Using Web Technologies to adapt Data Visualizations for Mobile Devices
A use case in Eco Visualizations

Author: Arlind Musliu
Supervisor: Dr. Jorge L. Zapico
Examiner: Dr. Ilir Jusufi
Subject: Social Media and Web Technologies
Level: Master
Course code: 5ME11E
Abstract
Visualizations, web technologies and mobile devices are subjects which are trending nowadays in the world of technology and many research projects are tackling different issues. The originality of the thesis is in the aspect of bringing all these mentioned subjects together and providing findings that will help web designers when implementing visualizations for mobile phones. The thesis explores the use of web technologies for the visualization of complex data for mobile devices, both looking at the technical state of the art and capabilities, and at the difference in information needs for users in a mobile usage context. The first part deals with an in-depth research of the existing projects that deal with similar issues, analyzing the official documentation of the technologies and the community of developers. The other part of the research is focused on providing insights on the required changes for adapting to the needs of mobile device users by doing a usability testing on a specific visualization. The results provide information valuable for adapting visualizations, such as font sizes, color combinations, animation complexity and data simplicity. The use case that is used for feeding the visualizations with data belongs to the domain of eco visualizations, in particular dealing with sustainable food consumption.

Keywords
Information Visualization, Eco Visualizations, Mobile HCI, Web Technologies, D3.js, Node.js, Usability Testing, Literature Review
Acknowledgement

First of all, all praise is due to Allah the Almighty for everything provided for me. Peace and blessings are upon the prophet Muhammad who made it obligatory upon us to seek knowledge. I’m grateful to my parents for all the financial and moral support. I express my sincere love to my fiancé Ajla for motivating me during this journey. I deeply admire my brother’s struggle to complete my tasks in the company and release me from my obligations so that I can work with the thesis. None of this would have been possible without the constant guidance and assistance of Professor Arianit Kurti. I want to thank all my friends and other family members for believing in me and inspiring me to move forward. Most importantly, I want to make it clear that this master thesis was shaped, elevated and enhanced by my mentor, Dr. Jorge L. Zapico.
Contents

1 Introduction .......................................................................................................................... 1
  1.1 Interacting with Mobile Devices .................................................................................. 1
  1.2 Using Web Technologies ........................................................................................... 2
  1.3 Applying Visualizations ............................................................................................. 2
  1.4 Importance of Sustainable Food Consumption ....................................................... 3
  1.5 EcoPanel ..................................................................................................................... 3

2 Research Questions ........................................................................................................... 5

3 State of the art .................................................................................................................... 6
  3.1 Literature Review Method ......................................................................................... 6
    3.1.1 Conference Papers ............................................................................................. 7
  3.2 Mobile HCI Methodology .......................................................................................... 7
    3.2.1 Usability Testing guidelines .............................................................................. 8
  3.3 Mobile HCI ................................................................................................................ 10
  3.4 Data Visualizations .................................................................................................. 11
    3.4.1 Eco Visualizations ........................................................................................... 13
  3.5 Web Technologies ..................................................................................................... 14
    3.5.1 HTML5 .............................................................................................................. 17
    3.5.2 CSS3 ................................................................................................................ 18
    3.5.3 Bootstrap 3 ....................................................................................................... 18
    3.5.4 JavaScript ........................................................................................................ 19
    3.5.5 D3.js ................................................................................................................. 20
    3.5.6 Node.js ............................................................................................................. 21

4 Research Approach .......................................................................................................... 24
  4.1 Eco-Donuts ................................................................................................................. 24
  4.2 Mobile adaptation ....................................................................................................... 25
    4.2.1 Mobile-first with Bootstrap 3 .......................................................................... 26
    4.2.2 Model 1 (modifying Eco-Donuts) ...................................................................... 27
    4.2.3 Model 2 (alternative version) ........................................................................... 28
  4.3 Implementing the Usability Testing ............................................................................ 28
    4.3.1 Participants ....................................................................................................... 29
    4.3.2 Data Collection ................................................................................................. 30
    4.3.3 Data Analysis ................................................................................................... 34

5 Findings ............................................................................................................................... 36
  5.1 General Quantitative Statistics .................................................................................. 36
  5.2 Analyzing Data ........................................................................................................... 38
  5.3 Qualitative Feedback ................................................................................................ 40

6 Discussion and future work .............................................................................................. 43
# Table of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Combining different technologies for the development of Ekopanelen</td>
<td>4</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Mobile HCI research methods, 2000-02 vs 2009, in % (Kjeldskov and Paay, 2012)</td>
<td>8</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Choosing data versus artistic freedom (Keefe, 2005)</td>
<td>11</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Design of elevator buttons - Correct (a) vs incorrect (b) (MacKenzie, 2012)</td>
<td>12</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Correct (a) vs misleading(b) visualization presentation of data (Kirk, 2012)</td>
<td>13</td>
</tr>
<tr>
<td>Figure 6</td>
<td>General architecture of cross-platform application development (Dalmaso et al., 2013)</td>
<td>15</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Responsive web design example (smaller to bigger screen, left to right)</td>
<td>17</td>
</tr>
<tr>
<td>Figure 8</td>
<td>The default grid system of Bootstrap (Spurlock, 2013)</td>
<td>19</td>
</tr>
<tr>
<td>Figure 9</td>
<td>The three layers of the web design (Wright, 2012)</td>
<td>20</td>
</tr>
<tr>
<td>Figure 10</td>
<td>The event-loop of Node.js (Wilson, 2014)</td>
<td>22</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Eco-Donuts view on a laptop device</td>
<td>24</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Modified Eco-Donuts (left) vs Alternative visualization (right)</td>
<td>26</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Participant taking the test</td>
<td>31</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Comparing the answers on both models</td>
<td>37</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Comparing the ecological consumption of some categories</td>
<td>38</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Comparing the metrics for Eco vs Non-Eco group</td>
<td>39</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Time (seconds) spent on experiencing the app vs correct answers</td>
<td>40</td>
</tr>
<tr>
<td>Figure 18</td>
<td>Web View of EcoPanel</td>
<td>I</td>
</tr>
<tr>
<td>Figure 19</td>
<td>Questions for the first model (Q1-5) and for the second model (Q6-10)</td>
<td>II</td>
</tr>
<tr>
<td>Figure 20</td>
<td>True (1) and false (0) answers given by the users for the ten questions</td>
<td>III</td>
</tr>
<tr>
<td>Figure 21</td>
<td>Time spent, interactions and required assistance by the Eco group</td>
<td>III</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Time spent, interactions and required assistance by the Non-Eco group</td>
<td>III</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Rating some elements from both models</td>
<td>IV</td>
</tr>
<tr>
<td>Figure 24</td>
<td>Rating both models</td>
<td>IV</td>
</tr>
<tr>
<td>Figure 25</td>
<td>Choosing only one visualization model, or none</td>
<td>IV</td>
</tr>
<tr>
<td>Figure 26</td>
<td>Comments during the qualitative questions</td>
<td>V</td>
</tr>
</tbody>
</table>
1 Introduction

The first computers needed many engineers to compute one simple equation in the late 1960s, the first Personal Computer (PC) required only one user on the 1980s, while now we have one person playing around with many devices (Harper, 2008). From an initial many-to-one relationship, we gradually improved to a one-on-one situation so that we can have today a one-to-many relationship with the technological devices. Smartphone devices are getting bigger screens, better processing power, high definition cameras, Wi-Fi, and many other features. Cisco (2015) shows that mobile devices are surpassing the population of people and the 4G (fourth generation) has generated ten times more traffic than non-4G connections during 2014. Websites are now becoming responsive to meet the needs of the different screen sizes. However, the problem with mobile devices is the vast number of different platforms and developing apps for each platform means knowing many programming languages. This is a rather costly solution and web technologies are offering cross-platform development which makes it easier to build applications (apps) for mobile devices. So, despite the native apps, we can also build pure web apps or hybrid apps that are platform independent. The combination of technologies such as HTML5, CSS3 and JavaScript have made it possible to build mobile apps and access native device features through the mobile browsers (Stark, 2010a; Stark, 2010b). Thus, responsive visualizations can change their size and information complexity accordingly with the screen size of the device. The size of the screen is not the only difference between desktop and mobile devices. One example is the difference between using a mouse (or a touchpad) against the touchscreen on the mobile device. These differences play a crucial role on the visualization techniques that support interaction. That’s why it’s important to understand the changes that need to be addressed when deploying visualizations for mobile devices (Chittaro, 2006).

This thesis tackles the combination of complex data that is visualized through web technologies for mobile devices. It provides an in-depth research of projects dealing with visualization techniques and web technologies in the field of Mobile Human-Computer Interaction (Mobile HCI), as well as other similar fields. Eco-visualizations in particular are used for promoting sustainable behavior on consumption (Pierce et al., 2008), which in this use-case is directed towards sustainable consumption of food products. It’s rather challenging to provide technological suggestions that will be applicable for all the different topics that concern with visualizing complex data for mobile devices, hence presenting data about sustainable food consumption guides the choice of visualization techniques used in the solution. The proposed models were also evaluated by a user perspective and the feedback was important for understanding if the needs of sustainable food consumption were met by the design. The usability study dealt with the validity of the insight rather than technical choices.

1.1 Interacting with Mobile Devices

The term mobile device is also valid for devices such as tablets and PDA’s, but in this thesis we use the term to denote smartphone devices because the findings are upward compatible. On one hand, the increase of the size of the screen makes it more difficult to use the phone with only one hand and the thumb can’t reach all the different areas of the
screen (Yu et al., 2013). On the other hand, the size of the screen is not big enough when we want to enter text comfortably or display visualizations properly (Chittaro, 2006). The difficulty of using visualizations is inversely proportional to the size of the screen, which means that the smaller the size of the screen the more difficult it is to use visualizations (Firtman, 2013). That’s why the main focus of this thesis is to deal with visualizations for mobile devices such as smartphones, with the current models having screen sizes starting from 3 up to 6 inches diagonally, such as the small sized Samsung Galaxy Young (3.0"), the standard size iPhone 6 (4.7") or the bigger Nokia Lumia 1520 (6.0"). Nonetheless, screen sizes that are a bit bigger than 4.3" are more preferred for combining ease of use, portability, one hand control, watching videos and playing games (Raptis et al., 2013). Other barriers exist that need to be addressed when dealing with mobile devices, and these will be explained later on.

1.2 Using Web Technologies
The term web technologies in this thesis is referring to the programming languages, libraries and frameworks that are used for developing web applications. The switch between the static Web 1.0 into the much more interactive Web 2.0 has changed the way we use the Internet. The Web 2.0 has put users in the role of content creators, while developers are only worried about providing them the web apps for creating content (O’reilly, 2007). The development of these apps is made possible by the improvement of programming languages such as JavaScript, PHP, Java, Python, Ruby, etc. These are only a few leaders of a longer list of programming languages that are used for web development.

The vast use of mobile phones and the difficulty of cross-platform deployment have pushed the improvement of web technologies. Many research projects try to grab the benefits of pure web technologies such as JavaScript and Node.js for various applications (Zbick et al., 2014). Being able to create web and hybrid apps in contrast to native apps is seen as a major benefit for web developers. The use of web technologies for creating native looking apps for mobile users provide new opportunities for the developers. These web technologies can create a wide range of mobile apps, such as for gaming, health, content management, social interaction, information visualization, etc.

1.3 Applying Visualizations
Nowadays, the companies are collecting huge amounts of data that can be used for providing beneficial knowledge and statistics. That’s where visualizations come into the scene as the main actors for making sense of the data in an easily understandable format. During this thesis “visualization” is used to indicate “data visualization”. Visualizations provide an opportunity to comprehend huge amounts of data (Spence, 2000). They can be one of the best means for presenting the data to everyday customers, to people that are not much knowledgeable about that information. The well known example of using visualization techniques is the famous periodic table of elements designed by Mendeleev (Gordin, 2004). The periodic table is an interesting technique of presenting data in an easily understandable method. Visualization techniques may include graphs and bar charts which are simple and understandable for extracting
information out of data. Although visualization itself is not something new, web-based information visualization provides a link between applications, data, information and users (Rohrer and Swing, 1997). Furthermore, visualizations are getting their dominion on mobile devices as well, such as for health data, food consumption, stock market statistics, tourist maps, financial records, etc. However, developing visualizations for mobile devices has some constraints and adaptations which need to be addressed (Chittaro, 2006).

