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Theia Street Navigation

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Resumo

Com a rápida evolução e desenvolvimento urbano que são possíveis de observar ao redor do mundo, o processo de documentação e manutenção do ambiente urbano torna-se crucial para uma ação rápida e eficaz no espaço de rua, para além de beneficiar a relação entre cidadãos e municípios. Apesar deste processo se mostrar progressivamente mais complexo, o advento tecnológico reduziu o esforço necessário para a documentação do espaço cidade, através de ferramentas como o Google Street View.

No entanto, há limitações com estas ferramentas, uma vez que a quantidade de capturas em determinadas regiões não se estende muito na dimensão temporal. Desta forma, há uma necessidade de uma ferramenta que mais facilmente permita avaliar a evolução temporal do espaço de rua.

O objetivo principal deste projeto é desenvolver uma funcionalidade multiplataforma para a aplicação móvel Theia que permita a navegação em imagens e vídeos georreferenciados. Estas capturas são previamente recolhidas por cidadãos comuns ou com câmeras instaladas em veículos. Após serem recolhidos, estes são usados para criar uma timeline do estado das ruas composta por todas as fotos tiradas no local.

Estas timelines são integradas na aplicação e acedidas através de um visualizador de rua, na qual o utilizador pode navegar espacialmente pelas imagens disponíveis nessa timeline. O utilizador final escolhe a data da timeline a ser exibida de acordo com as datas disponíveis para aquele local, adicionando assim uma vertente temporal à análise urbana. É também possível ao utilizador adicionar "area flags", que consistem em indicadores utilizados para apontar a necessidade de capturas de imagem em determinadas localizações geográficas.

Após o processo de desenvolvimento, o produto é testado quer com cidadãos comuns quer com utilizadores profissionais na vertente de manutenção urbana, de forma a validar o produto, garantindo que as necessidades e objetivos dos utilizadores pretendidos são tidas em consideração, e certificando que o produto desenvolvido atinge metas de usabilidade e carga de trabalho.

Desta forma, o projeto visa melhorar processo de mapeamento e gestão de ruas e do espaço urbano, através de dimensões como resíduos, vegetação e estado de conservação de infraestruturas e edifícios. Promove também uma melhor documentação da transformação das ruas, permitindo assim uma evolução mais positiva do espaço urbano, para além de estabelecer relações mais fortes entre cidadãos e municípios.

Palavras Chave: Georeferenced Image Navigation, Street View Imagery, Street Timelines, Urban Management

Abstract

With the rapid evolution and urban development observable around the world, the process of documenting and maintaining the urban environment becomes crucial for quick and effective action in street spaces, as well as benefiting the relationship between citizens and municipalities. Although this process is becoming increasingly complex, technological advancements have reduced the effort required for documenting city spaces through tools like Google Street View.

However, there are limitations to these tools, as the frequency of captures in certain regions does not extend much in the temporal dimension. Therefore, there is a need for a tool that more easily allows for the evaluation of the temporal evolution of street spaces.

This project's primary objective is to develop a multi-platform feature for the Theia mobile application that allows for navigation in georeferenced images and videos. These captures would have been previously collected by average citizens or with dashboard cameras installed on vehicles. After being gathered, they would then be used to create a timeline of the state of the street composed of all captures taken at the location.

These timelines would be integrated with the app and accessed through a road viewer, where the user can spatially navigate through the available images on that timeline. The end-user would then choose the date of the timeline to be displayed according to the available dates at that location, thus adding a temporal dimension to urban analysis. It is also possible for the user to add "area flags," which are indicators used to point out the need for image captures in certain geographic locations.

After the development process, the product is tested with both ordinary citizens and professional users in the field of urban maintenance to validate the product, ensuring that the needs and objectives of the intended users are taken into account and certifying that the developed product meets usability and workload targets.

This way, the project aims to better street mapping and the urban space through dimensions such as waste, vegetation, and the condition of infrastructure and buildings. It also allows for better documentation of the street space's transformation, thereby enabling a more positive evolution of urban spaces, as well as establishing stronger relationships between citizens and municipalities.

Keywords: Georeferenced Image Navigation, Street View Imagery, Street Timelines, Urban Management

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Diogo Santos Pereira

*“Oh well...
Whatever happens, happens.”*

Spike Spiegel

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Abbreviations and Symbols

ADDIE	Analyze, Design, Develop, Implement, and Evaluate
API	Application Programming Interface
BSV	Baidu Street View
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GSV	Google Street View
NASA-TLX	NASA Task Load Index
QUIS	Questionnaire for User Interaction Satisfaction
RAD	Rapid Application Development
SDK	Software Development Kit
SUS	System Usability Scale
SVI	Street View Imagery
TSV	Tencent Street View
UI	User Interface
UX	User Experience
VSVI	Volunteered Street View Imagery

Capítulo 1

Introduction

1.1 Problem

In today's rapidly evolving urban landscapes, ensuring the well-being and optimal functionality of public spaces presents a significant challenge [7]. This task demands continuous monitoring and prompt intervention to address any issues that may arise. Traditionally, the methods used for overseeing urban infrastructure and managing occurrences within public areas have been both labor-intensive and time-consuming. Moreover, these conventional approaches often tend to be reactive, addressing problems only after they have occurred, rather than being proactive in preventing them.

The introduction of digital technologies, particularly the development of advanced web applications, offers a promising way for enhancing the efficiency, scope, and responsiveness of urban management efforts. These innovative tools have the potential to shape the way cities monitor and maintain their public spaces by providing real-time data and insights, allowing for quicker and more informed decision-making.

However, despite the potential of these digital solutions, the current tools available are not yet fully capable of meeting the demands of modern urban management. Although platforms like Google Maps[13] and Google Street View[14] are valuable resources for documenting streets and aiding navigation, they fall short in certain critical areas. One of the primary limitations of these tools is the frequency with which their images are updated, which hinders the ability of urban planners and managers to effectively analyze and understand the ongoing development and changes in street environments.

The update rate of images could be vastly improved by the employment of crowd-sensing[26], allowing citizens to voluntarily contribute images of the urban space. However, despite being in demand in recent research, that method of data collection is still not widely employed for reporting urban occurrences, as issues such as the number of users and privacy arise[9].

This way, the mentioned problem is being approached having the Sustainable Development Goals in mind.

In 2015, the UN developed the United Nations' Agenda 2030, which is a plan to achieve sustainable development across the globe[21]. From the 17 outlined Sustainable Development Goals, which aim to address a wide range of global challenges, 3 go in line with the mentioned problem:

- **Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation**
- **Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable**
- **Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels**

1.2 Theia

The Theia project consists of a cross-platform mobile application whose goal is to allow for citizens to report urban issues, making the urban management process more aware of the needs of its inhabitants, as well as allowing for the establishment of a better relationship between citizens and municipalities. Users are able to create accounts and report urban issues by capturing photos or videos, which are then analyzed by an AI which catalogues occurrences in the images and frames. However, it is challenging to geographically pinpoint these occurrences and distinguish them solely on their addresses, and there is no current sense of street evolution display on these occurrences, considering the current lack of the temporal dimension on the evolution of the street. There is also no current global overview of images and videos captured by users, which would give users a better sense of the app's coverage, as well as enabling the viewing of images and videos taken by other users.

1.3 Motivation

There is a pressing need for further development and enhancement of digital tools to fully realize their potential in supporting the dynamic and complex nature of urban management, allowing for more efficient and comprehensive method to analyze, document, and manage changes in urban street environments. We aim to program a component capable of transforming how public authorities, private entities, and communities interact with and manage urban spaces, as well as providing a richer, more dynamic understanding of urban life, paving the way for better management of public spaces.

While Google Street View offers a valuable service by providing panoramic images of streets at a single point in time, its utility is limited when it comes to understanding how urban spaces evolve over time. The proposed street management module goes beyond this by introducing the capability to navigate street images across different dates, allowing users to observe and analyze

changes in the urban environment over time. This temporal navigation opens up new possibilities for understanding the dynamics of city life and responding to the ongoing transformation of urban spaces.

The potential applications of this component are vast and varied. For instance, public authorities could use it to monitor waste disposal practices and parking violations, or to assess the condition of infrastructure such as roads, bridges, and public buildings. This component could also be invaluable in monitoring and documenting the state of historical monuments, green spaces and public art. By capturing real-time occurrences such as graffiti, vegetation overgrowth, or public safety incidents, authorities and organizations would be able to respond more swiftly and effectively, ensuring that public spaces remain clean, safe, and well-maintained.

Lastly, this tool has the potential to create a deep impact for its target users. For public authorities, it would mean more efficient assignment of resources, better-informed decision-making, and enhanced capacity for maintenance and incident response. For private companies, it could present opportunities for insights into consumer behavior, advertisement effectiveness, and strategic planning for infrastructure development. For the community at large, it could guarantee cleaner, safer, and more engaging urban spaces, and allows for a stronger and more stable relationship with municipalities.

1.4 Objectives

In order to better the interaction and management of urban spaces by authorities and organizations, we will undergo the following objectives:

- Develop a cross platform street management component for the Theia mobile app;
- Enable users to view different street timelines (collection of street images at different moments in time);
- Enhance urban spaces by promoting better urban management processes through improved documentation of the roads and active citizenship.

A research question was created using the PICO (Population, Intervention, Comparison, Outcome) framework, where its components were defined as shown:

- **Population:** Local residents, authorities, private organizations.
- **Intervention:** Theia's street images visualization component.
- **Comparison:** Other street navigation digital technologies, such as Google Street View.
- **Outcome:** Increased satisfaction and ease of street management.

