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Motivating the Use of Public Transit Through a Mobile Glanceable Display

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Abstract

With increasing concerns about the impact of global warming on human life, policy makers around the world and researchers have sought for technological solutions that have the potential to attenuate this process.

This thesis describes the design and evaluation of an information appliance that aims to increase the use of public transportation. We developed a mobile glanceable display that, being aware of the user's transportation routines, provides awareness cues about bus arrival time, grounded upon the vision of Ambient Intelligence.

We present the design process we followed, from ideation to building a prototype and conducting a field study, and conclude with a set of guidelines for the design of relevant personal information systems.

More specifically we seek to test the following hypotheses: 1) That the tangible prototype that provides ambient cues will be used more frequently than a similar purpose mobile app, 2) That the tangible prototype will reduce the waiting time at the bus stop, 3) That the tangible prototype will result to reduced anxiety on passengers, 4) That the tangible prototype will result to an increase in the perceived reliability of the transit service, 5) That the tangible prototype will enhance users' efficiency in reading the bus schedules and 6) That the tangible prototype will make individuals more likely to use public transit. In a field study, we compare the tangible prototype against the mobile app and a control condition where participants were given no external support in obtaining bus arrival information, other than their existing routines. Using qualitative and quantitative data, we test the aforementioned hypotheses and explore users' reactions to the prototype we developed.

Keywords

Gobal warming, technological solutions, mobile glanceable displays, public transportation

Resumo

Com o aumento de preocupações sobre o impacto do aquecimento global na vida das pessoas, os formuladores de políticas e pesquisadores ao redor do mundo têm procurado soluções tecnológicas que tenham potencial para atenuar este processo.

Esta tese descreve a conceção e avaliação de um dispositivo de informação que visa aumentar a utilização dos transportes públicos. Nós desenvolvemos um dispositivo móvel de informação que, tendo conhecimento de rotinas de transporte do utilizador, fornece pistas de sensibilização sobre o tempo de chegada do autocarro, fundamentado na visão de Inteligência Ambiental.

Nós apresentamos o processo de design que seguimos, desde a idealização à construção de um protótipo e realização de um estudo de campo e concluímos com um conjunto de diretrizes para a conceção de sistemas de informações pessoais relevantes.

Mais especificamente procuramos testar as seguintes hipóteses: 1) Que o protótipo tangível, que fornece pistas de sensibilização será usado com mais frequência do que uma aplicação móvel com propósito semelhante, 2) Que o protótipo tangível irá reduzir o tempo de espera na paragem, 3) Que o protótipo tangível terá como resultado a redução da ansiedade nos passageiros, 4) Que o protótipo tangível vai resultar num aumento da confiança sentida pelas pessoas em relação aos serviços de transporte público, 5) Que o protótipo tangível irá aumentar a eficiência dos utilizadores na leitura dos horários de autocarros e 6) Que o protótipo tangível vai tornar os indivíduos mais propensos a usar o transporte público. Num estudo de campo, comparamos o protótipo tangível com a aplicação móvel e uma condição de controle, onde os participantes não receberam nenhum apoio externo na obtenção de informações de chegada do autocarro, além das suas rotinas existentes. Usando dados qualitativos e quantitativos, testamos as hipóteses acima mencionadas e exploramos as reações dos utilizadores para o protótipo que desenvolvemos.

Palavras-Chave

Aquecimento global, soluções tecnológicas, dispositivos móveis de informação, transporte público

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List of Acronimus

AVL – Automotive Vehicle Location

ATMS – Advanced Transportation Management Systems

ATIS – Advanced Traveler Information Systems

AVCS – Advanced Vehicle Control Systems

APTS – Advanced Public Transportation Systems

ARTS – Advanced Rural Transportation Systems

CVO – Commercial Vehicle Operations

CSS – Context-Sensitive Systems

TFT – Thin-Film Transistor

ITS – Intelligent Transportation Systems

M-ITI – Madeira Interactive Technologies Institute

SD – Standard Deviation

M – Average

CHAID – Chi-Square Automatic Interaction Detection

HQS – Hedonic Quality-Stimulation

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1. Introduction

Public transport is recognized as an essential resource for the quality of life in cities and in addition impacts positively urban mobility [31]. In this way, Public Transit Systems were developed to improve the mobility of people within cities [13]. However, this process has not been easy because even with the Public Transit Systems, it is still necessary to deal with the continued reduction of the number of passengers in public transport. This is mainly due to the increased use of private cars [4].

There are a great number of people who are dependent on private transport instead of public transport. This dependence allows the passenger to experience a variety of sensations as feelings of power, freedom, status and superiority. Furthermore, people often drive not by necessity, but by choice (See Figure 1) [5].

Figure 1- Example of a group of friends socializing inside the car.

We know that if mobility increases in cities, the use and demand for transport also increases. However, the choice of transport generates major concern to the government entities in the sense that if the number of cars circulating in the cities continues to increase, the use of public transportation could possibly decrease. This situation raises great concern in terms of transit congestion and environmental pollution (See Figure 2 and 3) [4].

Figure 2- Transit Congestion.

Figure 3- Example of Environmental pollution.

With these challenges in mind researchers have focused on technologies that aim at increasing the use of public transit. Over the past years a number of solutions emerged to improve the use of public transportation. These solutions are classified as Information and Persuasive Technologies. They use different forms of information divulgation but have the same goal in common, that is encourage people to make more use of public transportation, thus contributing to adopt a more sustainable style of life.

While these technological solutions focus in to provide real-time information our solution is an information appliance in attempt to motivate the use of public transit through a mobile glanceable display.

1.1. Motivation

Personal transportation is one of the greatest contributors of CO_2 emissions, accounting for 17% to 26% of the total emissions of average household worldwide [21] Since the 1990s there have been huge efforts to motivate citizens to use public transport. At the same time also has been a lot of developments in mobile computing and technological solutions that have helped in the search for essential measures to combat negative environmental effects.

As a negative consequence of automotive transportation we have global warming issues, such as: traffic congestions, energy consumption and the emissions of various pollutants are increasing. In this way, it is important to apply measures to decrease these problems by converting the car drivers into public transport passengers [17].

The use of public transportation is a positive alternative that contributes not only for the increase of mobility in the society, but offers benefits in terms of environmental impact such as: traffic decrease, decrease in fuel consumption and CO_2 emissions reduction [13].

Yet public transportation companies are losing their passengers because many of citizens prefer to use their car instead of the bus. In user's perspective, travelling by car is: convenience, speed, comfort and individual freedom [2]. In relation to public transport, users have a different perspective. The service quality of public transport is the key factor for user satisfaction and also contributes for user reliability in the service.

Some studies say that the most important factor that contributes to passenger satisfaction with the service is the reliability (being on time).

The reliability is not only about delays that are predictable, but for situations where for instance the bus takes longer than it is supposed to (uncertainty) or if the passenger loses it due to lack of information. This will reduce the passenger reliability with the service [24].

In this sense, the public transport companies have to create more means of passengers attraction, such as: lower rates and reduction in the tickets price.

In last 5 years, Information and Persuasive Technological solutions for public transportation have been introduced to help the bus companies in providing essential information to bus users.

Information Technologies aim the task of taking a bus easier with resource to real-time information, such as: waiting time, number of the bus, schedules, bus route, fullness, among others. The diversity of technological information solutions has led to a significant increase in reliability, anxiety reduction, security and traveler satisfaction in relation to the service provided by public transport companies, being them: mobile applications, open source/social networking and real-time displays in bus stop or bus stations. As example of these solutions we have *Tiramisu*, *Horários do Funchal*, *OneBusAway*, *ThisIsOurStop* and *Real-time Information Displays*.

Persuasive Technologies aim at raising awareness of CO_2 emissions, the cost, the number of footprint and other factors when people compare taking the car versus the bus and attempt to modify their behaviors so that people are motivated and empowered to use more sustainable (public) means of transportation. As example of these solutions we have *UbiBus*, *OK*, *CarbonDiem*, *UbiGreen* and *Calculation Platforms*.

These two technological solutions, using different forms of information but they all contribute for to improve the public transit use.

1.2. Contributions

The main goal of our work was to provide an approach for the design of an information appliance that aims to increase the use of public transit. The tangible prototype provides users bus arrival time information through awareness cues in order to reduce the waiting time in the bus stop. Our approach highlights directions for developing personal information systems that promote the use of public transit.

1.3. Structure

In Chapter 2, we review prior work on efforts that aimed at increasing the use of public transportation. We will first present how the quality of service is understood from the user's perspective. Afterwards, we will describe the traveler's behavior and the attributes factors that influence in their choice of the transport mode. Finally, we will present an overview of how users evaluate the bus service comparing to private cars.

In Chapter 3, we will review the state of the art of the technologies that aim at increasing the use of public transportation. Initially, we will discuss Information and Persuasive Technologies that have been used to improve public services over the past years. In second place, we will review systems that have been developed within the ideology of these technologies. Finally, we will describe two taxonomies of related work, based on the technologies solution.

In Chapter 4, we will present a Mobile Glanceable Display, our discussion about the different phases of design and the respective stages of prototype development that follows on the vision of Ambient Intelligence, that could provide awareness information cues of bus arrival time (lights and vibration) to motivating the use of public transit.

In Chapter 5, we will present the analyze results about the tangible prototype against the mobile app and a control condition where participants were given no external support in obtaining bus arrival information, other than their existing routines. We tested our research hypotheses and we explored users' reactions with the prototype we developed.

In the last chapter, we will present the study conclusions, limitations and future work.

2. Public Transportation

In this Chapter we review the factors that influence individuals' likelihood to use public transportation. We first present how the quality of service is understood from the user's perspective. Secondly, we describe the traveler's behavior and the attributes factors that influence in their choice of the transport mode. Finally, we present an overview of how users evaluate the bus service comparing to private cars.

2.1. Service Quality on User Perspective

Mobility, society and the lifestyle in Europe has grown in recent decades. However, mobility is more associated to private car travel than by public transport. This situation raises great concern in terms of transit congestion and environmental issues. To change this, we must create and promote measures that can help to reduce private car travel to significantly increase the number of public transport trips [4].

However, there are a number of people who are dependent on private transport instead of public transport. The dependence causes a set of sensations to the passenger as feelings of power, freedom, status and superiority and moreover people often drive not by necessity, but by choice. Therefore, it is essential to promote policies that reduce the dependency and driving need by the passenger, introducing other alternatives such as cycling, walking [5] and traveling by bus.

To try to change this situation it is necessary that Public Transport Systems are more market-oriented and competitive [5]. The first step is to improve the quality of service to respond to the needs of the passenger / customer. This improvement is to discover what is the level of service (the customer's perspective) in order to identify favourable and less favourable aspects of public transport systems. Based on this principle it is possible to improve the quality of service and increase customer satisfaction [4].

Improve the quality of service is not an easy process, because it deals with the perceptions and attitudes of people. It is an important area of research and it is necessary to know how passengers assess the level of service [4].

2.2. Travel Behavioral and Choice of Transport Mode

Performing a journey may involve the use of a specific transport to get to a particular destination at a particular time. The choice of transport can be influenced for instance, by the person's lifestyle, the kind of trip that will make (short or long), the cost, among others. Travel can then be made through a public transport or through private car (user or someone who can give him a ride) [4, 5]

The affluent movement of cars in cities is still large and raises concerns especially in big cities, since there are more cars travelling on the road and where the traffic congestion is greater and therefore leading to more pollution in the atmosphere and also frustration in whom travels on the roads.

To get around these facts it is important to understand which is the patterns of travel behavior, so that the public transport companies can captivate people to use more public transport [4, 5].

In user's perspective, travelling by car is, as already implies convenience, speed, comfort and individual freedom [2]. Thus, the service provided by public transport should follow these guidelines as a basis to entice customers and non-users. However, traveler's behavior is influenced by psychological factors and therefore it is difficult to measure consumer evaluation of quality as it is the case of perceptions, habits and attitudes of customers [16, 18].

From the service providers' perspective it is very important to find out what attributes of quality of service contribute to customer satisfaction [4], to keep current customers and win new customers for the service. Some studies say that the most important factor that contributes to passenger satisfaction with the service is *reliability* (being on time). Reliability is not about delays that are predictable, for example, at rush hour, people know that there is the possibility of the bus having a few minutes delay, but if it takes longer than it is supposed (uncertainty) helps to reduce the passenger reliability [24].

Attributes such as the frequency and comfort are also extremely important to passenger satisfaction in the use of public transport. Additionally, the attributes as clear and simple information, vehicle condition and the passenger requirements and expectations are important and may represent indications for service providers to improve their service. However, the waiting time and the cost of tickets are considered negative attributes [5, 20]

So, passenger satisfaction is influenced by all these attributes, but one must take into account that passengers are people with different needs, beliefs and expectations, therefore evaluate the quality of the attributes of a service in a different way [5].

2.2.1. User´s evaluation between private car and bus

Previous studies claim that the best way to measure consumer evaluation of quality is through qualitative methods, for instance, *focus groups* where people discuss about the differences between the use of the car versus bus [18] and car users *interviews* to find out the benefits and drawbacks of the use of cars (See Table 1) [5].

Advantages	Disadvantages
Public transport	
Cost	Waste of time
Less stress	Too crowded
No need to drive	Lack of comfort
Be able to relax	Time uncertainty
Be able to rest or read	Lack of control
Travel time on bus lanes	Unreliability
Less pollution	Long waiting times
Talk to other persons on the vehicle	Need of transfers
	Traffic
	Lack of flexibility
	Long walking time
Private car	
Freedom/ independence	Cost
Ability to go where I want	Difficulty of parking
Convenience	Cost of parking
Rapidity	Stress of driving
Comfort	Traffic
Flexibility	Waste of time in rush-hour traffic
Know what I can expect	Pollution
Safety	Accidents
Having my own private space	Isolation
Listen to music	

Table 1- Advantages and disadvantages between the bus and the private car use [5].

These methods are valid because they exploit what people really feel and think about a service or product. In this sense, the speech is more fluid between the people and the interviewer, so it's more likely that they will talk than simply answering a series of questions. Therefore, the use of qualitative methods is relevant to the investigation of the problems that occur when using public transport.

When users decide the type of transport to be used on a particular journey the travel time factor is relevant in the choice. Travel time in relation to public transport has positive and negative aspects. For positive aspects should be mentioned the fact that for short trips (only in the inner city) bus is the most viable option as it can get faster to the destination. As regards the negative aspects, we have the case where the trips are longer (outside the urban area), where users assume that the bus will take longer to reach the destination, if we consider that it is most likely there is traffic congestion, especially during peak hours [5].

In exceptional situations where the user is not sure what time the bus arrives the waiting time factor is perceived as "too long to wait" [5] and can prevent or decrease the use of the bus as an alternative mean of transport.

The cost level in public transport is cheaper than traveling by car, however this does not contribute to increase the use of public transport [5].

The bus ride causes less stress because driving is the responsibility of the driver of the bus and there is opportunity to rest (to play on the phone or reading a book) and socializing (chat with a friend) unlike the private car trip. Also, it should be noted that comfort is important, although many bus users and car drives say that normally the buses are uncomfortable, very noisy, smelly and airless except when they are new[5].

The main problem appointed by the bus users and non-users is the lack of information especially when service providers do not inform them about new information updates, like bus schedules alterations or even bus routes [5].

Also, the bus performance is judged by users in terms of user's traveler experience. Frequent trips, service quality and satisfaction are also the key factor for public transportation improvement. Those traveling by bus regularly claim that like to travel by public transport, except when it is full and the waiting time is long.

As far as the car drives they claim that don´t like public transport because it is not reliable, not frequent enough, uncomfortable, noisy and sometimes the driving is a bit abrupt [5].

Besides these problems we have also to deal with another negative consequence of automotive transportation, global warning. Environmental issues are increasing, such as traffic congestions, energy consumption, and the emissions of various pollutants. In this way, it is important to apply measures to decrease these problems by converting the car drives into public transport passengers [17].

An experimental analysis of habit and attitude change study [17] investigated a temporary structural change (See Figure 4) in one bus company to see if that would contribute to car drives converting into buses users. The idea was to give a one-month free bus ticket to car drives to measure their attitudes regarding habits and frequency of using car and bus. The results obtained were very positive in this matter, because increased car drivers attitudes concerning to the bus and also the frequency of use. However, the habits of traveling by car decreases before and one month after the study [17].

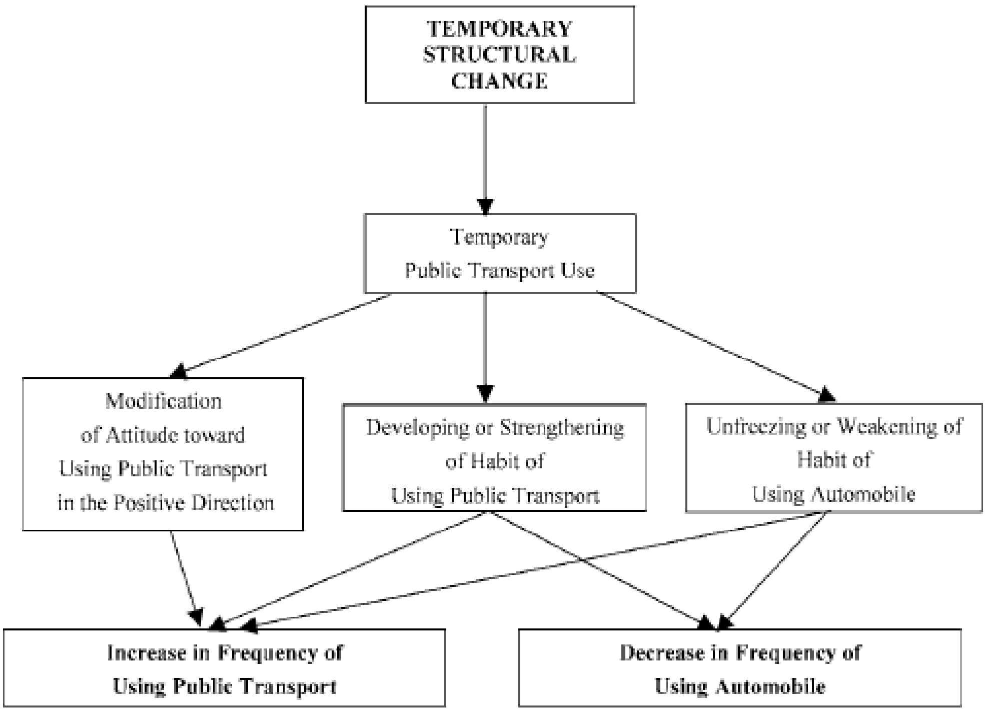


Figure 4- Example of the one temporary structural change of [17] study.

The application of this type of measure (free tickets) can be important to break the negative image that many car drivers have about public transport and encourage them to use more often.

In conclusion of this chapter, it should be emphasized that for public transportation companies its vital to find new strategies to improve their service quality, for example in publicity campaigns, lower rates or tickets. It is good come out of "routine" and surprise customers with appealing innovations in service like improving for instance in the information they provide to users like Information and Persuasive Technological solutions. It’s important to not forget that we have different kind of customers that have different habits, needs, attitudes and their expectations normally are high in the beginning.

Increasing the customer satisfaction is the key to improve the public transportation overall quality. If customers are unhappy the public transportation image ceases to be attractive and customers will continue to prefer to use their private car.

3. Literature Review

In this Chapter we review the state of the art of the technologies that aim at increasing the use of public transportation. First, we discuss Information and Persuasive Technologies that have been used to improve public services over the past years. Secondly, we review systems that have been developed within the ideology of these technologies. Finally, we describe two taxonomies of related work, based on the technologies solution.

3.1. Information Technologies for Public Transit

Public transit systems are nowadays the cornerstone for citizens commute around their cities every day. The use of public transit brings significant benefits. Not only does it increase the mobility of the society, it offers benefits in terms of environmental impact such as traffic, fuel and CO_2 emissions reduction [13].

In this way it is important to keep or enhance user's satisfaction and safety because it brings social benefits for public transportation. However, it is difficult because from customer's perspective mobility its important since is fast enough, comfortable and reliable. Several studies show that if transit agencies offer improvements in their service, through the real-time information it could prevent the unreliability.

Real-time information gives travelers a new perspective of freedom, because they decide when to depart and freedom to choose the bus stop location to pick up the bus. As a result, commuters feel more control on their journey and also their safety [13].

Information Technologies for public transportation aim the task of taking a bus easier. In order words, provide information as to when the bus is arriving, which bus is need to take to go to a given destination, how full is a bus, among others.

The diversity of technological information solutions has led to a significant increase in reliability, anxiety reduction, security and traveler satisfaction in relation to the service provided by public transport companies, being them: mobile applications, open source/social networking and real-time displays.

Next we describe some of this solutions that are currently available to the travelers and have contributed to improve the use of public transportation.

3.1.1. Tiramisu

Thinking on how to encourage the population to use transit service more often, it was developed the mobile application *Tiramisu*. Based on the concepts of crowd sourcing and service design, the researchers aimed to engage users with the service through participation as co-owners [48] (See Figure 5).

This application enables commuters to share their GPS traces while on the bus and report on its fullness, thus supporting other users to estimate when to start their journey to the bus stop. *Tiramisu* processes the users input and then gives real-time information for the bus.

After the use of the application, the results of the study revealed that users participation was positive, because they share their GPS traces, the bus fullness, used the real-time information and the application historic correctly [48].