1.4 Importance of Sustainable Food Consumption
The use case of this thesis is about sustainable food consumption and the visualizations are fed with such particular data. Three important factors can aid the improvement of sustainable food consumption, including the consumers, businesses and the government. First of all we as consumers should engage ourselves and increase our awareness of ecological products (Todd, 2005). According to the Swedish Environmental Protection Agency (1999), the population should demand food products that are environmentally acceptable as a means to push the food supply chain on moving towards sustainability. Second, Vermeir and Verbeke (2006) add that businesses should imply the benefits of sustainable consumption and thus increase the attitude towards consuming these products. They also show that the consumers are having difficulties on finding sustainable food products and they require easier reach. Their study found that the consumers are willing to consume sustainable food products, but the information about the benefits and the availability of these products should be pushed to them. Sheth et al. (2011) agree as well that companies should focus on the consumers when dealing with sustainable consumption. Lastly, we have those that argue that it’s the government that should start working towards sustainable consumption and the consumers will follow them (Roundtable, Sustainable Consumption, 2006). Consumers themselves, businesses and the government are all playing an important role on increasing sustainable food consumption.

1.5 EcoPanel
EcoPanel is a project that helps households to gain insights about their consumption by visualizing their data (Bohné, Zapico and Katzeff, 2015). The consumption data are usually recorded in the databases of supermarkets for consumers that own fidelity cards. However, these data are not available to consumers and EcoPanel uses visualizations to present this data in an understandable format. The service is mainly focused on organic food and providing eco-feedback for a particular consumer. The current design of the application from a desktop device can be seen in the Appendix A of this document. The service uses a composition of a few technologies, such as JavaScript, Node.js1, D3.js2, Bootstrap 3, as well as HTML5 and CSS3. It combines the power of JavaScript features and popularity among developers, Node.js ability to load JavaScript codes on the server side, the vast number of examples provided by D3.js and content adaption to

---

1 https://nodejs.org/en/
2 https://d3js.org/
3 http://getbootstrap.com/
different screen sizes by Bootstrap 3. Figure 1 shows the combination of all these technologies for configuring EcoPanel. Although the entire service can be easily adapted for mobile devices with the help of Bootstrap 3, the problem still persists with the main visualization, named Eco-Donuts. The horizontal shaped Eco-Donuts visualization technique was developed and tested by Dragomoiris (2015), albeit only for desktop devices. It’s rather easy to resize all its elements and make the design fit for the smaller screen sizes of mobile devices. However, this method is not effective in this case because the text becomes hard to read and the color differences can’t be identified smoothly. This thesis provides a usability testing of a modified version of Eco-Donuts and a new simplified version, both suitable for mobile devices. It explores how such visualization techniques can be adapted to mobile devices and the changes they require. The findings can guide developers when designing complex visualizations for mobile devices.

Web technologies can be used for deploying various applications for mobile devices and visualizations are part of that trend. There is not enough research on exploring the possibilities, challenges and problems when combining the visualization of complex data, mobile devices and web technologies together. There are researchers that tackle visualization issues for mobile devices, although most of them are focused on maps and health apps. According to Levkowitz and Kelleher (2012) some projects deal with data visualization as well. Many differences already exist among desktop and mobile devices, such as input methods, animation triggers, touching, zooming, without even mentioning the screen size issue. For example, although mouse hovering is seen as an interesting method to apply animation on visualizations, it’s currently impossible to implement the hovering on mobile devices (Heer and Shneiderman, 2012). Some of these problems are tackled in this thesis and the usability testing is used as a validation for the design choices.
2 Research Questions

The aim of this master thesis is to explore, analyze and design a solution that will use visualizations for interpreting complex data on mobile phones through web technologies. The main research question to be addressed is:

*What are the existing possibilities, challenges and problems of visualizing complex data for sustainable food consumption in a mobile device with current web technologies?*

The question to be addressed can be further explained and decomposed into four subquestions:

A. *Which web technologies or tools can be used for building visualizations of complex data for mobile phones?*

B. *What are the benefits and issues of using web applications for developing visualizations for the specific requirements of mobile devices?*

C. *What kind of information complexity and design changes are needed for adapting the presented information and visualizations to the different screen sizes?*

D. *Do the adapted Eco-Visualizations for mobile devices address the aim of providing insights to the consumers about their organic food purchase patterns?*

The above mentioned research questions will be explored during this master thesis. For answering this research questions first a literature review will be performed exploring the topics of mobile HCL, eco visualizations and web technologies. An in-depth research is conducted on the technologies used at EcoPanel and the most appropriate technical solutions for implementing the visualizations in smartphone devices (chapter 3). Chapter 4 presents an already existing desktop visualization which adapts to the needs of mobile users by two proposed models. The same chapter explains the methodology used for testing both models by doing a usability testing on real users. The results are then analysed in relation to the presented research questions using statistical formulas and different metrics (chapter 5). Finally, chapter 6 discusses some of the challenges and limitations of this thesis and proposes future work on some issues.
3 State of the art

This master thesis touches upon a few important fields such as data visualization, mobile devices and web technologies, while aiming to combine them together. The final product brings the need of investigating projects that tackle issues that can aid this combination. This section begins by explaining the methods used for compiling the literature review. The 3.2 subsection explains the methodologies that are currently used by other researchers that have dealt with similar topics on the field of mobile HCI. The proceeding part contains an in-depth analysis on the technical state of the art for the technologies that are used at EcoPanel and the most appropriate tools or programming languages that can make this project doable. It explores the existing possibilities for visualizing complex data in mobile devices, tackling topics like Mobile HCI (subsection 3.3), Data Visualizations (in particular, mobile visualizations) (subsection 3.4) and Web Technologies (HTML5, CSS3, Bootstrap 3, JavaScript, D3.js, Node.js) (subsection 3.5).

3.1 Literature Review Method

The literature review is a very important part of the documentation because it lays the groundwork for the research that is being conducted. The chosen keywords, articles, authors, publication sites are all factors that can shape the trajectory of the research findings. The papers were retrieved from the known digital libraries of ACM and IEEE Xplore, both containing important research papers and I had access to them with my university account. Google scholar was the main source of researching other articles that deal with some minor issues which are mentioned in this thesis. The keywords for searching the right literature projects are very crucial. Although I did reference some papers that were published before the new millennium, I based most of my conclusions on the research projects that were conducted from the year 2000 and onwards, especially the later years. The reason behind this decision is because some of the technologies that are used in this thesis are new in the field, such as D3.js and more importantly Node.js. This means that the papers which use Node.js have been written after the year 2008, because the first version of Node.js was released in 2008 by Google (Wilson, 2012). Another very important reason is the introduction of the first version of D3.js, version 1.0.0, which was officially pushed to GitHub on February 17, 2011. It's obvious that the combination of Node.js and D3.js can only be found after the public presentation of D3.js.

The majority of the books that were used for explaining the web technologies are published at O'Reilly Media, Inc (www.oreilly.com). This company publishes books that deal with the topic of computer technology. These books were helpful in explaining some of the programming languages that are used for the development part. Conference papers were useful mostly for building the groundwork of this thesis. Journals were important for analyzing relevant research projects, in particular the Information Visualization journal published by SAGE (ivi.sagepub.com). However, most of these published papers dealt with visualizations in general, with only a few tackling the needs of mobile devices.

3.1.1 Conference Papers
There are many conferences that deal with the issues of Mobile HCI. Computer Human Interaction (CHI) is the leading conference in HCI according to the ranking of March, 2015 by the Microsoft Academic Search\textsuperscript{5}. But, since my field of research is concerned more directly with the mobile devices, I decided to focus my research more on papers that were published on the Mobile HCI - Conference on Human-Computer Interaction with Mobile Devices and Services. This conference currently has 809 publications with a total of 4,583 citation count according to the Microsoft Academic Search ranking. The first conference was held in Glasgow in 1998, and the latest one for the year 2015 will take place in Copenhagen\textsuperscript{6}. However, taking into consideration that some technologies used in this thesis are newly introduced, I have based my research on the latest conference papers, starting from 2008, with some minor exceptions.

Furthermore, the research papers were filtered with their relevance to web technologies and visualization techniques. Another important conference that was researched is IEEE Information Visualization Conference (IEEE InfoVis), including papers during the years 2008-14. However, this conference proved beneficial only as much as visualization is concerned, with only a few papers tackling visualizations for mobile phones. The papers of this conference invested much effort on explaining, innovating, evaluating and using visualization techniques. This thesis tackles cross-section issues and thus there was the need to connect research that was done on different areas, such as the combination of mobile HCI and InfoVis. This was a must to understand what has been done as far as visualizations are concerned, the challenges, size and device adoption, problems and the best practices proposed. In the other hand, mobile devices with smaller screen sizes have specific needs in comparison to larger screens, interaction is more difficult, text input is also a challenge, and screen size adaption is the main concern.

3.2 Mobile HCI Methodology
The choice of methodology is very significant for the outcome of the project. Håkansson (2013) strongly suggests that the methodology is chosen and implemented during the entire project, because the choice of methods and methodologies can steer the course of the project. She mentions that a researcher chooses to implement a qualitative research, but then uses methods and research strategies that belong to quantitative research. However, she does mention that the researcher may decide to use both methodologies for developing a better understanding and a complete view of the situation. According to the findings of Håkansson (2013), my research belongs to the quantitative research area while tending towards qualitative as well, which shows that a mixed approach was used. The philosophical assumption of this thesis is pragmatic approach where the researcher is free to combine methods and strategies from both

\textsuperscript{5} http://academic.research.microsoft.com/RankList?entitytype=3&topDomainID=2&subDomainID=12&last=0&start=1&end=100
\textsuperscript{6} mobilehci.acm.org/2015/
qualitative and quantitative approaches (Creswell, 2013). The research strategy that is used in the thesis is a usability testing (Rubin and Chisnell, 2008) that evaluates two proposed models, using methods from qualitative and/or quantitative approaches. Two types of data collection methods were used, questionnaire and interview. Questionnaires are proposed as means of collecting data from the users by using semi-structured questions. The unstructured interview was needed to get a more in-depth opinion from the users and give life to the quantitative data of the survey. Using this type of questions means that the data will be analyzed using statistics and metrics proposed by Rubin and Chisnell (2008).

“It (Mobile HCI) has also become increasingly multi-methodological, combining and diversifying methods from different disciplines.”
- Kjeldskov and Paay (2012)

This means that researchers are currently using different methodologies when developing their projects. Kjeldskov and Paay (2012) have gathered and evaluated papers about mobile HCI published during 2009, and compared the findings with a previous study that they did for papers published during the years 2000-02 (Kjeldskov and Graham, 2003), which can be seen in Figure 2. The older review showed that new systems were built on trial-and-error manner and most of them were not even evaluated. The first designers couldn’t find enough research papers to base their work on, so they had to lead the way up front for the upcoming projects. However, the second review showed that there have been plenty of changes on the area of mobile HCI. The 144 papers that were evaluated have used methodologies from all kinds and combined different methodologies from other disciplines as well. However, field evaluation has also increased. We have researchers that go out on the field and experience the research project as participants (Morgan et al, 2014). Kjeldskov and Skov (2014) propose the use of longitudinal field studies that would evaluate the application in the real world in contrast to short evaluations.

3.2.1 Usability Testing guidelines
According to Rubin and Chisnell (2008), the usability of a product/service is defined by being useful, efficient, effective, satisfying, learnable, and accessible. The product is useful when it meets the user’s initial goals and it’s efficient depending on the time needed to meet those goals. They further explain that the service should behave in the
way the user expects it to behave to be effective and satisfaction is connected to the user’s feelings towards the service. Learnability defines the easiness in which the user can learn to use the service, while accessibility offers access to the required products for fulfilling the goals of the user. The above mentioned criteria will guide the questions on the usability testing. According to them, the designers need to put significant effort on understanding their users.

Some of the research projects that deal with eco-visualizations have tested the visualizations with a chosen group of people, by allowing them to play around with the application and then complete the survey, for example Grevet (2010), Valkanova et al. (2013). The most practical and famous approach is to do a questionnaire, with qualitative (Makonin et al., 2011; Valkanova et al., 2013) or quantitative questions, or a combination of both (Kim et al., 2010; Bonino et al., 2012). The difference between qualitative and quantitative survey is very narrow because both options tend to have a few questions from the other, so the overall goal of the survey can define better in which group it belongs.

There can be a various number of people taking the survey, such as 24 participants (Grevet et al., 2010; Makonin et al., 2011) or 30 (Valkanova et al., 2013), and even 992 individuals (Bonino et al., 2012). Because most of the eco-visualization projects deal with household issues, it’s also common to have couples doing the survey together as one.

Researchers have also preferred the use of interviews by arguing that it provides more flexibility to the orientation of the feedback (Strengers, 2011; Valkanova et al., 2013; Costanza et al., 2012). The interview provides a qualitative approach for analysing the experience of the user and asking unprepared questions as the user continues to give his feedback. The interview can be done on 12 (Costanza et al., 2012) or 18 (Valkanova et al., 2013), or 23 (Rodgers and Bartram, 2011) individuals or couples, but the number depends on the issue that is being tackled and other possible constraints.