This way, the main research question which will guide this dissertation was developed:

For local residents, authorities and private organizations, does the use of Theia's street images visualization component compared to other street navigation digital technologies improve the satisfaction and ease of the street management process?

1.5 Dissertation Structure

The remainder of the dissertation is organized as follows: in Chapter 2 the current state of the art will be discussed, as well as the steps taken in this process, the information retrieved and the attained conclusions. In Chapter 3 the research methodology will be approached, with its respective design, methods and work plan. In Chapter 4 the module's specification is discussed. Chapter 5 will delve onto the architecture of the street management component, and Chapter 6 will focus on the implementation process and the features of the project. Chapter 7 will discuss the results obtained and analyze them. Finally, in Chapter 8 possible future work is considered and the achieved conclusions of the project are presented.

Capítulo 2

Street View Imagery Systems Analysis and Comparison

2.1 Literature Review

A literature review based on the scoping review [1] method was performed to analyse the state of the art in visualisation of georeferenced street images.

The following questions were created, to allow for a better understanding of the current landscape of Street View Imagery (SVI) services:

- *What are the key features offered by different street view imagery services, and how do they compare in terms of functionality?*
- *How do street view imagery services handle updates and maintenance of their imagery, and how do they ensure image quality?*
- *What are the main issues and considerations to have when dealing with street view imagery services?*

2.1.1 Eligibility Criteria

In order to choose articles and papers for the review, certain eligibility criteria were used to select relevant documents. These are as follows:

1. Articles were written in the English language;
2. Articles were published from 2019 onwards;
3. Articles must mention specific SVI and mapping services or applications;
4. Articles should focus on the technical, usability, or application details of SVI and mapping services;

5. Articles must discuss technologies or methodologies that are still in use or have influenced current SVI services.

If an article met the criteria, it was read and analyzed in total.

2.1.2 Search and Information Sources

In order to determine which databases were to be used, a search on Google Scholar[22] was employed with keywords such as "street view imagery" and "volunteered geographic information".

From the results obtained in this search, the most relevant databases were selected. The picked databases can be seen in table 2.1.

Tabela 2.1: Databases used

Data Source	Type	URL
MDPI	Digital Library	https://www.mdpi.com
ScienceDirect	Digital Library	https://www.sciencedirect.com/
IEEE Xplore	Digital Library	https://ieeexplore.ieee.org/

for the selected databases, the same query was used for document extraction.

2.1.3 Selection of Sources of Evidence, Data Charting and Data Items

In order to select which documents were to be analyzed, the titles, keywords and abstracts of the retrieved articles were examined in order to determine their relevancy. In case they met the eligibility criteria, they were then inspected in full. The data extracted was charted in an iterative process in order to allow for a more seamless analysis process.

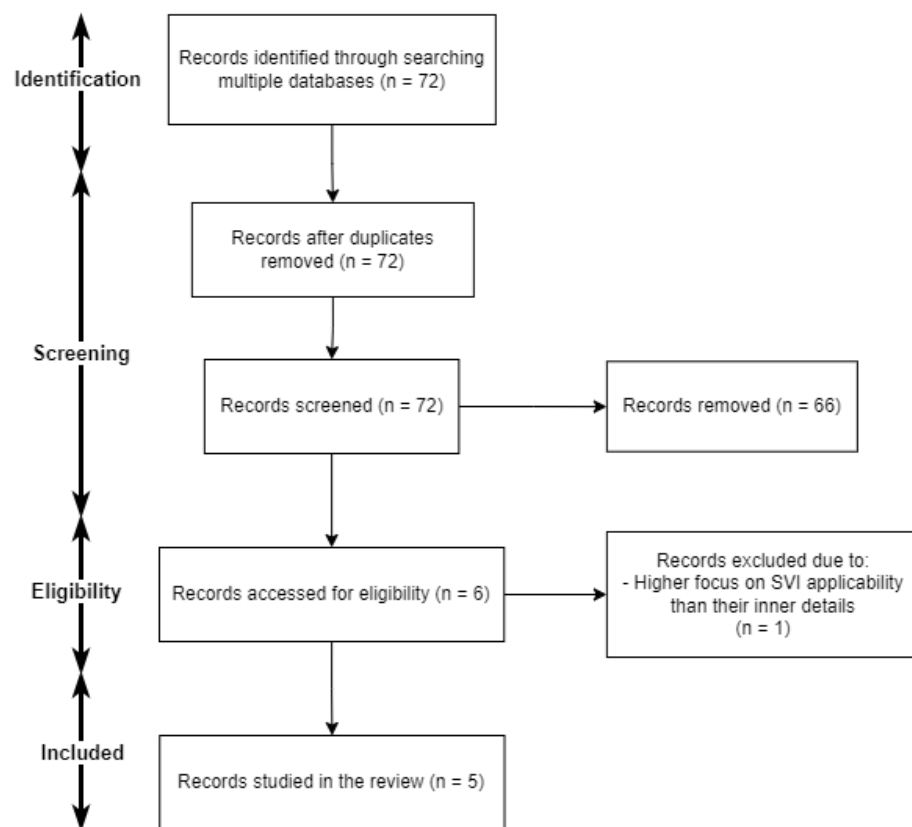
Data was abstracted on article characteristics (e.g. authors, year of publication), SVI-specific characteristics (e.g. SVIs analyzed, coverage area, coverage methods), and results of any formal assessment of engagement (e.g. main findings, barriers and challenges). The review program's flow diagram is shown in Figure 2.1.

2.1.4 Synthesis of Results

After the careful analysis of the retrieved documents, considerable and significant information was retrieved.

(author?) discovered that most of the current research on SVI focuses on Google Street View[14] (GSV), followed by Baidu Street View[4] (BSV) and Tencent Street View[25] (TSV), which are two SVI services focused in China, then followed by Mapillary[2] and KartaView[16], with global coverage. However, most studies do not focus on the functionalities of the SVI services, as they predominantly retrieve images and metadata from SVI applications in order to apply them to other areas of impact. While some of these areas of impact of SVIs have some dedicated research, most studies do not use SVI for a purpose beyond data collection. This review also denotes common issues in SVI services, such as:

Figura 2.1: Flow diagram of the review protocol



- Quality of images - "dark images and poor lighting conditions, images that turn out not to be outdoor (e.g. tunnels and shops), blurriness, and heterogeneous weather"
- Obstruction - some of the captured images have obstructions which might hinder the applicability of certain projects, such as cars and people blocking captured images, and greenery obscuring buildings, among others.
- Update Frequency - most SVI applications do not have frequent updates of their imagery, as image captures in the same area could temporally differ in years.
- Temporal and Spatial Heterogeneity - some SVI applications suffer from temporal or/and spatial heterogeneity, as in, some areas might have a lot of image coverage while other areas have little to no coverage, and some areas might have a lot of temporally distributed images while other areas have very few images across time.
- Non-panoramic Images - some SVI services provide non-panoramic images, which will limit the amount of information that an investigator will be able to retrieve from those images.

It should be noted that although significantly detailing both GSV, Mapillary and KartaView, few elements of interest were noted from either BSV and TSV in this document.

This article also notes that there is a subset of SVI with specific characteristics, that in the current existing research is titled as Volunteered Street View Imagery (VSVI), which consists in SVI services whose image capture process is crowdsourced to their users. The largest VSVI services are Mapillary and KartaView. The following reviewed records will also note the distinction between SVI and VSVI.

(author?) also note the issues with current SVI services, while expanding these shortcomings.

Concerns with image heterogeneity seem particularly relevant, especially when dealing with VSVI. Considering that this type of service relies on crowdsourcing, different individuals with devices of varying conditions will lead to discrepancies in quality of images.

In this article, a framework for evaluating the quality of the imagery of SVI services was created. This framework appraises data sources in line with the most predominant issues which SVI services face, evaluating them regarding image quality, metadata availability and accuracy, spatial quality, temporal quality, logical consistency, redundancy and privacy.

(author?) developed an analysis on one of the most prominent VSVI services in the market: Mapillary. This service provides global coverage with a focus on Europe and North America. Most of their images are captured by their contributors while they are driving cars, riding bicycles, or walking.

The article also notes some technical details of Mapillary. Each image on this SVI service can be represented as a GPS node with a timestamp, and consecutive nodes form a trajectory, which in Mapillary is called a sequence. Images can be retrieved in batch either by area with a bounding box, by distance to a certain coordinate, or by timeframe.

Most Mapillary users were concentrated in Europe, the United States of America, China and India, and most images were captured with smartphones on various brands. These differences in hardware and software explain to some extent the heterogeneity in image quality.

(author?) developed a systematic review on the application of SVI services in areas of impact, as well as focusing on the common dilemmas of adopting SVI data for the development of other technologies, which are image acquisition and quality, spatial and temporal distribution and accuracy, which have already been mentioned in previous articles. This article also makes note of two other SVI not mentioned previously in this review, which are Carte.ma Street View[8], focused in certain cities in Morocco, and the Apple Maps[3] app on iOS-enabled devices, through the "Look Around" feature. However, these SVI services are only mentioned in passing, with no further analysis or considerations added.

They concluded that SVI services are data-rich tools which can provide several insights on the chosen areas of impact. However, adopting SVIs for projects is not an easy task, both in regards to the technology as well as the imagery.

(author?) developed a comparison in between Mapillary and OpenStreetCam, which is an older version of KartaView. Comparisons were drawn in regards to contribution patterns and road coverage in both services across US metropolitan areas, considering both of these SVI applications rely on volunteered image capture, and they are the only two publicly available online VSVI platforms.

