive version."

P4 (interactive): "With the interactive version, user can see the animation like the real value of chart in the maps and overall statistics box. Besides that, with the interactive version the user interface looks simpler than static because it can hide information that user doesn't need to see like the condition of another bus lines or detail condition for each bus lines."

P5 (interactive): "Interactive version is more fun and easier to use, you can imagine if you use static images, you will need thousands file and it should be named clearly. But if we use interactive image, we just need one page, and it can fulfill every query"

5. CONCLUSION

We have presented Visuäly, a set of visualization techniques to monitor bus conditions. Visuäly combines contextual information with spatial and temporal information. We have modified and implemented a human-centered design process in developing and evaluating the visualization prototype. We have also compared the prototype with the existing solution. In this research, we sought to answer the following questions *a*) Is the proposed visualization easy to understand and learn? *b*) How does the proposed solution as perceived by human subjects response compared to the existing system? *c*) How can we implement Human-Centered Design process in interactive visualization development?

Based on the analysis and results of all the design iterations, our proposed solution is easy to be understood and learned. Participants' feedback from the usability testing sessions were positive. Participants' performance in time and completion rate were great, even though they were not the municipality or transportation manager.

Participants also preferred the proposed solution to the existing solution. The comparison survey shows that the proposed solution has higher satisfaction rating than the existing solution. Detailed analysis of their response in the insight generation survey reveal the fact that most of them were confused about the existing solution. On the other hand, most feedback were also positive in the comparison survey.

The implementation of Human-Centered Design process yielded in positive results for the design iteration. Recommendations from the previous iteration could be executed in a fast manner, due to the use of the interactive prototype. The design sprint also enabled us to test more design options compared to the traditional development cycle.

Unfortunately, our research comes with several limitations. First, only few of our participants are currently doing research or have a job that related to transportation management. While it is still acceptable for the user performance and user experience evaluation in visualization (Lam et al., 2012), involvement of more specific participant could reveal new problems and ideas for the visualization.

Second, our proposed solution stands in a stage between functional prototype and a mockup. This could cause a misinterpretation from the participants, especially in an unmoderated testing such as a survey. Due to the nature of the prototype,

we only designed detailed user interfaces and interaction techniques for some parts of the prototype. Even though we have explicitly stated on the survey that some parts may be not working properly, from the analysis result, some participants have higher expectation of the prototype's functionality.

Nevertheless, those limitations could lead to further exploration of the study. For instance, by doing specific case study with municipality or the transport management in the city. Another possibility is to develop an application using real data based on the prototype. Hopefully, with these two possible directions the information visualization community will benefit from more realistic data and case study research.

REFERENCES

Aigner, W., Miksch, S., Schumann, H., and Tominski, C. (2011). Survey of visualization techniques. In *Visualization of Time-Oriented Data*, Human-Computer Interaction Series, pages 147–254. Springer London.

Andrienko, G. and Andrienko, N. (2008). Spatio-temporal aggregation for visual analysis of movements. In *Proceedings of the 2008 IEEE Visual Analytics Science and Technology Symposium*, VAST '08, pages 51–58.

Andrienko, G., Andrienko, N., and Wrobel, S. (2007). Visual analytics tools for analysis of movement data. *SIGKDD Explor. Newsl.*, 9(2):38–46.

Anwar, A., Nagel, T., and Ratti, C. (2014). Traffic origins: A simple visualization technique to support traffic incident analysis. In *Proceedings of the 2014 IEEE Pacific Visualization Symposium*, PacificVis '14, pages 316–319, Washington, DC, USA. IEEE Computer Society.

Axure Software Solutions, I. (2002). Interactive wireframe software & mockup tool | axure. Retrieved April 13, 2015, from: `http://www.axure.com/`.

Brooke, J. (1996). Sus-a quick and dirty usability scale. *Usability Evaluation in Industry*, 189(194):4–7.

Buxton, B. (2007). - interacting with paper. In Buxton, B., editor, *Sketching User Experiences*, Interactive Technologies, pages 371 – 392. Morgan Kaufmann, Burlington.

Card, S. K., Mackinlay, J. D., and Shneiderman, B., editors (1999). *Readings in Information Visualization: Using Vision to Think*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.