According to Reiss (2012), the preferred method of doing usability testing is by the “think-aloud” method. This method requires participants to express aloud what they are thinking while using the service. The researcher closely observes the actions of the participants and collects usage data that can be used on evaluating the design on usability. The participants can be assisted by asking them questions such as:

1. What are you thinking now?
2. What are you looking at?
3. What do you want to do now?

Some researchers suggest that the users should be allowed to spend a longer duration with the app before conducting the survey (Banovic et al., 2014). Väänänen-Vainio-Mattila and Wäljas (2009) propose an expert evaluation method for user experience (UX) of cross-platform web services. Others have placed the burden of testing on softwares rather than people (Roy Choudhary et al., 2014; Abascal et al., 2006).
3.3 Mobile HCI

Around a decade and a half ago, Mobile HCI began to evolve separately from the HCI as a slightly different field (Kjeldskov and Skov, 2014). It explains the specific needs of mobile devices, especially mobile phones because of their dominance in the market. The touchscreen feature, portability, smaller screen size, wireless, integrated digital keyboard, are some of the features that draw the line between desktop and mobile devices. That’s why it’s important to design applications that meet the needs of these devices.

When we talk about mobile devices we have to include interaction as the feature that has become very important in the field of Mobile HCI. According to Swanson (2012), there are four different forms of interaction: informational, cooperational, transactional, and social. Interaction is very crucial for the role of visualizations in modern applications, but interaction as a feature should be used very carefully, according to Lam (2008). During her research on 61 papers that were mentioning interaction problems, she found out that interaction needs to be used with care although it is seen as a vital factor of the success of modern visualizations. She proposes a framework that shows interaction costs when deploying information visualization techniques. A few suggestions can be mentioned such as the use of simpler interaction techniques, allowing users to save current visualization state for later retrieval, and maintain a balance between the need to guide the users through data and motivate them to explore freely.

The smaller screen size of mobile devices such as smartphones presents new issues that need to be tackled. A rather interesting study was conducted on understanding the impact of mobile phone screen sizes in correspondence with usability, effectiveness and efficiency (Raptis et al., 2013). 60 participants were tested with three very similar phones, Galaxy Ace (3.5"), Galaxy SII (4.3") and Galaxy Note (5.3"). The phones were given to three groups of 20 participants, each group with one specific phone only. The findings showed that as much as browsing, playing games or watching videos is concerned, the bigger screen sizes are much better, but this comes with the expense of decreased mobility, reduced battery life and difficult to use with only one hand. Screen sizes such as 4.3" are seen as a better choice for getting the advantages of mobility and bigger screen size at the same time. The final findings from their research showed that mobile phone screen size does matter. However, recently a new framework was proposed for a more efficient visualization resizing in accordance with the device screen size, ViSizer (Wu et al., 2013). Their algorithm makes enough deformation so that the text and image is resized in compliance with the screen size without losing the intended effect. It also allows manual size fixing by the users and it’s also efficient for smaller screens on selecting the target in a crowded area with different choices. However, they do emphasize that ViSizer may not be adequate for resizing visualizations that require precise positioning of visual elements.

The text input and touchscreen feature of the mobile devices are also functions that need attention. Text input in mobile devices is more difficult than on devices with larger screen sizes. Shrinking the keyboard to fit the size of the screen or reducing the number of letters on the main layer are some of the options that exist for tackling this
issue (Hudson et al., 2005). Smartphones use touchscreen method for allowing interaction with the device. However, the small screen size makes it easier to miss the intended button and fail to hit the target, with different ideas being proposed for solving this issue as well (Buschek, Rogers and Murray-Smith, 2013).

Browsing the internet through mobile browsers is not an uncommon thing to do. A few years ago, the loading of web sites in mobile devices was slower in comparison to personal computers (Roto and Oulasvirta, 2005). However, nowadays the response time is gradually improving for mobile devices. Nonetheless, the duration of using an app should not require too much of user's time, as they prefer to have apps that will notify them quickly with appropriate news (Banovic et al., 2014). That’s why it’s important to value the time of the users without frustrating them with too much purposeless app use. A balance should be maintained between the time required for using the app and the number of notifications sent during the other part of the day.

3.4 Data Visualizations

It’s common nowadays to store the data and keep track of all the different actions, changes, files and logs that are being created every moment. However, extracting information and knowledge out of this huge ocean of data is a very difficult task. Visualization techniques provide a different solution to the problem by visualizing the data into meaningful information. The usage of visualization is seen on various areas and the benefits of using them are many. Segel (2010) mentions some examples for data visualization such as the visualization about baseball star Barry Bonds, White House budget forecasts compared with reality, Human Development Trends, Minnesota Employment Explorer, and many more.

Figure 3 Choosing data versus artistic freedom (Keefe, 2005)

Pierce et al. (2008) distinguishes two general types of data-visualization, pragmatic and artistic. The difference is that artistic visualizations tend to create an art with the data they have, without presenting the information openly to the user. On the other hand, the pragmatic visualizations put more emphasis on the context and the easiness, while they might look beautiful as well. Nevertheless, Rodgers and Bartram (2011) argue that ambient and artistic feedback is much more effective than traditional visualization techniques, because they can attract the interest of the user much better. Figure 3 shows how the designers have to choose between presenting more precise data or displaying beautiful visualizations. That’s why a balance should be kept when
visualizing complex data that needs to be understood by people with different backgrounds. According to Steele (2010), a beautiful visualization should be aesthetically pleasing as well as novel, informative, and efficient. This means that visualization is not just a method for showing the data in a beautiful way. It should be informative and present the intended information, be efficient in a way that the user will understand the right message, and additionally provide something novel for the user.

“The purpose of visualization is insight, not pictures”  
- Card et al. (1999)

Despite the famous quote that “A picture is worth a thousand words”, the importance should be placed on reflecting the information, because without the insight the visualization is just a picture. If the users can’t grasp the knowledge of the visualization then the value is lost. That’s why it’s very important to design with the consumer in mind. The choice of the visualization technique, color, information complexity and size should focus on the user perception. The insight should be more important than the beauty of the visualization.

![Figure 4 Design of elevator buttons - Correct (a) vs incorrect (b) (MacKenzie, 2012)](image)

The design should also focus on what is commonly known for the people and not to change their behavior. A good example is the design of the elevator buttons that is presented in the picture above. Some behaviors are placed deeply in our everyday life and changing that can prove costly for the offered service. Figure 4, on the left shows the correct way of designing the elevator buttons, while the figure on the right innovates a design that is not acceptable for the normal behavior. If the design doesn’t comply with the industry standards and user expectations, then new users will take much longer to learn the service (Myers, Sandler and Badgett, 2011). This means that even innovation should be brought forward with great care of user perception and expectation. Too many changes from what is common to the users and there might be the need of redesigning the entire solution or risking to have a commercial failure. Another problem is that visualizations may be misleading and fail to present correctly the data by not using them accordingly. If the user gets the wrong message then the effect of using visualization is lost and furthermore it damages the initial purpose of using visualization. Figure 5 shows an example where the data is presented accurately.
by the 2D visualization, in relevance with the percentage. But, the 3D visualization hides the truth and deceives the receiver of the information by showing the blue part more than the gray, which is in contrast with the proportional division of the data. Kirk (2012) shows how the visualization on the left presents accurate information of 82 percent blue and 18 percent orange, while the 3D dimension shows 91 percent visibility of the blue in contrast with only 9 percent gray. This presentation misleads the user and distorts the facts of the actual proportional division.

![Figure 5 Correct (a) vs misleading(b) visualization presentation of data (Kirk, 2012)](image)

As far as mobile visualizations are concerned, Chittaro (2006) claims that researchers are investigating data that can categorize visualizations into five main classes: visualizing text, pictures, maps, physical objects and abstract data. The different examples may include the visualization of health data, food consumption, stock market statistics, tourist maps, financial records, etc. Furthermore, visualizations should respond to the actions of the users for them to be called responsive (Verpoorten et al., 2009). So, the meaning of the term responsiveness is not solely attached to the idea of adjusting the different screen sizes.

3.4.1 Eco Visualizations
This area of research is narrowed down even further by exploring the needs of Eco Visualizations. These kinds of visualizations are used for promoting sustainable behaviors and encouraging users towards sustainable practices (Pierce et al., 2008). They can indicate various issues, such as the global warming, the use of water and energy, sustainable food products, etc. Overall, the use of eco-visualizations has proven to be successful for many projects (Froehlich, 2009; Kim et al., 2010; Costanza et al., 2012; Jain et al., 2013) or at least indicate future success (Grevet et al., 2010; Makonin et al., 2011). In respect to sustainable food products, the study conducted by Vermeir and Verbeke (2006) proves that people are interested in buying such products, but the problem is that they are not well informed about the benefits and availability of these products. Eco Visualizations can express and emphasize the importance of using sustainable practices.

Froehlich (2009) provides a framework that can help researchers and designers when evaluating or manipulating the design of eco-visualizations that target the increase of awareness on the consumer side:

- Frequency - Updating the data more frequently has proved to be more beneficial
● Measurement unit - Allowing the user to change the measurement unit (example: from dollar to euro) provides more flexibility and acceptance from the user
● Data Granularity - Grouping, filtering and combining different data is needed for the consumer to play around with the feedback
● Push/Pull - The data can be pushed to the user through some device at any time or it can be available at some other place (example: website) for the user to pull.
● Presentation Medium - The feedback of energy consumption may be provided through printed papers or electronic display, with the latter being the preferred option because it delivers more interactivity
● Location - The feedback may be presented near the device or at some other place such as a website or paper. The cost of installation plays a major role on deciding the best option, with the localized being the most promising choice
● Visual Design - The choice of visualization technique can prove to be very important in the acceptance of the consumer for using the proposed solution. We have the choice between a more pragmatic visualization which is up to the point with precise information in contrast with an artistic visualization which touches the curiosity of the user in a more abstract manner
● Recommending Action - Prompting the user with textual messages has proved to be beneficial, and further improvement may be to link the solution with the outside world. For example, if a water boiler is consuming more energy than the normal consumption, the system may provide links to other boilers that are more sustainable and energy efficient
● Comparisons - Using comparison of data from the current month with the data from a month before or the same month from last year may prove to be beneficial feedback. The data may also be compared with other users, for example with neighbors, with the intention of motivating sustainable behavior. However, these comparisons should be provided with great care so that they don’t influence negative effects or frustrate the users
● Social Sharing - Although not every consumption information should be shared, using the social networks for sharing sustainable consumption data can feel rewarding for the actual consumer sharing the data as well as increase the awareness of the people connected

3.5 Web Technologies
Web technologies play an important part in the current technological developments. They are very significant for developing services and apps that are available in different devices, with various screen sizes and operating systems. We can see how the trend goes towards the unification of devices, developing one solution for all of them. This unification would have been much more complicated without the development of web technologies.

Nowadays, we have more than 3,000 different mobile devices on the market
This is very good for the users because it offers them a wide range of choices, but it’s a nightmare for developers that need to suit the requirements of those devices. Three possible routes exist when implementing applications for mobile phones, building native, hybrid or pure web apps. The most known method is to deploy a native application that is built specifically for each particular platform. Almost each platform has its programming language for developing apps. Although until recently the iOS of Apple required the use of Objective-C, it decided to switch to the Swift programming language. On the other hand Android and RIM need Java, Symbian needs Symbian C++, Windows Phone requires C#, whereas Palm is a bit more advanced with HTML, CSS and JavaScript (Christ, 2011). These are the most important platforms and many minor platforms also exist. This makes it difficult and costly to deploy applications that will be run on all the different platforms. Web technologies such as HTML5, CSS3 and JavaScript provide easy and cross-platform development. These apps can be pure web apps that are loaded from the browsers of the mobile devices, or hybrid apps that run inside a native container. Web apps generally use the same code and design for all the different screen sizes, and adapt the size via responsive designs. Hybrid apps use most of the code for all the different platforms, but they need to use special frameworks for the final deployment for each platform. Firtman (2013) mentions the advantages of using web apps, such as the speed of sharing the app, cross-platform code sharing, continuous update, etc. He also mentions some disadvantages such as the problem of debugging, lower performance, limited usage area of possible apps, native features restriction, etc.

As we can see from Figure 6, cross-platform apps need the mediation of a
framework that will connect with the operating system of the particular mobile device. This bridge allows access to the hardware features of the native device as well. The hybrid approach is as close as it can get to a native developed app. In contrast, the web app approach is directly rendered on the mobile browser (Chuan, 2012). The browser takes the responsibility of rendering and presenting the application to the user. Since the app will be accessed via a browser, it means that the files should be transferred to the device through internet connection. Using the web technologies is not a straightforward approach as rendering is slower in mobile phones in contrast with desktops and laptops, because of the processing power differences. Nicolaou (2013) proposes practices such as eliminating http requests, using compression, managing JavaScript parse time, avoiding layout and style calculation, optimizing images, reducing DNS lookups, and some other practices. These practices can contribute a lot on adapting the web applications for the mobile devices while adapting to the needs and constraints of those devices. Despite the difficulty of applying the mentioned practices, their usage is very valuable for mobile developers.