When compared to an authoritative data source, which was the Topologically Integrated Geographic Encoding and Referencing (TIGER), it was discovered that coverage was similar in both platforms and mostly focused "along local roads and control-access highways". However, both Mapillary and KartaView experienced varying coverage in different cities, which again highlights the coverage heterogeneity issue. It was also discovered that for both platforms, most data was produced by the same few users. However, this fact does not equate to low coverage overall. In spite of both platforms having good future prospects, the issues of gaps in spatial coverage and image privacy still have to be considered.

2.1.5 Summary of Evidence

In this review, 5 articles addressing SVI services' characteristics published from 2019 forwards were investigated.

The analysis found that SVI is a rapidly growing field, especially for studies regarding certain areas of impact, such as spatial data infrastructure and physical environment assessment, greenery studies, health and well-being, urban morphology and perception, transportation, mobility and walkability, safety, and urban planning and development.

It was established that Google Street View dominates both the SVI market as well as the SVI research. The image quality homogeneity, spatial and temporal accuracy, and panoramic images, provide information-rich images, ideal for data extraction. However, GSV spatial and temporal coverage is very heterogeneous, with some geographical locations having close to no image captures, or very few image captures spaced very scarcely across the time dimension.

Some clear distinctions are also deliberately noted between GSV and similar SVI services to VSVI, the main one being the image capture method: while GSV and similar services deal with the image capture process themselves, through cars mounted with multiple cameras and sensors on their roofs, backpack-mounted cameras, or other methods, VSVI leave the image capture process for their users, who usually capture images through smartphones, dash-cams or other image capturing devices, with images being taken mostly while contributors are driving cars, riding bicycles, or walking.

These differences in image capture will lead to different overall image quality. GSV-like services usually collect omnidirectional or panoramic images, mostly during the day and with good weather conditions, which will lead to clearer, more information-dense images. On the other hand, VSVI, by lending the capture process to their users, who capture images of different formats in different angles and in varying weather conditions and time of the day, while using different devices with different GPS coordinate accuracy, and contributors having varying experience, which will lead the images taken to be of varying quality, increasing the heterogeneity of the dataset.

However, this trade-off does have benefits. The GSV-like capture process is more costly when compared to the methods adopted by VSVI, which hinders the quantity of captures. Therefore, while when GSV has captures in a certain spatial location, their coverage is usually almost complete, VSVI has a greater temporal coverage as well as providing their services in locations where GSV has no access for capturing.

In order to combat quality issues, SVI services have adopted different quality assurance practices, such as quality policies, neural network-based quality scoring systems and reporting of images. Nevertheless, these imagery services continue to face several problems regarding their datasets.

Several issues arise when dealing with SVI services, although certain platforms can mitigate particular concerns considering their choices in functionality and process. Most common issues regard image quality and homogeneity, metadata availability and accuracy, spatial and temporal quality and coverage, consistency, redundancy and privacy. However, with the current approaches, some of these concerns do not seem to be addressed at the same time in an easy way, such as image quality homogeneity and spatial and temporal coverage.

With the analysis of the main findings, it is now possible to answer the developed research questions:

- *What are the key features offered by different street view imagery services, and how do they compare in terms of functionality?* - SVIs allow for the spatial navigation of the streetspace. Some services also allow for temporal navigation. Volunteered SVIs also allow for the capture of images and videos. Services can also provide focused or panoramic/omnidirectional images.
- *How do street view imagery services handle updates and maintenance of their imagery, and how do they ensure image quality?* - SVI services such as GSV mostly manage and

update their images privately, through cars mounted with cameras on the roof or backpack-mounted cameras. VSVIs deal with image capture by crowdsourcing this process, letting users capture images for display. There are several processes adopted to improve image quality, such as quality policies, neural network-based quality scoring systems and reporting of images.

- *What are the main issues and considerations to have when dealing with street view imagery services?* - When considering SVIs, there are some common issues to have in mind, such as image quality and quality heterogeneity, heterogeneity in temporal and spatial coverage, temporal and spatial metadata accuracy, consistency, image redundancy and privacy.

2.1.6 Limitations and Future Work

There are some shortcomings on the information which was able to be retrieved from this literature review.

As mentioned above, there is not equal representation of SVIs on research. GSV is a giant on the SVI market, and it takes most of the attention for research handling SVIs.

There is also the previously mentioned issue of most research dealing with SVIs do not delve into a deep-dive on their content and inner workings, but rather focus on the data they provide in order to create models to apply to other areas of impact. Although some of these areas of impact go in line with the project at hand, such as urban planning and management, most research focuses on the applicability of SVI data for deep learning and neural networks, which are not relevant for the project to be developed.

Lastly, although (author?) explore the inner workings of Mapillary and its functionality in depth, other sources delving onto this issue were not found, which would be interesting to explore in the future.

2.2 Significance of study

This Literature Review lacked in providing sufficient insight on the development process for SVI services aligned with this project's objectives, specifically the implementation of street image information visualization and its suitability for professional uses of different types. Arguably, this is due to lack of literature aligned with this project's main goal. Nevertheless, The developed Literature Review allow for a better understanding of the current landscape of SVI services, and having them in mind for the development of the street management component.

This Literature Review shed lights on the current landscape of SVIs. It was possible to determine that the component to be developed would go more in line with VSVI, considering the nature of image capture, as they will be done by phones or dash cameras on specific vehicles, such as garbage collection trucks and delivery vans, while driving. This way, it is legitimate to assume it will have to address most of the issues volunteered SVIs have to face, such as image quality, spatial coverage, image and spatial heterogeneity, redundancy and privacy.

While considerations such as image quality, heterogeneity and privacy fall outside of the scope of this project, issues such as temporal and spatial coverage and heterogeneity can be somewhat addressed with the concept of area flags. By flagging certain geographical areas as areas of interest for image capture, heterogeneity and coverage should be addressed both spatially and temporally in the long run.

The concern with data redundancy can also be addressed with some data processing, such as discarding images in the same timeline which are too close together. However, this would not completely eliminate the issue, considering that sometimes imagery captured in places such as highways do not provide too much change in a considerable range, and other methods to infer redundancy would be needed, such as Artificial Intelligence models, which fall outside the scope of this project. Nevertheless, the mentioned approach would still show improvements in reducing redundancy.

Capítulo 3

Research Methodology

In this project, both quantitative and qualitative methods were employed through an Exploratory Sequential Mixed Methods[10] research design, in order to guarantee that the research problem was thoroughly analyzed. Firstly, qualitative methods were used and then quantitative methods were employed, whose results were collected and examined. Through the employment of qualitative methods, opinions and feedback regarding the functionalities of the street management component could be gathered, allowing for a better understanding of the wants and needs of users, while also allowing for the identification of issues that arose. Using quantitative methods allowed for a better and more objective analysis and evaluation of certain aspects of the street management component by comparing the answers of different testers.

This approach aimed to provide a better understanding of the strengths of the application as well as which areas required further work.

3.1 Qualitative Methods

For the qualitative methods, a sample of participants were selected to participate in a Think-Aloud protocol in order to better understand their disposition towards the component's User Interface (UI) and functionality, as well as to have their feedback regarding the User Experience (UX). During the study, each participant was asked to perform specific fundamental tasks on the component while communicating their thoughts and reactions and giving feedback in real time. By collecting this data, a general sense of which aspects would cause the most trouble to the general user could be gathered, which could then be worked in the future.

The researcher conducting these sessions kept track of which tasks each participant was able to complete as well as the number of mistakes made while trying to complete each task (e.g. user navigates to the wrong screen, user clicks the wrong button).

The tasks to be completed were comprised of fundamental actions for the street management component. While each participant was trying to complete a task, they were encouraged to share their opinions and thoughts regarding the component with the attending researcher.

3.1.1 User Testing Tasks

Before starting the testing process, each participant was able to choose their preferred language between English and Portuguese. Testers were provided with credentials in order to log into the system and complete their tasks.

The tasks to be completed by the professional users were the following:

- Open the map component - For this task users had to select the map component on the navigation bar.
- Center map on current geographical position - For this task users had to either:
 - press the center on current position button;
 - manually move the map to the current position.
- Find the city of Funchal on the map - For this task users had to either:
 - type "Funchal" on the map's search bar;
 - manually move the map to Funchal.
- Visualize a portion of a street timeline - For this task users had to:
 - press one of the lines on the map in order to access that street timeline;
 - press the arrow pointing up and down in order to see the next and previous street images.
- From the current timeline, expand the map - For this task users had to press the expand map button.
- From the expanded map, view the map in split screen - For this task users had to press the split screen button.
- From the split screen, focus on the map again - For this task users had to press the current street image.
- Change between street timelines - For this task users had to access the street timelines drop-down and choose a different timeline from their current one.
- Mark a zone with few street timelines with a "place of interest" flag - For this task users had to:
 - access the area flag mode;
 - center the map on a zone with few street timelines;
 - press the flag button in order to flag the area.

For this task, the concept of area flags was first explained to the tester.