Chong, C.-Y. and Kumar, S. (2003). Sensor networks: evolution, opportunities, and challenges. *Proceedings of the IEEE*, 91(8):1247–1256.

Chu, D., Sheets, D., Zhao, Y., Wu, Y., Yang, J., Zheng, M., and Chen, G. (2014). Visualizing hidden themes of taxi movement with semantic transformation. In *Proceedings of the 2014 IEEE Pacific Visualization Symposium*, PacificVis '14, pages 137–144.

Clearleft (2015). Silverback 3. Retrieved April 15, 2015, from: `http://silverbackapp.com/`.

Coding, B. (2015). Bohemian coding - sketch 3. Retrieved April 16, 2015, from: `http://bohemiancoding.com/sketch/`.

Cohn, M. (2004). *User Stories Applied: For Agile Software Development.* Addison-Wesley. Pearson Education.

Commission, T. E. (2013). Strategic implementation plan. Retrieved April 9, 2015, from: `http://ec.europa.eu/eip/smartcities/files/sip_final_en.pdf`.

Commission, T. E. (2014). Operational implementation plan: First public draft. Retrieved April 9, 2015, from: `http://ec.europa.eu/eip/smartcities/files/operational-implementation-plan-oip-v2_en.pdf`.

Cooper, A. (2004). *The Inmates Are Running the Asylum.* Sams Publishing, 2nd edition.

Du, F., Brulé, J., Enns, P., Manjunatha, V., and Segev, Y. (2013). Metroviz: Visual analysis of public transportation data.

Ethnio, I. (2015). Remote ux research – remote usability and ux research tools. Retrieved April 15, 2015, from: `http://remoteresear.ch/tools/`.

Fekete, J.-D., van Wijk, J., Stasko, J., and North, C. (2008). The value of information visualization. In Kerren, A., Stasko, J., Fekete, J.-D., and North, C., editors, *Information Visualization*, volume 4950 of *Lecture Notes in Computer Science*, pages 1–18. Springer Berlin Heidelberg.

Few, S. (2013a). Bullet graph design specification. Retrieved March 16, 2015, from: `http://http://www.perceptualedge.com/articles/misc/Bullet_Graph_Design_Spec.pdf`.

Few, S. (2013b). *Information Dashboard Design: Displaying Data for At-a-glance Monitoring.* Analytics Press.

Finstad, K. (2006). The system usability scale and non-native english speakers. *System*, 1(4):185–188.

Garland, K. (1994). *Mr. Beck's Underground Map.* Capital Transport Publishing.

Goodwin, K. and Cooper, A. (2011). *Designing for the Digital Age: How to Create Human-Centered Products and Services.* Wiley.

Haider, J., Pohl, M., and Fröhlich, P. (2013). Defining visual user interface design recommendations for highway traffic management centres. In *Proceedings of the 17th International Conference on Information Visualisation (IV)*, pages 204–209.

Hart, M. A. (2012). The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses eric ries. new york: Crown business, 2011. *Journal of Product Innovation Management*, 29(3):508–509.

Hof, T., Conde, L., Garcia, E., Iviglia, A., Jamson, S., Jopson, A., Lai, F., Merat, N., Nyberg, J., Rios, S., Sanchez, D., Schneider, S., Seewald, P., van der Weerdt, C., Wijn, R., and Zlocki, A. (2013). D11.1: A state of the art review and user's expectations. ecodriver project. Retrieved April 29, 2015, from: `http://www.ecodriver-project.eu/library/project-deliverables/`.

Jarrett, C. (2011). Sus: a good enough usability questionnaire | rosenfeld media. Retrieved April 16, 2015, from: `http://rosenfeldmedia.com/surveys-that-work/sus-a-good-enough-usability-qu/`.

Keim, D., Andrienko, G., Fekete, J.-D., Görg, C., Kohlhammer, J., and Melançon, G. (2008). Visual analytics: Definition, process, and challenges. In Kerren, A., Stasko, J., Fekete, J.-D., and North, C., editors, *Information Visualization*, volume 4950 of *Lecture Notes in Computer Science*, pages 154–175. Springer Berlin Heidelberg.