Debugging and testing the web apps is crucial for successful development. Many tools provide easy app testing that allows the developer to check how the app behaves on different mobile devices with different platforms. Server-side debugging can be done by using the User Agent Switcher plug-in in Firefox, or the Chrome Developer Tools in Google Chrome, while the difficult client-side debugging can be implemented through the Web Inspector on iOS 6.0 or newer, Chrome Developer tools for Android, BlackBerry remote Web Inspector, the Opera Dragonfly tool, etc (Firtman, 2013). We can also use emulators and simulators to test the app on different devices and check for any errors, although this is connected more with the usage problems.

“Ease of use may be invisible, but its absence sure isn’t”
- IBM (Lowdermilk, 2013)

People usually don’t appreciate the easiness of use because everything is working as expected. But, when things are not right, then we understand the importance of a good design. The website design should adapt the users, the screen size, the device and many other factors, but the design preference of the designer itself should not be the main factor (Lowdermilk, 2013). Cisco (2015) predicts that by 2018 we will have 1.4 connected mobile devices per capita, with a total of over 10 billion mobile devices. This increase on mobile device use has brought the term Responsive Web Design (RWD). Web designers are forced to adapt their designs for suiting the needs of smartphone and touchpad users. The main goal of RWD is the principle of “write once, run anywhere” (Sharkie and Fisher, 2013). We aren’t forced to make websites that fit all screen sizes, we could also build specifically for the mobile users and a different solution for desktop users. However, building a responsive web design is more efficient and effective solution (Robbins, 2012).
Figure 7 shows how the given website has used responsive web design for adapting to different screen sizes. We have the mobile page design on the left, which gradually shows more information if we use a tablet. In the end, we have the standard look of the website as it’s seen from a laptop or desktop computer. The growing number of mobile device users has changed the standard of website creation. Nowadays, web developers start the design of a website with the terminology “mobile first” in mind. According to Voas (2012), Adobe CTO was the first to use the term “mobile first”. The statement presented below shows the importance of the “mobile first” approach which gives emphasis on designing for devices that have more constrained environments and afterwards enhance the design for devices that have better performance capabilities.

“Our approach at Adobe is to take a mobile-first view on the new work that we are doing to design for the more constrained environments, then look to ways to enhance that experience for higher performance environments.”

- Kevin Lynch, Adobe CTO (Lynch, 2011)

3.5.1 HTML5

The Document Object Model (DOM) is constructed as soon as a browser renders a page, which is a collection of objects that represent the HTML elements on that particular page (Pilgrim, 2010). These elements can be used for specifying the different features that the designer wants to include in the web page. So, HTML5 is the language that describes web pages (http://www.w3.org/standards/webdesign/html5less) and it’s the language that brings other languages together, such as CSS, JavaScript, PHP, etc. This is not just a minor improvement of HTML4, but rather a major upgrade that is still evolving. While the primary idea of HTML was all about interconnection, the HTML5 is still about connection, and that is between rich media (McLaughlin, 2011). He further mentions that HTML5 has the chance of connecting all the different devices through the power of web. Now we don’t just connect documents via links, we can also connect audio and video. HTML5 is also a threat to Flash in some aspects and we can mention the example of YouTube which contrary to using Flash now has begun using HTML5
for video playback (https://www.youtube.com/html5). Another important addition to the functionality of HTML5 is the canvas that can be used for drawing. The canvas is an HTML tag that we can embed inside an HTML document and draw with the help of JavaScript (Rowell, 2011). We can also draw various visualizations within the canvas. The addition that caught the eyes of the developers is the ability to access mobile features. The real power of HTML5 is the combination it makes with CSS3 and JavaScript to form a bundle that creates many improvements to the technology (Freeman, 2011).

However, the latest research shows that the ability of HTML5 to allow data and code to be combined together makes injection attacks possible (Jin et al., 2014). Their evaluation showed that 478 apps were vulnerable from a total of 15,510 apps that were checked from the Android Market. They propose a patch called NoInjection for the PhoneGap framework in Android. The patch filters out the malicious code, but different attacking options are still available. That’s why it’s important to make sure that security issues are tackled in detail before any final release. Another problem is that not all the features of HTML5 are supported by all the browsers, so it’s the duty of the designer to check beforehand the availability (Pilgrim, 2010). The new HTML5 has removed some elements that are seen as obsolete (<frame>, <font>, <big>, etc), and has included some new tags such as the <audio>, <video>, <canvas> and some other (Kosmaczewski, 2012). Testing should be conducted on different browsers to ensure proper display of the web application.

3.5.2 CSS3
Removing the presentational information from the HTML and using Cascading Style Sheets (a.k.a CSS) is of great importance for web designers (Collison, 2006). By using CSS on a separate file we have higher code flexibility, maintenance ease, more control, better design, and many other benefits as well. Implementing responsive web design has never been easier than with the introduction of HTML5, CSS3 and jQuery (LaGrone, 2013). The new features of CSS3 offer a wide range of possibilities, such as different screen size adaption. With CSS3 we can build rich User Interfaces without using images, and this can enhance the speed of the website (Chuan, 2012). Sending less traffic to the mobile device when rendering the app is very critical and reducing the use of images can boost the performance.

3.5.3 Bootstrap 3
Twitter Bootstrap (short. Bootstrap) is an open source CSS framework built in 2011 by Mark Otto and Jacob Thornton, both Twitter developers (Rahman, 2014). The real purpose of Bootstrap is to help designers build web sites for different screen sizes, with a special focus for smartphone screen sizes. Bootstrap can adapt to different screen sizes by using the grid system that constructs the view into columns (Spurlock, 2013). The grid system allows flexible and dynamic adaption of the commonly known screen sizes, starting with mobile phones, touchpads, standard laptop/desktop computers, and large displays. The idea behind the grid system is to divide the screen into twelve identical columns (Rahman, 2014). However, these columns can also use a combination of
numbers which give the outcome twelve when adding up with one another. The combinations that can be used when applying the grid system are shown in Figure 8 below. To demonstrate, we can make a division of the screen into three columns by using the number four three times, because if we add the number four three times then we get the total twelve. Bootstrap has many advantages like cross-browser support, easy customized, supports useful jQuery plugins, mobile-first, etc, while cons include the difficulty to customize those jQuery plugins and all the sites using it look alike (Niska, 2014). These features are helpful when implementing a web application with mobile users in mind.

![Figure 8 The default grid system of Bootstrap (Spurlock, 2013)](image)

3.5.4 JavaScript

_Around the time of the Ajax revolution in 2005, JavaScript went from being a “toy” language to something people wrote real and significant programs with._

- Cantelon et al. (2014)

JavaScript is a scripting language that is used for transforming static web applications into dynamic, customized, personalized and interactive apps (Wilton, 2004). It’s one of the best ways of making use of the browser APIs for creating dynamic websites. The most important feature of JavaScript is that it can interact with the elements of an HTML page (Stark, 2010a). This interaction means that we can have access to the canvas element and produce various graphs. Together with HTML and CSS, JavaScript completes the “three layers” of web design, the structure (HTML), presentation (CSS) and behavior (JavaScript) which can be seen in Figure 9 (Wright, 2012). So, HTML places the structure of the website with the different elements while CSS presents those elements in an artistic and beautiful form. JavaScript on the other hand is responsible for including behavior into the static elements that are defined by HTML and beautified by CSS. It can also make use of the HTML canvas or the SVG for creating complex, static, dynamic, interactive or animated graphs (Nelli, 2013).
The power of JavaScript is that it’s one of the easiest programming languages for learning, if not the easiest. Many things can be done fairly easy by knowing very little of this language (Crockford, 2008). But, this doesn’t mean that it’s not a powerful language because JavaScript can do a lot by interacting with the DOM (Stark, 2010a). With the introduction of Node.js there is an integration of JavaScript on the server side as well. This involvement makes JavaScript a “double-edged sword” that can cut from both sides of it. We can still use it on the client’s browsers and we have the new possibility of implementing it on the server. If this is not enough to prove the power of JavaScript, we can mention that it can be used for building hybrid mobile applications too. We can build for the users of the Windows Store (Sarieddine, 2013), the Play Store (Stark, 2010a) or the App Store (Stark, 2010b) with the help of frameworks such as Sencha (Clark, 2013) or PhoneGap (Shotts, 2013).

### 3.5.5 D3.js

According to the founders of D3, it is a novel representation-transparent approach to visualization for the web (Bostock et al., 2011). To put it more simply, D3.js is a JavaScript library used for creating data visualizations. The abbreviation of D3 means Data-Driven Documents and the biggest contributor of this tool is Mike Bostock, together with Vadim Ogievetsky and Jeffrey Heer. Mike is also the creator of Protovis library, which is supposed to be replaced by D3 (Nelli, 2013). D3 takes the full advantage of the browser functionalities by manipulating the DOM for creating visualizations. Murray (2013) argues that D3.js is very easy to use by those that understand JavaScript and it’s also possible to be learned by beginners as well. He further argues that D3 is not suitable if someone needs a quick creation of a chart or a graph. However, D3 is very useful for creating complex and innovative visualization techniques for presenting different data. The official documentation and examples can be found on the d3js.org website.

This is not the only option that exists for deploying visualizations of complex data through web technologies. There is Google Charts (developers.google.com/chart/) that
allows easy creation of charts and data tools. We have Prefuse (www.prefuse.org) and Flare (flare.prefuse.org) which are almost outdated nowadays. Matplotlib (www.matplotlib.org) can be used in Python scripts for generating plots, histograms, bar charts, etc. Processing (www.processing.org) has become quite famous for artists, designers and programmers alike. We can also use Raphæl (www.raphaeljs.com) for working with vector graphics. The mentioned tools are not even half of what exists out there on the field of visualization. Many other tools exist such as ManyEyes, Circos, Knoema, Arbor.js, DataWrangler.js, R, Sigma.js, Unveil.js, NodeBox, InfoVis Toolkit, CartoDB. Most of them are useful for making interactive visualizations and graphs. Some of them even provide solutions for those that have no knowledge of coding at all. However, a few problems arise when implementing these solutions for the research at hand. They have at least one of the issues that are mentioned below:

- Lack of support for mobile devices
- No support for interactive visualizations
- Static visualizations instead of dynamic and responsive
- Redesign and editing of visualizations through coding is not allowed
- Developers’ community not available
- Missing readymade examples for novice and professional users
- Gradually becoming out of date

D3.js tackles all of these issues and it does so in style. It allows flexible coding on the offered visualization techniques. It works as a framework of one of the most popular browser based programming languages, JavaScript. It integrates with the currently trending server side language Node.js. The small drawback that can be found with D3.js is that it works with SVG and it requires some effort on getting used to it. But, this is rather a challenge than a problem. D3 provides three different advantages in contrast with Protovis, such as transformation, immediate evaluation and native representation (Bostock et al., 2011). In D3, designers can do transformation of scenes by altering only the elements and attributes that need to be changed, without computing the entire screen again. This transformation can help increase the speed of processing animated visualizations. The immediate evaluation allows more flexible control over the code exactly when the change happens, not after the system crashes. Using native elements can improve the compatibility and debugging of the tool. D3 uses selectors for identifying document elements and supports locally made changes (Bostock et al., 2011).

3.5.6 Node.js
Node.js was introduced at the European JSConf (JavaScript Conference) in 2009, by a young programmer named Ryan Dahl (Teixeira, 2012). It has already established itself as a serious programming choice for the server side development. Node.js is currently the second most watched project on GitHub and more than 15,000 community modules have already been published (Cantelon et al., 2014). It provides a purely evented, non-blocking infrastructure for building highly concurrent software. Node.js is extremely fast because it’s running on top of Google’s V8 JavaScript engine (Nguyen and Ferron, 2012). The primary purpose of Node.js is for building fast and scalable network
applications, by being lightweight and efficient at the same time. Node.js is not built to solve the problem of high computational needs, but rather for dealing with high I/O (input/output) threads. One of the main advantages is that it’s very easy to install and start coding, while third-party modules are available for those that need to solve more complex issues (Teixeira, 2012). Node also uses the Node Package Manager (NPM) for installing and managing third-party modules.

The traditional programming uses the model of completing one operation at a time. So, when the server receives a user request, it performs some I/O operation (file reading or database query) and until that operation is completed, the server is blocked from doing anything else. Multi-threading allows other processes to make use of the CPU if the initial process is waiting for an I/O operation, but the thread scheduling is a serious drawback that can make the server to crash. On the other hand, event-driven programming makes use of event callbacks that don’t block while doing I/O operations and many I/O operations may occur in parallel (Teixeira, 2012). The event loop performs event detection and event handler, both functions running in a continuous loop. When the event happens, the event handler runs without interruption, which means that one thread is running inside one process. Actually, Node has only one thread and if that thread is blocked then the entire server will hang. That’s why Node uses non-blocking I/O operations (Ihrig, 2013). For example, if Node has to read a file from the server, it starts the reading and on the meantime it processes something else. After the file is read, an asynchronous callback function that was responsible for displaying the result will be executed. Figure 10 explains it better how the event-loop of Node.js functions. As we can see, while the program is running, Node.js can execute some other callbacks. The event-loop of Node.js will keep spinning until there is nothing left to do (Wilson, 2014).