The tasks were adapted for the common citizen, considering the two user groups had access to different parts of the application. These tasks were the following:

- Open the videos component - The common citizen did not have access to the map component, as it is only for professional users. Therefore, for this task, users had to select the videos component on the navigation bar instead of the map component.
- Visualize a portion of video - For this task users had to:
 - access one of their videos (a video was recorded before performing the user tests in order to prevent testers from having to record a video, which falls outside of the testing scope);
 - press the "view on the map" button;
 - press the line on the map in order to access the current video;
 - press the arrow pointing up and down in order to see the next and previous street images.
- From the current timeline, expand the map - For this task users had to press the expand map button.
- From the expanded map, view the map in split screen - For this task users had to press the split screen button.
- From the split screen, focus on the map again - For this task users had to press the current street image.

The user's responses and feedback was recorded through two google forms: one filled by the tester and the other filled by the investigator. These forms can be accessed in the appendix A.

3.2 Quantitative Methods

After the qualitative methods had been employed, each user evaluated the component's functionality, experience and usability. This step employed the usage of several standardized tools, and each user's input was gathered in order to attain numerical data which was comprehensive and thorough.

3.2.1 NASA Task Load Index (NASA-TLX)

The NASA Task Load Index[15] is a tool used to check the perceived workload of a set of tasks for a user. Considering that the management component does not demand physically from the user, the NASA-TLX tool was adapted, discarding this dimension from the conventional six. This way, the remaining five dimensions were: Mental Demand, Temporal Demand, Performance, Effort, and Frustration.

After each participant completed their tasks from the Think-Aloud section, they filled out this adapted version of the NASA-TLX. This way, it was possible to analyze and better understand the user experience and perceived workload, in order to determine which areas of the component required further work and improvement.

3.2.2 System Usability Scale (SUS)

The System Usability Scale[6] (SUS) is a ten item questionnaire where each item can be answered with one of five options, ranging from Strongly Agree to Strongly Disagree. After each participant completed their testing session, they filled the SUS, this way providing insights regarding the overall usability of the management component.

3.2.3 Questionnaire for User Interaction Satisfaction (QUIS)

The Questionnaire for User Interaction Satisfaction[23] (QUIS) is a tool which aims to assess user satisfaction regarding specific aspects of the human-computer interface. It inquires regarding overall system satisfaction across interface factors such as software, screen factors, learning factors, terminology and system information, system capabilities, and technical manuals.

Lastly, each participant completed the QUIS, allowing the survey to provide quantitative baselines for user satisfaction, as well as pinpoint positives and negatives of the developed component.

3.3 User Profiles

For evaluating the component, two primary user profiles were considered:

- Professional Users
 - Age groups: 25-35, 36-50, 50+;
 - Digital Competency Levels: Moderate, High;
 - Demographic Diversity: mix of educational backgrounds occupations and genders.
- Common Citizen
 - Age groups: 18-25, 26-45, 46-60, 60+;
 - Digital Competency Levels: Low, Moderate, High;
 - Demographic Diversity: mix of educational backgrounds occupations and genders.

Capítulo 4

Specification Analysis

Before starting the implementation process, the specifications of the street management component were created. This way, these User Stories are shown on table 4.1.

Tabela 4.1: Theia Street Management User Stories Table

Number	User Story	Description	Priority	Effort
1	As a user I want to be able to access the street viewing capabilities so that I can analyze the state of the street in a specific location at a given point in time.	Nothing to add.	High	High
2	As a user I want to be able to navigate streets through the module so that I can inspect the state of the whole street at a given point in time.	Moving through the current timeline, being able to navigate to the next and previous images from the current one.	High	High
3	As a user I want to be able to select what moment in time the street pictures were taken, out of a set number of timelines, so that I can better understand the development and change of the street.	When using street viewer, the current timeline's date should appear, with the option to choose another time period from an available list.	High	High

Number	User Story	Description	Priority	Effort
4	As a user I want to be able to flag certain areas to be updated so that there are more road images of the area.	Nothing to add.	Medium	Medium
5	As a user I want to be able to see which areas I have already flagged so that I don't flag the same area twice.	Nothing to add.	Medium	Low
6	As a user I want to be able to search for locations by name so that I can more easily navigate the map.	Nothing to add.	Low	Medium
7	As a user I want to be able to center the map on my current location so that I can identify timelines close to me.	Nothing to add.	Low	Medium
8	As a user I want to be able to purchase an up-to-date images paid package so that I can have access to the street management component.	Payment prompt must open, allowing for payment of image package.	Medium	High
9	As a user I want to be able to purchase different paid packages so that I can have different benefits on the street management component.	Different image package options should appear, each one leading to the payment prompt.	Medium	Medium
10	As a user I want to be able to see my own photos and videos on the map so that I can review the path I took.	Nothing to add.	Medium	Low

Out of the previously described user stories, the ones related to image packages (8 and 9) were not implemented because further details and considerations have to be discussed by the project team before being implemented in the module.

A non-functional requirement was also identified, which is displayed on Table 4.2.

Tabela 4.2: Theia Street Management Non-Functional Requirements

Number	Non-Functional Requirements
1	The mobile street management module must support the latest versions of major mobile operating systems, including iOS and Android. This way, we can minimize the risk of the operating system being a limitation to the availability of the component, making the analysis of street space more convenient.

However, in spite of the non-functional requirement always being taken into account during the development process, due to external policies, lack of resources and high monetary costs, the street management component could not be tested on the iOS operating system, therefore the non-functional requirement could not be implemented at this time. The implementation and validation of this requirement will remain a priority for future work.

Having the specifications been defined, mockups were created for the management module with the required functionalities.

Capítulo 5

Architecture

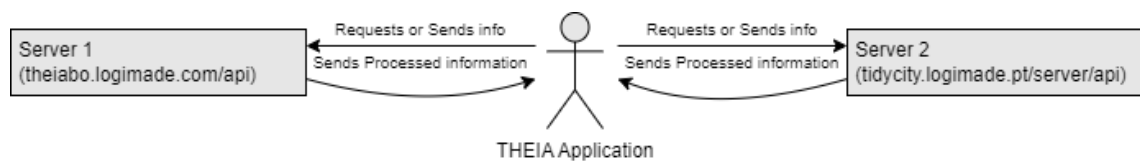
The Theia mobile application runs on the user's mobile device. Currently, it is connected to two servers: one related to the current version of the app (Server 1), responsible for more general operations (such as the login and logout, user information, and operations regarding occurrences reported by users), and the other used on an old version of the app (Server 2), with operations regarding the street management component.

This means that the images and videos (which consist of image captures at around 5 frames per second) being displayed are not the ones supplied by the existing app, but by the previous app which was being used in Funchal by different groups of people. This was due to the large volume of existing images from the previous app, making it easier to implement the street view functionality. In the future, the provided images should come from user's captures exclusively.

Eventually, both servers will be merged into one, but for the duration of the development process servers will be separate.

The full overview of the architecture of the system is displayed in Figure 5.1

Figura 5.1: Theia Application architecture diagram, with the new server (Server 1) and the old server (Server 2)



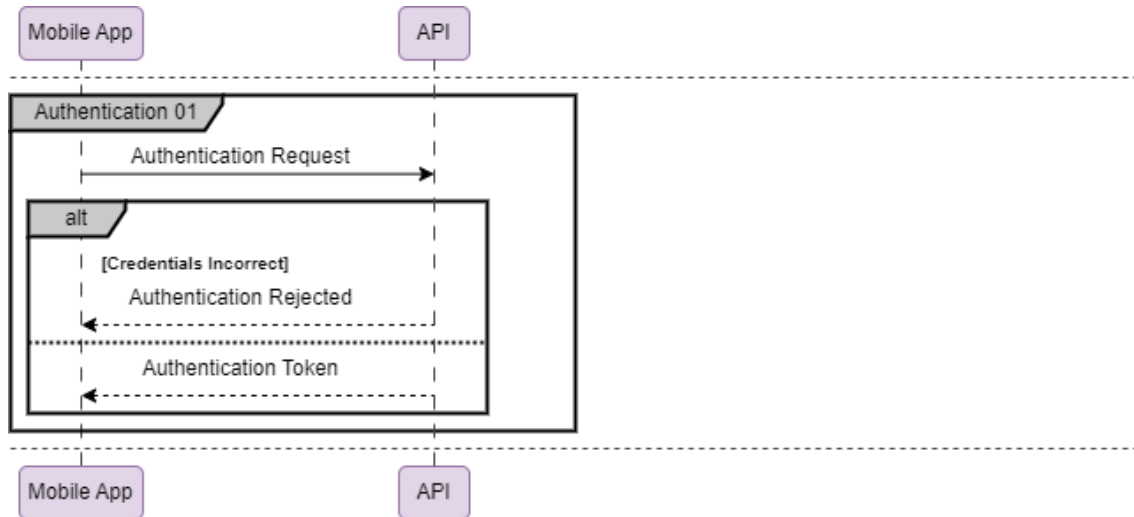
A total of ten endpoints were established on the old server. These endpoints allow for the retrieval of data available on the old version of the Theia app, regarding the image and video captures on the city of Funchal, and were created to manage user interaction with the street management component as well as data retrieval, facilitating client-server communication for submitting and retrieving data as needed.