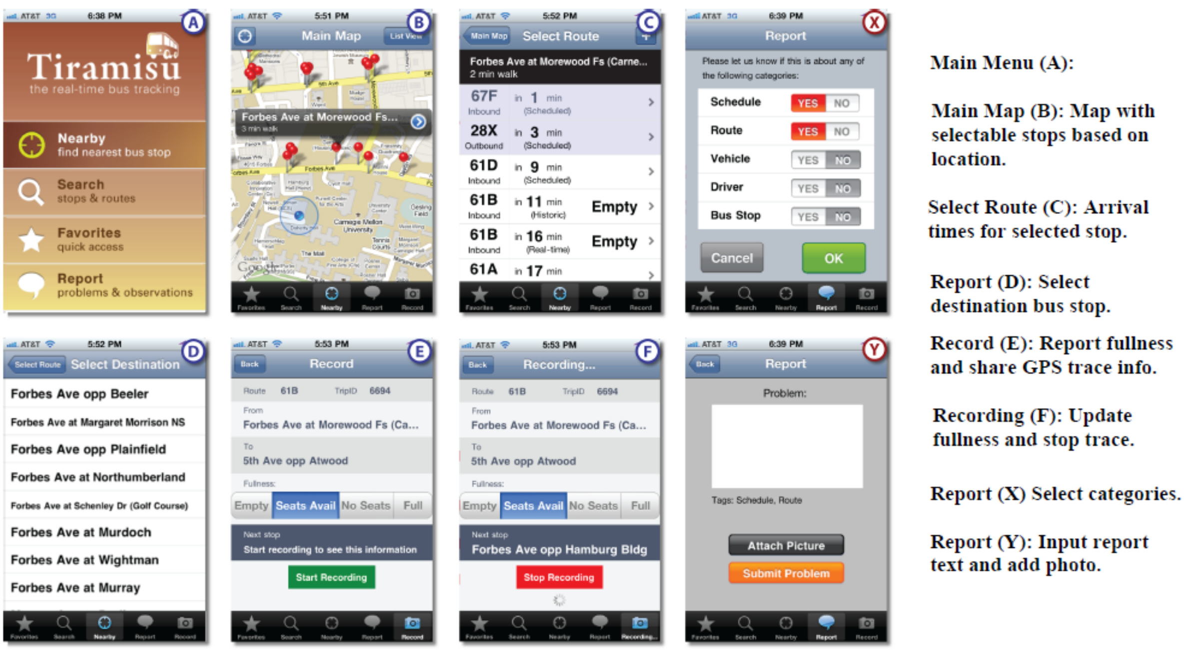


Figure 5- *Tiramisu* application interface.

3.1.2. Horários do Funchal

In the context of the completion of the Master's thesis of a student of the University of Madeira, an application was developed for travelers of public transport company, *Horários do Funchal*. It was conceived with the aim of reducing anxiety and the waiting time for bus travelers. The information is available in real time (See Figure 6). It is available in Android format and it can be accessed on mobile devices (phone and tablet). It allows [22]:

- checking the next bus, real-time schedules at stops, routes and locations of bus/stops on the map;
- travel schedule through Google Calendar;
- reception of information related to the bus departure and the proximity of the bus relative to the stop;
- looking for commercial spots.

Figure 6 - *HF Bus* interface for mobile devices.

The information provided by the company can also be viewed through the website: www.horariosdofunchal.pt (See Figure 7) [33].

Figure 7 - *HF Bus* website.

3.1.3. OneBusAway

There are two main reasons for public transportation companies to improve their transit traveler information: raising existing rider's satisfaction and raising ridership in the new riders and the riders who don´t use the bus service frequently. In this way two PhD students wanted to improve their daily travels in the Puget Sound region at U.S. [36]. Thereby, they developed *OneBusAway*, an open source platform that provides real-time information for public transit.

The main highlights from this platform are: raising of public transit satisfaction; waiting time reduction; raising the number of transit trips per week and increase the user safety and health. Furthermore, transit agencies have been also using the *OneBusAway* transit tools to give real-time information to bus users. This system allows the user access to a variety of tools for querying / receiving information, such as: the website, the standard telephone number by which arrival information is received by SMS, a website optimized for mobile devices with Internet connection and an application available on Android and IOS format [13, 36].

In Figure 8, we have an example of *OneBusAway* mobile application for Android, that allows commuters search for the nearest stops, select a bus stop from the favorites list and set reminders.

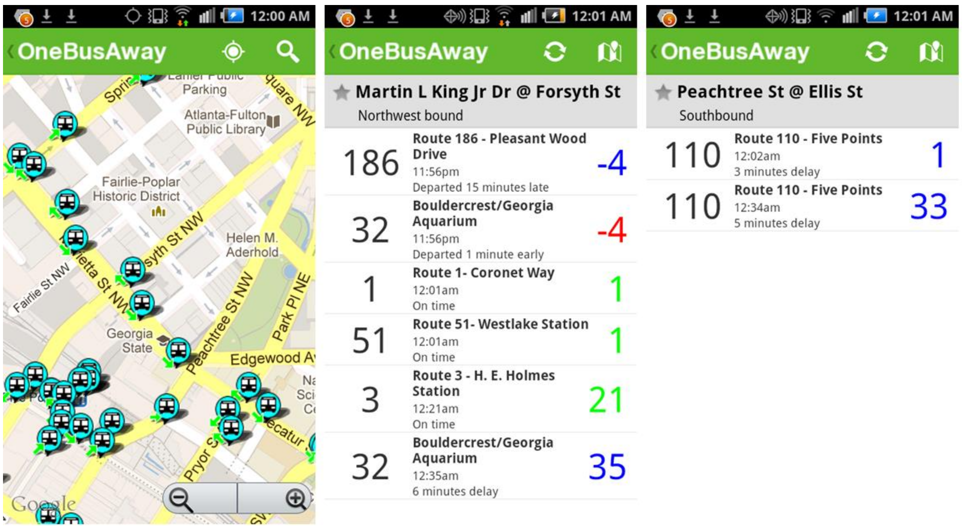


Figure 8- *OneBusAway* application interface.

3.1.4. ThisIsOurStop

ThisIsOurStop is a social networking service that provides bus time arrival information and supports communication between commuters, centered around bus stops in Vancouver, Canada (See Figure 9).

Resorting to the Internet on the phone, people enter the number of the desired stop (5-digit number), so as to have access to the map and the corresponding schedule. In addition, they can also view the feedback (conversation about the weather, interesting suggestions, among others) from other passengers and yet if they wish to submit their own comment [43, 44].

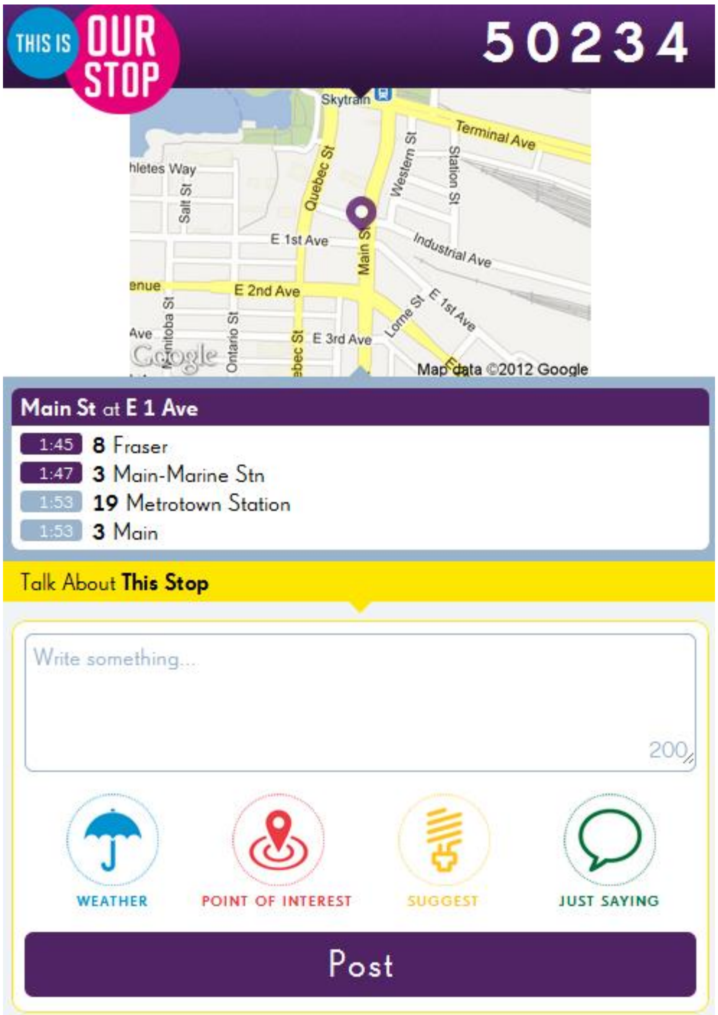


Figure 9- Example of *ThisIsOurStop* mobile Interface.

3.1.5. Real-time Information Displays

Real-time information displays are another way for citizens getting access to the information. This kind of information is available only in the buses and train stations where the travelers can see it (See Figure 10). The goal of this system is to increase traveler information and to improve the quality of the service.

Figure 10- Modern real-time information display in Germany [12].

When compared with the mobile applications the implementation of this systems are very expensive if we have a display for each bus stop in a city. Cities like Chicago and London in the early 1970's have already *Automatic Vehicle Location* (AVL) for providing travelers information and real time information at the bus locations.

Moreover, Sweden was another city to implement in the beginning of 1980's such system in Stockholm metro station. The passenger could see the waiting time minutes and the destination of a particular train when it was closer to the train station. In Gothenburg for instance, they had a route map with current locations of the trains when approaching to the stations (See Figure 11 an example) [12].

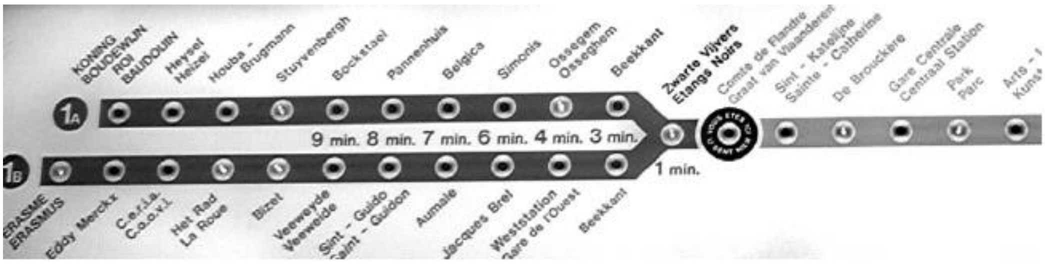


Figure 11- Example of route map real-time information in Brussels in 1980's [12].

Through the years there was an improvement on the design and the quality of the information available. Next we present some examples of current *Real-time information displays models* [45]:

- ✓ **Ashby Flag Pole**

This system is located at bus stops, has the form of a flag and shows six data lines (See Figure 12). In the first 5 lines users have access to information related to the bus arrival (bus number and the minutes remaining until arrival) and the last line shows various pertinent information.

Figure 12- Example of Ashby Flag Pole display.

- ✓ **TFT (Thin-Film Transistor) Displays**:

These systems show information about the next bus, train or subway (See Figure 13). They provide transport arrival time information in real-time. Furthermore, the screens are essential to make updates in service, network information and events.

Figure 13- Example of TFT displays.

✓ Interactive Displays

Such displays (see figure 14) enable passengers to plan the trip and find points of interest in different areas according to their needs, making use of the information provided.

Figure 14- Example of Interactive displays.

- ✓ **BCCI Totems**

These systems are part of a project that aims to facilitate the movement within a particular city. They are usually located in the main stops in the city center, as is the case of Birmingham in England (See Figure 15). The information is provided through two panels on each side. An electronic panel with the bus number and the other with information regarding the bus arrival in real time and schedules.

Figure 15- Example of the one BCCI Totem in Birmingham.

3.2. Persuasive Technologies for Public Transit

In a way to attract potential users to public transport is crucial to facilitate the access to information. Based on this principle, it is possible to make a more attractive city for those who live there or to those who visit, using technological solution, such: interactive displays in the bus stops, smartphones, among others.

However, it is difficult to apply these solutions in highly developed countries because the buses do not have exclusive lines passing through and the traffic is very constant and thus, is difficult to predict the waiting time for the bus. In these cases, it is essential to provide users with access to information, so that can decrease the long and uncertain waiting time at bus stops, e.g. current location of the bus or the estimated time for the bus to arrive.

Persuasive Technologies in the context of public transit aim at raising awareness of CO_2 emissions, the cost and other factors when people compare taking the car versus the bus and attempt to gamify their behaviors so that people are motivated and empowered to use more sustainable (public) means of transportation.

The *Intelligent Transportation Systems* (ITS) can help in this matter given user dynamic information “anytime, anywhere and from any device” thought the context of a bus trip [47].

ITS includes: information systems, communications, sensors and advanced mathematical methods to improve the quality of the transportation system. These systems provide six categories of application and all have and they all follow the same principle, implementation and improvement the passenger information automated systems, such as [42, 47]: **ATMS** (*Advanced Transportation Management Systems*), **ATIS** (*Advanced Traveler Information Systems*), **AVCS** (*Advanced Vehicle Control Systems*), **CVO** (*Commercial Vehicle Operations*), **APTS** (*Advanced Public Transportation Systems*) and **ARTS** (*Advanced Rural Transportation Systems*). All of them implies that there is a constant behavior range (navigation, traffic and mobility) which supports the development and implementation of **CSS** solutions.

*Context - Sensitive Systems (**CSS**)*, uses the context to provide the best services and information to the passenger in order to help him in carrying out its tasks. Besides that, allows for the filtering of information, for instance, stock selection from a list of possibilities or restrict the information delivery [47].

Next we describe some systems that use context information and *ITS* solutions for the travelers.

3.2.1. UbiBus

The *UbiBus* (See Figure 16) is a *context - sensitive public transportation system*, that has real-time dynamic context information by users and vehicles mobility. Users can obtain different services through different devices, e.g. the bus estimated arrival time is displayed on the bus stop. The goal was the implementation of solutions to improve public transportation systems though helping passengers in their daily decisions [47].

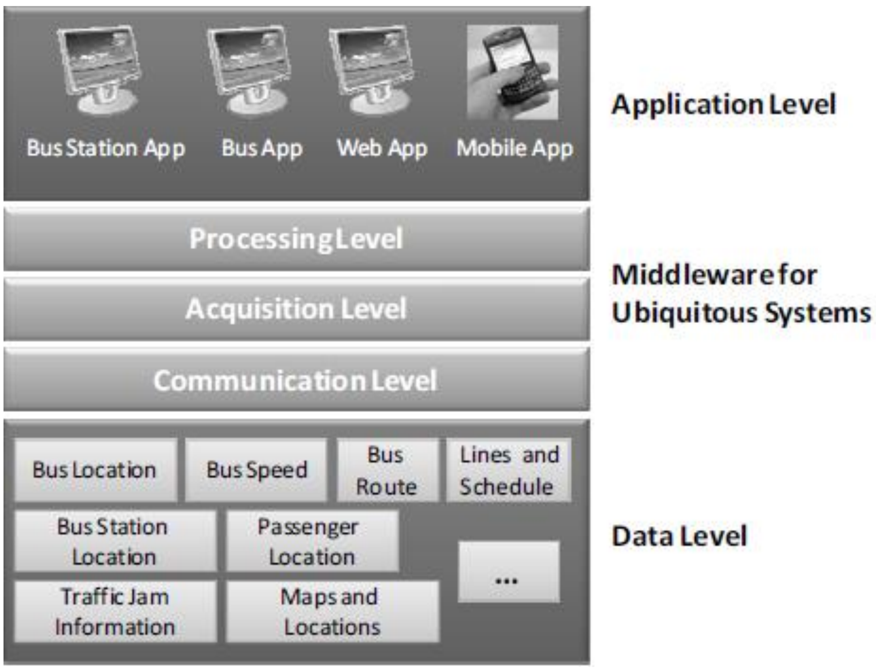


Figure 16- *UbiBus* architecture.

3.2.2. Opportunity Knocks(OK)

Mobility for humans is essential, because through it is possible to be independent in the sense that we can move at any time anywhere. Mobility is important to [38]: in social life, employment, ability to receive goods and services. However, unfortunately not everyone have same cognitive abilities to travel alone on public transportation.

Taking account, the above aspects and in order to offer a better quality of life, independence and security to these people without relying on others, it was created *Opportunity Knocks (OK). OK*, it is a *Personal Travel Assistant application* [47], consists on a Bluetooth GPS beacon that connects with the user's mobile phone and detect his movement and behavior.

OK checks user´s context for information, as their current localization and guide them to a destination through real-time directions. Dependent on the destination that the user wants to go the system provides the location of a bus in the user's area (See Figure 17) [38, 47]. Unlike other systems *OK* is user-centric, because do not need a lot of input.

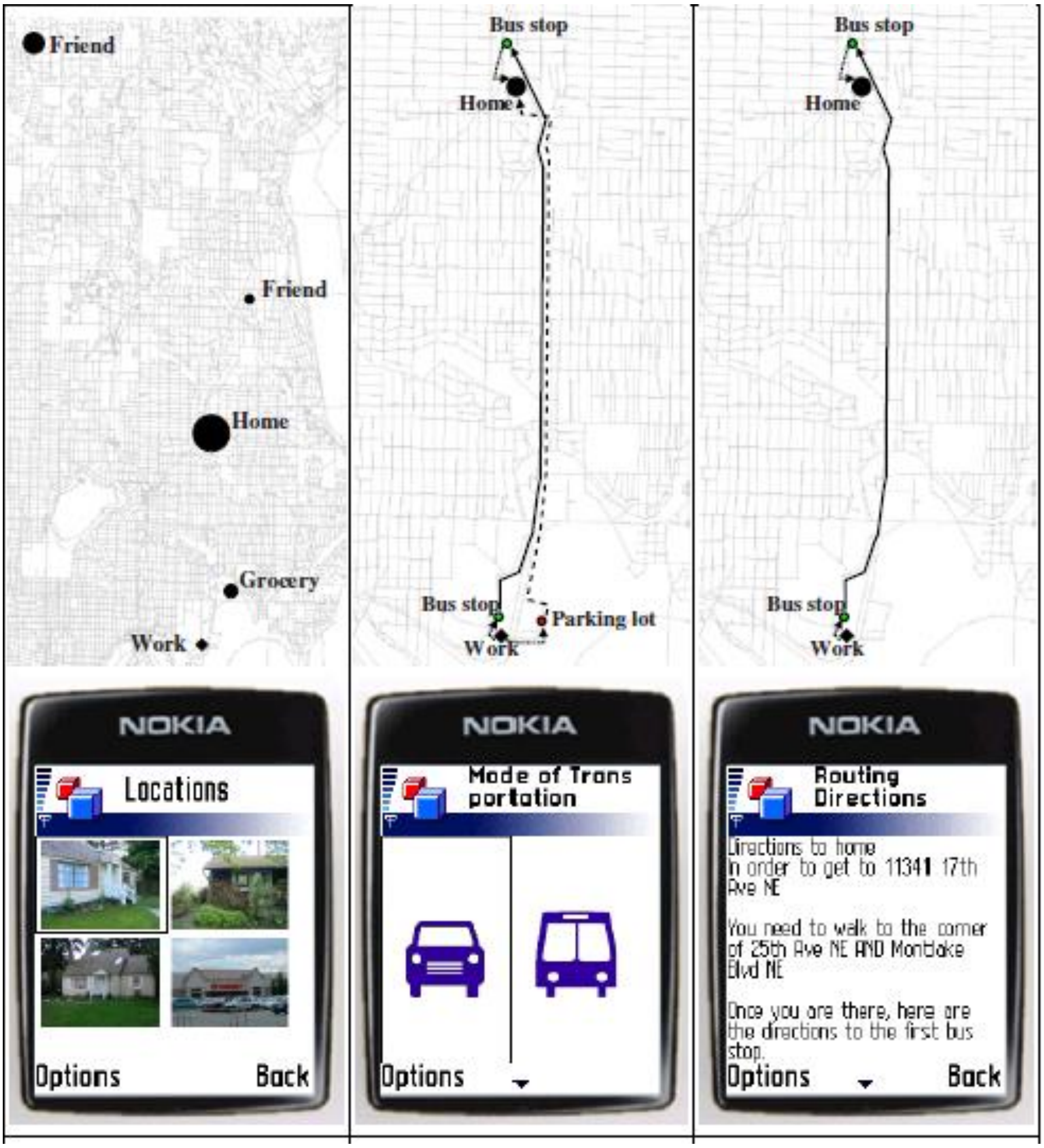


Figure 17- Examples of *OK* directions [38].

Furthermore, if the system detects the user is currently at the wrong bus, sends a door-knock sound, an alert to change the bus in the next bus stop (See Figure 18).