Node.js is quickly gaining recognition and it’s already being used by some big companies such as Microsoft, LinkedIn, PayPal and many other (www.nodejs.org/industry/). LinkedIn was running 15 servers with 15 instances on each physical machine without Node.js, and now it only needs four instances that can handle double the traffic for the mobile app (Ihrig, 2013).
companies shows that Node.js has a bright promising future. Some of the advantages of Node.js emphasized by Hughes-Croucher and Wilson (2012) are:

- **High-Performance Web Servers** - About a decade ago when web applications were getting started, not many people used to get online. However, nowadays we have web applications that need to support thousands of requests at once. If a user is requesting some data, Node.js doesn’t wait for a confirmation to see if the user has received it or not, but it rather continues with the next user waiting in line. This makes Node.js much faster than a traditional server.

- **Professionalism in JavaScript** - The popularity of JavaScript is very important for the development of Node.js. There are many choices when it comes to server side programming, but Node.js is chosen because almost every website developer has had to program something in JavaScript.
4 Research Approach

The EcoPanel prototype is developed as a web service that will provide insights to the consumers about their buying behaviour of sustainable food (Bohné, Zapico and Katzeff, 2015). The service contains information about ecological food and uses different visualizations to show consumption data. One of the visualization techniques used in the service is named Eco-Donuts, which was evaluated in another thesis (Dragomoiris, 2015). Overall, EcoPanel can be easily modified to meet the needs of mobile device users with the help of Bootstrap 3. Despite this, the Eco-Donuts visualization needed deeper modifications for adapting without losing its effectiveness. Thus, the prototype was modified in accordance to the needs of mobile device users and thorough details which are given in this section. A screenshot of the entire service, EcoPanel, is placed in Appendix A.

4.1 Eco-Donuts

Eco-Donuts was developed and evaluated within the scope of a thesis in relation to desktop devices (Dragomoiris, 2015). It contains consumption data of 8 different categories of food products during different months of the year. It begins by showing data of the current month with pie charts representing the categories. The included categories are shown in Swedish language as Kött; Fisk; Mejeri och ägg; Frukt och Grönt; Torvaror och annat; Godis, läsk och snacks; Bröd och såd; and Frysen (In English they mean: Meat; Fish; Dairy and Eggs; Fruits and Vegetables; Dry goods and pantry items; Sweets, drinks and snacks; Bread and corn; Frozen). The circle size is determined by the total amount of money spent for that category during a particular month. The color opacity within the circle shows the comparison of Ecological consumption versus Non-Ecological consumption, with the darker contrast representing the Ecological part. The users can navigate through the data of the different months by clicking the arrows above the pie charts.

![Eco-Donuts view on a laptop device](image)

When the user changes the month, the circles change their size and opacity according to the amount spend on that category. If the user has spent less money on a category, the circle will have a smaller radius. If the category has more money spent on it, the circles will appear bigger. The more money is spent on ecological products, the darker the color is shown in a circle. The consumption of non-ecological products is shown with
brighter color opacity. The empty categories during the months that the user didn’t make a purchase are shown with smaller circles. The colors of the pie charts are chosen in relation to the category, for example green for fruits and yellow for bread. Below the pie charts we have the names of the categories followed by the total amount of money spent for that category. Next we have the percentage of ecological consumption for that category and there’s a “plus” button which shows details at a product level.

4.2 Mobile adaptation

“We are designing for mobile people, not mobile devices.”

- Nadav and Braiterman (2007)

The sentence above fully summarizes the ideas of the research papers that are focused on design. We as designers of web services should keep in mind the target group that will be using our service. It’s not the device that will make use of our products, those are only the tools that we use for approaching the solutions to those in need. The needs of the users on the other hand should orient the development of the service/product design. While keeping in mind that we are dealing with people from various ages, the design should be informative, enjoyable and easy to use.

Information complexity is truly significant when developing for mobile devices. The smaller screen sizes can cause many difficulties for the developers. The level of detail and the presented information should be easy to identify and understand, because people may find it difficult to extract the intended message (Strengers, 2011). Although interaction is seen as an important feature of touchscreen smartphones, deploying visualizations with interaction for smaller screen sizes is highly challenging. Using interaction for the visualizations in smartphones can cause additional problems for the users. There is not enough space in the screen of the smartphones for presenting too much information within a single visualization. A compromise should be made regarding the size of the visualization and the information presented. I believe that a service should be simple in the beginning and gradually provide new features along the way, because simplicity is better (Yi et al., 2008). Lam (2008) also argues that interaction can turn out to be very costly if not used in the right manner.

Another issue may be the use of mouse hovering in triggering a certain animation on visualizations, which is not feasible for mobile devices (Heer and Shneiderman, 2012). Touching, panning and zooming are well known movement techniques for mobile users, whereas mouse hovering, dragging, clicking are used on desktop computers. When designing for both desktop and smartphone devices, a greater attention should be placed on how the design will act on the user actions. A better practice is to reduce the complexity of interaction and provide alternate ways of achieving the same result. One example may be to activate a certain animation by holding the finger longer on the same place where mouse hovering occurs. However, this may be a problem if the touch of the screen activates some other activity. That’s why it’s difficult to give general solutions that will work on services that try to implement mobile and desktop adaption.
4.2.1 Mobile-first with Bootstrap 3

The idea behind mobile-first is that the design of websites can be upward compatible. It’s much harder to design for the needs of mobile device users while keeping in mind the different screen sizes and specific native features. Bootstrap 3 provides the grid system that can design for various screen sizes. For example, if the design has a row with three columns, the mobile adaptation will have three rows and only one column. For tablet users the design can switch to three or four columns, while larger screen sizes can make use of the entire dozen columns.

Although Bootstrap 3 allows a mobile-first approach when designing responsive websites, desktop computers have some advantages that come with the bigger screen. Shrinking the visualizations to fit mobile devices is not a straightforward approach because some techniques risk losing the impact they possess on desktop computers. For example, the visualization that contains lots of text needs to reduce the size of the text, or reduce the amount of text presented. However, both solutions may not be adequate for some visualization techniques that require more text. Another issue may be to minify graphs that contain multiple columns, or charts that are formed by many slices. The more details that are involved in presenting certain data, the harder it is to fit the needs of mobile devices. It’s complicated to fit Eco-Donuts to the smaller screens without modifying the current design. The circles will be too small, and the text size will be almost impossible to read. Figure 12 shows two design models which are proposed for solving the issues of Eco-Donuts. The proposed solutions use different design elements for presenting the same information. The following subsections discuss both models in greater detail.

![Figure 12 Modified Eco-Donuts (left) vs. Alternative visualization (right)](image-url)
4.2.2 Model 1 (modifying Eco-Donuts)
The Eco-Donuts visualization is a technique for presenting data about different categories, making visual and textual comparison of them, and navigating through different months. The information of the categories is presented in circles and the more money is spent the greater the circle size becomes. So, while navigating through the different months, the size of the circle changes, the colors within the circle also change to comply with the ecological and non-ecological data. Each category has a different color that fits the nature of the category, such as the “green” color for the “fruits” category or the “yellow” color for “bread”. During some months a category may also have no data, but the design still shows a static small sized circle. The text shows data about the category name, amount of money spent for that category during a certain month and the percentage of ecological products bought during the same month. All of these features, details and animations are part of a single visualization.

In this part I’ve tried to modify the existing design of Eco-Donuts so that it fits the criteria of mobile devices. The desktop version had fixed font size for the numbers displaying the visualization. These values were adequate for desktop devices but they lacked support for mobile devices. That’s why some “if conditions” were added for changing these numbers when the device screen size appeared smaller. These conditions controlled the size of the circles, the font and the distance among each category. However, these changes were not enough because the horizontal shape of the visualization was not suitable for vertically positioned smartphone devices. We could as well force the users to change the position of the device by holding them horizontally while displaying the app, but this is not a worthy solution.

The proposed solution splits the entire design in half, displaying the first four categories on top, and the last four below them. Thus, from one row and eight columns, now we have two rows and four columns. A further division of four rows and only two columns is not an efficient solution because no comparison can be made as such. Furthermore, the proposed distribution of the design elements allows more flexibility to modify the elements. Now, the font size is increased to a more convenient format that makes it easier to read. The ecological consumption is presented with a darker color in contrast to non-ecological products of the same category. The original design had a minor difference in the level of difference in the color shade. However, in the mobile design the level of difference is increased by reducing the level of appearance for non-ecological products and thus making it brighter than the color of ecological products.

The header presents the months by initiating from the current month of the user. The modified version changes the format of displaying the month from “January” to “JAN”. This format takes less room and it’s easier to read in a mobile device. The text that presents more details about each circle is placed below each category. In the modified version, this arrangement is still the same. We could have placed the two rows of circles in the center and then place one part of the text on top and the other text below the circles. This would be better for direct comparison of the categories without the distraction of the text. However, this would be the same design mistake as the elevator buttons example that were presented in the literature review section, because the users will have difficulties on making sense of the text.
Despite modifying some of the elements, others were removed as well. The Eco-Donuts visualization had a mouse hovering interaction possible on desktop devices, but this was removed in the mobile version. Another element was the link which was placed under each category for further details. This part was also removed as for the scope of this thesis, as not to confuse the users with too much information.

4.2.3 Model 2 (alternative version)

As shown in the literature review, the user preferences have changed and they don’t mind having complicated things. But, significant importance should be placed in the level of complication, as not to frustrate the users. Despite simply evaluating the modified version of Eco-Donuts, an alternative visualization was also displayed. The new visualization presented the same kind of data, but the design and animation was slightly different. While Eco-Donuts is seen as more interactive visualization, this one is more static and up to the point. It presents the same navigation bar with much bigger left/right buttons and month display. There is just single additional information placed above the visualization. It informs the user that the green color indicates ecological products in a currency that is known to them. The assumption is that the user will automatically understand that the other color displays information about non-ecological products. The display of the total money spent on a single category is also removed. The percentage is seen as an excess in this design because the color difference is more vivid and it makes it easier to differentiate between ecological and non-ecological consumption.

The numbers that show the amount of money spent on each category are placed in the according arcs. There was also a modest animation that would make it more appealing to the users. It shows a fade-in fade-out effect on the circles when changing the months. When a user changes the month, the circles with all the information fade-out, and then the circles gradually fade-in with new information on them. But, the size of the circles is the same for all categories and this makes it harder to calculate which category was mostly consumed. The empty categories had no circle at all and they presented a number “0” which indicated that there was no consumption. The order of the categories is also different in comparison to the previous modified version. It has three categories on the first two rows and two categories in the last row. This formation allows more space to be used and the visualizations could be made bigger. This ordering is not possible in the first modified version because it has much more text to display.

It’s more beneficent to have two different models presenting the same information, with more or less text details and animation complexity separating them. This comparison offers the user an idea of what is good and bad, what is possible to implement or modify. It was up to the users to decide which features are better, and what should be further modified. Both models were evaluated by users during the conducted usability testing which will be explained in the following subsection.

4.3 Implementing the Usability Testing

The usability testing focused on extracting feedback on the easiness to perceive the intended information and teaching the right message. It was concentrated in the sense of meeting the requirements of eco-visualizations in the particular case of sustainable food
consumption. It’s important to mention again that the desktop version of the service, with emphasis on the Eco Donuts visualization, was already evaluated in another thesis by Dragomoiris (2015). He showed that the technique is successful in providing insights on complex data concerning food consumption. The difference in this thesis is that the evaluation is done on two slightly different models that are adapted for mobile devices. The first is an adapted and modified mobile version of the same visualization (Eco Donuts), while the other is an alternative visualization that presents the same information with different visualization techniques. Both techniques are evaluated from the participants in this study.

Researchers have used various approaches for implementing the usability testing on eco-visualizations. Some have used surveys to test the knowledge of the users without any actual implementation, while others have chosen to give the users a month or so to try the prototype and then do the survey. Somewhere in between there are researchers that have allowed enough time to shortly experience the prototype before doing the survey. I decided to conduct a more balanced approach of combining experience and feedback. A combination of qualitative and quantitative questions is seen as ideal for answering the research questions.