These endpoints are the following:

1. Authentication Endpoint:

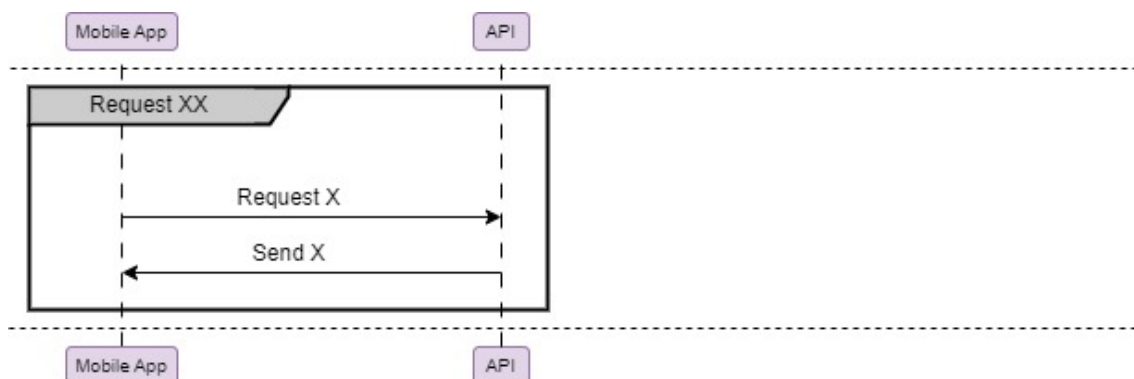
- This endpoint allows for the authentication of users who already have an account.

Figure 5.2: Theia Street Management sequence diagram - Authentication Endpoint



All of the following requests are similarly constructed, and fall on the following structure:

Figure 5.3: Theia Street Management sequence diagram - Default Request Structure



2. Get All Video IDs Endpoint:

- This endpoint retrieves all video IDs from the server.

3. Get Video Endpoint:

- This endpoint retrieves a specific video which is identified by its ID;
- Each video has a start date, an end date and a list of frame IDs.

4. Get Frames in Radius Endpoint:

- This endpoint retrieves a list with metadata of all frames contained within a given radius in a circle from a given point;

- Each item on the list contains its frame ID as well as the ID of the video where it was captured.

5. Get Frame Endpoint:

- This endpoint retrieves the metadata of a specific frame which is identified by its ID;
- Each frame contains its date, coordinate, and the ID of its corresponding image.

6. Get Image Endpoint:

- This endpoint retrieves the bytes of the image related to a frame, which is identified by its ID.

7. Get All Flagged Areas Endpoint:

- This endpoint retrieves a list of all area flags of each user.

8. Get Area Flag Endpoint:

- This endpoint retrieves an area flags, identified by its ID;
- Each area flag includes a center coordinate and a radius.

9. Send Flagged Area Endpoint:

- Sends area flag to the server (its flag ID, center and radius).

10. Delete Flagged Area Endpoint:

- This endpoint deletes a specific area flag from a user.

With these endpoints, the user is allowed to more easily use the street management module, and their interactions with the server are ensured protection and efficiency.

Two endpoints in total were developed on the new server. These endpoints were created in order to allow for the common citizen to have access on the map to the videos they recorded.

These endpoints are the following:

1. Get Video Frames Endpoint:

- Retrieves frame URLs of a specific video identified by its ID.

2. Get Video Path Travelled Endpoint:

- Returns the travelled path of a specific video.

Capítulo 6

Implementation

The Theia mobile app was developed in Flutter with compatibility for both Android and iOS. Consequently, only packages and functionalities available on both platforms were utilized, even though the app is not currently available on iOS.

The implemented application functionalities will be outlined in the following sections as well as any caveats regarding the implementation process.

6.1 General

A Flutter package was required in order to facilitate communications between the street management component and the server through REST requests. The `http` package¹ was chosen over other packages, such as the `dio` package², due to its straightforwardness and the familiarity with the package.

The `latlong2` package³ was used as a lightweight package for storing coordinates coming from the server, as well as calculating distances between timeline frames.

A Route Generator was also used to navigate between the street management module of the Theia app and its other functionalities, in order to make the application as a whole and its navigation more organized and streamlined.

6.2 Map

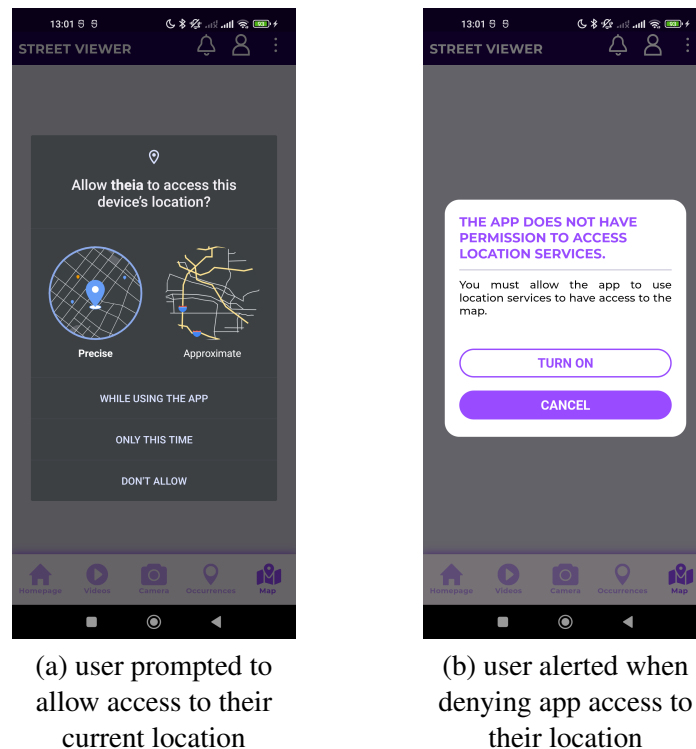
When a user boots up the street management component for the first time, they are prompted to allow the application to access the device's location. If the user denies access to their location, they are alerted that in order to have access to the navigation component, they have to grant permission to access their current position. This behavior is shown in figures 6.1a and 6.1b

¹<https://pub.dev/packages/http>

²<https://pub.dev/packages/dio>

³<https://pub.dev/packages/latlong2>

Figura 6.1: First boot of the Street Management Module



In order to be able to access the current location of the device, the geolocator package⁴ was used.

After allowing the geolocation functionalities of the component, access to the navigation module is granted. The user is then presented with the default map, whose raster map tiles are provided by OpenStreetMap[24]. Pressing one of the lines on the map expands the view of the corresponding street timeline. The default map is shown in Figure 6.2.

The numbered elements in Figure 6.2 correspond to the following functions:

1. search bar - used to search for location by name;
2. zoom buttons - used to increase or decrease map zoom;
3. location button - used to center map on current location of the device;
4. area flag - used to access area flag mode.

The map functionality was implemented with the fluttermap package⁵, as well as the layers used for its implementation, such as the polyline layer, which will be further discussed later in the document.

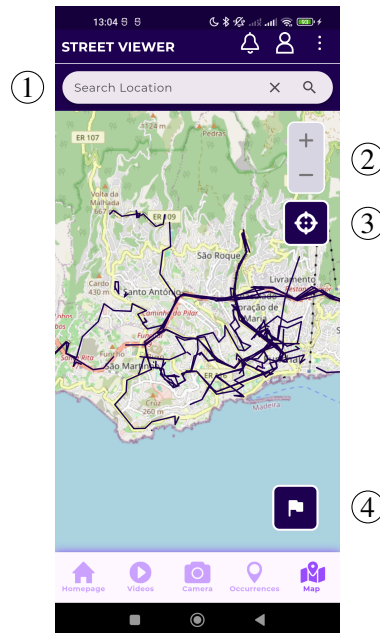
The location button, as mentioned previously, was implemented using the geolocator package⁶, which provides access the the device's current geographical position.

⁴<https://pub.dev/packages/geolocator>

⁵https://pub.dev/packages/flutter_map

⁶<https://pub.dev/packages/geolocator>

Figura 6.2: Street Management Component Map Screen



The search bar functionality was implemented using the geocoding package⁷ which allows the conversion of addresses to coordinates and from coordinates to an address. For this project only the conversion from address to coordinate was used.

6.3 Road Viewer

Before being able to implement the road viewing portion of the module, the available data required some processing. Some of the timelines in the server had no frames, and some frames had no associated timeline, no associated image, or no defined coordinates. Some of these fields also had values with an incorrect type. Therefore, these faulty videos and frames could not be used.

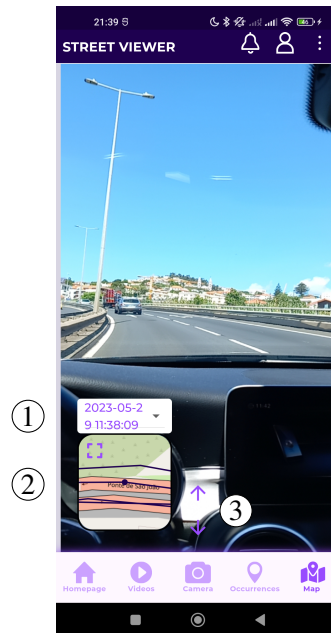
Pressing any of the lines present on the map leads the user to the road viewer portion of the street management module, which can be seen in Figure 6.3.

The numbered elements in Figure 6.3 correspond to the following functions:

1. timeline dropdown;
2. minimap showing the location of the current image being displayed, as well as a button to expand the map;
3. navigation arrows - used to move to the next or previous image in the current timeline.

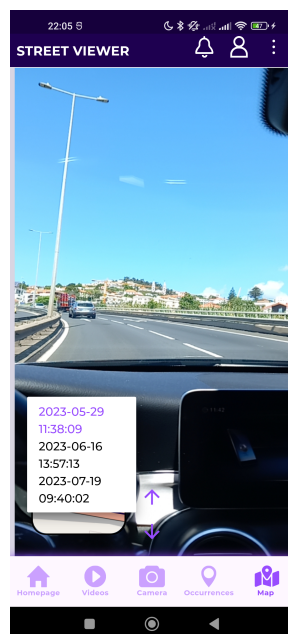
⁷<https://pub.dev/packages/geocoding>

Figura 6.3: Street Management Component Road Viewer Screen



Pressing the timeline dropdown opens a list of timelines which have images close to the current location. Pressing one of them changes the image being displayed to it. This behavior is represented in images 6.4a and 6.4b.