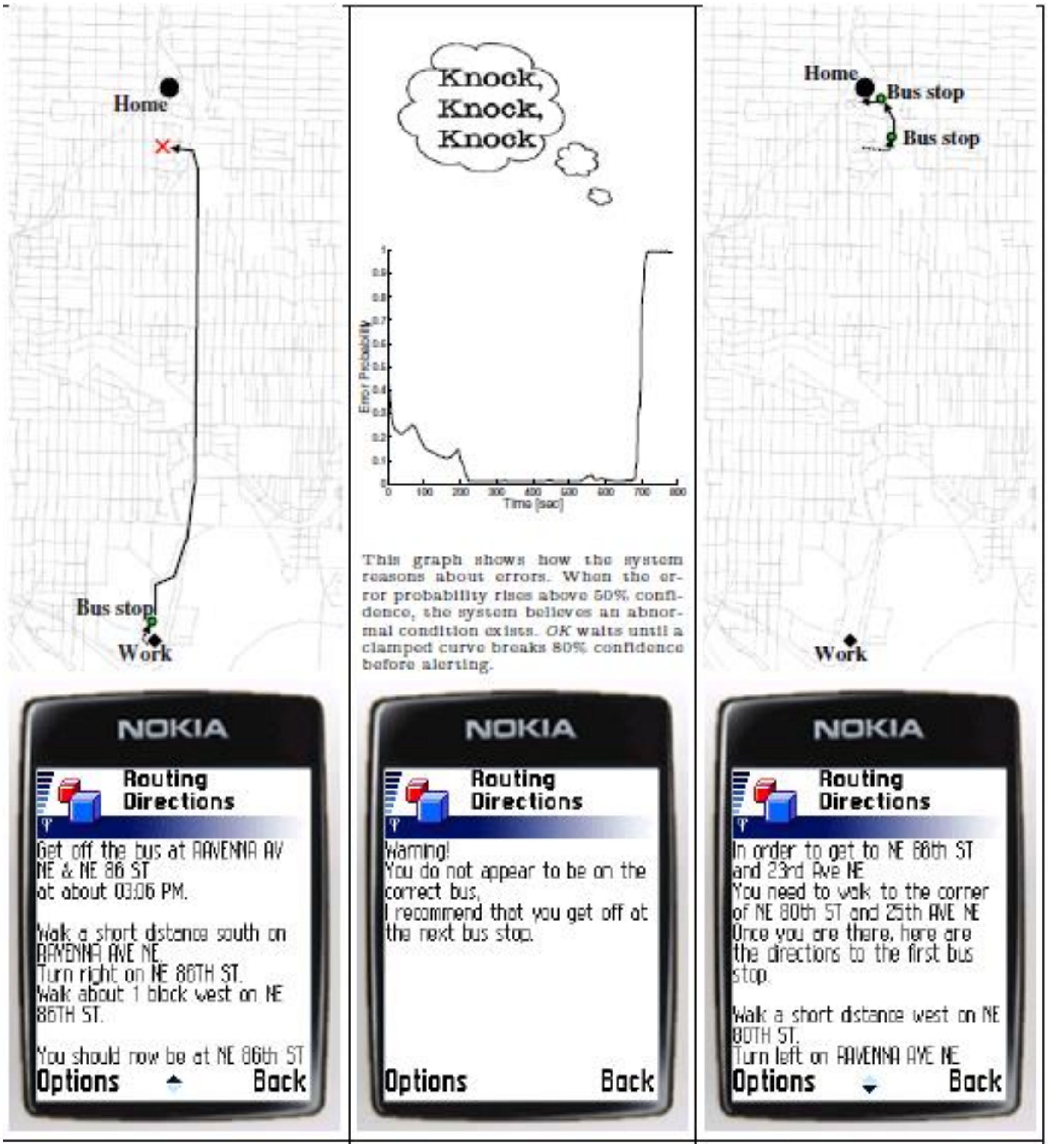


Figure 18- Example of a situation when *OK* alerts the user with a Door-knock sound [38]

Thus, after the tests performed with the *OK*, it was confirmed that ensures the user safety as well in mild confusion, memory lapses and inattention [38]

3.2.3. CarbonDiem

Andreas Zachariah [3] created *CarbonDiem* (See Figure 19), a mobile application that infers mode of transportation (e.g., walking, driving) from GPS and mobile phone sensors (e.g. accelerometer) and provides, historical information to the user about the modes of transportation he used and the environment impact. The mode is detected by real-time information.

This application aggregates a CO_2 multiplier for each mode and the distance traveled by the user. The result gives the footprint for the journey [9]. Additionally, there is also *CarbonDiem* for business (See Figure 20) [7].

Figure 19- *CarbonDiem* application. Interface.

Figure 20- *CarbonDiem* for business.

3.2.4. UbiGreen

The *UbiGreen* (See Figure 21) is a mobile application that gives ecological awareness about green transportation toward users behavioral. Depending on the mode of transport used (bus, train, walking, biking or carpooling), the application feedback is based on images or dynamic graphs according to the context and the calculation of the CO_2 emissions in each user activity [15, 47].

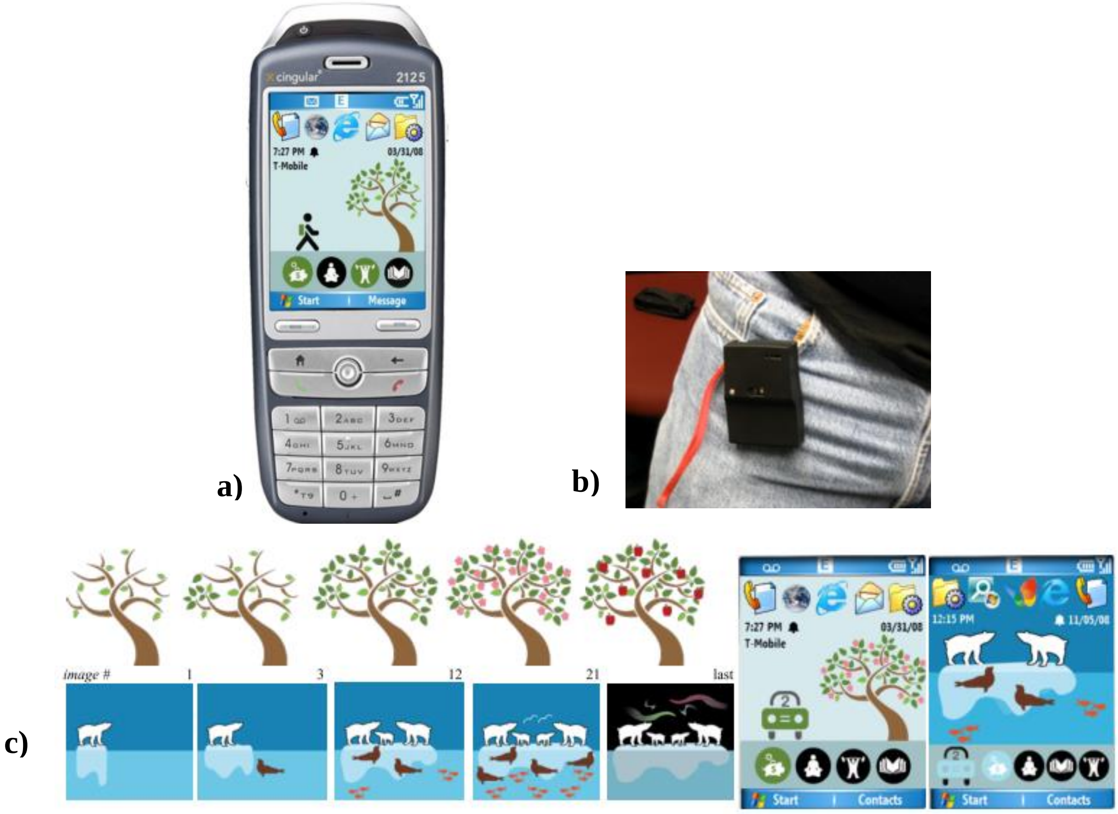


Figure 21- **a)** *UbiGreen* Transportation Display in mobile app, **b)** MSP sensor and GSM cell tower data and **c)** (bottom-left) imagens and graphics examples in context of green transportation, e.g. a progressing tree and polar bear habitat and in (bottom-right) user carpooled (the number “2” in the car represents that user saved money because the “piggy” is green).

3.2.5. Calculation Platforms

The growth of global warming and dioxide carbon joined governmental organizations around the world and researchers in searching for solutions that could attenuate this process. To do so, it is necessary to catch the citizens attention for this reality by showing them what they can or cannot do in order to help in reducing this process. Over recent years, governments have released information about the environmental impact in different ways, such as TV, radio, Internet, bus stops, among others.

Changing citizens' attitudes and behaviors may contribute to reducing climate pollution, because the CO_2 emissions are created to a large extend by human activity: public transport, electricity, heating, cooling, among others [41].

In order to make people more aware of this situation, many websites been developed to help people understand and calculate their footprint produced by activities performed throughout the year, whether at home (electricity), transport, food, among others. As an example, we have the platforms such, *Footprint* [14] and *Carbondiem* [8] in Figure 22.

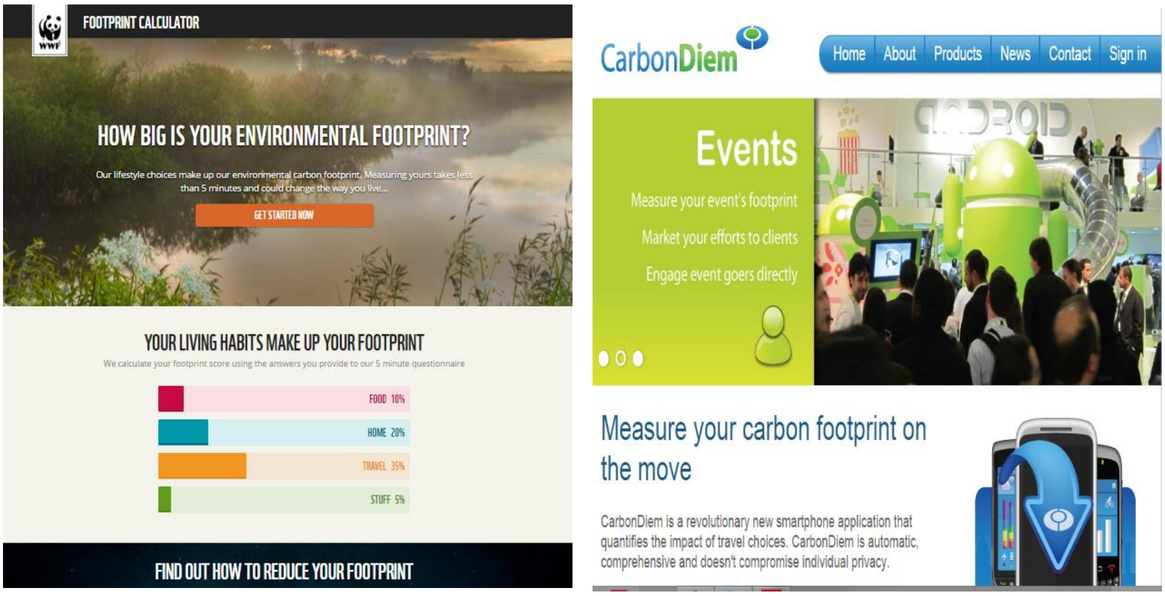


Figure 22- *Footprint* [14] and *Carbondiem* [8] webpages.

Moreover, with the use of these platforms it proved that people are increasingly susceptible to change their behavioral habits to reduce the environmental changes.

3.3. Information versus Persuasive solutions

In conclusion of this chapter, we present two taxonomies of technological solutions, which although using different forms of information divulgation have the same goal in common, that is encourage people to make more use of public transportation, thus contributing to adopt a more sustainable style of life (See Table 2 and 3).

	Information Technologies Systems				
Classification Items	**Tiramisu**	**HF Bus**	**OneBusAway**	**ThisIsOurStop**	**Displays**
Location	In the bus	Anywhere	Anywhere	Bus Stops	Bus Stops
Within - Context Vs Out Context	Within Context	Out Context	Within Context	Within Context	Within - Context
Crowdsourcing Vs Networking or Both	Crowdsourcing	Networking	Crowdsourcing	Both	Networking
Real-Time Information	Sharing GPS traces	Bus arrival time	- Nearest stops; - Bus arrival time.	- Bus arrival time; - Comments about weather, suggestions among others.;	- Bus arrival time; -Destination; -Current location; - route map; - Bus number; - Pertinent information; - Events; - Bus schedules.
Participation (Users Vs System or Both)	Users	System	Users	Both	System
Goal	Encourage population to use transit service more often	Decrease: - anxiety; - waiting time.	Increase: - satisfaction; - more trips; - safety; - health. Decrease: -waiting time	- Bus time arrival information; -Communication between commuters.	Encourage population to use transit service more often.

Table 2- Taxonomy of Information Technologies Systems.

	Persuasive Technologies Systems				
Classification Items	**UBiBus**	**OK**	**CarbonDiem**	**UbiGreen**	**Calculation Platforms**
Location	Anywhere	Anywhere	Anywhere	Anywhere	Anywhere
Within - Context Vs Out Context	Within Context	Within Context	Within Context	Within Context	Out - Context
Crowdsourcing Vs Networking or Both	Networking	Networking	Networking	Networking	Networking
Real-Time Information	Bus: - Location: - Speed; - Route; - Stop Location. Others: Passenger location; Traffic jam; Maps and location; Lines and Schedule.	Bus: - arrival time; - Stop location; - Bus number. User: -location; -movement; -behavior; -directions.	Historical information: - Transportation modes; - environment impact (Calculating the CO_2emission).	-Images or dynamic graphs according to user context; - Calculating the CO_2emission.	- Calculating the CO_2 emission (footprint produced); -Pertinent information about global warning.
Participation (Users Vs System or Both)	Both	Users	Both	Both	System
Goal	Encourage passengers to use public transportation and help them in their daily decisions.	Independence and Security.	Encourage passengers to use public transportation and make people aware of global warming.	Ecological awareness about green transportation toward users behavioral.	Making people more aware through their attitudes and behavior.

Table 3- Taxonomy of Persuasive Technologies Systems.

4. The design of a Mobile Glanceable Display

The goal of this thesis is to build a prototype that follows on the vision of Ambient Intelligence that could provide awareness cues of time arrival information. In this chapter, we will discuss about the different phases of our design process and the respective stages in development.

4.1. Design Steps

Initially, the design process had some complication in the ideation phase, because one of criteria was to create a prototype to make an intelligent product in limited form size.

The main goal was to find a way to motivate young adults, that represent sensitive customer groups of Horários do Funchal company, to the use of public transportation. These young adults reduce their bus journeys once they acquire a personal car or in case of going with a friend.

Taking into account that the target audience were young and many of them students, we felt the need to create a system that had innovative character and that would provide useful information about buses.

Knowing that other colleagues have developed an Android application for the company of Horários do Funchal we tried to find out what kind of information they provide to passengers. After testing we verified that it provides real-time information on bus timetables, as the time left for the bus to arrive in minutes, bus stops and maps, in order to reduce the passenger's anxiety while waiting at the bus stop. Once that there are an application available, the information can be easily accessed and can be installed on any smartphone. Keeping in mind that this application already exists on the market the challenge to build the prototype was even greater.

The first step was to reflect on how we can provide information about the bus without using a smartphone. It was on this point that some ideas emerged that were based in systems that distribute awareness cues in user's spatial environments, such as:

- ✓ public installations through embedding awareness cues in existing public objects (e.g. expanding wall clocks in public locations with color cues or changing the strength of water fountains to represent time remaining till bus arrival);
- ✓ personal objects that people can decorate in their house in the living room or workplace while increasing the user´s awareness of bus arrival time.

Our prototype follows the principle of a personal object that users can carry anywhere on an backpack or in a trousers pocket or jacket. The size really matters because being small makes it easier to transport and this way the user can have it always and take it anywhere. Therefore, the design of the prototype was based on the famous antique pocket watches. These watches were small enough to slip into a pocket, light and easy to hold in hand. They had only one button to open and then we could check the time. Afterwards we just had to close the top cover and put it back in the pocket.

Following this line of thought, we start from the principle that the prototype had to be small and light. Furthermore, it is shape would be round as the pocket watches. In Figure 23 we have the first sketches of possible prototypes.

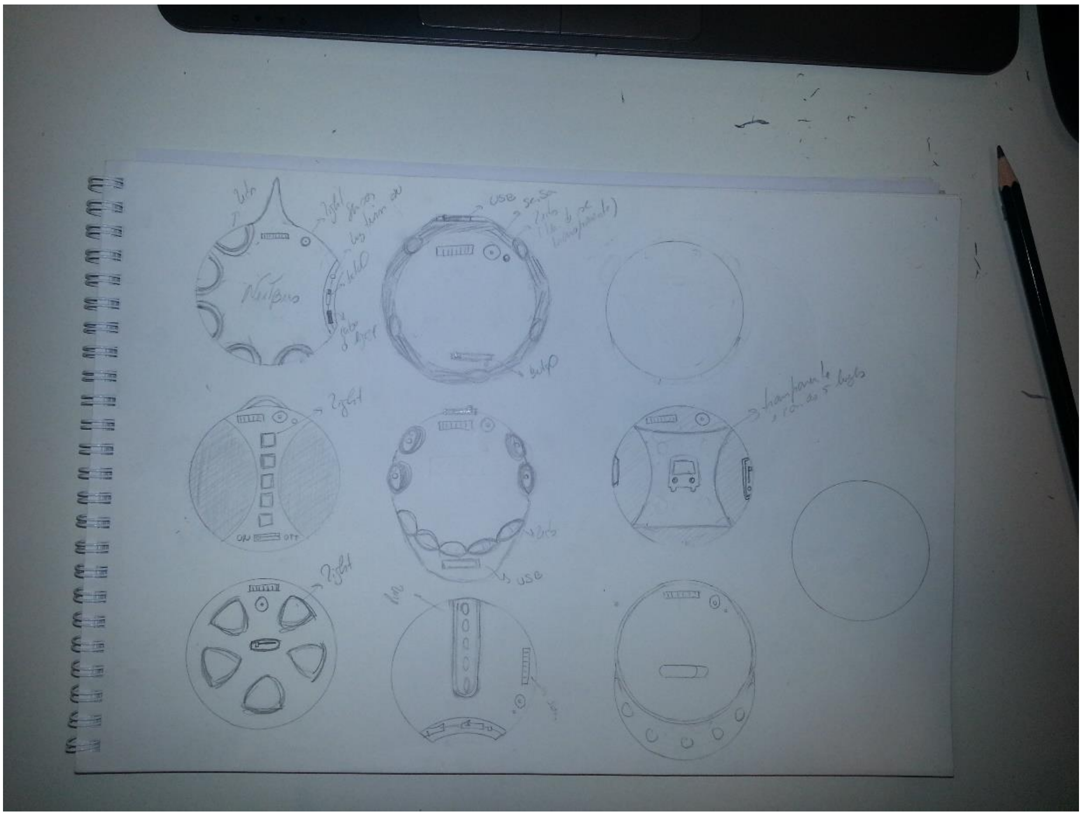


Figure 23- The first sketches of possible prototypes.

The type of information and how it could be viewed by the user, at first, seemed easy to arrange, but curiously there were some obstacles during the procedure. In particular, was not allowed the use of displays so that people could access the information about buses (e.g. bus number, waiting time or other information) because as already mentioned we had to use low technology resources and preferably that were available in the laboratory.

Nowadays, people are very familiar to interact with the latest technology, particularly systems with interactive screens. The interactive screens allow we to view information and users can interact with them. In relation to the prototype, the situation was really challenging because we could not rely on a screen to display our information. Having this into account, how would the users interact with it?

Our solution is an information appliance. The information transmitted to the user is through light and vibration and shows the time remaining to the next bus arrival. In Figure 24 there are examples of possible prototypes designs and we painted with "yellow" color the lights positions in each one of them.

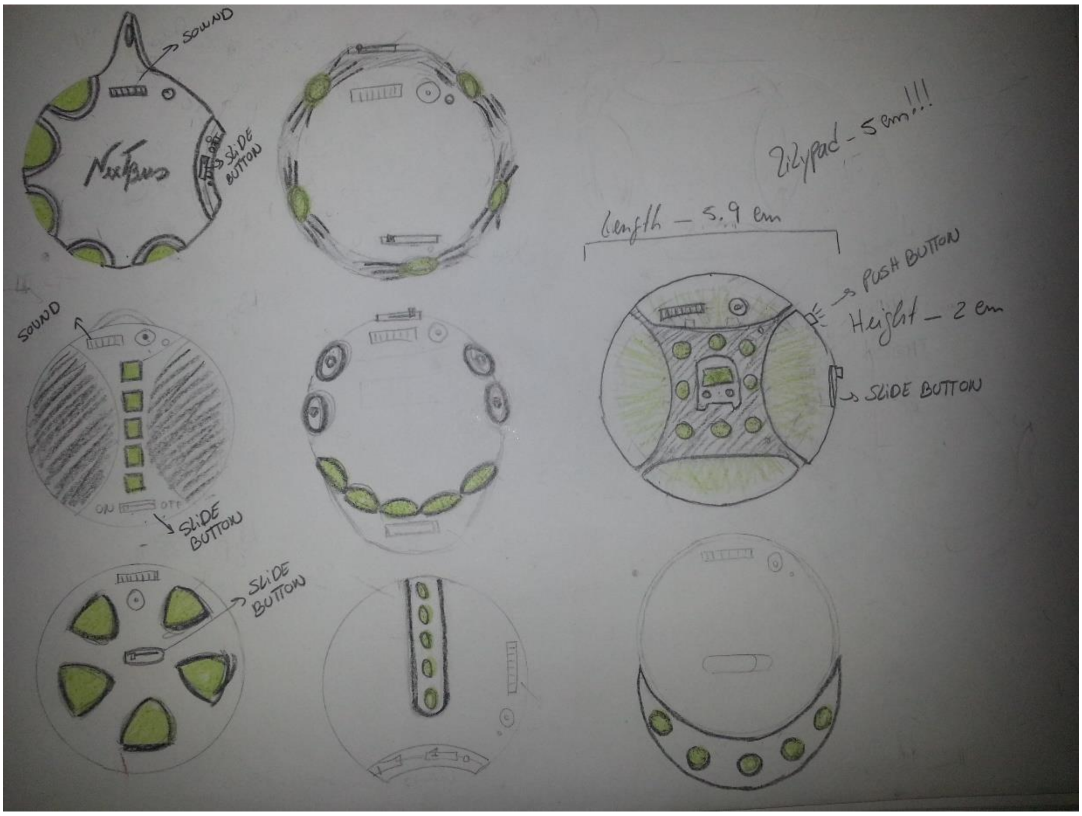


Figure 24- The first sketches of possible prototypes with lights.

As we have said previously, the lights represent information but we choose three different colors to indicate a different type of information, as:

- ✓ *Green* – The user has to depart in less than 12 minutes for the bus stop;
- ✓ *Yellow* – The user has to depart in less than 6 minutes for the bus stop;
- ✓ *Red* – The user has to depart in less than 3 minutes for the bus stop;

In addition, for each type of information we associate a different type of vibration, to draw the user's attention. For instance, the user cannot see the information, when the prototype is within the pocket. Thus the prototype produces a different vibration for each color. In the green color the vibration is produced at a slower rhythm. In the yellow color the vibration the rhythm becomes a bit more frequent and finally in the red color the rhythm is faster and more intense.

4.2. First Experience

From the set of drawings that we have done (See Figure 24 previously), we chose the one that at first seemed to be more interesting to develop, as shown in Figure 25.