It’s worth noting that the issue of user experience is a highly subjective matter and thus it’s highly important to do usability testing with real users instead of experts or softwares. I preferred using the “think-aloud” method proposed by Reiss (2012), so that new questions can be asked while the participants are using the application. This is valuable for taking notes on what difficulties or suggestions they have on the instant that they test the app. The users were encouraged to test the app from their own mobile devices (Banovic et al., 2014), thus the solution is assessed by different operating systems, browsers, screen sizes, etc. The detailed guidelines provided by Rubin and Chisnell (2008) were very helpful for preparing, running and evaluating the usability test. The data was analyzed through the Video Data Analysis method which is described in the final subsection.

**4.3.1 Participants**

People with diverse backgrounds were selected for the evaluation of the solution, all living in the city of Gostivar, FYR of Macedonia. I had a total of 13 participants, 12 included in the analysis and 1 being part of the pilot testing. The participants were recruited through direct phone calls, emails and social media contact, while keeping in mind their knowledge of the English language, because the presented information and the test are in that language. All the participants are Albanians and their native language is the Albanian language, but the English language is taught during primary school and high school as a second language. Having previous knowledge about ecological products and sustainable food consumption is favorable but it’s not a requirement because details of the ecological importance are given in the application. Moreover, the final mission of the service is to grab the attention of a wider range of user group and visualize their buying behavior in relation to ecological products. That’s why no recruitment test was done for filtering the participants, except the requirement of the English language and the possession of a smartphone. The participants were mainly
students, ranging from 16 to 25 years old, with an average of 21. Half of the participants were employees or self-employed. The temporary link of the service, ekopanelen.mod.bz, was sent to all of them and they were encouraged to use their own mobile phones for accessing the service. They were allowed to play up to 5 minutes with the app before doing the survey, which made them feel more comfortable. It’s worth noting that the identity of the participants remains anonymous throughout the survey and they were not given any incentive for participating. The main difference between the experiences of each user is the fact that they used their own mobile phones. This is very important for the development of the app because we got feedback from different smartphone models and thus ensured that the app is usable from a wider range of devices. It’s worth mentioning that the data used for the visualizations was not their personal consumption data, generated data was used instead. However, all the participants had access to exactly the same data and this was very important for the questions that were followed in the survey.

4.3.2 Data Collection
A pilot testing was completed before the actual usability testing. The pilot testing ensured that everything works well and the real testing can be conducted as planned. The pilot testing had a single volunteering participant which was not later on included in the actual testing. Many improvements were made to the test plan and thus it’s highly recommended to have a pilot testing (Rubin and Chisnell, 2008). It’s worth acknowledging the fact that this usability testing is part of a thesis, and so the budget and possibilities are limited in a certain extent. Therefore I had to take the role of the camera guy, moderator, interviewer and controller. This brought the need of doing a video recording that will be accessible for later analysis so that critical information wouldn’t be lost during the process. The most important task was to make sure that each session runs smoothly, implement the “think-aloud” method and take notes.

The participants were requested to appear at the office of Lucky Media Inc, a design and printing house in the city of Gostivar, FYR of Macedonia. I had full control to prepare the room for testing and provide comfortable room settings. The time schedule for each participant was booked with respect to their availability by using Doodle7. The survey took place on Saturday and Sunday, 12-13th of September, 2015. Having the survey during the weekend is valuable for removing the possible distractions and the participants were available as well. The computer was already turned on and the survey was already loaded.

7 http://doodle.com/
A Sony HXR-MC2000E camera was used for recording each participant during the testing process. The recording had full high-definition quality and the light in the room was adjusted for better quality. The participants were notified that the recording will only be used for extracting useful patterns and analyzing the behavior of the users while testing the app. The recordings were not labeled by the name of the participant, but rather by the order of each participant (P2 for the first participant, until P13 for the last one). The angle of the camera was from behind the back of the participants and their face was not inside the recording frame. This was useful firstly for the comfort of the user and secondly for recording their interactions with the mobile device. There were some apps that provided screen recording and different feedback for implementing usability testing. However, there were many obstacles as some services didn't have support for web apps, or they only provided camera recording towards the user’s face, or they were too expensive. Another problem was that the apps were not compatible with all the different mobile devices. One solution was to install such an app in three distinct mobile devices (running iOS, Android and Windows Phone), but this would add a burden for some users to adapt to the new device. Thus, the camera was used as a substitute for documenting the user’s behavior, despite the greater efforts required from the researcher. The camera was placed in an angle that makes it possible to record the user’s actions for later analysis, as can be seen in Figure 13.

The users were asked beforehand to bring their smartphones for completing the evaluation. They had to change their network to airplane mode so that they wouldn’t be interrupted by a phone call or short messages. However, they had to turn the Wi-Fi on for accessing the web application through their mobile browsers. Thus, other apps like Viber or Whatsapp could still interfere or distract the user. A fast and reliable internet connection was already provided through the Wi-Fi connection of the facility. The table below shows more details about the type of devices used for testing the app. We can see that almost all the users, except two of them, had different devices. The screen size ranges from the tiny 3.5” up to the bigger 5.7” screen, with the average being 4.6”. The users were not restricted to the type of browser to use as the application should be able to run on different settings. It’s worth noting that none of the devices had any difficulties on using the application. There was a slightly noticeable design difference on the bigger screen of the iPhone 6+ and the Samsung Note 4.
The service began by asking the users to log in with the “userid” and “password” that was given to them beforehand. The homepage contained different visualization techniques that present sustainable consumption data of a typical customer in a supermarket. However, the main point of this thesis is to reflect the effectiveness of the adapted visualization models for the mission of providing consumption insights to mobile device users. The visualizations included the modified version of the Eco-Donuts visualization and the new alternative version that fits the same criteria. Both models had the same data, a total of eight food categories that were visualized for a time scale of twelve months. The study was focused on the data gathered from January and up to September, which could be manipulated through the navigation bar. The main objective was not to confuse the regular user by having many differences between the desktop and the mobile version. Thus, both visualization techniques looked similar, with slight changes in navigation design, color, circle size and animation.

For better results, the questions were presented in a desktop computer, with the help of Google Forms. This allowed the users to look at the question on the computer monitor and search for the answer in the app on the mobile device too. The survey contained open and closed ended questions regarding the sustainable food consumption information that was presented on the visualizations. The survey was accessible online because it was developed entirely by the Google Forms service. The data was later embedded within the automatically created Google Spreadsheet file that is provided by the service. The questionnaire was divided into three main parts:

A. Personal Information

<table>
<thead>
<tr>
<th>Participant</th>
<th>Model</th>
<th>mobile OS</th>
<th>CPU</th>
<th>Screen size</th>
<th>mobile browser</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Cubot x12</td>
<td>Android 5.1</td>
<td>Quad Core 1.0 GHz</td>
<td>4.3&quot;</td>
<td>Native browser</td>
</tr>
<tr>
<td>P2</td>
<td>Samsung S III</td>
<td>Android 4.3</td>
<td>Quad Core 1.4 GHz</td>
<td>4.8&quot;</td>
<td>Chrome v35.0</td>
</tr>
<tr>
<td>P3</td>
<td>iPhone 6+</td>
<td>iOS 8.4.1</td>
<td>Dual Core 1.38 GHz</td>
<td>5.5&quot;</td>
<td>Safari</td>
</tr>
<tr>
<td>P4</td>
<td>HTC One XL</td>
<td>Android 4.4.4</td>
<td>Dual Core 1.5 GHz</td>
<td>4.7&quot;</td>
<td>Chrome v45.0</td>
</tr>
<tr>
<td>P5</td>
<td>iPhone 4s</td>
<td>iOS 8.4</td>
<td>Dual Core 1 GHz</td>
<td>3.5&quot;</td>
<td>Safari</td>
</tr>
<tr>
<td>P6</td>
<td>Samsung S5</td>
<td>Android 5.0</td>
<td>Quad Core 2.5 GHz</td>
<td>5.1&quot;</td>
<td>Chrome v45.0</td>
</tr>
<tr>
<td>P7</td>
<td>Lenovo a536</td>
<td>Android 4.4.2</td>
<td>Quad Core 1.3 GHz</td>
<td>5.0&quot;</td>
<td>Opera v30.0</td>
</tr>
<tr>
<td>P8</td>
<td>Samsung Ace 4</td>
<td>Android 4.4.4</td>
<td>Dual Core 1.0 GHz</td>
<td>4.0&quot;</td>
<td>Chrome v45.0</td>
</tr>
<tr>
<td>P9</td>
<td>Samsung Note 4</td>
<td>Android 4.4.4</td>
<td>Quad Core 2.7 GHz</td>
<td>5.7&quot;</td>
<td>Native browser</td>
</tr>
<tr>
<td>P10</td>
<td>iPhone 5s</td>
<td>iOS 8.4.1</td>
<td>Dual Core 1.3 GHz</td>
<td>4.0&quot;</td>
<td>Safari</td>
</tr>
<tr>
<td>P11</td>
<td>iPhone 6</td>
<td>iOS 8.4.1</td>
<td>Dual Core 1.4 GHz</td>
<td>4.7&quot;</td>
<td>Chrome v45.0</td>
</tr>
<tr>
<td>P12</td>
<td>Samsung Alpha</td>
<td>Android 4.4.4</td>
<td>Quad Core 1.8 GHz</td>
<td>4.7&quot;</td>
<td>Native browser</td>
</tr>
<tr>
<td>P13</td>
<td>iPhone 5s</td>
<td>iOS 8.4.1</td>
<td>Quad Core 1.3 GHz</td>
<td>4.0&quot;</td>
<td>Safari</td>
</tr>
</tbody>
</table>

Table 1 Technical details of the devices used for testing
B. Visualization Part
   a. Visualization Model 1 (adapted version of Eco Donuts)
   b. Visualization Model 2 (alternative version)

C. Final Remarks
The questions from the survey were chosen on the basis of answering the research questions, as well as allowing the opportunity of tackling other issues that the users may come up with. The questionnaire starts by acquiring some personal information with the intention to record some background data about the users. The Visualization Part had the most important questions challenging the user’s understanding on the information that the visualization presents. This part was divided into two subsections, one for each visualization model. The partition allowed for more specific questions to be asked. I want to make it clear that the survey was used to understand which elements are more preferred by the users. Different questions were used for both models and the results were compared among Eco group and Non-Eco group, and not between Model 1 and Model 2. The constraint of testing and comparing the models are explained in chapter 6. A couple of open-ended questions in the end were not mandatory as not to force the user into giving their opinion without their own will, while closed-ended questions were all mandatory. The results from the survey can be found at chapter 5, while a screenshot from the entire survey is placed in the Appendix B. Below is the list of all the major questions that were asked in accordance with our research questions:

**Visualization Model 1 (adapted version of Eco Donuts)**
1. What do the letters SEP indicate?
2. What does the bigger circle mean?
3. Which category has the greatest % of EKO during May?
4. Which product group was not bought at all the last six months (until March)?
5. Look at the Fruits category on August, what does the part with dark green color indicate?

**Visualization Model 2 (alternative version)**
6. During July, which of the purchased products had less ecological kind?
7. Look at the Bread circle during April, what does the “99” mean?
8. The last four months (until June), which product was not bought at all, except Meat?
9. Which category/ies are purely ecological during some months?
10. During which month besides September, three types of products are not bought?

Eco-Donuts is only a part of EcoPanel and there are many explanations that guide the users throughout the service. I wanted to note if the users can understand Eco-Donuts only by reading the information that was presented to them. Thus, I didn’t give...
any further explanation about the meaning of the elements on both presented models. Up to 5 minutes of app usage before doing the survey was seen as a sufficient duration to understand the elements and answer the questions.

Although the questions do look up to the point, they have an indirect meaning. For example, if most of the users fail to understand that the darker color presents the percentage of ecological products (question 5), it means that there is something wrong with the design. Either the color shades level is too narrow for being spotted by the users, or the color differences don’t succeed on presenting the point of ecological vs. non-ecological importance. These indirect questions are intended at challenging the users’ intellect so that the user provides more suggestions on what should be improved or modified in the visualization models.

Despite the online survey, the moderator was asking questions and taking notes during the entire session, trying to motivate the user to “think-aloud”. This method is useful for finding unpredictable patterns and design ideas that could come up from the user’s initial experience. However, most of the participants were concerned on solving the tasks perfectly and they were very focused on that. They shared their opinion only amid answering the final questions of the survey.

4.3.3 Data Analysis
The analysis of the data was organized into two separate parts. The first part has data gathered through the survey which was completed at the Google Form service. The survey was automatically collecting answers and the data was generated in another file, Google Spreadsheet document. The second part was more focused on video data analysis by observing the behavior of the participants during the session. Both parts had their qualitative and quantitative data output which was helpful for further pattern extraction. The survey had the qualitative and quantitative questions while the video analysis had the users’ think-aloud comments and the statistics on using the app.