Figura 6.4: Changing timelines through the timeline dropdown behavior



(a) user opens timelines dropdown

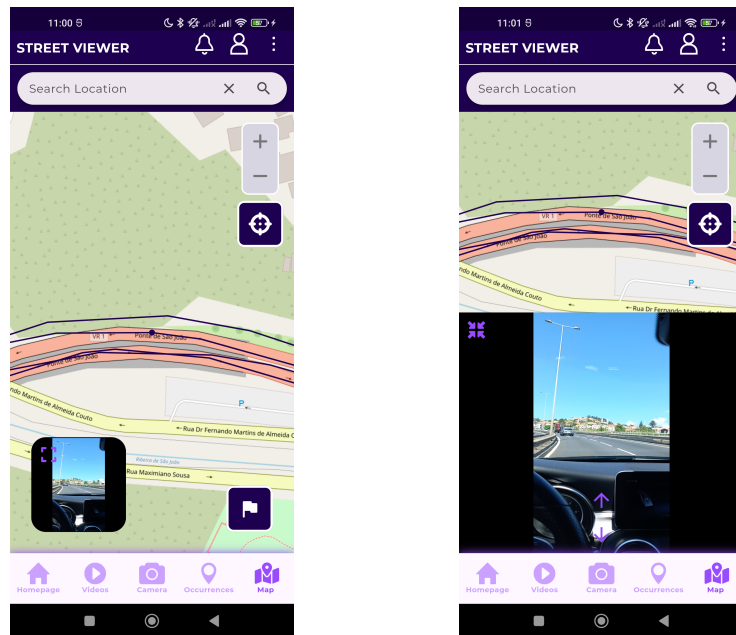


(b) user selects different timeline

6.4 Split Screen

Returning to the expanded map screen from the road viewer, this time the user is presented with a box containing the current street image, as well as a button to access the split screen state. This screen was implemented in order to ameliorate the UX of the street management module. This state is shown in images 6.5a and 6.5b.

Figura 6.5: Split Screen



(a) returning to the map
after accessing a street
image

(b) split screen state
after pressing the button
on the street image box

6.5 Area Flag

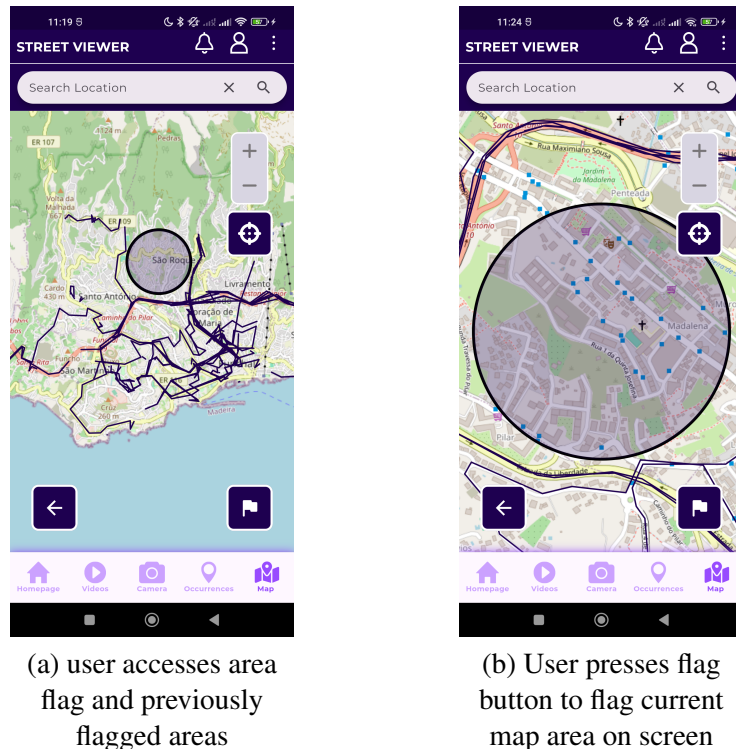
On the expanded map screen, pressing the button on the bottom right corner, with the flag, leads the user onto the area flag mode. In this screen, the user is able to flag certain areas in order to indicate the need of more street images in that region. The user is also able to see which areas they had already flagged. The number of area flags each user is able to use was limited due to performance issues of the app.

If the user presses the flag button while on the area flag mode, the current area being displayed on the map is flagged and either added to the area flags or it replaces the oldest area flag in case the number limit is reached.

Pressing the return button on the bottom left corner returns the user to the expanded map state.

The area flag behavior is shown in images 6.6a and 6.6b.

Figura 6.6: Area Flag



6.6 User Videos

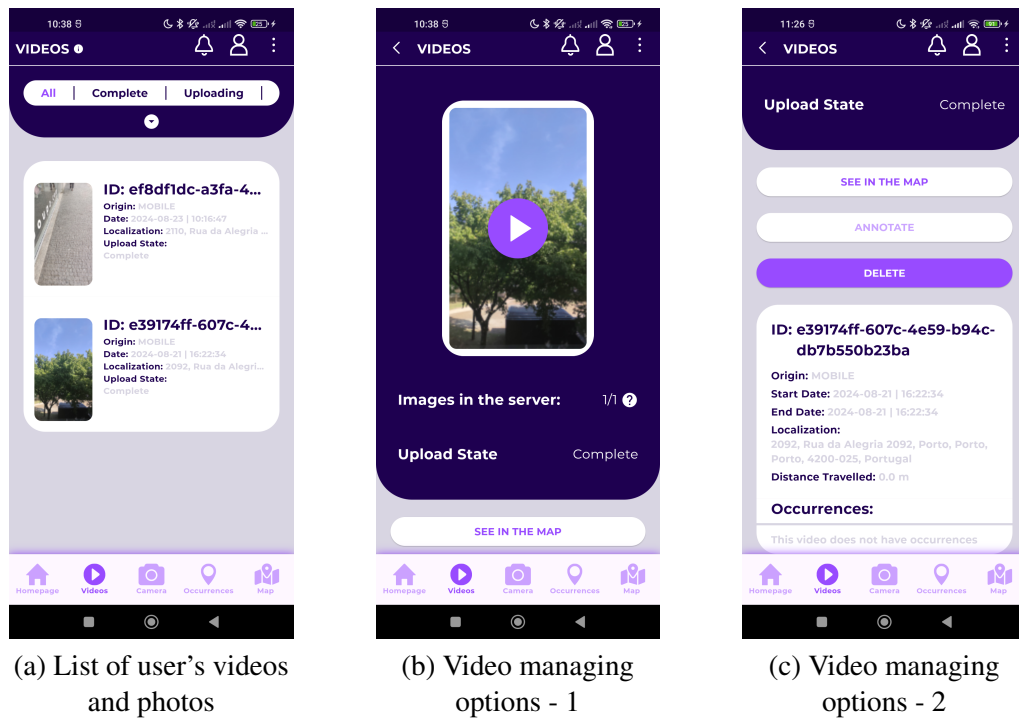
While the previous mentioned features are aimed for the professional user, there was also an interest in allowing the common citizen to view their own recorded videos on a map.

When the user pressed the Videos button on the navigation bar on the bottom of the screen, they are shown all photos and videos taken by them, as well as managing options for these captures. While the list of videos and the managing options were already implemented in previous versions of the app, it was not possible to view the geographical location of these captures on a map. The list of videos is shown in Figure 6.7a, and the video management is shown in Figures 6.7b and 6.7c.

If the user presses the option to see the video in the map, a similar functionality to the available street view would open, although with limited functionalities. Considering the focus of this section is the geographical analysis of the current video, the options to center the map on the current geographical location of the device, to search for a location by name and to flag areas are disabled. However, it was still possible to navigate inside the video as if it were a timeline in the street management component. It is also still possible to expand the map, expand the video and split the screen as it was on the street management module.

The display of the video on the map differ depending on the video characteristics. If the video consists of only one frame (i.e. a photo) or if all the frames on the same video are geographically

Figura 6.7: Video List and Management



very close together, the video is displayed on the map as a Marker⁸. If the video consists of frames with considerable distance between them, it is displayed on the map as a Polyline⁹. The video display is shown in Figures 6.8a and 6.8b

6.7 Map Optimization

6.7.1 Data Persistence

When the component is first booted, the application sends a request to the server to retrieve all available timelines, which are then displayed on a map for the user. This request is quite data-intensive, as it requires fetching a large amount of information stored on the server. If the request were to be executed every single time the user accessed the street management component, it would place a heavy load on the server and significantly degrade the UX due to increased load times and potential delays.