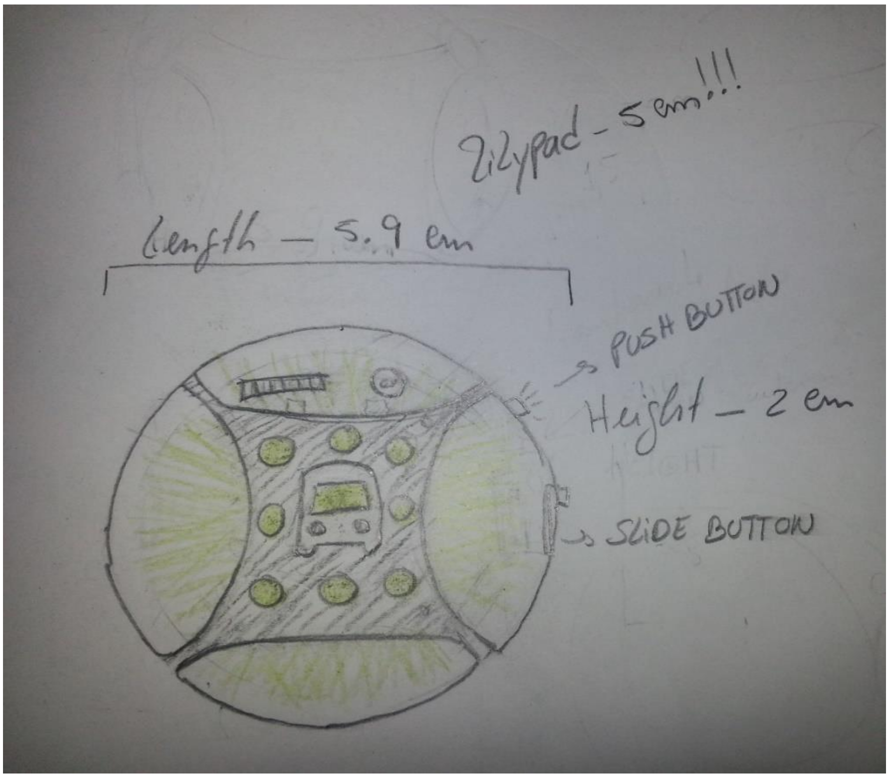
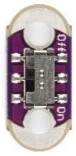


Figure 25- Representation of the chosen model

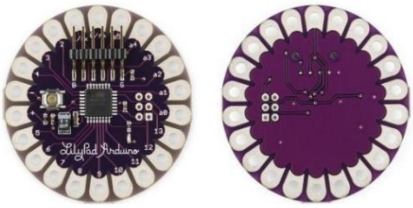
For the first test, we used the material available in the laboratory. The applied material was:

- ✓ 1 RGB LED [25]: to reflect three colors: green, yellow and red.

- ✓ 1 LilyPad Slide Switch [27] to turn on and off the prototype.



- ✓ 1 LilyPad Arduino Main Board [29].



- ✓ 1 LilyPad Vibe Board [28] for the vibration.

- ✓ 1 Bluetooth Mate Silver [6].

- ✓ 1 Polymer Lithium Ion Battery - 110mAh [40].

- ✓ Wires

All these components are economical and small. In addition, they were interconnected in the LilyPad Arduino Main Board [29] because it takes up less space, it is small and round. After the material choice (See Figure 26) we move from sketch to something more realistic and reliable, creating the prototype in 3D.

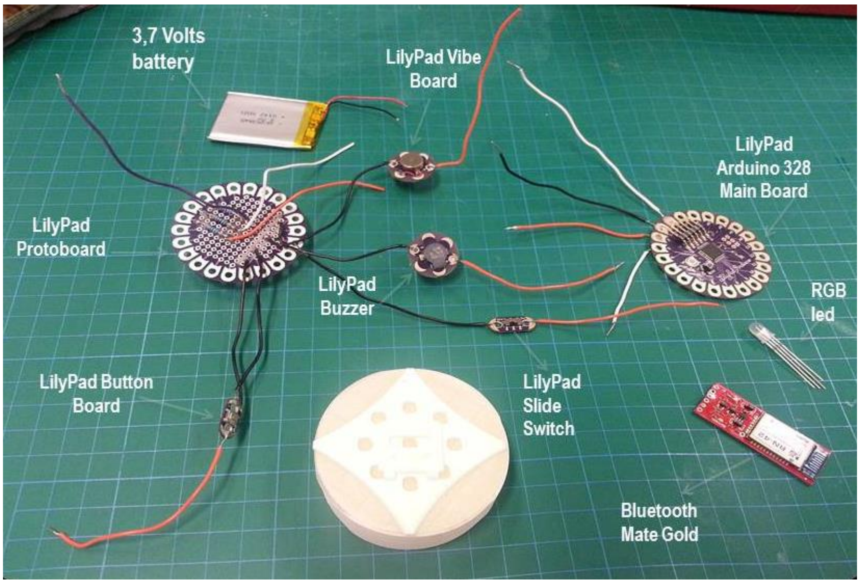


Figure 26- Material for the first step.

The 3Ds Max software [1] was the chosen program to make our 3D design and through the Cura software [10] of Ultimaker printer 3D [46] we printed the first prototype (See Figure 27, 28 and 29) with 5.9 cm long and 2 cm in height.

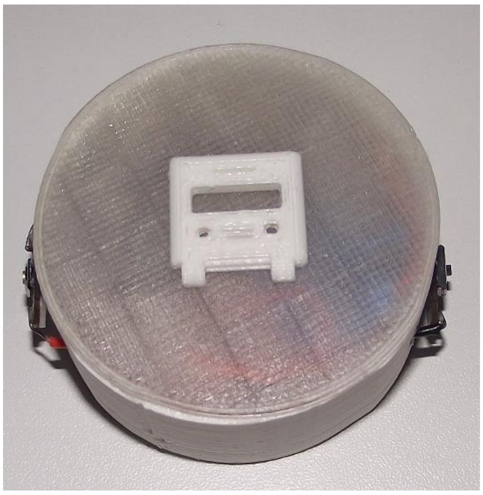


Figure 27- First Prototype.

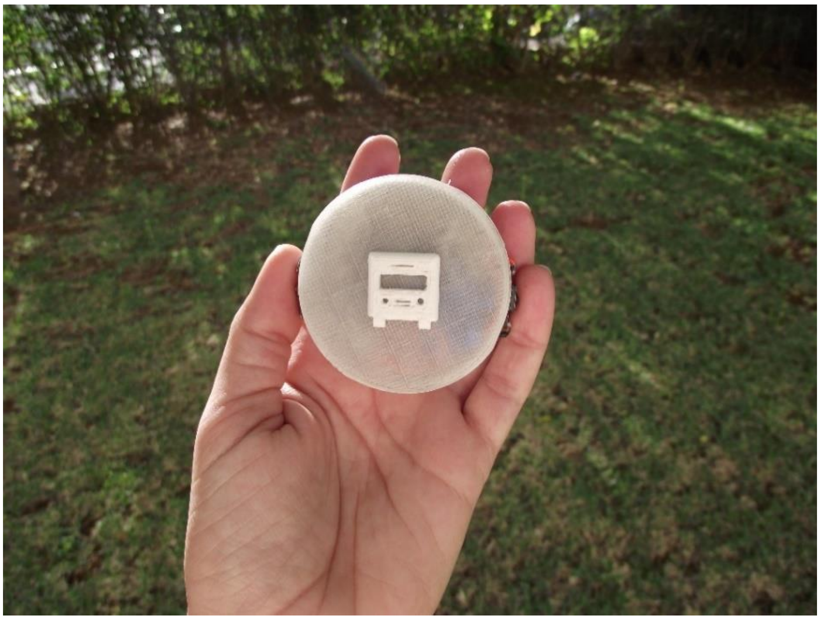


Figure 28- Prototype seen from the front in the hand.

Figure 29- Prototype side perspective.

4.2.1. Findings

During the printing process we encountered some obstacles, particularly with the measures and printer calibration. In 3ds Max software, dimensions appeared to be correct, but when converting to the printer software Cura the dimensions dispersed.

We realized then that we had to be careful with the selection of prototype measurements. In addition, it was necessary to make some adjustments in the design and printing due to the size of the prototype because in reality it was too big to fit in the pocket and too small to fit all the electronic modules.

The printing process was divided into 2 parts as the 3D printer does not support printing of two or more different colors simultaneously, so it was necessary to redesign the prototype. First we printed the base (white color), then a cover (with a transparent color) with a thickness thinner than the base which served to close the prototype and protect the hardware.

The prototype base was printed with white filament not allowing proper reflection of the LED colors to the exterior. Although the top was transparent, we needed more transparency in the prototype.

In what is related to the information provided to the user it was also necessary to make some adjustments because the time set for the transition of each color and vibration were uncoordinated and very fast. The information related to the time left for bus arrival at the stop was not noticeable to the user, because it generated some confusion in its interpretation.

We had problems also with Bluetooth Mate Silver because we could not make the connection of the module with Arduino LilyPad Main Board despite being tested before on a Breadboard and work with our circuit. In this sense the Bluetooth was removed from the project.

4.3. Tangible Prototype

Bearing in mind the findings we obtained from the first prototype tests, it was decided to follow new goals. The first goal was to improve the design in order to be more attractive and interesting to the user. For this, we have changed its round shape and size.

To choose the form for the prototype, we made a search and curiously we come to an interesting pattern, the "shell" of the turtle. The "shell" is oval, small, and its top has a hexagonal pattern (e.g. See Figure 30).

Figure 30- Shape of Turtle shell.

Following the hexagonal concept was created some experimental sketches on paper to better visualize this concept. In Figure 31, we have examples of such designs.

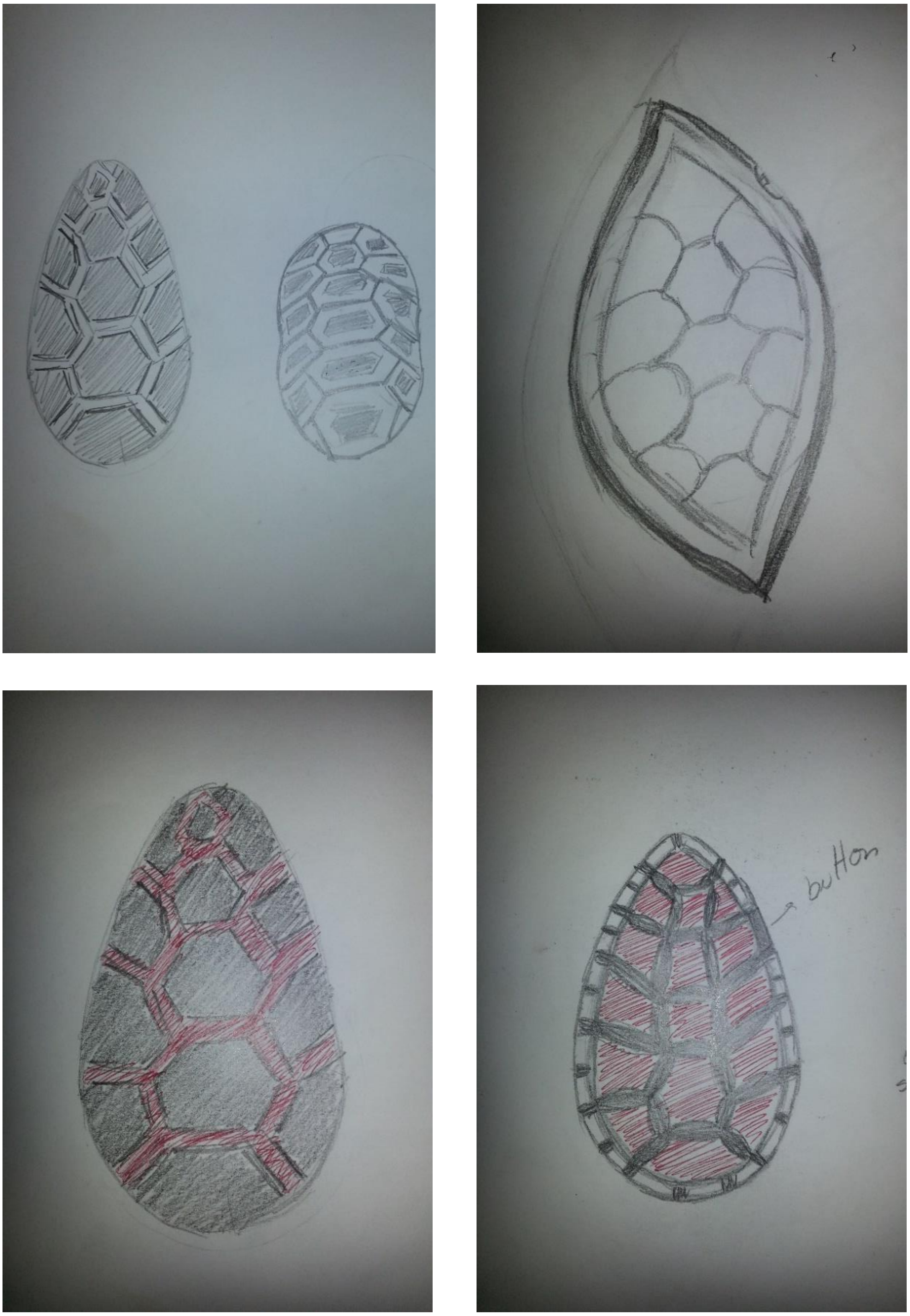


Figure 31- Experimental sketches.

Starting from what has been created on paper we build the experimental sketches to 3D using 3ds Max software[1]. While performing, the sketches were subjected to some changes because the 3Ds program offers a range of options to manipulate objects.

In Figures 32, 33, 34 and 35 we show the results obtained from printed designs in 3D. Figures 32, 34 and 35 were printed with transparent filament and Figure 33 with white filament. The black color in the 3D object was painted by hand to better highlight the emphasis of the edges of the hexagons (See Figure 32, 33 and 35). We applied this technique because the printer was not printing with two different colors at the same time, so we tested this way.

Figure 32- Prototype 1

Figure 33- Prototype 2

Figure 34- Prototype 3

Figure 35- Prototype 4

After printing we noticed that the most suited color for our prototype was transparent filament (See Figure 36, 37 and 38), because it transpires the colors of the LEDs. On the other hand, in other colors such as white, black and blue it was impossible to transpire the colors of the LEDs.

Figure 36- Prototype 1 with green light feedback.

Figure 37- Prototype 4 with blue light feedback.

Figure 38- Prototype 3 with red light feedback.

The printing of the previous objects, also revealed that it is important to pay attention to the thickness in which an object is printed in 3D, because the smaller the thickness of the object will be better to reflect the color of the LEDs to the outside. By diminishing the size of our objects we noticed that the printed design had an unfinished look. In this sense, we return once again to making adjustments to design until we reached the following final prototype design (See Figure 39 and 40). In Figure 39 we have the front prospect of the prototype and in Figure 40 we have the side prospect where the slide switch button is pressed to turn on and off the prototype and insert an SD card.

Figure 39- Front prospect of the Prototype.

Figure 40- Front prospect of the Prototype.

The measures chosen for the prototype was: 89 mm long, 59 mm wide and 15 mm high. These measures have been adapted according to the size of the modules which constitute the electronic circuit of the prototype.

4.3.1. Function

We have developed a new prototype, using some components of the first experience as *LilyPad Arduino Main Board* [26], *LilyPad Vibe Board* [28] and *Polymer Lithium Ion Battery - 110mAh* [40]

and add other modules as:

- ✓ *MicroSD Card breakout board* [34] to store data about the number of times that users check the prototype (e.g. hour, day and minutes) and record the schedules of buses that are part of the user routine;
- ✓ *Lithium Battery Charging Module* [30] to be possible for the user to charge the prototype battery via USB;
- ✓ *DS1307 I2C Real Time Clock Module* [11] to make it possible to count the time;
- ✓ 2 RGB LEDs [25].

In Figure 41 we have the example of the interconnection between all modules which constitute the internal circuit of the prototype.

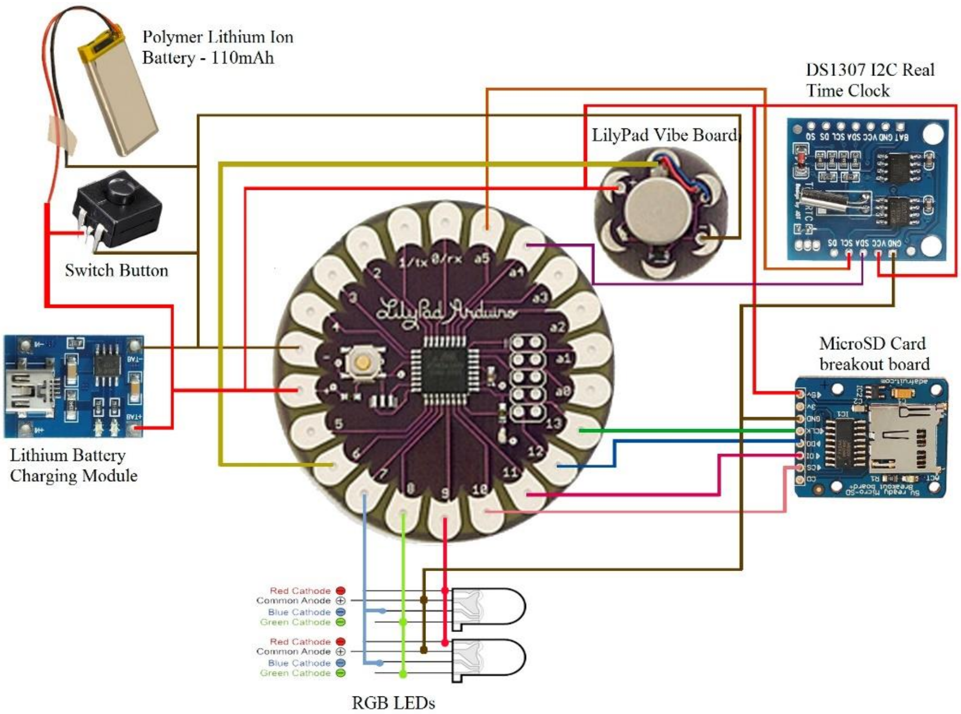


Figure 41- Prototype Electronic Circuit.

In Figure 42 and 43 we have the example of the circuit mounted within the tangible prototype.

Figure 42- Circuit within the prototype.

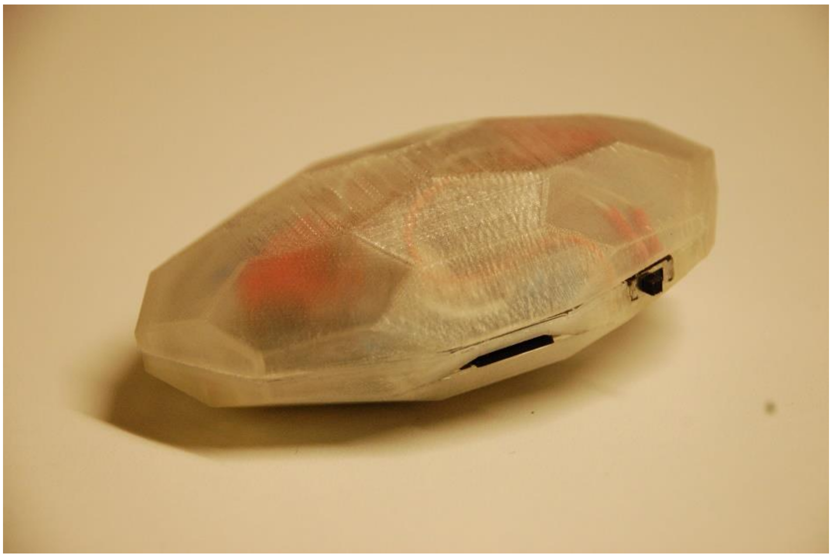


Figure 43- Tangible Prototype finished.

The prototype function as mentioned in the first experiment, it is to give clues to the user through light and vibration concerning the time left to catch the next bus. The lights represent different types of information.

4.3.2. Behavioral

The general behavior of the prototype (See Figure 44) follows a set of processes, from reading and writing on the MicroSD card until the information is transmitted to the user about the minutes left until the bus arrival, through awareness cues (light and vibration).

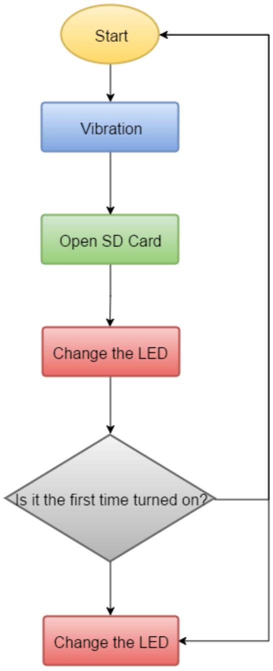


Figure 44- General Behavior of the prototype.

Initially it is introduced into the Micro SD Card the schedule of the bus that user wanted to be notified about. The user could schedule multiple bus schedules from different buses in the MicroSD Card by usual user route.

Whenever the user connected the prototype, the system read the schedule of the bus through the MicroSD Card Breakout Board [34] and then process the information. In Figure 45 we have represented the Micro SD card reading process.