Keim, D. A., Schneidewind, J., and Sips, M. (2004). Circleview: A new approach for visualizing time-related multidimensional data sets. In *Proceedings of the Working Conference on Advanced Visual Interfaces*, AVI '04, pages 179–182, New York, NY, USA. ACM.

Kimani, S., Leva, M., Mecella, M., and Catarci, T. (2013). Visualization of multidimensional sensor data in industrial engineering. In *Proceedings of the 17th International Conference on Information Visualisation (IV)*, pages 156–161.

Krueger, R., Thom, D., and Ertl, T. (2014). Visual analysis of movement behavior using web data for context enrichment. In *Proceedings of the 2014 IEEE Pacific Visualization Symposium*, PacificVis '14, pages 193–200.

Krug, S. (2009). *Rocket Surgery Made Easy: The Do-It-Yourself Guide to Finding and Fixing Usability Problems*. Voices That Matter. Pearson Education.

Lam, H., Bertini, E., Isenberg, P., Plaisant, C., and Carpendale, S. (2012). Empirical studies in information visualization: Seven scenarios. *IEEE Transactions on Visualization and Computer Graphics*, 18(9):1520–1536.

Lazar, J., Feng, J., and Hochheiser, H. (2010). *Research Methods in Human-Computer Interaction*. John Wiley & Sons.

Liu, S., Pu, J., Luo, Q., Qu, H., Ni, L., and Krishnan, R. (2013). Vait: A visual analytics system for metropolitan transportation. *IEEE Transactions on Intelligent Transportation Systems*, 14(4):1586–1596.

Masoodian, M., Endrass, B., Buhling, R., Ermolin, P., and Andre, E. (2013). Time-pie visualization: Providing contextual information for energy consumption data. In *Proceedings of the 17th International Conference on Information Visualisation (IV)*, pages 102–107.

Ming-wei, L. and Jun, Y. (2014). Calculating the contribution rate of intelligent transportation system for the smooth general characteristic of urban traffic. In *Proceedings of the 2014 International Conference on Management Science Engineering (ICMSE)*, pages 1855–1859.

Mzee, P. and Chen, Y. (2010). Implementation of bus rapid transit system as an alternative for public transportation in developing countries case of dart system in dar es salaam. In *Proceedings of the 2010 International Conference on Intelligent Computation Technology and Automation (ICICTA)*, volume 2, pages 489–493.

Ries, E. (2011). *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. Crown Publishing Group.

Rubin, J., Chisnell, D., and Spool, J. (2011). *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests*. Wiley.

Shah, A. and Dal, L. J. (2007). Intelligent transportation systems in transitional and developing countries. *IEEE Aerospace and Electronic Systems Magazine*, 22(8):27–33.

Spence, R. (2007). *Information Visualization: Design for Interaction*. Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 2nd edition.

Sun, G., Liu, Y., Wu, W., Liang, R., and Qu, H. (2014). Embedding temporal display into maps for occlusion-free visualization of spatio-temporal data. In *Proceedings of the 2014 IEEE Pacific Visualization Symposium*, PacificVis '14, pages 185–192.

Typeform (2014). Forms done awesomely | typeform. Retrieved April 13, 2015, from: `http://www.typeform.com/`.

Vaccari, A., Martino, M., Rojas, F., and Ratti, C. (2010). Pulse of the city: visualizing urban dynamics of special events. In *Proceedings of the 20th International Conference on Computer Graphis and Vision*, GraphiCon'2010. ACM.

van Wijk, J. (2006). Views on visualization. *IEEE Transactions on Visualization and Computer Graphics*, 12(4):421–432.

Ventures, G. (2015a). The design sprint — google ventures. Retrieved April 13, 2015, from: `http://www.gv.com/sprint/`.

Ventures, G. (2015b). Google ventures research sprint sample nda. Retrieved May 5, 2015, from: http://www.gv.com/wp-content/uploads/2014/07/Google-Ventures-Research-Sprint-Sample-NDA.pdf.

Wang, Z., Ye, T., Lu, M., Yuan, X., Qu, H., Yuan, J., and Wu, Q. (2014). Visual exploration of sparse traffic trajectory data. *IEEE Transactions on Visualization and Computer Graphics*, 20(12):1813–1822.