The data from the survey was firstly analyzed from a quantitative view by analyzing different statistics. The Google Spreadsheet app offers the possibility of visualizing the acquired data and other statistical calculations are also possible. Some of the most valuable graphical outputs are imported in this documentation as well. Statistical calculations include formulas such as the average, mode, minimum, maximum, standard deviation from the mean, percentages, etc. All quantitative questions were required to be filled by the participants, in contrast with the qualitative part. Nonetheless, the feedback from the qualitative questions was also analyzed for understanding the difficulties and suggestions of the participants.

The video materials were prepared with the software Adobe Premiere CS6 and the output was encoded in appropriate video formats such as mp4. The recording of each participant was filtered from the useless material and each question was put into a different video file for easier comparison. This allowed a more comprehensive approach to analyze the time duration of each question, count number of interactions with the device, catching errors and other useful patterns. This was a rather long and time consuming process which had to be done for having objective results. Video data analysis is safer for a one-man team, but instant data analysis is the preferred method for teams.
There was also a combination of both data formats for performance data analysis, for example counting the errors and task accuracy, combined with the time factor. This kind of data is useful for understanding the difficulty of the task completion which can lead to further enhancement of the solution. The metrics used in this section are:

- Task Accuracy
  - Successful Task Completion (STC)
  - Successful Task Completion with Assistance (STC-A)
  - Required Assistance (RA)

- Task Duration
  - Mean of Time to Complete (MTC)
  - Standard Deviation of Completion Time (SDCT)

- Task Interaction
  - Total Interactions (TI)

- Errors
  - Critical Errors (CE)

The STC presents the participants that have successfully completed a particular task, in contrast with those that have given wrong answers. The STC-A shows a slightly different group of people, those that have required some assistance while doing the task. We will also show the total number of participants that have required assistance. Thus, we can see how many didn’t solve the task even with assistance. The MTC will show the average time of completing one particular task by the participants, as well as the total average time of completing the entire testing. SDCT will act as a controller of the time differences between each participant. This exposes the level of time distribution for more accurate results. Furthermore, the TI will count the number of times the users have interacted with the app while completing a task. The interaction includes actions such as navigating, scrolling, touching and zooming. Hopefully there will be no critical errors to display, but nevertheless they will also be recorded if they appear.

The survey participants were categorized into two groups, Eco and NonEco. The separation was done according to the answer given in the question “What do you think sustainable food products are?” Thus, we could see which users had it clear what the term “sustainable food product” means. The assumption is that users having prior knowledge about the tackled topic will perform better.
5 Findings
Real users evaluated the solution in the context of how informative and understandable it is. No matter how many tests will be done on users, there is a great chance that not all usability issues will be found (Myers, Sandler and Badgett, 2011). But, this doesn’t mean that an evaluation shouldn’t be implemented at all. It rather shows that our focus should be on fixing the major issues and making sure that a greater amount of users are able to use the application effectively. The subsections below present a detailed explanation of the findings and feedback from the usability testing. The goal was to find patterns that will help on answering the research questions raised in the beginning.

5.1 General Quantitative Statistics
This part contains some general statistics that can be extracted from analyzing the quantitative part of the data. It’s a true coincidence that only half of the participants answered correctly the question about sustainable food products. Thus, we have 6 people in the Eco group and 6 in the Non-Eco group that we mentioned previously. We will categorize the other answers in accordance with these two groups. We will explain only the questions that had more differentiating feedback and the reasoning behind their choices is valuable. But, we will omit the detailed explanation of those questions that were solved by the majority. The graph on Figure 14 presents a comparison among the answered questions. The comparison is valid between the Eco vs. the Non-Eco group, and not between Model 1 and Model 2. The darker colors represent the Eco group while the lighter colors are for the Non-Eco group. The first five questions are in regards with the first visualization model, while the final five evaluate the second visualization model. The left part shows the wrong answers while the right side corresponds to the correct answers. Questions 1-5 and 6-10 correspond to the already presented questions in the sub-section 4.3.2. This figure is used for understanding the efficiency of the elements on both models by comparing the results between the groups. Generally, there are questions that are easily solved by both groups and there are tasks where one group performed better than the other.

For the modified Eco-Donuts, the initial questions revealed that the users had a clear understanding of the function of the navigation bar. The percentage was also recognizable from the written text below the circles. Meat was the only category that was not bought during the last six months, and the users could spot the difference. The color difference among the ecological vs. non-ecological consumption was recognized by the majority of the users. The only problem was to understand why there is a difference in the circle sizes, while half of the users made a mistake on this one. The users couldn’t agree about the determinant for this change, is it the total money spent or the ecological part. However, I believe that spending some more time with the visualization will provide better results as the revealed information will be understood better.
Continuing with the next part about the second visualization, we have even more complicated answers. Users from both groups couldn’t agree on which bought product had less ecological kind. The Dry Goods category had less than one percent of ecological consumption, while its neighbor Sweets on the right had zero percent, see Figure 15. This means that the numbers placed on the visualization didn’t make much sense to them. The same was confirmed with the following question when the users couldn’t understand what the numbers mean, although there was a short legend on top of the visualization. However, the color difference was straightforward to understand as confirmed by the remaining questions. The most ecological product and the products that are not bought at all were also solvable issues. This implies that the users need more information for understanding the visualization data presented in the second model.
The users were generally satisfied with both visualization models, while rating slightly better the modified Eco-Donuts. As far as this model is concerned, the color element was the most attractive and the revealed information was sufficient. Half of the participants were fond of the circle size changes as well, but there was no admiration for the navigation bar and the font size. The new alternative model had different feedback on the same features. In contrast, the circle size was unanimously approved by the majority of the participants, except two of them. The same is true for the font size. However, the other elements had less admiration by the users, with the revealed information being the better of the rest with 5 admirers. This general evaluation has revealed that the users want more colorful visualization, with more information, bigger font and greater circle sizes. More detailed statistics and graphs can be found in the Appendix C.

5.2 Analyzing Data

This section uses a combination of the previously mentioned statistics, the time spent, the needed interactions and the required assistance while solving the tasks. I’ll try to analyze and find patterns that provide some meaningful information out of the raw data. However, for further analysis of the responses the Appendix C contains graphs and statistics that present different types of patterns with the same data.

As far as the STC is concerned, the Eco group does better by only one participant for almost each question, which is not a huge difference. However, Figure 16 shows us that the Eco group scored 4 more answers on both models. The STC-A also shows a fair distribution of points among both groups for the first model, but on the second model Eco group does better. However, the RA shows us that only one participant from the Eco group couldn’t solve the task of Model 2 even after requiring assistance. But, for the Non-Eco group we have more participants asking for help and six of them weren’t able to solve the tasks on both models. Most of them had difficulties on the first model. The sixth question has the worst solving record on both groups, with one participant also asking for help (Question 6: “During July, which of the purchased products had less ecological kind?”). This explains the request of some participants to have more information on the second model. Almost the same record is for the second question, while adding to the fact that two participants solved the task only after asking assistance (Question 2: “What does the bigger circle mean?”). From these data we can further confirm that the circle size representation of Eco-Donuts was not understandable at first. Maybe substituting the fifth question with the second one would have given better results, as the users would have paid more attention to the meaning of the color.
difference (Question 5: “Look at the Fruits category on August, what does the part with dark green color indicate?”).

![Figure 16 Comparing the metrics for Eco vs Non-Eco group](image)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th></th>
<th>Model 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STC</td>
<td>STC-A</td>
<td>RA</td>
<td>MTC</td>
</tr>
<tr>
<td>Eco</td>
<td>26</td>
<td>7</td>
<td>7</td>
<td>160</td>
</tr>
<tr>
<td>Non-Eco</td>
<td>22</td>
<td>7</td>
<td>11</td>
<td>155</td>
</tr>
<tr>
<td>Eco</td>
<td>24</td>
<td>8</td>
<td>9</td>
<td>180</td>
</tr>
<tr>
<td>Non-Eco</td>
<td>20</td>
<td>5</td>
<td>7</td>
<td>209</td>
</tr>
</tbody>
</table>

The MTC of the total duration of the questions presents the average time in seconds that is needed for solving all the tasks of a particular model. The findings show that both groups needed approximately 2.5 minutes to solve all the tasks of Model 1, so there was no difference among the groups. However, as far as the second model is concerned, we see that the Eco group needed less time to complete the answers in comparison with the Non-Eco group. It required 3 minutes from the Eco group and 3.48 minutes from the Non-Eco group to solve all the questions. Thus, having prior knowledge about sustainable food consumption shows a fractional positive difference in this case as far as the second model is concerned.

The SDTC is not much different for both groups on the second model. However, the Non-Eco group has a lower standard deviation on the first model. This means that the Non-Eco group had less divergent spreading of the time for solving the tasks. Further analysis of the data showed that the time factor can produce some significant findings, presented in Figure 17. All the users were given up to five minutes introduction time for getting familiar with the application, but they decided that one or two minutes are enough. Although the average time spent by the Eco group was 85 seconds, participant number 6 solved only 6 tasks, besides spending 90 seconds with the app. It’s worth noting that the average score for this group was 8.3 correct answers, which shows that overall the group did well. The Non-Eco group in the other side had only 7 correct answers on average, with 120 seconds spent with the application. Again we have a complication, because the participants number 5 and 7 scored 6 successful tasks each, the former spending a record of 275 seconds with the app and the later spending 180 seconds. This further indicates that spending a few minutes with the app doesn’t necessarily provide better results. As noted by the literature review, spending a few days with the application provides more reliable results, which was not feasible during this master thesis.
The most diverse results come from the TI where the Eco group needed fewer interactions to complete the answers of both models. Diving deeper into the data, each Eco group user needed an average of 63 interactions to complete all the tasks, and 83 interactions are needed for the Non-Eco group. As far as interactions are concerned, the Eco group seems to have the edge.

There were no significant errors during the entire usability testing. Minor issues such as entering the correct user id and password, as well as finding the required visualizations models are not issues that may influence the usability testing.

5.3 Qualitative Feedback
Solving tasks aside, the users were also encouraged to provide some suggestions and critiques regarding the visualization techniques. They explored the application for a couple of minutes and “think-aloud” was planned to be implemented in this phase. But, the application had other features as well and not all the users were fond of talking at that time. Nevertheless, they were pleased to share their final impression after completing the usability testing. Thus, the “think-aloud” method was not entirely implemented on all users, and the procedure in the end was more similar to an interview. Analyzing the qualitative feedback from the initial experience and the final suggestions gives life to the quantitative findings that were extracted in the previous subsections. This part provides the stories behind the scenes, the difficulties and the reasons guiding the choices that were made.

The “think-aloud” method didn’t prove to be useful as expected because the participants looked shy in the beginning and they continued with the survey while feeling that the visualizations looked fine, in particular the Eco-Donuts model. Some participants considered that Model 2 needed a change of color, while they liked the colors and the animation of Eco-Donuts. These were a few first impression comments that could be recorded, while much more detail was provided in the final stage of the survey.

The question “What would you change at Model 1 (2)?” proved to be quite a success for extracting qualitative feedback. Most of the users were keen on delivering some suggestions and critiques for further development of the presented models. As far as the first model is concerned, most users emphasized the need for having a greater font size at the presented information, although the font was easy to read. The same thing was with the size of the circles which didn’t meet the full expectation of the users as they wanted a bigger radius. However, this is not possible with the current design.
changes, because the circles will interfere with one another. A few participants proposed a change in the colors that presented the different visualization techniques, as they wanted a better combination of colors. However, the results from the survey showed that these were not major issues because the users could still solve the tasks. The thing that is more important is the fact that the users couldn’t understand what the numbers mean. For example, having a number and a currency value below the category name implies the total money spent on a category, but it also may be the total money spent on ecological products for that particular category. Their proposed solution was to have a column on the left side that will make the information more clear. For example, we could have the first column saying “Total:” and on the following columns we could understand that the numbers are representing the total money spent. On the next row we would have another hint saying “EKO:” and the next numbers would only be the percentage. The same can be implemented for the names of the categories. The other issue is the meaning of the color difference within a circle representing a category. Most users understood that the darker color represents the EKO percentage only after spending more than half a minute looking at the circle and the data. Then, they pointed out the need of having a legend on top that describes the color difference. Overall, the first visualization was eye catching to most users and they liked the colors, the animation and the overall organization. However, from the qualitative feedback we understood that it’s better to have more information that explains the data of the visualization.