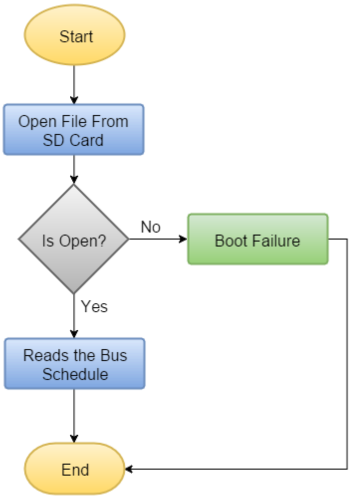
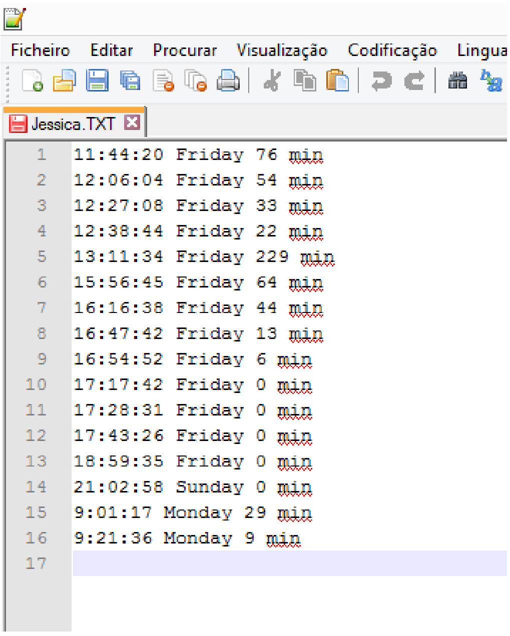


Figure 45- MicroSD card reading process.

If the system would detect that it was the first time that the user was starting the prototype, it would create a file on the MicroSD Card breakout board [34] to record the hours, day of week and the minutes that were missing for the bus to arrive (See Figure 46). This information allowed identifying if the users check or do not check the prototype information and when they did.




```
11:44:20 Friday 76 min
12:06:04 Friday 54 min
12:27:08 Friday 33 min
12:38:44 Friday 22 min
13:11:34 Friday 229 min
15:56:45 Friday 64 min
16:16:38 Friday 44 min
16:47:42 Friday 13 min
16:54:52 Friday 6 min
17:17:42 Friday 0 min
17:28:31 Friday 0 min
17:43:26 Friday 0 min
18:59:35 Friday 0 min
21:02:58 Sunday 0 min
9:01:17 Monday 29 min
9:21:36 Monday 9 min
```

Figure 46- Example of user record.

In the Figure 47 we have the example of the writing process on the MicroSD Card.

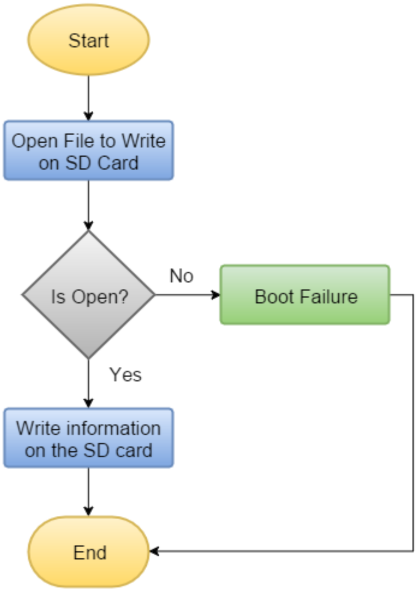


Figure 47- The writing process on the MicroSD card.

As the DS1307 I2C Real Time Clock Module [11] recorded hours, the system made the information transition process, including the transition of colors of LEDs. This transition took place depending on the time that was missing for the arrival of the next bus (See Figure 48), such as:

- ✓ if the time for the next bus was greater than 15 minutes, the green LED would light;
- ✓ if the time for the next bus was between 10 to 15 minutes the yellow LED would light;
- ✓ if the time for the next bus was less than 10 minutes the red LED would light.

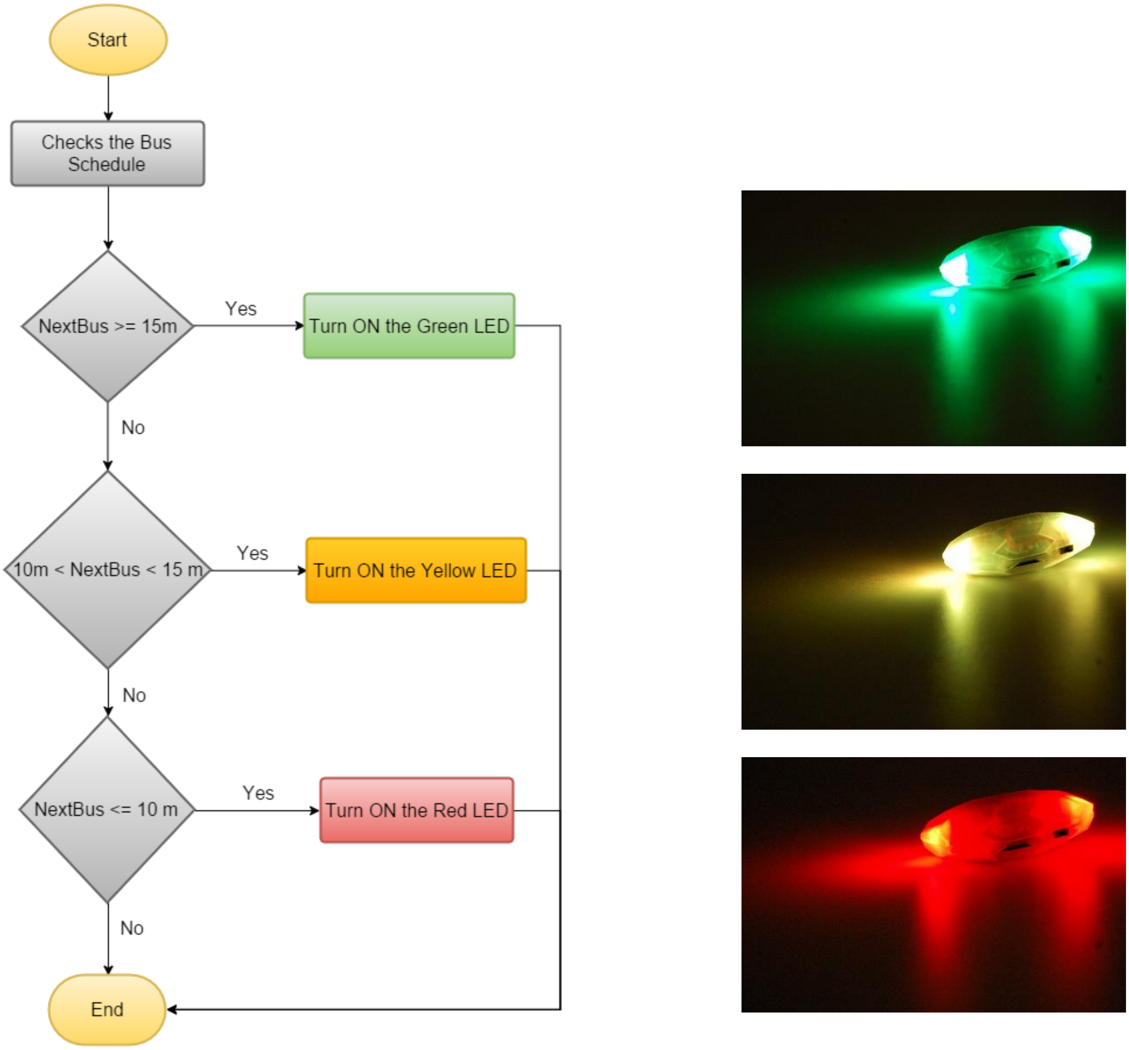


Figure 48- Colors transition process.

Simultaneously with the colors transition process (See Figure 48), the system also performs the vibration intervals process. We decided that the best way to draw the user's attention to check the information was to apply a different vibration rate for each color. In cases where the user, for example, didn’t had the prototype connected, would not be able to see the corresponding color of the time missing to the bus arrival, because he could be in a meeting or have the device in the pocket, but through the rhythm of vibration he might be able to identify the type of information that the prototype wants to transmit.

In the green color, we decided to put a vibration rhythm to indicate that the user has more time to catch the bus (more than 15 minutes).

The yellow color has a steady rhythm less than green for alerting the user that now has less time to take the bus (between 10 and 15 minutes). Finally, the vibration rhythm of the red color is the most intense and repetitive to indicate to the user that lacked little time to catch the bus and could possibly lose it if he doesn't go to the bus stop.

In Figure 49 we have the example of vibration intervals process. This process executes the time interval to light the LED. Each round is 20 seconds but the initial 6 seconds are vibration and LED color flashes always. The LED color lasts half second on and half second off, to make a blinking effect.

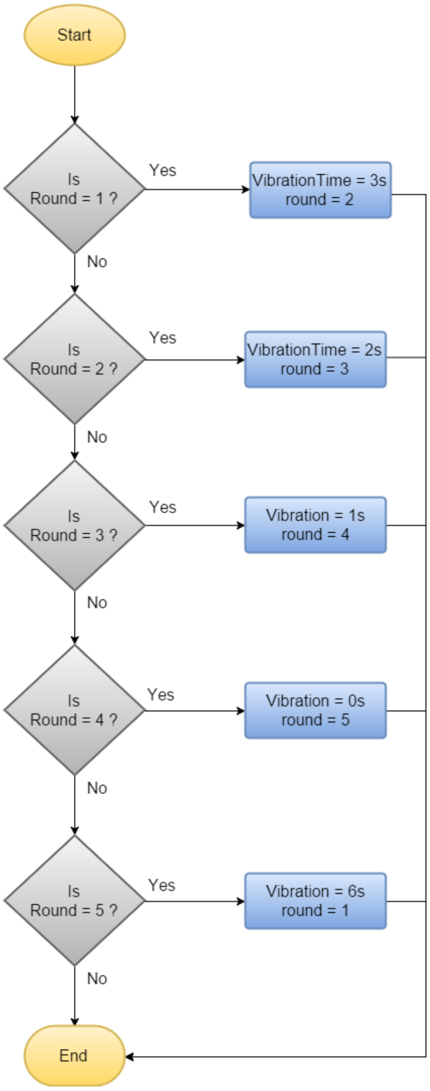


Figure 49- Vibration intervals process

4.4. Discussion

The prototype design process was long. As we added new modules in electronic circuit the design had to be changed. This procedure often happened, because it was necessary to reset the measurements of objects in 3ds Max software [1] and convert the same to millimeters in Cura software [10] of Ultimaker printer 3D [46]. In addition, the modules have their own measures and we needed to measure (height, length and thickness) each of them to find a balance between these measures and the final measures of the prototype.

The development of a small prototype is not an easy process, because we must always take into account its size and its internal space because they are conditioning factors in placing a circuit. The addition of modules, such as: MicroSD Card breakout board [34], Lithium Battery Charging Module [30], DS1307 I2C Real Time Clock Module [11] and 2 RGB LEDs [25] were necessary for the proper functioning of the prototype.

It was necessary to store and have access to the schedules of the buses users, so we added the MicroSD. We remind that the prototype did not provide information in real-time, but static information.

We added another LED on the prototype for more enhance the information color to the outside. However, it was difficult to see, especially when you had plenty of sunlight.

Furthermore, it was important to increase the time intervals to notify the user some time in advance about when the bus would arrive. Knowing that the information is important, the user has some time to decide what to do.

5. Field deployment of a Mobile Glanceable Display

5.1. Study Motivation

In this chapter, we will compare and analyze three conditions (A, B and C). The tangible prototype (C) against the mobile app (B) and a control condition (A) where participants were given no external support in obtaining bus arrival information, other than their existing routines. Using qualitative and quantitative data, we test the following hypotheses and we explored users' reactions to the prototype we developed. We checked the veracity of the following hypotheses:

- H1 – The tangible prototype will be used more frequently than the mobile app;
- H2 – The tangible prototype will reduce the waiting time at the bus stop;
- H3 – The tangible prototype results to reduced anxiety;
- H4 – The tangible prototype results to an increase in the perceived reliability of the transit service;
- H5 – The tangible prototype enhances users' efficiency in reading bus schedules;
- H6 – The tangible prototype makes individuals more likely to use public transit.

5.2. Procedure

The participants in study were students from University of Madeira, Madeira Interactive Technologies Institute – MITI and students who working in Madeira Tecnopolo, SA. All of them are bus users. Initially the study had 10 participants but during the procedure only 8 were accepted because, two not had a smartphone. This study lasted for twenty-four days.

Throughout the study participants used two different approaches to access public transportation schedule. First, we provide a android mobile application with bus information and alarms settings. Secondly, we provided our tangible prototype that log user regular schedules and provide awareness clues about bus arrival time.

Following an ABC method, participants were divided in 8 groups; all joined in three different conditions: A represents *baseline*, B an existing *bus mobile application* (*HF Bus*) and C the *developed prototype*. The order was counterbalanced.

Baseline phase (A): participants *not had access to the prototype and the mobile application* (HF Bus). At the end of the day, they had to fill a short daily questionary (See Appendix I, page 89-90). After three days, an interview was conducted and participants were asked to review commutations events, using day reconstruction method and description of significant events that occurred. Also at the end of the interview the participants filled out a questionnaire to identify the AttracDiff attributes [19] that most characterized the conditions A (See Appendix II, page 95).

Mobile app phase (B): participants *had access to the mobile application* (HF Bus). At the end of the day, they had to fill a short daily questionary (See Appendix I, page 91-92). After three days, an interview was conducted and participants were asked to review commutations events, using day reconstruction method and description of significant events that occurred. Also at the end of the interview the participants filled out a questionnaire to identify the attributes that most characterized the condition B (See Appendix II, page 96).

Prototype phase (C): participants *had access to the prototype*. At the end of the day, they had to fill a short daily questionary (See Appendix I, page 93-94). After three days, an interview was conducted and participants were asked to review commutations events, using day reconstruction method and description of significant events that occurred. Also at the end of the interview the participants filled out a questionnaire to identify the attributes that most characterized the condition C (See Appendix II, page 97).

5.3. Analysis and Methods

Data analysis began with descriptive statistics of people's answers in the daily questionary (See Appendix I) according to three conditions (A, B and C). In this way, we started to analyzing the data through analyze of the statistical significance tests as: Friedman test, Kruskal-Wallis, Mann-Whitney test, and Chi-Square Test of Homogeneity to confirm to the veracity or not of the hypotheses.

In some cases, it was needed measurements such as: average (M) and standard deviation (SD) to complement some of the findings.

Furthermore, in some statistical tests the results were not conclusive enough for the study. In this cases, we used the *Decision trees* approach to find new results or justify the results achieved and *One Way ANOVA* test [37]. The decision trees are data analysis tools that allow the definition of groups without the researcher set to match the cut-off point, the results come from data interactions that define the points that define the groups in the case of continuous variables and join groups in the case of categorical variables [32].

Decision trees create classification conditions. They can be used to segment and to separate, to make predictions or to identify interaction between variables. They are exploratory and confirmatory procedures. The researcher in the decision trees, do not chooses the cutoff point or the groups that will be joined, because the results arise from the interactions between dependent variable and the set of independent variables. In the study we used the CHAID method (Chi-square automatic Interaction Detection) because the dependent variable was the ordinal or nominal level. In each interaction is chosen the independent variable that correlates more closely with the dependent variable [35]. At each step appear nodes that represent homogeneous groups and reveal the interaction between the variables. This tree growing method, statistic Chi-Square defines the division of the nodes and the categories to merge [23]. Decision trees can be obtained for continuous and discrete variables the results are similar.

One Way ANOVA test was used to determine whether there was any significant differences between the means of two or more independent (unrelated) groups [37].

5.3.1. Initial Approach

At first was need to verify, if the conditions of use could all be paired (if individuals from various samples are somehow related to each other), but was conclude that we have measures with different dimensions and we would have problems in the analysis results. The way to solve the problem was to see, if users over time kept the use characteristics, for each condition. So the solution adopted was to look for an evolution in temporal terms of the use as independent observations.

Before starting the data analysis, the *Friedman test* was used in case of the numeric variables, to compare if there was significant changes over time in each condition of use [39]. If the sample value is less than 0.05 we conclude that over time differences occurred. Based on the average number of times the user used the bus and average duration of trips made (see Table 4), the Friedman test confirmed that there are no significant variations over time in the distribution of these variables.

This result allows that each utilization is independent of the others. So we confirm, the hypothesis that the condition of use (A, B, C) does not change significantly (sig) over time, because the obtained results are greater than 0.05 (see Table 4).

	Conditions			**Test**	
	Baseline (A)	**Mobile App (B)**	**Tangible Prototype (C)**	**Fridman**	
	M (SD)	**M (SD)**	**M (SD)**	**X**	**sig**
Average number of times the user used the bus.	4,9 (3)	5,4 (2,4)	4,4 (1,6)	3,071	,215
Average duration of trips made.	14,1 (8,1)	11,8 (5,2)	11,5 (5,2)	1,000	,607

Table 4- Fridman test results over each variables in the three conditions (A, B and C).

In this way to confirm the thesis hypotheses we used Distribution equal tests of two independent samples were used to compare the results between the users that used the application (condition B) with the users that used the prototype (condition C). The Mann-Whitney for ordinal variables, Kruskal-Wallis test for numerical or ordinal variables and Chi-Square Test of Homogeneity for categorical variables [39].

The null hypothesis for this tests says that the distribution of the groups is statistically the same, for test values less than 0.05 and we must reject the null hypothesis. This means, that there are significant (sig) differences between groups.

Secondly, we examined the first three questions answers of the daily questionary with *Chi-Square Test of Homogeneity* to see if there were significant differences (sig) between the conditions (see Table 5). In the question 1, there are no significant differences (sig) in the three conditions, in the way of transport used, in all cases more than 80% of the users used the bus, the second way that is most common is the car, and then the paths made on foot (see Table 5).

The question 3, confirms that in the set of utilizations, 39 were made by bus in condition A, 44 in B and 31 in C, but the distribution is identical only in B and C (see Table 5). In relation to checking the waiting time in question 4 (see Table 5), there was significant differences (sig) according to the condition, because Chi-Square Test of Homogeneity results are less than 0.05. This means that users checked the waiting time more often in the prototype (C) with 80.6% of "Yes" than 50% in the application (B).

Daily questions		**Conditions**			**Homogeneity Test (B and C condition)**	
		Baseline (A)	**Mobile Application (B)**	**Tangible Prototype (C)**	X	**sig**
1. How did you travel during this trip?	Bus	39 (83%)	44 (93,6%)	31 (91,2%)	2,884	0,236
	Car	6 (12,8%)	1 (2,1%)	2 (5,9%)		
	Walk	2 (4,3%)	2 (4,2%)	1 (2,9%)		
	Other	0 (0%)	0 (0%)	0 (0%)		
	Total	47 (100%)	47 (100%)	34 (100%)		
3. Did you travel by bus?	No	6 (13,3%)	3 (6,4%)	3 (8,8%)	0,339	0,844
	Yes	39 (86,7%)	44 (93,6%)	31 (91,2%)		
	Total	45 (100%)	47 (100%)	34 (100%)		
4. Did you check the bus schedule information before or during this trip?	No	28 (71,8%)	22 (50%)	6 (19,4%)	10,882	0,001
	Yes	11 (28,2%)	22 (50%)	25 (80,6%)		
	Total	39 (100%)	44 (100%)	31 (100%)		

Table 5- Homogeneity test results over B and C modes according to the daily questions

5.4. Research Hypothesis

H1 - The tangible prototype will be used more frequently than the mobile app

A first analysis aimed to identify what users appreciated in the tangible prototype. Our qualitative findings revealed a number of features, such as:

- ✓ **Simpler**, *"Only one button and the information is there* [P1]*."*
- ✓ **Faster**, *"If the time is correct, I chose the prototype, because we don´t normally use the phone, or the phone doesn´t have battery or we don´t see the messages. Also we can´t do all this at the same time in the work and if we do, probably the phone would be slow. I only need to turn it on and see the information, it is faster and intuitive* [P2]*."*
- ✓ **Good**, *"There are moments where the vibration indicates warning and in others it seems a countdown, such as the time left for the next bus* [P7]." *"The prototype is good, because we can program it for the next days. In the app, that doesn't happen, because it is only possible to program the alarm for the same day. E.g.: in the morning if we need to see the time left for the next bus quickly* [P4]*."*
- ✓ **Clear**, *"In the first day I didn´t had difficulty to understand how it works. It was very clear* [P2]*."*
- ✓ **Easy to manage the time**, *"I have noticed, that it motivated me to leave more lately than the usual. I spent less time waiting in the bus stop* [P1]*."*

In order to check the validity of hypothesis H1, we employed the Kruskal-Wallis and Mann-Whitney tests to confirm if the three conditions (A, B and C) have the same rate of usage ('Yes' or 'No') during the three phases of the trip (i.e., before, during and after the trip).

Table 6 summarizes the rate of usage during the three phases of the trip, for the three conditions of the study (baseline where users were provided with no tool but could check for bus schedule information on the transit agency's website, along with our two interventions, the mobile app and the tangible prototype).

Daily question		Conditions			Tests				
5. Did you check the information?	**User Answer**	**Baseline (A)**	**Mobile App (B)**	**Tangible Prototype (C)**	**Kruskal-Wallis**		**Mann-Whitney**		
		Users percentage	Users percentage	Users percentage	**X**	**sig**	**A-B (sig)**	**A-C (sig)**	**B-C (sig)**
Before	No	0 (0,0%)	1 (4,5%)	1 (4,0%)	16,647	,000	690,5 (,070)	307,0 (<0,001)	479,5 (,010)
	Yes	11 (100,0%)	21 (95,5%)	24 (96,0%)					
During	No	11 (100,0%)	21 (95,5%)	21 (84,0%)	7,553	,023	838,5 (,346)	526,5 (,022)	609,5 (,071)
	Yes	0 (0,0%)	1 (4,5%)	4 (16,0%)					
After	No	10 (90,9%)	22 (100,0%)	23 (92,0%)	2,877	,237	-	-	-
	Yes	1 (9,1%)	0 (0,0%)	2 (8,0%)					

Table 6- Tests results about the rate of usage during the three phases of the trip, for the three conditions (A, B and C) of the study.

Concerning to checking of information *before the journey*, the Kruskal-Wallis test confirmed that there are significant differences (sig) between the three conditions (A, B and C) with $p<0,001$ (see Table 6). The Mann-Whitney test, concludes there are significant differences (sig) between the groups of pairs A-C ($p<0,001$) and between the B-C ($p<0.01$), but not between A-B ($p>0.05$) (see Table 6).