Wapice (2013). Älynysse. Retrieved April 9, 2015, from: http://public1.wrm247.com/alynysse/.

Wood, J., Beecham, R., and Dykes, J. (2014). Moving beyond sequential design: Reflections on a rich multi-channel approach to data visualization. *IEEE Transactions on Visualization and Computer Graphics*, 20(12):2171–2180.

Zeng, W., Fu, C.-W., Arisona, S., Erath, A., and Qu, H. (2014). Visualizing mobility of public transportation system. *IEEE Transactions on Visualization and Computer Graphics*, 20(12):1833–1842.

A. SURVEY INFORMED CONSENT FORM

Before we start, here is something that you need to know:

We ask you to participate in a research study that is part of a master thesis in University of Tampere. We will ask you to examine a website and ask your opinion about it. In addition, we will ask you to fill in a questionnaire.

RISK AND BENEFITS: During the test you will be asked to visit a website which does not involve any considerable risks. This experiment will help us to give more understanding about the current website. Unfortunately, we are unable to compensate your time but we do appreciate your contribution.

DURATION: The experiment will take approximately 15 minutes.

PARTICIPANT RIGHTS: The results of the test will be reported anonymously. Participation is voluntary, you can withdraw your consent to the experiment and stop participation at any time.

CONTACT INFORMATION: If you have any questions, concerns or complaints about this experiment, its procedures, risks and benefits, please contact Arganka Yahya (yahya.arganka.x@student.uta.fi)

ELECTRONIC CONSENT:
Please select your choice below. Clicking on the "I accept" button below indicates that:

- you have read the above information
- you voluntarily agree to participate
- you are at least 18 years of age

If you do not wish to participate in the research study, please decline participation by clicking on the "I don't accept" button.

B. REMOTE TESTING NON-DISCLOUSURE AGREEMENT

Arganka Yahya, located at Kalevantie 4, Tampere, Finland, for itself and its subsidiaries and affiliates ("Researcher"), and the other party identified below ("You") wish to enter into this agreement to discuss and exchange information and to assure that the confidentiality of exchanged information is maintained and that rights to ideas or suggestions are properly allocated.

The parties agree as follows:

A. Purpose. You agree to take part in a study under this agreement for the purpose of assisting Arganka Yahya in researching and analyzing the usability of its current and proposed products and services (the "Purpose").

B. In the course of Your participation in the study, You may be requested to provide comments, feedback, ideas, reports, suggestions, data or other information to Arganka Yahya (collectively "Feedback"). You agree that Your voice and/or image may be recorded and such recording will also be considered "Feedback". You agree to permit Arganka Yahya to use any Feedback provided by You without limitation to develop and enhance Arganka Yahya's current or future products and services. Notwithstanding the foregoing, You agree that You will not disclose to Arganka Yahya any third-party information that You are otherwise obligated to maintain as confidential.

C. For any Feedback provided by You that You communicate to Arganka Yahya as being confidential in writing and any information provided to You by Arganka Yahya during the study period shall be considered confidential (the "Confidential Information"), and the following terms shall apply: (i) each party may use such Confidential Information only for the Purpose; (ii) the receiving party will use a reasonable degree of care to protect Confidential Information and to prevent any unauthorized use or disclosure of Confidential Information; and (iii) You may not share Confidential Information with any third party in any manner. Arganka Yahya will not disclose Your personal information without Your consent. Except as otherwise provided by this agreement, any personally identifiable data collected by Arganka Yahya during the study shall be used by Arganka Yahya in accordance with Ethical Principles Of Research In The Humanities And Social And Behavioral Sciences by the Finnish Advisory Board on Research Integrity (available: http://www.tenk.fi/en/ethical-review-human- sciences/ethical-principles#3) incorporated in this agreement by ref-

erence.

D. Confidential Information does not include information that: (i) was known to the receiving party without restriction before receipt from the disclosing party; (ii) is publicly available through no fault of the receiving party; (iii) is rightfully received by the receiving party from a third party without a duty of confidentiality; or (iv) is independently developed by the receiving party. A party may disclose Confidential Information when compelled to do so by law if it provides reasonable prior notice to the other party.