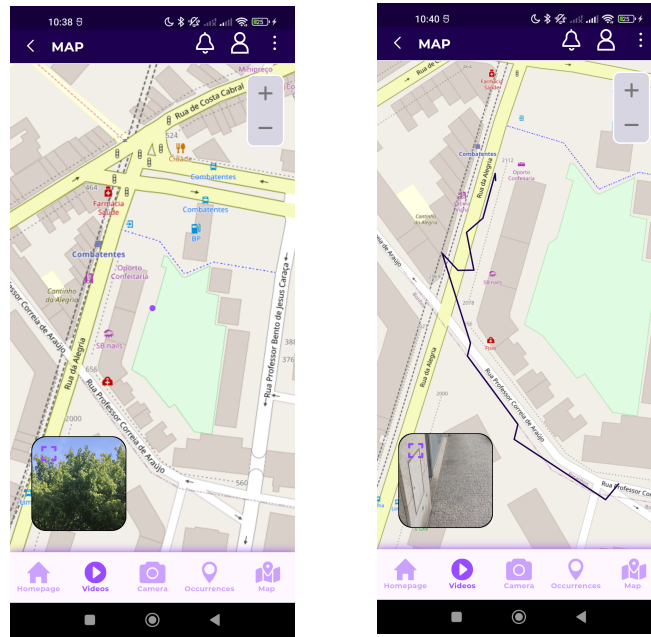
To address this issue and optimize the module's performance, the provider package¹⁰ was integrated into the system. This package plays a crucial role in managing state across the entire application. By using the provider package, we can persist the retrieved timeline data between different pages or screens within the app. This means that once the data is loaded for the first time,

⁸https://pub.dev/documentation/flutter_map/latest/flutter_map/Marker-class.html

⁹https://pub.dev/documentation/flutter_map/latest/flutter_map/Polyline-class.html

¹⁰<https://pub.dev/packages/provider>

Figura 6.8: Video Map Display



(a) Video display as a Marker

(b) Video display as a Polyline

it does not need to be re-requested from the server each time the user navigates to a different part of the app. This approach not only reduces the number of heavy requests made to the server but also ensures a smoother and faster UX, as the necessary data is readily available without the need for repeated loading processes.

6.7.2 Timeline Display

Issues also arose regarding the display of the timelines on the map. In the early stages of development, the street timelines were being displayed with `flutter_map`'s marker layer^[11]. The ease of coupling their usage with gesture management, as well as the fact that during the initial stages of implementation, only a segment of the total data on the server was being used for testing, made markers the primary choice for development. Although performance was slightly affected while using virtual devices in debugging, issues were minimal when testing with a physical device.

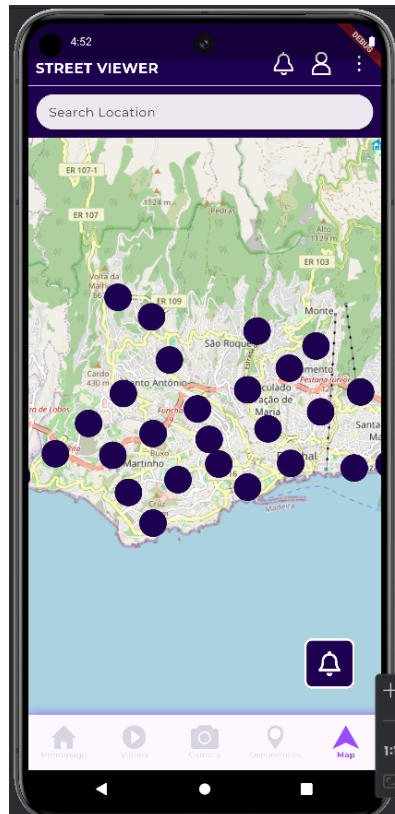
However, issues became apparent when dealing with the totality of data available on the server. After displaying the timeline markers on the map, performance was severely affected both in virtual and physical devices. A high number of markers being shown on the map extremely affects performance, which meant that changing methods of displaying street timelines was imperative.

The first approach considered was using the Flutter Map Marker Cluster package^[11] in order to display street timelines. This package implements a marker cluster layer which can be used instead of `flutter_map`'s default marker layer. As the name suggests, this marker cluster layer clusters markers by proximity to each other, reducing the number of markers effectively being

^[11]https://pub.dev/packages/flutter_map_marker_cluster

displayed and improving performance, and the clusters would change based on the current zoom level on the map, up to a maximum zoom value, when clustering would stop and the regular markers. The visual result of this previous implementation can be seen in Figure 6.9.

Figura 6.9: Timeline Display - Initial Implementation with Clustering



This approach proved to be far from optimal. While clustering improved performance somewhat, it was not improved enough to enhance UX significantly. There was also the concern of the changing of clusters. Whenever the zoom level were to be changed and the clusters were modified, and when the maximum zoom value was hit and clusters dissolved, performance was still harshly affected, which defeated the purpose of employing this package. Coupled with how visually different this approach would make it from the originally envisioned visual design, the marker cluster approach was discarded.

The approach which ended up being the one selected for the final product was using the polyline layer from `flutter_map`. While coupling this layer with gesture management, although possible, was not as trivial as with the marker layer, this polyline layer has built-in, customizable ways to optimize performance[12], such as polyline culling, which consists in not rendering and displaying polylines that are off screen, and polyline simplification, which changes the number of points being displayed in a polyline based on the zoom level.

This solution ended up being the most optimal one. Although gesture management had some caveats to be addressed, the built-in optimizations proved to significantly improve the performance of the component. Considering also that using lines to display the street timelines would go more

in line with the initial vision for the module, the polyline layer was the selected solution for this performance problem.

6.8 Geographical Caching

In order to improve the UX while using the street management module, the issue of image fetching had to be addressed. Whenever the user selects a new street timeline or navigates to different images inside a street timeline, the component requests the image to the server, which could take a few seconds. This would negatively affect the UX, considering that every change of image would result in a wait time. Therefore, some implementation of a caching technique was in order.

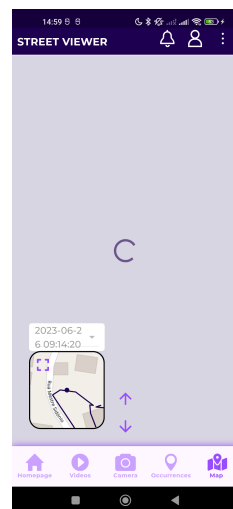
Initially, a simple caching technique was used: whenever a new image was accessed, its ID and image were saved in memory in order to avoid unnecessary repeated API calls. Whenever the user were to change to a different timeline, the cache would be cleared.

This solution, however, was far from perfect. The initial approach, although avoiding repeated API calls in case the user were to visit images they had previously seen already, it did not address the main problem of having to wait every time a new image was accessed, which would still negatively impact the UX. This way, a new solution had to be developed.

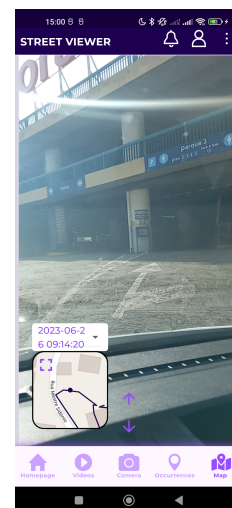
The agreed upon solution was geographical caching. When a user was to select a geographical point in a certain timeline, there would be a request to fetch all images within a close radius of the current coordinate which belonged to the same timeline. If the user were to navigate to a point in the same timeline which was outside of that radius, the same call would be made again for that new coordinate. This way, although the initial wait time would be longer, the UX would benefit by users not having to wait for every image change. For this version of caching, the Cached network image package¹² was used. The caching solution is shown in images 6.10a and 6.10b.

¹²https://pub.dev/packages/cached_network_image

Figura 6.10: Caching



(a) Images in an area being fetched



(b) Images were fetched and now moving forwards and backwards will have no wait time

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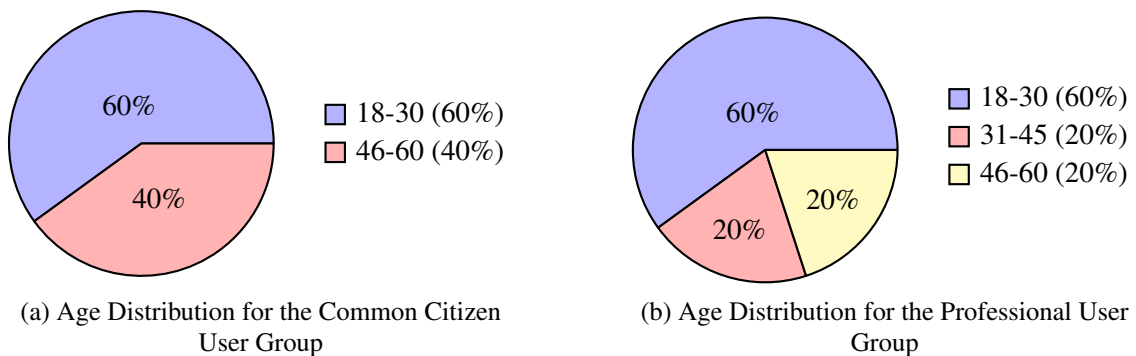
Results and Discussion

A total of 20 different participants were gathered in order to participate in the user tests, none of whom had any prior contact with either the Theia application or the street management component. Due to time constraints and scheduling issues, only 1 of the testers was what would be described as an actual professional user. Therefore, in order to test the developed project in its totality, some users belonging to the common citizen user group performed user tests intended for the professional user instead of the tests aimed for their actual user group. In the end, 10 participants performed the user tests aimed for the common citizen while the other 10 participants performed the tasks for the professional users.

Participants could either use their own mobile phone or use a mobile phone with the application pre-installed. Most users preferred to use their own phone. However, iPhone users, unable to easily install applications from outside the App Store and considering the street management component's lack of thorough testing for iOS, had to use an available Android phone instead.