The percentage of users who have consulted the information through the mobile app (B) before the journey was 95.5%, which rose to 96% in the case of the tangible prototype (see Table 6). This means that individuals are more likely to check the information on the tangible prototype (C), either due to *curiosity* or due to *users' need for time arrival information*. As participants noted, "*I didn´t need to check the prototype but I had some curiosity to see witch color was on it at a certain moment, so I checked, before in home, when walking to the bus stop, in M-ITI, inside the bus and after the bus journey* [P2]." "*In the morning I usually pick up the same bus every day, but even so, I turned on the prototype to see the waiting time. I checked at 8:30 am because the bus normally arrives at 8:40 am* [P3]."

However, in the baseline (A) the percentage of checks before the journey was 100% compared to the mobile app (B) and the tangible prototype (C). This happened because users did not have access to this tools but could check for bus schedule information on the transit agency's website or in the bus stop.

As one may note, in most cases users did not consult the information during and after the trip, once the trip was already under way and they felt no need to re-consult. The Kruskal-Wallis test (see Table 6) indicated significant differences (sig) between the three conditions A, B and C with $p<0.05$. However, when we compared the results of the groups of pairs A-B, A-C and B-C separately, through the Mann-Whitney test we found that there aren´t significant differences (sig) between them ($p>0.05$, see Table 6).

Our qualitative findings revealed that people typically do not consult the information because of two reasons: due to an *established routine* and due to *unexpected situations*. Established routines imply that individuals know time arrival information for predefined time, as a participant commented: *"I do not usually check [the timetable] because I tried all possible ways and it didn't work. I try to follow my plan* [P3]."

Sometimes unexpected situations happened, which the tangible prototype didn't not properly accommodate. As one participant noted, *"If the prototype had all the buses schedules that I need I would prefer to use it more than the app or even the HF website, because I don´t have to do much things. I have only to turn on the button. But in this case I prefer the app because it has all the information I need* [P3]." In other times, confusion emerged due to the seamless design of the tangible prototype. Designed with simplicity in mind, the tangible prototype would not clarify which schedule it was visualizing when breakdowns occurred. As one participant noted: *"I forgot the schedule that has been placed in the prototype, so the information was confusing to understand. It was green when I was walking to the bus stop* [P7]."

In conclusion, we accept hypothesis H1 – The tangible prototype will be used more frequently than the mobile app.

H2- The tangible prototype will reduce the waiting time at the bus stop

A first analysis aimed to identify if the tangible prototype can influence when users decide to depart.

Our qualitative findings revealed that some participants (25%) departed after seeing the red color in the tangible prototype. As participants noted: *"I decided to depart always when the prototype went red* [P1]." *"I gave more importance to the red light, because it is intuitive. Like a clock, it is the hour that is beating, or like a game* [P4]". The red color along with the vibration sparked more importance in users to verify the information than the other colors (green and yellow), because the red indicated the waiting time for the next bus less than 10 minutes. As participants noted: "*In the prototype is easier to see the information about the next bus through the light and vibration. However, the app is easier to forget because the alarm sends a short sound that we can mix up with a phone call or even a message* [P2]." "*I normally decide to depart around 5 to 10 minutes before the bus arrival* [P3]."

In order to check the validity of the hypothesis H2, we employed the Kruskal-Wallis test to confirm if the three conditions (A, B and C) have the same rate of cutback on the waiting average time.

Table 7 summarizes rate of cutback on the waiting average time when users traveling alone ("Yes") or accompanied ("No") for the three conditions (A, B and C) of the study (the waiting time were estimated by users and the data were collected from the answers of question 5 in the daily questionary).

Daily Question	**User Answers**	**Conditions**						**Test**	
		Baseline (A)		**Mobile App (B)**		**Tangible Prototype (C)**		**Kruskal-Wallis**	
		Nº	**M (SD)**	**Nº**	**M (SD)**	**Nº**	**M (SD)**	**H**	**sig**
5. Did you travel alone?	No	15	6,9 (6,7)	19	5,4 (5,2)	10	5,2 (3,1)	,430	,807
	Yes	24	5,6 (6,5)	25	7,3 (7,6)	21	4,1 (2,5)	1,679	,432
Total (waiting average time)		39	6,1 (6,5)	44	6,5 (6,7)	31	4,5 (2,7)	,592	,744

Table 7- Summarizes the waiting average time when users traveling alone or accompanied for the three conditions (A, B and C) of the study.

The waiting average (M) time in baseline (A) was 6.1 minutes with 6.5 SD and increased to 6.5 minutes with 6.7 SD in mobile app (B), but in both cases we observed that the standard deviation (SD) is very high (see Table 7). Higher than the average (M), which results in a coefficient of variation higher than 100%. Yet, in the case of the tangible prototype (C), we observed a cutback on the waiting average (M) time to 4.5 minutes (see Table 7) and this cutback is consistent, because the standard deviation (SD) is only 2.7 minutes, making the coefficient of variation closed to 50%. Although this is positive, the Kruskal-Wallis test do not confirm a significant cutback on the waiting average (M) time.

We also aim to identify if there was an association between traveling alone with more waiting time. The Kruskal – Wallis test (see Table 7) result does not confirm that there is an association between them ($p>0.05$), although the descriptive statistics point in this direction between mobile app (B) users.

Departing time depends on the time that users have to wait for a bus. That time is typically estimated by the user before the trip. Independently of the three conditions (A, B and C) users have a routine as we previously approached in hypothesis H1. The user decides when to leave and this decision depends on two aspects: where the user is and where he wants to go.

All users pointed the waiting time as the major problem for bus user´s. People don´t like to wait, especially in the bus stop. As participants noted: *"It depends on the waiting time, but 15 minutes before, depending where I am. When I was living in the student residence I like it since it was the first bus stop, I could leave 15 minutes before the bus depart. 10 minutes to walk and 5 for wait (...) I prefer waiting 5 than 40 minutes* [P1].

Regarding the waiting time in the three conditions (A, B and C), we found through the Box Plot (see Figure 50), that with exception of the outliers on the right, the waiting time was 15 minutes at most in baseline (A) and mobile app (B), but in the tangible prototype (C) the waiting time was 10 minutes at most. Thus, given these results there is a difference of less 5 minutes between the tangible prototype and the two other conditions (B and C).

This means, that if user decides to depart when the tangible prototype is red, would spend less time in the bus stop than the mobile app (B) and change user behaviors, as a participant commented: *"I have noticed, that it motivated me to leave more lately than the usual. I spent less time waiting in the bus stop* [P1]."

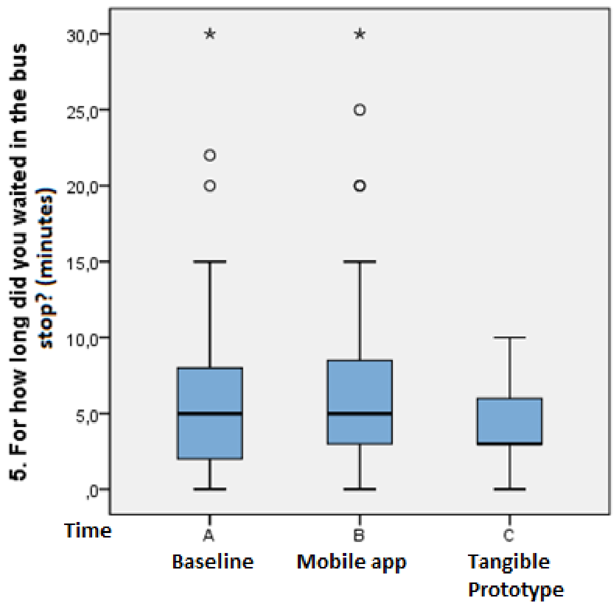


Figure 50- Box Plot results of the waiting time (in minutes) for the three conditions (A, B and C) of the study.

On the other hand, our qualitative data reveal that users fill more confidence when check the waiting time information in the transit agency's website or even the mobile app (B) because of users experience with the tools. As participants noted: "*The HF webpage is easier to understand, because typically I use the same buses and I only need to know the waiting time for the next bus. I put there the bus stop code and generates the time in minutes for catching the bus and I leave 10/15 minutes before (I put an alarm in my pc). In the app I have to look to the map, choose the bus and after I receive information about the waiting time. The app has many steps* [P1]." "*I like the app because I can quickly see the routes, where it goes and where I have to go. Beyond that, if I end my things earlier I can quickly know which bus I have to catch. I can estimate if I go by foot or not* [P6]."

Overall, the prototype does not reduce the waiting time at the stop. It is difficult to measure the waiting time and when users are alone, the values will suffer variations, because it depends on their perception of time.

In conclusion, we reject hypothesis H2 – The tangible prototype will reduce the waiting time at the bus stop

H3- The tangible prototype results to reduced anxiety

Our quantitative findings revealed that, before the bus journey users estimated two periods of times: one for leaving from point A and another to arrive at the point B. Users had a common characteristic, they like to manage their time.

Users had the feeling that the tangible prototype (C) helped them to manage anxiety. As participants noted: "*With both colors you get the feeling of time control. The red color means to hurry up. When you get the green color you know that you can do more things than before, you still have time. E.g.: People who have to change between buses when arriving in Funchal and don´t know if they have time to catch the next bus or not, which can be of another company or not. This controls the anxiety. E.g.: If I had a work presentation in the morning, with the prototype I would feel more confident, although anxious for the presentation but I would have control, because I would see the information in the prototype* [P4]." "*To catch the 1st bus is very handy. I know I have to catch the bus, when the prototype becomes red. In this way the bus arrives in more than less 10 minutes. The bus stop is closer to my home, so, I know that I need to leave 5 minutes before. To catch the 2nd bus, the prototype doesn't make difference; I have to run to catch it, because I have less time to do that. In this case I didn´t felt anxious about losing it. So it is more useful to use the prototype for the 1st bus* [P6]."

In order to check the validity of the hypothesis H3, we employed the Distribution Homogeneity test to confirm if the two conditions (B and C) have the same rate of anxiety. Table 8 summarizes the rate of users anxiety when travelling for the two conditions (B and C) of the study (the data were collected from the answers of question 6 ranked by participants in the daily questionary).

Daily Question	Answers (scale 1 to 5)	Conditions			Distribution Homogeneity Test (B and C)	
		Baseline (A)	Mobile App (B)	Tangible Prototype (C)	X	sig
6. Bring to mind the time you were waiting in the bus stop. How anxious did you feel during this period?	1 – I felt not anxious at all	22 (56,4%)	27 (61,4%)	18 (58,1%)	1,936	0,748
	2	6 (15,4%)	3 (6,8%)	4 (12,9%)		
	3	7 (17,9%)	7 (15,9%)	5 (16,1%)		
	4	3 (7,7%)	5 (11,4%)	3 (9,7%)		
	5 – I felt very anxious during this period	1 (2,6%)	2 (4,5%)	1 (3,2%)		

Table 8- Test results about the rate of user's anxiety when travelling for the two conditions (B and C) of the study.

In table 8, independently of the condition that participants used (A, B and C), the results revealed that more than 50% of users trips were held without no anxiety (row number 1, column 2). In particular, the Homogeneity test confirms that between the mobile app (B) and tangible prototype (C) there are no significant differences (sig), because p> 0.05.

Through the Decision Tree method (See Appendix III) we discover that there are two important factors that influenced people anxiety level: traveling alone and the waiting at the bus stop. In the journeys where participants travelled with someone, 86.4% reported that didn´t felt anxious (Node 1, level 1). When people are anxious they prefer to wait with someone known, because they felt the time passing more quickly. As one participant noted: "The waiting time passes faster when *I'm with another person, one classmate or a friend. I think that always decreases the anxious level. It is better to wait with somebody than alone, even if, for only 5 minutes* [P1]*."* Among the participants who *travel alone*, 41.4% reported that also didn´t felt anxious (Node 2, level 1) and this percentage is about half of the one observed among users who travel with someone.

In the journeys where *user´s traveled alone* (See Appendix III) there was more users that felt less anxiety when the *waiting time* was *less or equal to 10 minutes* (Node 3) from 41% (Node 2) to 46% (Node 3) at level 1. On the other hand, when the *waiting time is higher than 10 minutes* (Node 4), users point to higher anxiety level with 57.1% in level 4 (Node 4). The fact of waiting longer than expected contributes to the increase the level of anxiety felt, as participants noted: *"If I leave after the hour or if I take a long time at the bus stop, my anxiety level is higher* [P3]*."*

"My anxiety level depends on the things I have to do next. E.g.: When I have classes at school I do not feel anxious, but if I have exams I like to arrive earlier or when I have a work appointment with my colleagues, I do not like to be late and I feel anxious for the bus arrival [P4]*."*

In fact, in the Hypotheses H2 it was clear that the waiting time in the tangible prototype (C) is 10 minutes at most and have a difference of less 5 minutes between the baseline (A) and the mobile app (B). However, with these results, we cannot relate directly the use of the tangible prototype (C) with the reduction of user's anxiety level.

Therefore, the results allows us to confirm that the if the waiting time at the bus stop is greater than 10 minutes between users who travel alone exists a significant (sig) increase of anxiety level. So, as the tangible prototype (C) provides waiting times less than 10 min (in the red color), we can say that the prototype will reduce anxiety of users who are traveling alone.

In conclusion, we accept hypothesis H3 – The tangible prototype results to reduced anxiety.

H4- The tangible prototype results to an increase in the perceived reliability of the transit service

In order to check the validity of the hypothesis H4, we employed the Kruskal-Wallis test to confirm if the three conditions (A, B and C) had the same rate of bus schedule consultation.

Table 9 summarizes the percentage of consultation of the bus schedules for the three conditions (A, B and C) of the study (the data were collected from the answers of question 7 ranked by participants in the daily questioner).

Daily Question	Answers (scale 1 to 5)	Conditions			Kruskal-Wallis Test	
		Baseline (A)	**Mobile App (B)**	**Tangible Prototype (C)**	**X**	**sig**
7. Did you feel the need to consult the bus schedule?	1- I had no need to consult the bus schedule.	26 (66,7%)	34 (77,3%)	27 (87,1%)	3,616	0,164
	2	1 (2,6%)	0 (0%)	0 (0%)		
	3	0 (0%)	2 (4,5%)	0 (0%)		
	4	6 (15,4%)	4 (9,1%)	1 (3,2%)		
	5- I need to consult the bus schedule.	6 (15,4%)	4 (9,1%)	3 (9,7%)		

Table 9- Test results about the percentage of consultation of the bus schedules for the three conditions (A, B and C) of the study.

As to the need to consult the bus schedule information, 66.7% of user's didn´t need in the baseline (A), 77.3% in mobile app (B) and 87.1% in tangible prototype (C). Yet, the Kruskal-Wallis test confirmed that there are no significant differences (sig) between the three conditions (A, B and C) with $p>0.05$ (see Table 9).

We found also, through the Decision Tree with CHAID method (Chi-square automatic Interaction Detection) the factors that influence the need to consult the bus schedules (See Appendix IV). Between users who consulted the bus schedule there are two distinct groups. In the baseline (A) group (Node 3), the probability of consultation is higher with 45.5% in the level 4 (Node 3).

Our qualitative findings revealed that people typically need to consult the information in A because of two reasons: don´t have tools (i.e. smartphone, the mobile app or the computer) and in unexpected situations. Routines can be broken when unexpected situations happen and sometimes users cannot control them.

These situations can be as: losing a bus, unknown bus schedule, or new bus stop or because the bus is late. As participants noted: *"It was necessary, because I was not familiar with the bus stop, it was out of my routine. I checked the PDF paper at the bus stop.* [P3]*"; "In the morning I don´t check because it's routine, unless I notice that the bus is late.* [P8]*"* Even if users have the tangible prototype they would not consult it. Users knew from the beginning that, the prototype didn´t has real time arrival information's, as the mobile app. The tangible prototype was designed for the user to schedule the amount of minutes that they want to be alerted for the bus arrival. As one participant commented: *"At the beginning I checked the prototype to see when would the bus arrive, but then I came too late to the bus stop and I lose the bus. Knowing that the prototype don´t have more bus schedule I had to use the app to check for the next bus. The prototype has limitations, I can´t use for unexpected situations like this* [P5]*."* This means that the tangible prototype can only be used in user routine.

On the other hand, (See Appendix IV), mobile app (B) and prototype (C) (Node 4) are in the same group and have the same behavior, with 75.5% of users (Node 4), which means, that there are more users that felt less need to consult. Our qualitative findings revealed that in both conditions people knew the bus schedule, as long they were inside their routine, so they didn´t need to consult. As one participant noted: *"No at this time, because I catch my usual bus and I knew it* [P3]*."*

Furthermore, the results show that inside the B and C groups (Node 4) we can find two kinds of users: the less anxious (Node 5) and the most anxious (Node 6) (See Appendix IV). The less anxious do no need to consult with 85% of users, because they waited between 1 to 3 minutes (Node 5), but 57.1% of users need more to consult because they waited between 4 and 5 minutes (Node 6). This means that users felt more anxiety when they needed to wait more time for the bus arrival.

Secondly, we employed the Decision Tree (See Appendix V) to find what factors influenced the users reliability in the service. We found the factors that most contributed to the variation of the user confidence in the service was *traveling alone* or *accompanied* (i.e. college, friend or family).

When *traveling alone* (Node 1), users are more likely to trust less in the service. The percentage was decreased from 56.1% (Node 0) at level 4 to 44.3% at level 3 (Node 1). However, there are significant differences (sig) with $p<0.05$ in the confidence levels when users *traveling alone* with a waiting *less than 4 minutes* (Node 3) and when the waiting time was *greater than 10 minutes* (Node 7), because the percentage of confidence distribution was similar in both with 57.1 % in level 3.

When users *travelled accompanied* (Node 2), the confidence level increased to 75% at level 4 (See Appendix V). There are significant differences (sig) when users checked or not the bus schedule information. The results confirmed that between the users who *traveling accompanied* and *checked the bus schedule* information (Node 8), felt less confidence in the service with 60% in level 4, comparing to 82.8% of users who didn't check (Node 9).

Overall the users who travelled accompanied (Node 2) and did not check the information felt more confidence in the service than the users who traveling alone (Node 9). Although it is not possible to relate the use of the tangible prototype with the reliability in the service, because our qualitative data reveal that independently of the tools people have, the reliability is related with the user experience with the quality of the service. As one participant noted: *"No. Because already happened more than once that the buses failed and even one day the bus reach halfway the journey and the bus driver said:" Leave the bus please, the journey is over". So I had to get out, and walk until finally get home. They should have more bus options* [P1]."

In conclusion, we reject the hypothesis H4 - The tangible prototype results to an increase in the perceived reliability of the transit service.

H5- The tangible prototype enhances users' efficiency in reading bus schedules

A first analysis aimed to identify which of the AttracDiff attributes [19] (See Appendix II, page 97) users considered relevant to characterize the tangible prototype. Our qualitative findings revealed a number of attributes, such as:

- ✓ **Integrating**, *"Despite my routine, I had always curiosity, to view if was within the times or not t. It is easily integrable* [P3]*." "Fit´s well in my routine* [P6]*."*
- ✓ **Isolating**, *"It is separated from other technologies and the others services* [P5]*." "It is limited because it only has my routine* [P8]*."*
- ✓ **Professional**, *"It is different* [P4]*." "Lights* [P6]*."*
- ✓ **Valuable**, *"The information, yes. Generally, when it changes to red I become more alert and I view the hours* [P3]*." "It is interesting to have the information provided by lights. In this way I don´t need to go to the site or even to the app* [P8]*."*
- ✓ **Inclusive**, *"If it's well planned it can help me to arrive early to the places I want* [P6]*." "Easy to use* [P7]*."*
- ✓ **Brings me closer to people**, *"People ask me, for instance, the time that bus will arrive* [P2]*." "Yes, because people ask me what is it? My father said: see mine* [P3]*."*
- ✓ **Presentable**, *"The color, the touch and the brightness* [P2]*."*
- ✓ **Original and Creative** *"Yes. There is no app with light that catches people's attention as the prototype* [P6]*" "We can use it for the following days* [P7]*."*
- ✓ **Courageous**, *"We´re used to see the schedules in a more traditional way and with the prototype it is different* [P4]*." "It is different from the mobile app* [P5]*."*
- ✓ **Innovative**, *"There isn´t anything like the prototype* [P7]*."*
- ✓ **Exciting and challenging**, *"The colors change. I also had to discover what the vibration means, so yes, it was exciting and challenging* [P4]*."*
- ✓ **Easy and simple**, *"It is easy to use, and we only need to turn it on (one button) and view the information by the colors* [P8]*."*
- ✓ **New**, *"Without display. It has something that the competition does not have. I think it has good commercial potential* [P6]*."*

- ✓ **Technical**, *"It does everything, controls the time* [P2]*." "We do nothing. It gives all the information. We only have to understand the colors* [P4]*."*
- ✓ **Practical**, *"Colors* [P4]*." "It is small and ergonomic* [P6]*."*
- ✓ **Direct**, *"Has some limitations but it is direct, because it has the schedules. Has a little interaction. When we turn it on, we see the time left for the bus through the colors, but there isn't a display as in the app* [P1]*."*
- ✓ **Predictable**, *"Do not has extra features and performs well it is function* [P8]*."*
- ✓ **Clear, and Manageable** *"The information is easier to understand, than to look to a bus schedule* [P5]*." "It is flexible because we can program the schedule as we want* [P8]*."*
- ✓ **Beautiful**, *"Should have other sensation in the touch* [P2]*." "Design* [P7]*."*
- ✓ **Good**, *"The prototype was good. I didn't lose any bus. I think I spent less time in the bus stop. Before, I used the alarm in my pc that warns me in a specific time, but in the prototype with the red light, I left late from M-ITI* [P1]*." "Satisfies people's needs* [P7]*."*

In order to check the validity of the hypothesis H5, we employed the Kruskal-Wallis test to confirm if the three conditions (A, B and C) have the same rate of AttracDiff attributes [19].