E. This agreement imposes no obligation on Arganka Yahya to use Your Feedback. Neither party acquires any intellectual property rights under this agreement except the express and implied, limited rights acquired by Arganka Yahya to use the Feedback for the Purpose.

F. This agreement does not create any agency or partnership relationship between the parties. This agreement is not assignable or transferable by You. This agreement is the parties' entire agreement on this topic, superseding any prior or contemporaneous agreements. Any amendments must be in writing. Failure to enforce any of provisions of this agreement will not constitute a waiver.

This agreement is effective as of the date sent by Researcher and accepted by You.

Name : Arganka Yahya
Place & Date : Tampere, 16 March 2015

C. REMOTE TESTING SCRIPT

Introduction

Thanks for joining this session! My name is Arganka Yahya. We're now on the early stage of research and getting your frank feedback is a really important part of that.

Before we begin, I have some information for you, and I'm going to read it to make sure that I cover everything.

I would like to say thank you for agreeing the non-disclosure agreement. I'd like to mention two parts of that.

First, it's a reminder that what I show you and what we discuss here today are confidential. It also gets your permission for me to record our session, just for our own internal use. That way we can go back and review it later. And, of course, you're free to take a break or leave at any time during the session.

Then, I like to keep these sessions pretty informal. I'm just trying to learn from you today. **I'll ask a lot of questions, but I'm not testing you. There are no right or wrong answers.**

I'll start this session by asking some background questions. Then I'll show you some things we're working on, and ask you to do some tasks. As you work on the tasks, please think aloud. This means that you should try to give a running commentary on what you're doing as you work through the tasks. Tell me what you're trying to do and how you think you can do it. If you get confused or don't understand something, please tell me. If you see things you like, tell me that too.

Also, please don't worry that you're going to hurt our feelings. We're doing this to improve the site, so we need to hear your honest reactions.

If and when you do get stuck, I'm going to try not to answer your questions or tell you what to do. I'm just trying to see what you would do if you were using it on your own. But don't worry — I'll help you if you get completely stuck.

Today we're going to use a prototype. That means some links or buttons or features may not work quite right. You can still click anywhere you like to do the tasks. When you run into something that's not working, I'll let you know.

Do you have any questions before we begin?

Context questions

OK. Before we look at the site, I'd like to ask you just a few quick questions.

What kind of work do you do?
For how long have you been doing that?
What kinds of things do you like to do when you're not working?
Do you usually work with data? like tables? excel?

How do you usually present them?
Have you use any apps to help you communicate the data?
why? what do you think of that?
Do you have favourite site to look at related to this?

OK, great. We're done with the questions, and we can start looking at things.

Begin the test

Now I'd like to show you some rough prototypes of ideas we're experimenting with. These are just prototypes, or in some cases just pictures of screens. Even though they look real, they won't work completely. You don't have to worry about breaking anything. To begin, please I will send you the link to the prototype. Meanwhile, could you please share your screen? I will also share my screen to show the task that we have to do today.

During the test

If the participant stops think aloud
"I would like to remind you to think aloud."

If the participant is stuck, if he/she goes off to some other web pages etc.?
"It looks like something is confusing you. What do you think the button (relative) over here would do?"

When to offer help and how?
"Offer suggestive help when the time crosses 50% more than the estimated time."

What is this? What is it for?
What did you think of that?
So what happened there?
Was that what you expected? Why or why not?
So what goes through your mind as you look at this?
Did you find what you were looking for?
What would you do next? Why?
Is there anything else you would do at this point?
Is there any other way to do that?
In what ways would you want this changed to make it better for you?
What additional info would have helped?

SUS questionnaire

Now I'm going to ask you to fill a questionnaire to get a sense what you felt about the test. (Send the link to the questionnaire)

Interview

Can you describe to me what you see on this page?
Which parts of this page are most or least important to you?
What do you think this point (to UI element) might do?
What does this point (to UI element) mean?
If you wanted to (do something), how would you. . . ?
Under what circumstances would you use this? Why?
What do you like or dislike about this?
If you had three wishes to make this better for you, what would you wish for? Why?
How would you describe this to a friend?