The second visualization is much more static in comparison to the first visualization and it has less data. The category names are still there, but the total money spent is represented by showing the money spent on both products, ecological and non ecological. The other difference is that the percentage is expressed only in the color difference within the circle, one arc representing the ecological products and the other arc the non ecological. This was clear to most users, as they are more used to these kinds of visualizations. They also liked the legend on top which mentioned that the green color indicates the “Ecological consumption in den” (explanation: denar is the currency in FYR of Macedonia). However, although they understood that the green color represents ecological consumption, they were continuously forgetting what do the numbers inside the circle mean. This clearly shows that the users need a more clear indication of the presented information. One solution may be to have “den” on each number, and another solution was proposed by a user, inserting two buttons that will allow the user to switch between “Percentage” and “Money”. The most disliked element of this model was the combination of the colors between ecological and non ecological representation. Another problem was that the categories that were not consumed during that month were represented with a zero and no circle was shown. This made it easier to understand which category was not consumed at all during that month, but the participants thought that it destroys the design. The suggestion is to use the technique of the desktop version by placing a smaller circle, or a circle with the same size but a different color in comparison to the ones that are purchased. Overall, the participants felt that this visualization technique was much easier to understand, but there is the need for a better color combination.
To sum up the qualitative data, we can say that the participants provided some really good feedback. The ideal visualization for them is one that has more information like the first model, but with a bit more explanation offered for that particular information. They want a legend on top describing the color differences as in the second model. The various color differences among categories in the first model are definitely eye catching and should remain part of the design. The organization of the categories and the circle sizes of the second model are more desired. This proposed visualization technique is feasible and it can be implemented with the same technological solutions, but it will also need a further usability testing to assess the new design.
6 Discussion and future work

The thesis belongs to the field of HCI, more precisely the mobile HCI area. I have touched upon some of the research projects that deal with visualization techniques of data through web technologies for mobile devices. A modest user evaluation was done for testing the visualization techniques for presenting information about sustainable food consumption. Evaluating information visualization is seen as a very difficult task to do (Ellis and Dix, 2006). This thesis was more concerned with the issue of using the best practices for visualizing data through web technologies for mobile devices.

The usability study was not conducted with people that will actually use the website. The data was not their own personal consumption data and the focus was only on the Eco-Donuts visualization. The questions were different for both models and no identical questions were used. All the users were required to answer the tasks on both models. Thus, the current approach doesn’t provide a comparison among the models. I could only evaluate the different design elements on the models. This initial usability testing doesn’t show which model is more effective and efficient from the answers given on the required tasks. It shows which features are easier to understand and discusses them thoroughly during the interview. There is the need of doing another usability testing where two groups of users are given a separate visualization model. The survey with questions on that specific model is conducted after a few months of using the app. The questions are the same for both models and comparison can be made to understand the efficiency and effectiveness of each model.

The framework of Froehlich (2009), which was mentioned in the literature review, can also be applied to the use case of this thesis. Grouping and filtering is useful, but the visualizations already present grouped and filtered information. The most beneficial aspect is the presentation medium and location because the user can check the web application anytime, and it can do so from his mobile device as well. The data can also be compared with other users and shared on social sites.

The modified version of Eco-Donuts required some significant design changes for meeting the needs of mobile device users. These changes include the shortening of the categories by presenting less information, such as the change of “Dairy and Eggs” to “Dairy”. This was a short term solution as far as the thesis is concerned. A more appropriate solution might be to show a mutual icon which will represent both categories, and the icons will be explained in the legend above the visualization. Another approach may be to use a compound word that will present both products, an example may be to write “DaEg*” and explain “* Dairy and Eggs” in the legend.

One major improvement on the Eco-Donuts visualization technique may be to provide a mobile version that will act slightly different from the desktop version. For example, there could be an animation that will be triggered by touching one of the circles presenting the categories. This animation would resize the circle by making it bigger and thus the user could see more details regarding that particular category. Then, another touch of the resized circle would restore the previous size and allow the user to easily compare the categories. This implementation requires much more work on the coding part as well as new usability testing to see how the users will react on that particular animation.
7 Conclusion

The contribution of the thesis is on digging into the research of two different areas that can complement themselves, for supporting designers with some insight on the subject. First, research is done on the existing possibilities, challenges and problems of visualizing in a mobile device with current web technologies. Second, there is an investigation of the kind of changes in the information complexity and usage that are needed for presenting data about sustainable food products in a web application for smartphone devices. The research brings together various findings that show the highways and dead-ends on the road of using visualizations for mobile users. However, the focus was more on visualizing for the consumers of sustainable food products.

EcoPanel is a prototype developed for providing data about organic food consumption using visualization tools. The project uses the D3.js JavaScript library for designing the visualizations and Node.js renders the JavaScript files on the server. Bootstrap 3 is used for the mobile adaptation of the desktop design. The literature review showed that the combination of these web technologies is also feasible and preferable when developing for mobile devices, which answers the first sub research question (“Which web technologies or tools can be used for building visualizations of complex data for mobile phones?”). Other possible tools were also presented during this thesis.

Testing the application on different devices, operating systems, browsers and screen sizes was successful on all of them. This further confirms the use of the same combination of technologies for visualizing data on mobile devices. The benefit of using these technologies was at the straightforward application loading, without further installation and support for different devices. The developer’s greatest advantage is at using the exact same code without additional development for the specific operating systems. There are two other approaches when developing for mobile devices, hybrid or native, and I showed the advantages of using the web approach. This answers the second sub research question which states “What are the benefits and issues of using web applications for developing visualizations for the specific requirements of mobile devices?”.

EcoPanel consists of many features and visualization techniques, such as the Eco-Donuts visualization. However, the original Eco-Donuts model was not suitable to meet the needs of mobile device users. Thus, two models were proposed for solving this issue. The first uses the same features of Eco-Donuts, with the only major difference being the ordering of the categories that were presented. From one row and eight categories, we have two rows and four categories. Other changes included the font size, the diameter of the circles, the level of color differences, as well as the removal of the mouse hovering feature. In contrast to this interactive visualization, there was another model which appeared more static. That prototype included less text details, more vivid color contrasts, bigger diameter of the circle, and a different organization of the categories.

Feedback from the usability testing of the two models provided intriguing patterns and suggestions, hence presenting solutions to the raised research question. The design changes require elements that are easier to see and manipulate, in our case bigger circle sizes and font sizes, more vivid color contrasts, eye catching design with beautiful color
combinations and attractive animations. The Eco-Donuts adapted model was preferred for the animation of the circles, the color combinations and the presented data. The other model was liked for the bigger circle sizes, font sizes and a better contrast of color differences for comparing the Eco vs. Non-Eco. Improved Eco-Donuts may have a different formation of the categories which will allow having bigger circles, less text but more information, and different colors for in-circle comparison in contrast to the opacity of the color. This part shows the design changes that need to be considered when deploying for mobile devices, which was the concern of the third sub research question (What kind of information complexity and design changes are needed for adapting the presented information and visualizations to the different screen sizes?).

As far as the information complexity is concerned, the participants stressed the need for less data but more information. This means that the visualization shouldn’t be filled with data, but it should have valuable information that is clearly identified with hints and legends on the side. The majority of the tasks were completed successfully, which implies that both visualizations provided insights about the organic food purchase patterns. However, some tasks were also harder to solve, and that further emphasizes the need for a longer duration of app usage before the usability testing. Overall, the visualization techniques were engaging and pleasant for the participants and both models were desirable for them. The positive results on the Successful Task Completion and other metrics show that there is some signal of insight from this initial usability testing, which is part of the last sub research question (“Do the adapted Eco-Visualizations for mobile devices address the aim of providing insights to the consumers about their organic food purchase patterns?”).
References


Kim, T., Hong, H., & Magerko, B. (2010). Design requirements for ambient display that supports sustainable lifestyle. In Proceedings of the 8th ACM Conference on
Designing Interactive Systems (pp. 103-112). ACM.


Kjeldskov, J., & Skov, M. B. (2014, September). Was it worth the hassle?: ten years of mobile HCI research discussions on lab and field evaluations. In Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services (pp. 43-52). ACM.


Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat (pp. 1-8). ACM.


Roto, V., & Oulasvirta, A. (2005, May). Need for non-visual feedback with long response times in mobile HCI. In Special interest tracks and posters of the 14th international conference on World Wide Web (pp. 775-781). ACM.


Appendices
Appendix A  Application View on a Desktop Device

Figure 18 Web View of EcoPanel
Appendix B  
Survey Tasks

**Q1:** What do the letters SEP indicate?  
   a) Software Engineering Professionals  
   b) September  
   c) Nothing  
   d) Other

**Q2:** The bigger circle means:  
   a) More money is spent  
   b) More ecological products are bought  
   c) It’s only a choice of design  
   d) Other

**Q3:** Which category has the greatest % of TK0 during May?  
   a) Meat  
   b) Dairy  
   c) Bread  
   d) Other

**Q4:** Which product was not bought at all the last six months (from September to March)?  
   a) Meat  
   b) Frozen  
   c) Fish  
   d) Other

**Q5:** Look at the Fruits category on August, what does the part with dark green color indicate?  
   a) Money spent on Fruits  
   b) It’s only a choice of design  
   c) Ecological consumption of Fruits  
   d) Other

**Q6:** During July, which of the purchased products had less ecological kind?  
   a) Dairy  
   b) Dry Goods  
   c) Sweats  
   d) Other

**Q7:** Look at the Bread circle during April, what does the 99 mean?  
   a) Just a number  
   b) 99 den spent on ecological products  
   c) 99 % spent on ecological products  
   d) Other

**Q8:** The last four months (until June), which product was not bought at all, except Meat?  
   a) Fish  
   b) Frozen  
   c) Sweats  
   d) Other

**Q9:** Which category/ies are purely ecological during some months?  
   a) Fruits  
   b) Bread  
   c) Dry Goods  
   d) Frozen  
   e) Other

**Q10:** During which month besides September, three types of products are NOT bought?  
   a) March  
   b) July  
   c) January  
   d) Other

*Figure 19 Questions for the first model (Q1-5) and for the second model (Q6-10)*
Appendix C  General Data and Statistics

Figure 20 True (1) and false (0) answers given by the users for the ten questions

Figure 21 Time spent, interactions and required assistance by the Eco group

Figure 22 Time spent, interactions and required assistance by the Non-Eco group
Figure 23 Rating some elements from both models

What do you like at each Model?

<table>
<thead>
<tr>
<th>Circle Size</th>
<th>Color Difference among Categories</th>
<th>Color Difference Eco vs Non-Eco</th>
<th>Revealed Information</th>
<th>Navigation Bar</th>
<th>Font Size</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Model 2</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

Figure 24 Rating both models

<table>
<thead>
<tr>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 1</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 2</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>51</td>
</tr>
</tbody>
</table>

How would you rate the visualizations in general?

Figure 25 Choosing only one visualization model, or none

<table>
<thead>
<tr>
<th>MODEL 1</th>
<th>MODEL 2</th>
<th>NONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Participant</td>
<td>Topic</td>
<td>Comment</td>
</tr>
<tr>
<td>-------------</td>
<td>-------</td>
<td>---------</td>
</tr>
<tr>
<td>P2</td>
<td>Model 1</td>
<td>Will be better if it increases for 1 or 2 levels, the circles a bit bigger, the information is good</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>Play a little with the color of the circles, it has a better navigation bar</td>
</tr>
<tr>
<td>P3</td>
<td>Model 1</td>
<td>Is better, I'd change the navigation bar</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>I'd change the colors, their combination, and the navigation bar as well</td>
</tr>
<tr>
<td></td>
<td>Model 1</td>
<td>Is better based on the look and presented text, font size too small. I think everything is alright, but you need a couple of times to get familiar with it. If you give some additional information in the corners it would be easier to understand, that might be the key to use it. But, it's not that hard to understand it. Use a legend for more information</td>
</tr>
<tr>
<td>P4</td>
<td>Model 2</td>
<td>Definitely change the colors, the zero amount should be represented with a circle with a different color rather than no circle at all. I don't understand the numbers, maybe the currency should be next to the numbers, or present two buttons which will allow the user to change from percentage to money</td>
</tr>
<tr>
<td>P5</td>
<td>Model 1</td>
<td>I'd like to have more details about the colors, what do they mean</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>It was perfect</td>
</tr>
<tr>
<td>P6</td>
<td>Model 1</td>
<td>Put some lines, like columns, bigger font size</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>Change the colors, more detailed information about the number, if its percentage or denars</td>
</tr>
<tr>
<td>P7</td>
<td>Model 1</td>
<td>Change the contrast of the colors</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>It's good, I like it, I wouldn't change anything</td>
</tr>
<tr>
<td>P8</td>
<td>Model 1</td>
<td>It's perfect</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>More information is needed</td>
</tr>
<tr>
<td>P9</td>
<td>Model 1</td>
<td>I'd change a little the colors, the font size, a bit more information on the numbers</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>More information about the numbers, it made more sense compared to model 1</td>
</tr>
<tr>
<td>P10</td>
<td>Model 1</td>
<td>More information, greater font, bigger circle size</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>More information only</td>
</tr>
<tr>
<td>P11</td>
<td>Model 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td></td>
</tr>
<tr>
<td>P12</td>
<td>Model 1</td>
<td>Change the colors</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>Everything is fine</td>
</tr>
<tr>
<td>P13</td>
<td>Model 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td></td>
</tr>
</tbody>
</table>

Figure 26 Comments during the qualitative questions