Table 10 summarizes the AttracDiff attributes[19] that users have considered most appropriate to characterize each condition (A, B and C) of the study (in the end of each interview, participants were asked to judge in on a scale 1 to 5 the AttracDiff attributes (See Appendix II, page 95-97) that characterize each condition).

AttracDiff Attributes Results	Conditions						Kruskal-Wallis Test	
	Baseline (A)		Mobile app (B)		Tangible prototype (C)			
	M(SD)	Min-Max (Scale)	M(SD)	Min-Max (Scale)	M(SD)	Min-Max (Scale)	H	sig
Standard – Creative	2,4 (1,1)	1 - 4	3,4 (1,3)	1 - 5	4 (0,8)	3 - 5	7,509	,023
Conservative – Innovative	2,5 (1,4)	1 - 5	2,8 (1,3)	1 - 5	4,4 (0,7)	3 - 5	8,654	,013
Commonplace – New	2,1 (1,1)	1 - 4	2,8 (0,9)	1 - 4	4,1 (0,6)	3 - 5	12,249	,002

Table 10- The results about the rate of the attributes AttracDiff [19], for the three conditions (A,B,and C) of the study.

The Kruskal-Wallis test confirmed that there are significant differences (sig) between the three conditions (A, B and C) with $p<0.05$. We found that, the significant differences (sig) corresponding to 3 Hedonic quality-stimulation (HQS) of AttracDiff attributes (See Table 10) but not conclusive for the rest attributes. We used the statistic tests of Kruskal-Wallis and One Way ANOVA to compare the averages between the samples and the results were the same (Appendix VI). The attributes confirmed with significant differences are:

- ✓ ***Standard…Creative*** – The average (M) value was 2.4 in the baseline (A) and 3.4 in the mobile app. In the tangible prototype the average rose to 4 and the standard deviation (SD) was less than the others conditions (A and B) with 0.8, i.e. individuals less diverge from each other.
- ✓ ***Conservative…Innovative*** – The average (M) value was 2.5 in the baseline (A) and 2.8 in the mobile app. In the tangible prototype the average rose to 4.4 and the standard deviation (SD) was less than the others conditions (A and B) with 0.7, i.e. individuals less diverge from each other.
- ✓ ***Commonplace…New*** – The average (M) value was 2.1 in the baseline (A) and 2.8 in the mobile app. In the tangible prototype the average rose to 4.1 and the standard deviation (SD) was less than the others conditions (A and B) with 0.6, i.e. individuals less diverge from each other.

The results confirmed that the tangible prototype is more creative, innovative and new than the transit agency's website and the mobile app. Besides, our qualitative data revealed that individuals have justified the 3 Hedonic quality-stimulation (HQS) attributes (See Table 10) the same way. As participant noted: *"There is no app with light that catches people's attention as the prototype (...) "Without display. It has something that the competition does not have. I think it has good commercial potential* [P6]*." "We can use it for the following days* [P7]*."*

Individuals are more likely to check the colors feedback in the tangible prototype than in the mobile app (B) because awareness they the waiting time and they can do it in less steps. They only have to turn on the prototype button to visualize the information. As one participant noted: "*It's easy for people to use. Has only one button and the information is there* [P7]."

In the mobile app (B) users have to do more steps to get the information. As one participant noted: "*It is difficult, has many steps* [P1]." "*The mobile app loses it, because of the interaction. At first we thought it would take just one click, but in fact we had to go through several steps* [P3]."

We found also that is important to individuals manage their bus schedules for the next days and through the tangible prototype it is possible to do it. As one participant noted: *"It is nice. We can program the prototype for the following days and the app no* [P7]*."* In the mobile app (B) this not happened because has only the information at specific moment. As one participant noted: *"(...) app only gives information for the following minutes* [P4]*."* Even this are positive, users described some prototype features problems such as:

- ✓ Colors feedback**:**
  - o **Red,** "*I saw the red light but I didn´t know what was the specific time left for the bus arrival (10 minutes or less). But when I saw it I knew that I had to go* [P1]."
  - o **Yellow,** "*I have difficulty to distinguish the yellow and the green. I though the time for yellow was bigger. I preferred if the yellow light last longer than the red (e.g.: 4 minutes)* [P5]."
- ✓ Haptic feedback:
  - o **Vibration,** "*The vibration should be only in the red color and in the other colors I found it unnecessary* [P5]." "*The vibration is too noisy, but on the other hand we can see or listen anywhere. Unless we are in another room* [P2]."

- ✓ Bus schedule information:
    - *"I prefer the app, because the prototype has some limitations. I have to plan with some time in advance and don´t give me information if I lose the bus* [P1]*."*
- ✓ Time:
    - *"It is a little confusing, because we don't know if the color changed long time before or not* [P3]*."*

Our qualities findings reveal that these situations happened because the prototype was designed without a display as the mobile application and the information is perceived by the colors transitions (green, yellow and red) and not in real time information. In the tangible prototype each color represent a different time and users have to understand what they mean.

Even so, individuals describe the tangible prototype as a faster tool to check the information, as one participant noted: "*If the time is correct, I chose the prototype, because we don´t normally use the phone, or the phone doesn´t have battery or we don´t see the messages. Also we can´t do all this at the same time in the work and if we do, probably the phone would be slow. I only need to turn it on and see the information, it is faster and intuitive* [P2]."

In conclusion, we accepted the hypothesis H5- The tangible prototype enhances users' efficiency in reading bus schedules.

H6 - The tangible prototype makes individuals more likely to use public transit

In order to check the validity of the hypothesis H6, we employed the Kruskal-Wallis test to confirm if the three conditions (A, B and C) have same average of user's satisfaction. Table 11 summarizes the users satisfaction regarding public transport for each condition (A, B and C) of the study (statement were ranked (scale 1 to 5) by users at the question 8 in the daily questionnaire).

Statement	Conditions						Kruskal-Wallis Test	
	Baseline (A)		Mobile app (B)		Tangible prototype (C)			
	M(SD)	Min-Max	M(SD)	Min-Max	M(SD)	Min-Max	H	sig
Overall, I feel satisfied with the service.	3,4 (0,8)	2 - 4	3,4 (0,7)	2 - 4	3,2 (0,8)	2 - 4	,832	,362
I am positive toward public transportation.	4 (0,9)	1 - 5	3,8 (0,8)	2 - 5	3,6 (1)	1 - 5	1,212	,271
It makes sense to use public transportation.	4,4 (0,8)	2- 5	4,1 (0,8)	2 - 5	4 (1)	1 - 5	,271	,602
People should adopt the use of public transportation.	4 (1)	2- 5	3,7 (0,7)	2 - 5	3,7 (1)	1 - 5	,000	1,000

Table 11- Test results about the user's satisfaction regarding public transport, in the three conditions (A, B and C) of the study.

The Kruskal-Wallis test confirmed that there are no significant differences (sig) between the three conditions (A, B and C) with $p<0.05$. We found that, independently of the condition that have been used, didn´t change the users behaviors about public transportation, because the test values were greater than 0.05 (See Table 11).

Our qualitative data revealed that user's satisfaction depends in the quality of service that public transport provides them, as one participant commented: "*My satisfaction level depends on: Few people in the bus, seats available, no noise, not much time waiting in the bus stop, assurance of a calm trip, without sudden speed increases and safety inside the bus. E.g.: I prefer to seat, because when I travel standing, sometimes I don´t have time to grab myself because of the driver speed or due to hard braking* [P2]."

User’s satisfaction depends on important matters, such as:

- ✓ **More buses available** – *“The buses could pass more often. E.g.: I wait 40 minutes between two buses, for me it’s an absurd. When I go out from M-ITI, could exist more buses to catch* [P1]*.”*
- ✓ **Well- being** – *“I like the service when, I enter the bus and don´t have many people or older people, because I want to seat down. If there are elder people, I have to get up, because I respect their age. In the traffic time it is always stressful* [P2]*.”*
- ✓ **Driver´s speed** – *“Some drivers are crazy. We have to grab for not to fall. This happened especially when bus is full."*

However, people are still positive toward public transportation, as participants noted: *“It is good. We can save some money, we don't have to worry about the parking and it’s good for the environment* [P4]*.” “Yes, I feel positive. I like to travel by public transit. I just think that people should use more the buses to move around in the city* [P6]*.”*

Overall, the tangible prototype cannot change the commutation behaviors, because even people being on time at the bus stop the bus service may have delays.

In conclusion, we reject the hypothesis H6- The tangible prototype makes individuals more likely to use public transit.

6. Conclusion

The development of an information appliance including hardware and software, brought some limitations, but on the other hand also brought a number of benefits. We reflect below on the design aspects that need to be taken into account when developing such systems.

We found that users checked more often the information with the tangible prototype than with the mobile application of Horários do Funchal. This is because in the tangible prototype, the access to information requires less resources (less steps for the user to have access to the information) and actions (one button), and also the prototype colors feedback that provide awareness to the users about the waiting time, more easily than the mobile application. People do not want to waste time to find information they need, especially when they are late or miss a bus. That is why, the results confirmed that the tangible prototype enhances users' efficiency in reading bus schedules.

Regarding the waiting time, we found that the prototype did not reduce the waiting time at the bus stop. It is important to note though we were based on self-reported measures of time spent at the bus stop - this will evidently suffer from biases as it depends on the perception of time, which may vary with external factors, such as if someone was alone and whether he or she was in a hurry among others.

We found that usually people do not feel anxiety when they can carry out their activities within a daily routine they created themselves. However, if for some reason the waiting time for a bus takes longer than 10 minutes and the user is alone the anxiety level will increase. So, as the tangible prototype provides waiting times lower than 10 min (in the red color), we can say that the prototype will reduce anxiety of users who are traveling alone.

Another interesting aspect we found was that the main factor influencing the confidence of users in the public transport service is their experience with it, regardless of the tools they use (Horários do Funchal website, HF Bus - mobile application and even the tangible prototype).

The quality of service is mainly related to the waiting time (the bus arriving later than anticipated by the user or by the tools that the user uses), but also by other aspects such as: vehicle conditions (cleaning), bus fullness (places to sit, do not have to stand) and the speed imposed by the driver (travel safely with a calm driving), among others. If these particularities are within acceptable standards by users, can contribute to increase the user satisfaction level with the service provided.

However, the tangible prototype cannot change the commuting behaviors, because even when people are on time at the bus stop the bus service execution may have delays.

6.1. Limitations

The design and prototyping of an information system can be a long process and we can find various obstacles. After the knowledge we gain from the first experience of prototyping, we noticed that it is important to know first what kind of information will be provided to the user and what electronic equipment will be part of the system. Secondly, to perform the design according to the user requirements and the available resources iteratively. While we wanted to shrink the size of the device, technical limitations such as the number of used electronic components did not allow as to reach the size we initially wanted, and this required an iteration on the form of the prototype.

The prototype printing in 3D, also revealed a number of problems because sometimes we had to adjust the calibration of 3D printer until reaching the desired result.

Furthermore, due to the fact that we have developed a prototype with simple design, the information provided by the tangible prototype generated some confusion and surprise on users. Some doubts have arisen in the visualization of color transition (for instance, green to yellow) and the exact time that was missing until the bus arrival to the bus stop, once the prototype has no display.

We also found that users had doubts over the functioning and reliability of the prototype. They attributed more confidence to the website of Horários do Funchal and to the mobile application than to the prototype. This happened because the users have a better experience with these tools and due to the fact that the prototype is something new and mostly does not provide real-time information. The prototype could only be programmed and consulted within the usual user routine.

6.2. Future Work

We noted that users are very familiar to advanced information technologies such as applications, websites and open source platforms that provide more detailed information about the buses in real time. In this way it would be important that the prototype could provide information in real time. We found that real-time information is very important for users especially when unexpected situations take place, such as missing a bus. We also found that users need to know what is the next bus arrival time. One possible solution would be to connect the prototype to the website of Horários do Funchal and add a display so that the user can check the information in more detail, when these situations occur.

In addition, another possible improvement would be to add a small led (in the outside of the prototype) to provide information related to the state of the prototype battery.

7. Reference

[1] 3Ds Max: *http://www.autodesk.com/education/free-software/3ds-max#*. Accessed: 2016-02-22.

[2] Anable, J. 2005. "Complacent Car Addicts"; or "Aspiring Environmentalists"? Identifying travel behaviour segments using attitude theory. *Transport Policy*. 12, 1 (2005), 65–78.

[3] Andreas Zachariah: Carbon Diem: *http://www.greenchallenge.info/index.php/competition/finalists/andreas-zachariah-carbon-diem#*.

[4] Beirão, G. and Sarsfield Cabral, J. 2006. Enhancing service quality in public transport systems. *Urban Transport XII: Urban Transport and the Environment in the 21st Century*. 1, (2006), 837–845.

[5] Beirão, G. and Sarsfield Cabral, J. a. 2007. Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy*. 14, 6 (2007), 478–489.

[6] Bluetooth Mate Silver: *https://www.sparkfun.com/products/12576*. Accessed: 2016-02-22.

[7] Carbon Diem for business: *http://www.carbondiem.com/carbondiem-business.xhtml*. Accessed: 2016-02-02.

[8] Carbon Diem: *http://www.carbondiem.com/*. Accessed: 2016-02-11.

[9] CarbonDiem app: *https://play.google.com/store/apps/details?id=com.carbonhero.carbondiem.ui.android&hl=pt_PT*. Accessed: 2016-03-14.

[10] CURA AND 3D PRINTING: *https://ultimaker.com/en/products/cura-software*. Accessed: 2016-02-22.

[11] DS1307 I2C Real Time Clock Module: *http://www.atomsindustries.com/ASD1028*. Accessed: 2016-02-24.

[12] Dziekan, K. and Kottenhoff, K. 2007. Dynamic at-stop real-time information displays for public transport: effects on customers. *Transportation Research Part A: Policy and Practice*. 41, 6 (2007), 489–501.

[13] Ferris, B., Watkins, K. and Borning, A. 2010. OneBusAway: results from

providing real-time arrival information for public transit. *Proceedings of the SIGCHI Conference on Human Computer Interaction*. (2010), 1807–1816.

[14] FOOTPRINT CALCULATOR: *http://footprint.wwf.org.uk/*. Accessed: 2016-02-13.

[15] Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B. and Landay, J.A. 2009. UbiGreen: Investigating a Mobile Tool for Tracking and Supporting Green Transportation Habits. *Chi '09*. (2009), 1043–1052.

[16] Fujii, S. and Garling, T. 2003. Applications of attitude theory for improved predictive accuracy of stated preference methods in the travel demand analysis. *Transportation Research Part A: Policy and Practice*. 37, 4 (2003), 389–402.

[17] Fujii, S. and Kitamura, R. 2003. What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation*. 30, 1 (2003), 81–95.

[18] Guiver, J.W. 2007. Modal talk: Discourse analysis of how people talk about bus and car travel. *Transportation Research Part A: Policy and Practice*. 41, 3 (2007), 233–248.

[19] Hassenzahl, M. 2004. The Interplay of Beauty, Goodness, and Usability in Interactive Products. *Human Computer Interaction*. 19, 4 (2004), 319–349.

[20] Hensher, D.A., Stopher, P. and Bullock, P. 2003. Service quality - developing a service quality index in the provision of commercial bus contracts. *Transportation Research Part A: Policy and Practice*. 37, 6 (2003), 499–517.

[21] Hertwich, E.G. and Peters, G.P. 2009. Carbon Footprint of Nations: A Global, Trade-Linked Analysis. *Environmental Science & Technology*. 43, 16 (2009), 6414–6420.

[22] HF Bus application: *https://play.google.com/store/apps/details?id=onemploy.group.hftransit&hl=pt_PT*. Accessed: 2016-02-09.

[23] IBM 2013. *IBM SPSS Decision Trees 21*.

[24] König, A. and Axhausen, K.W. 2002. The reliability of the Transportation System and its influence on the Choice Behaviour. *Proceedings of the 2nd Swiss Transportation Research Conference*. (2002).

[25] LED 5mm - Difuse RGB CC: *http://ledsandchips.com/store/310?search=RGB*.

[26] LilyPad Button Board: *http://lilypadarduino.org/?p=430*. Accessed: 2016-02-22.

[27] LilyPad Slide Switch: *http://lilypadarduino.org/?p=421*. Accessed: 2016-02-22.

[28] LilyPad Vibe Board: *http://lilypadarduino.org/?p=514*. Accessed: 2016-02-22.

[29] Lilypad: *http://lilypadarduino.org/*. Accessed: 2016-02-22.

[30] Lithium battery charger module: *http://www.electrodragon.com/product/1a-lithium-battery-charger-module-wminiusb/*. Accessed: 2016-02-24.

[31] Machado, S., José, R. and Moreira, A. 2012. Social Interactions Around Public Transportation. *Information Systems and Technologies*. (2012).

[32] Maletic, J.I. and Marcus, A. 2005. *Data Cleansing Data Mining and Knowledge Discovery Handbook*.

[33] Measure your impact - WWF: *http://wwf.panda.org/how_you_can_help/live_green/footprint_calculator/*. Accessed: 2016-02-13.

[34] MicroSD card breakout board+: *https://www.adafruit.com/products/254*. Accessed: 2016-02-24.

[35] Oded Maimon, L.R. Data Mining and Knowledge Discovery Handbook.

[36] OneBusAway - The Open Source platform for Real Time Transit Info: *http://onebusaway.org/*. Accessed: 2016-02-04.

[37] One-way ANOVA in SPSS Statistics: *https://statistics.laerd.com/spss-tutorials/one-way-anova-using-spss-statistics.php*. Accessed: 2016-03-15.

[38] Patterson, D.J., Liao, L., Gajos, K., Collier, M., Livic, N., Olson, K., Wang, S., Fox, D. and Kautz, H. 2004. Opportunity Knocks: a System to Provide Cognitive Assistance with Transportation Services. *International Conference on Ubiquitous Computing (UbiComp}*. (2004), 433–450.

[39] Pestana, M.H. and Gageiro, J.N. 2014. *Análise de Dados para Ciências Sociais - A Complementariedade do SPSS*.

[40] Polymer Lithium Ion Battery - 110mAh: *https://www.sparkfun.com/products/731*. Accessed: 2016-02-22.

[41] Rahman, F., Ahamed, S.I., Hoque, E., O'Brien, C., Zhang, H. and Liu, L. 2010. UCFC - Ubiquitous personal carbon footprint calculation platform. *2010 International Conference on Green Computing, Green Comp 2010*. (2010), 425–432.

[42] Sussman, J.M. 2005. ITS: A short history and a perspective on the future. *Perspectives on Intelligent Transportation Systems (ITS)*. December 1996 (2005),

3–17.

[43] This Is Our Stop: *http://thisisourstop.com/*. Accessed: 2016-01-31.

[44] ThisIsOurStop: *http://denimandsteel.com/work/this-is-our-stop/*. Accessed: 2016-02-10.

[45] Types of displays: *http://www.networkwestmidlands.com/realtime/displaytypes.aspx*. Accessed: 2016-02-10.

[46] ULTIMAKER ORIGINAL: *https://ultimaker.com/en/products/ultimaker-original*. Accessed: 2012-02-22.

[47] Vieira, V., Caldas, L.R. and Salgado, A.C. 2011. Towards an Ubiquitous and Context Sensitive Public Transportation System. *2011 Fourth International Conference on Ubi-Media Computing*. (2011), 174–179.

[48] Zimmerman, J., Tomasic, A., Garrod, C., Yoo, D., Hiruncharoenvate, C., Aziz, R., Thiruvengadam, N.R., Huang, Y. and Steinfeld, A. 2011. Field Trial of Tiramisu: Crowd-Sourcing Bus Arrival Times to Spur Co-Design. *Hci*. (2011), 1677–1686.

8. Appendix

I – Daily Questionary (A, B and C conditions)

Condition A

Date: ___________

Time: ___________

1. How did you travel during this trip?

☐ Bus ☐ Car ☐ Walk ☐ Other: ________________.

2. Duration of the trip (end to end)? ______________.

3. Did you travel by bus? If yes, skip to next question. If not, Why not?

____
____
____

Please answer the next questions only if you travelled by bus.

4. Did you check the bus schedule information before or during this trip? How/where?

____
____
____

5. For how long did you waited in the bus stop? ______ minutes.

5.1. Did you travel alone? ☐ Yes ☐ No

6. Bring to mind the time you were waiting in the bus stop. Please circle the number that shows how anxious did you feel during this period?

I felt not anxious at all during this period.	1	2	3	4	5	I felt very anxious during this period.

6.1. Which part of your trip was the most stressful?

____
____.

7. Did you feel the need to consult the bus schedule?

I had no need to consult the bus schedule.	1	2	3	4	5	I needed to consult bus schedule.

7.1. Where/How?

____
____ .

7.2. Please respond to the following statement about how reliable do you feel about the service?

Statement:	Strongly disagree ... Strongly Agree
Overall, I feel the service to be reliable.	1 2 3 4 5

8. Please respond to the following statement about how you feel regarding public transportations.

Statement:	Strongly disagree ... Strongly Agree
Overall, I feel satisfied with the service.	1 2 3 4 5
I am positive toward public transportation.	1 2 3 4 5
It makes sense to use public transportation.	1 2 3 4 5
People should adopt the use of public transportation.	1 2 3 4 5

Condition B

Date: ___________

Time: ___________

1. How did you travel during this trip?

☐ Bus ☐ Car ☐ Walk ☐ Other: ________________.

2. Duration of the trip (end to end)? ______________.

3. Did you travel by bus? If yes, skip to next question. If not, Why not?

____

____

____

Please answer the next questions only if you travelled by bus.

4. Did you check the bus schedule information before or during this trip? How/where?

____

____

____

5. For how long did you waited in the bus stop? ______ minutes.

5.1. Did you travel alone? ☐ Yes ☐ No

5.2. When did you decide to depart? The mobile app in some way changed the way you made this decision?

____

____

6. Bring to mind the time you were waiting in the bus stop. Please circle the number that shows how anxious did you feel during this period?

I felt not anxious at all during this period.	1	2	3	4	5	I felt very anxious during this period.

6.1. Which part of your trip was the most stressful?

____

____.

7. Did you feel the need to consult the bus schedule?

I had no need to consult the bus schedule.	1	2	3	4	5	I needed to consult bus schedule.

7.1. Where/How?

____
____ .

7.2. Please respond to the following statement about how reliable do you feel about the service?

Statement:	Strongly disagree Strongly Agree
Overall, I feel the service to be reliable.	1 2 3 4 5

8. Please respond to the following statement about how you feel regarding public transportations.

Statement:	Strongly disagree Strongly Agree
Overall, I feel satisfied with the service.	1 2 3 4 5
I am positive toward public transportation.	1 2 3 4 5
It makes sense to use public transportation.	1 2 3 4 5
People should adopt the use of public transportation.	1 2 3 4 5

Condition C

Date: ___________

Time: ___________

1. How did you travel during this trip?

☐ Bus ☐ Car ☐ Walk ☐ Other: ________________.

2. Duration of the trip (end to end)? ______________.

3. Did you travel by bus? If yes, skip to next question. If not, Why not?

____

____

____

Please answer the next questions only if you travelled by bus.

4. Did you check the bus schedule information before or during this trip? How/where?

____

____

____

5. For how long did you waited in the bus stop? ______ minutes.

5.1. Did you travel alone? ☐ Yes ☐ No

5.2. When did you decide to depart? The prototype in some way changed the way you made this decision?

____

____

6. Bring to mind the time you were waiting in the bus stop. Please circle the number that shows how anxious did you feel during this period?

I felt not anxious at all during this period.	1	2	3	4	5	I felt very anxious during this period.

6.1. Which part of your trip was the most stressful?

____

____.

7. Did you feel the need to consult the bus schedule?

I had no need to consult the bus schedule.	1	2	3	4	5	I needed to consult bus schedule.

7.1. Where/How?

____

____ .

7.2. Please respond to the following statement about how reliable do you feel about the service?

Statement:	Strongly disagree Strongly Agree
Overall, I feel the service to be reliable.	1 2 3 4 5

8. Please respond to the following statement about how you feel regarding public transportations.

Statement:	Strongly disagree Strongly Agree
Overall, I feel satisfied with the service.	1 2 3 4 5
I am positive toward public transportation.	1 2 3 4 5
It makes sense to use public transportation.	1 2 3 4 5
People should adopt the use of public transportation.	1 2 3 4 5

II – Interview Questionary (A, B and C conditions)

Condition A

With the following word-pairs we ask you to characterize the bus schedule information. Please circle the answer you judge most appropriate.

Isolating	1	2	3	4	5	Integrating
Amateurish	1	2	3	4	5	Professional
Gaudy	1	2	3	4	5	Classy
Cheap	1	2	3	4	5	Valuable
Noninclusive	1	2	3	4	5	Inclusive
Takes me distant from people	1	2	3	4	5	Brings me closer to people
Unpresentable	1	2	3	4	5	Presentable
Typical	1	2	3	4	5	Original
Standard	1	2	3	4	5	Creative
Cautious	1	2	3	4	5	Courageous
Conservative	1	2	3	4	5	Innovative
Lame	1	2	3	4	5	Exciting
Easy	1	2	3	4	5	Challenging
Commonplace	1	2	3	4	5	New
Technical	1	2	3	4	5	Human
Complicated	1	2	3	4	5	Simple
Impractical	1	2	3	4	5	Practical
Cumbersome	1	2	3	4	5	Direct
Unpredictable	1	2	3	4	5	Predictable
Confusing	1	2	3	4	5	Clear
Unruly	1	2	3	4	5	Manageable
Ugly	1	2	3	4	5	Beautiful
Bad	1	2	3	4	5	Good

Condition B

With the following word-pairs we ask you to characterize the mobile application. Please circle the answer you judge most appropriate.

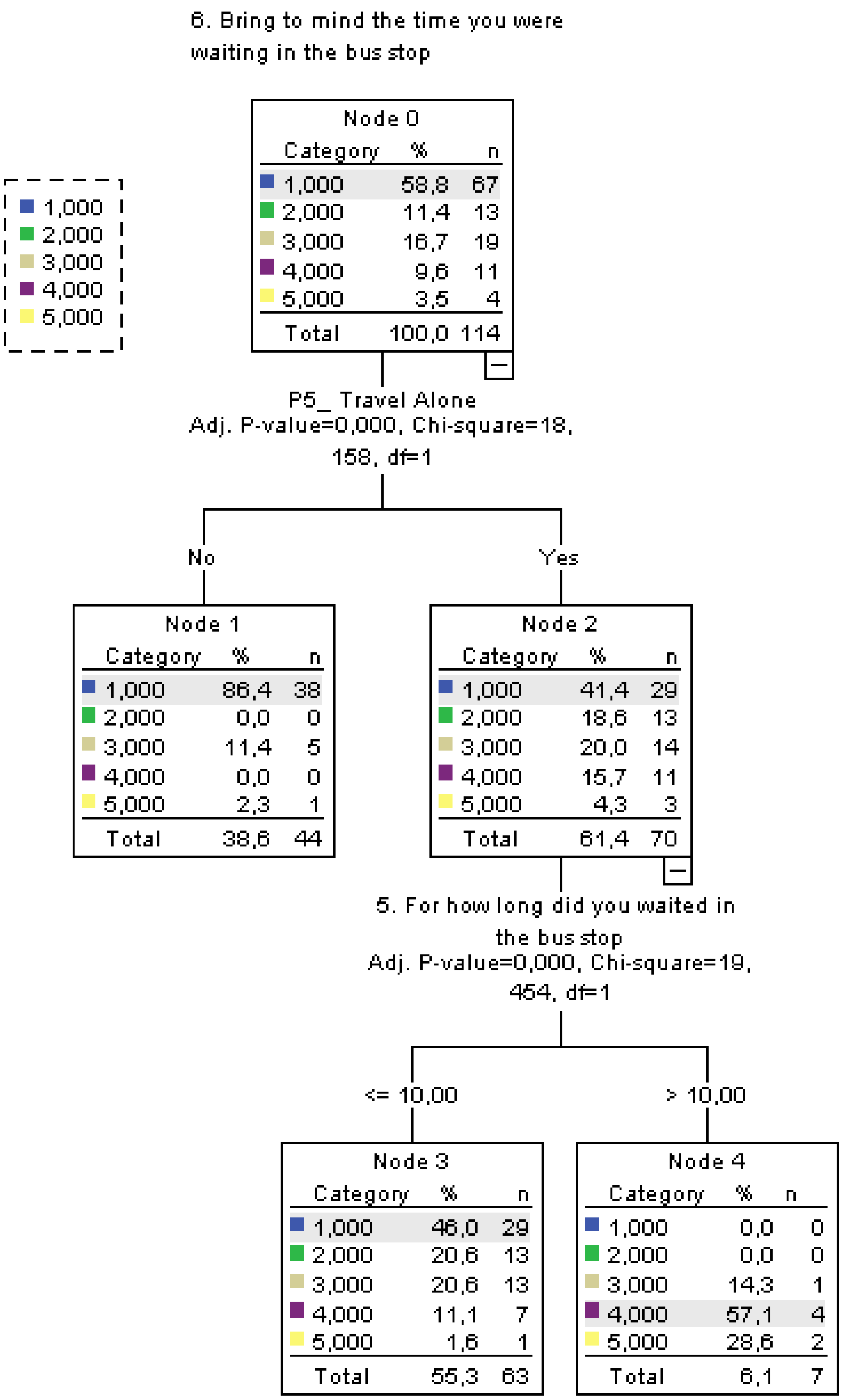
Isolating	1	2	3	4	5	Integrating
Amateurish	1	2	3	4	5	Professional
Gaudy	1	2	3	4	5	Classy
Cheap	1	2	3	4	5	Valuable
Noninclusive	1	2	3	4	5	Inclusive
Takes me distant from people	1	2	3	4	5	Brings me closer to people
Unpresentable	1	2	3	4	5	Presentable
Typical	1	2	3	4	5	Original
Standard	1	2	3	4	5	Creative
Cautious	1	2	3	4	5	Courageous
Conservative	1	2	3	4	5	Innovative
Lame	1	2	3	4	5	Exciting
Easy	1	2	3	4	5	Challenging
Commonplace	1	2	3	4	5	New
Technical	1	2	3	4	5	Human
Complicated	1	2	3	4	5	Simple
Impractical	1	2	3	4	5	Practical
Cumbersome	1	2	3	4	5	Direct
Unpredictable	1	2	3	4	5	Predictable
Confusing	1	2	3	4	5	Clear
Unruly	1	2	3	4	5	Manageable
Ugly	1	2	3	4	5	Beautiful
Bad	1	2	3	4	5	Good

Condition C

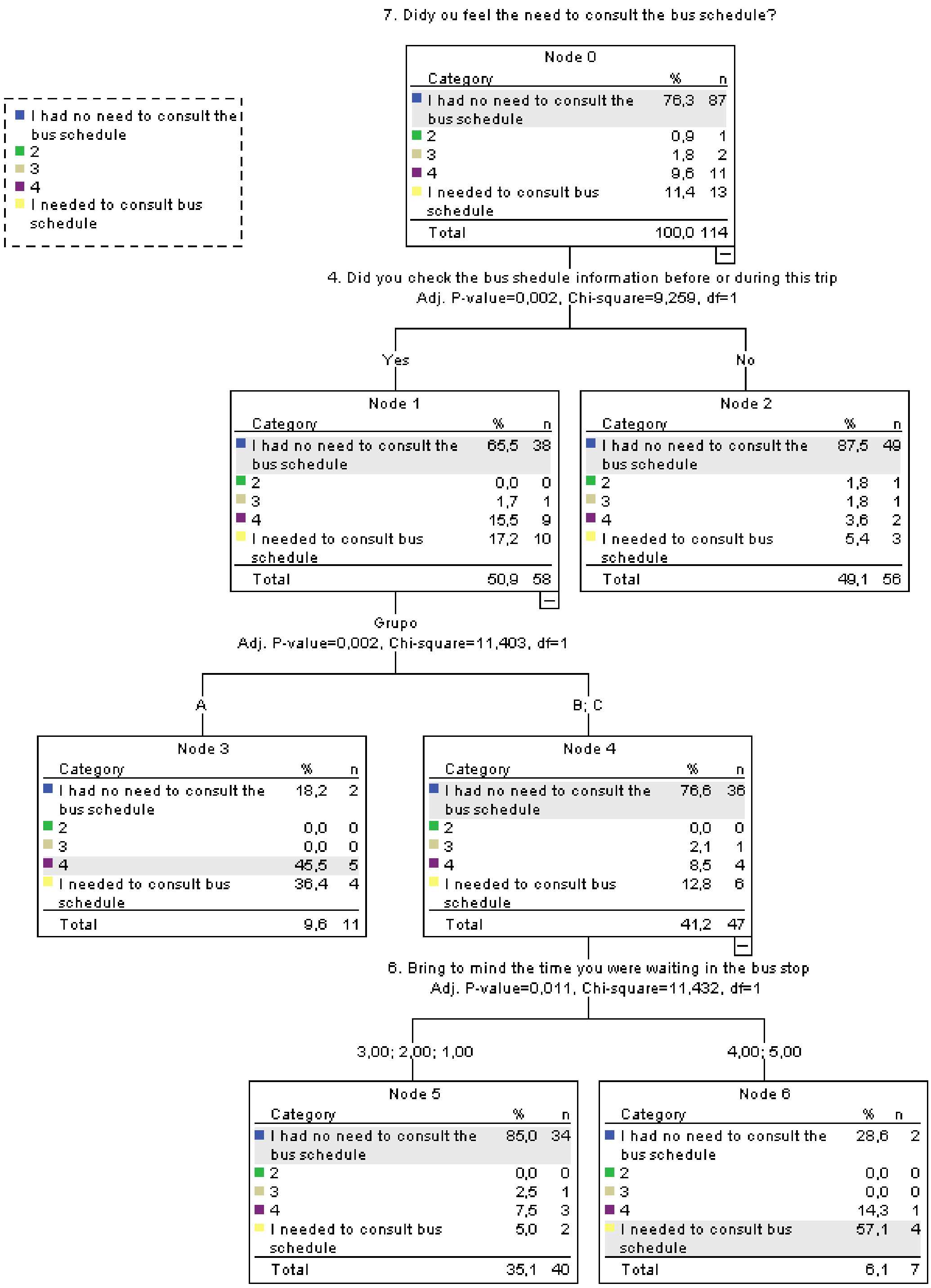
With the following word-pairs we ask you to characterize the prototype. Please circle the answer you judge most appropriate.

Isolating	1	2	3	4	5	Integrating
Amateurish	1	2	3	4	5	Professional
Gaudy	1	2	3	4	5	Classy
Cheap	1	2	3	4	5	Valuable
Noninclusive	1	2	3	4	5	Inclusive
Takes me distant from people	1	2	3	4	5	Brings me closer to people
Unpresentable	1	2	3	4	5	Presentable
Typical	1	2	3	4	5	Original
Standard	1	2	3	4	5	Creative
Cautious	1	2	3	4	5	Courageous
Conservative	1	2	3	4	5	Innovative
Lame	1	2	3	4	5	Exciting
Easy	1	2	3	4	5	Challenging
Commonplace	1	2	3	4	5	New
Technical	1	2	3	4	5	Human
Complicated	1	2	3	4	5	Simple
Impractical	1	2	3	4	5	Practical
Cumbersome	1	2	3	4	5	Direct
Unpredictable	1	2	3	4	5	Predictable
Confusing	1	2	3	4	5	Clear
Unruly	1	2	3	4	5	Manageable
Ugly	1	2	3	4	5	Beautiful
Bad	1	2	3	4	5	Good

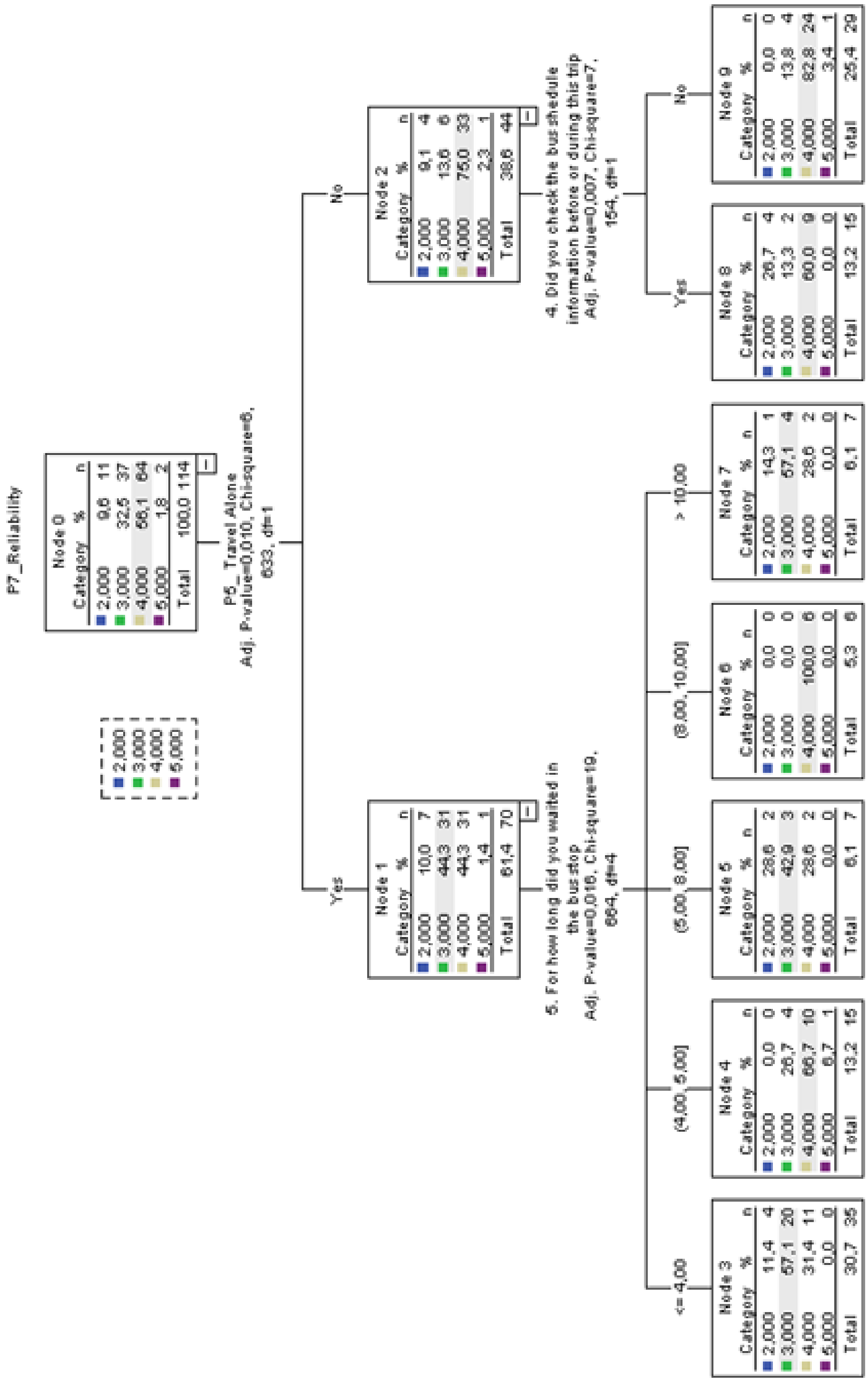
III – Decision Tree of the factors that influence the level of anxiety



IV – Decision Tree of the factors that influence the need to consult the bus schedule



V – Decision Tree of the factors that influence the reliability in the service



VI – Statistic tests in the AttracDiff attributes of Marc Hassenzahl

AttracDiff Attributes Results	**Conditions**						**Compare the Averages**	
	A		**B**		**C**		**Statistic Test**	**sig**
	M(SD)	**Min-Max**	**M(SD)**	**Min-Max**	**M(SD)**	**Min-Max**		
HQI	3,3(0,8)	2-5	3,4(0,9)	2-5	3,2(0,6)	2-4	F=,114	,893
Isolating … Integrating	2,8 (0,7)	2 - 4	3,1 (1,2)	1 - 5	3,1 (1,6)	1 - 5	H=,504	,777
Amateurish … Professional	3,5 (1,4)	1 - 5	3,6 (0,7)	3 - 5	3,4 (0,7)	2 - 4	H=,364	,834
Gaudy … Classy	3,6 (0,7)	3 - 5	3,6 (1,1)	2 - 5	2,9 (0,6)	2 - 4	H=3,951	,139
Cheap … Valuable	3,4 (1,6)	1 - 5	3,1 (1)	2 - 4	3,4 (0,9)	2 - 5	H=,463	,793
Noninclusive … Inclusive	3,1 (0,8)	2 - 5	3,4 (1,2)	1 - 5	3 (1,3)	1 - 5	H=,885	,643
Takes me distant from people … Brings me closer to people	3,4 (1,2)	2 - 5	2,5 (1,5)	1 - 5	3,4 (1,4)	1 - 5	H=1,993	,369
Unpresentable … Presentable	3,6 (0,9)	2 - 5	4,1 (0,6)	3 - 5	3,3 (0,7)	2 - 4	H=4,877	,087
HQS	2,5(0,9)	1-4	2,8(0,9)	1-4	3,6(0,4)	3-4	F=4,828	,019
Typical … Original	3 (1,4)	1 - 5	3 (1,4)	1 - 5	4 (0,8)	3 - 5	H=3,386	,184
Standard … Creative	**2,4 (1,1)**	**1 - 4**	**3,4 (1,3)**	**1 - 5**	**4 (0,8)**	**3 - 5**	H=**7,509**	**,023**
Cautious … Courageous	2,4 (0,7)	1 - 3	2,5 (1,1)	1 - 4	3,5 (0,9)	2 - 5	H=5,802	,055
Conservative … Innovative	**2,5 (1,4)**	**1 - 5**	**2,8 (1,3)**	**1 - 5**	**4,4 (0,7)**	**3 - 5**	H=**8,654**	**,013**
Lame … Exciting	2,5 (0,9)	1 - 4	3,1 (1)	2 - 5	3,4 (0,7)	2 - 4	H=3,744	,154
Easy … Challenging	2,4 (1,1)	1 - 4	2,4 (1,3)	1 - 4	2 (1,1)	1 - 4	H=,587	,746
Commonplace … New	**2,1 (1,1)**	**1 - 4**	**2,8 (0,9)**	**1 - 4**	**4,1 (0,6)**	**3 - 5**	H=**12,249**	**,002**
PQ	3,5(0,7)	3-5	3,6(0,8)	2-5	4,0(0,7)	3-5	F=1,255	,306
Technical … Human	3 (0,8)	2 - 4	2,6 (1,2)	1 - 5	2,6 (1,7)	1 - 5	H=1,042	,594
Complicated … Simple	3,9 (1)	2 - 5	4 (1,3)	2 - 5	4,6 (0,5)	4 - 5	H=2,610	,271
Impractical … Practical	4,1 (1)	3 - 5	4,4 (1,1)	2 - 5	4,3 (0,7)	3 - 5	H=,589	,745
Cumbersome … Direct	3,3 (0,9)	2 - 5	3,6 (1,4)	1 - 5	4,3 (0,9)	3 - 5	H=3 ,737	,154
Unpredictable … Predictable	3,5 (0,9)	2 - 5	3,1 (0,6)	2 - 4	4,1 (1,5)	1 - 5	H=4,789	,091
Confusing … Clear	3,3 (1,3)	1 - 5	3,4 (1,4)	1 - 5	4 (0,9)	2 - 5	H=1,803	,406
Unruly … Manageable	3,5 (0,9)	2 - 5	4 (1,1)	2 - 5	4,4 (0,7)	3 - 5	H=3,530	,171

Table 12- Kruskal-Wallis statistic test (H), comparison of averages from non-normal samples and One Way ANOVA statistic test (F), average comparison from normal samples in the AttracDiff attributes for the three conditions (A, B and C) of the study.