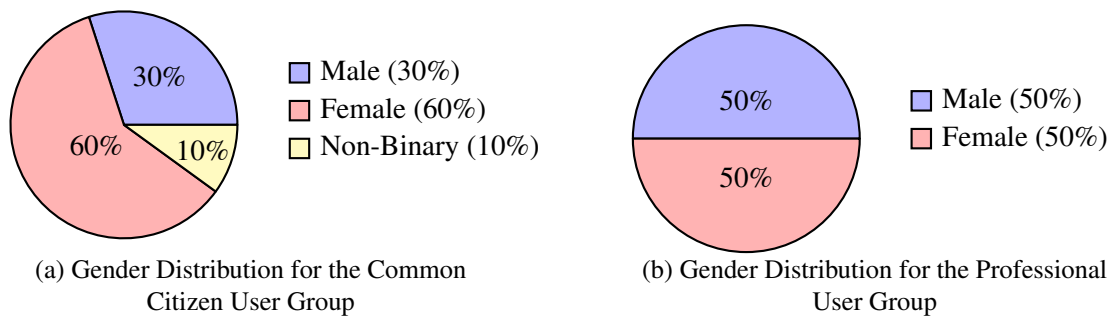
Out of the 10 participants belonging to the common citizen user group, 6 (60%) were part of the 18-30 age group while 4 (40%) belonged to the 46-60 age group. Regarding the professional user group, 6 (60%) of participants were part of the 18-30 age group, 2 (20%) belonged to the 31-45 age group and 2 (20%) belonged to the 46-60 age group. These distributions can be seen in figures 7.1a and 7.1b.

Figura 7.1: Age Distribution Across Common Citizen and Professional User Groups



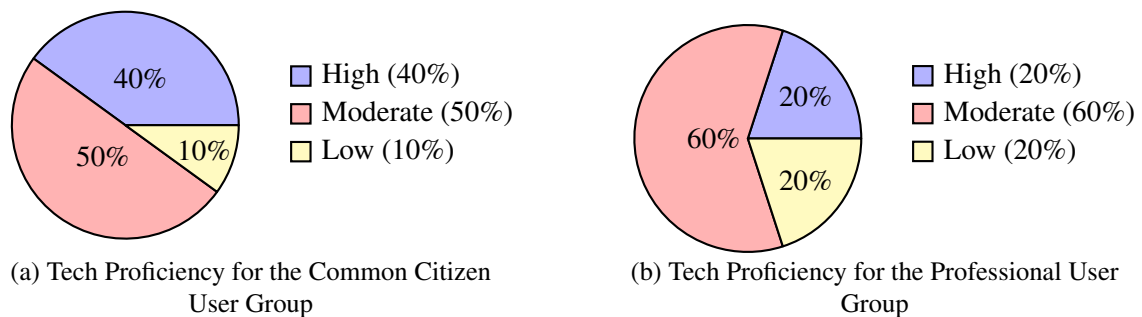
When it comes to gender distribution, in the common citizen user group, 3 (30%) out of the 10 participants identified as male, 6 (60%) as female and 1 (10%) as non-binary. In the professional user group, 5 (50%) identified as male and 5 (50%) identified as female. These distributions can be seen in figures 7.2a and 7.2b.

Figura 7.2: Gender Distribution Across Common Citizen and Professional User Groups



The tech proficiency level is shown in figures 7.3a and 7.3b. In the common citizen user group, 4 (40%) of participants reported a high digital competence, 5 (50%) a moderate tech proficiency and 1 (10%) a low digital competence. In the professional user group, 2 (20%) reported a high tech proficiency, 6 (60%) a moderate digital competence and 2 (20%) a low tech proficiency.

Figura 7.3: Tech Proficiency Across Common Citizen and Professional User Groups



It should be noted that the tech proficiency was self reported, and in some cases their perception of their own digital competence differed from their disclosed abilities during the performance of their tasks.

When it comes to occupation, 5 (50%) of the participants belonging to the common citizen user group were employed, 4 (40%) were students and 1 (10%) was unemployed. In the professional user group, 4 (40%) were employed, 3 (30%) were students and 3 (30%) were unemployed. The occupation distribution is shown in figures 7.4a and 7.4b.

Lastly, when it comes to education level, 9 (90%) of participants from the common citizen user group had completed or were partaking in higher education, while 1 (10%) participant had completed their studies in high school. From the professional user group, 8 (80%) had completed or were completing their higher education studies while 2 (20%) had finished or were finishing their high school education. These distributions are shown in figures 7.5a and 7.5b.

Figura 7.4: Occupation Across Common Citizen and Professional User Groups

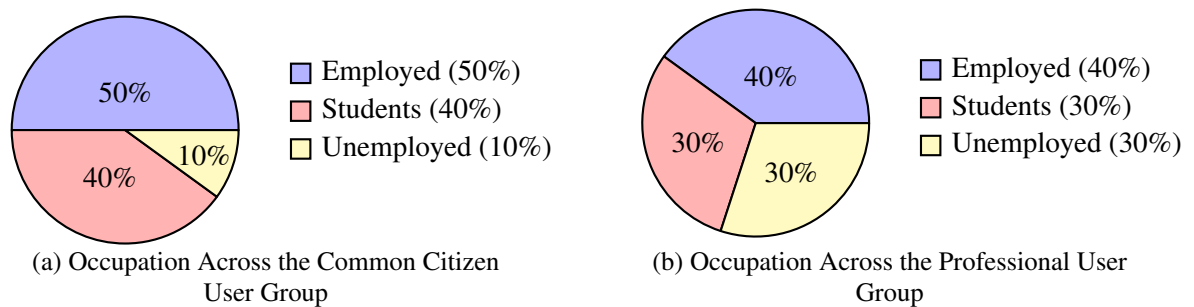
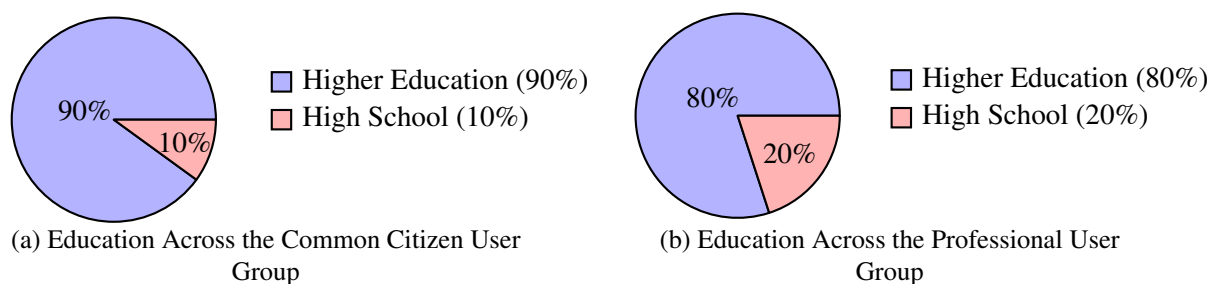


Figura 7.5: Education Level Across Common Citizen and Professional User Groups



The full overview of the user's demographic characteristics can be seen in Appendix B

7.1 Tasks

During the Think-Aloud portion of the user tests, participants were encouraged to share their thoughts and feelings on the developed Theia mapping component. All of the results are available on appendix B, and the provided feedback will be further analyzed in the next few sections.

7.1.1 General

The general feedback provided by users which is not particularly related to any task will be discussed in this subsection.

One participant mentioned that the current icons and some of the existing text were not very clear due to their size and color. This way, different combinations of colors and font sizes need to be tested in order to guarantee that the usage of the developed project is as easy and seamless to use as possible. In this aspect, a way to increase accessibility should also be studied, such as a way to globally increase icon size, like icon size options on the application's settings.

The same participant mentioned that the button's function should also be mentioned in a caption of some sort. This issue was not widely shared with other participants, and integrating these captions could prove to be an issue when visual bloat is considered. However, implementing these accessibility resources should at least be considered and further analyzed.

Some participants, especially in the 46-60 age group, tried to explore the frames on videos and timelines as if they were panoramic or omnidirectional. This could be due to a familiarity with other SVI tools who provide panoramic imagery, such as Google Street View. Even though the discovery of the images being fixed did not seem to affect the UX, a way of letting users know the nature of the provided images needs to be studied, as in the future some of the imagery might not be exclusively fixed.

Some participants also commented on the quality of the imagery. Some of the accessed images during the tests were of low quality, due to poor weather conditions, poor lighting, blurriness or bad angles. This could definitely affect the UX as well as the amount of information which would be able to be extracted from these images. While image validation and quality assurance fall outside the scope of this project, these are definitely issues which need to be analyzed and explored.

One participant reported that the street timelines dropdown was not displaying the current timeline ID correctly, as instead of highlighting the date and time, only the date was being shown. This behavior is due to the font size not being accommodated to different devices, and having a fixed value. This oversight was promptly addressed and fixed.

Another participant commented that there should be a way for users to report images and videos with quality issues or inappropriate content. The implementation of this feature will be considered for future work.

While performing the user tests with another participant, an error occurred where the image could not be accessed. While the remainder of the user tests with said participant were able to continue, as navigating to a different page and reopening the map fixed the issue, this bug could not be replicated. Nevertheless, further analysis is required for this issue, both to depict the issue and to fix it.

7.1.2 Open Map or Videos Component

The first task provided for each participant would vary depending on which user group they were inserted into: if they were part of the common citizen user group, their first task would be to either open their videos page on the app, while if they were part of the professional user group, they would have to open the map component. Both the map and the videos page were accessible through the navigation bar on the bottom of the screen.

For both user groups, no particular issues arose during this task and no further feedback was provided.

7.1.3 Center Map on Current Geographical Position

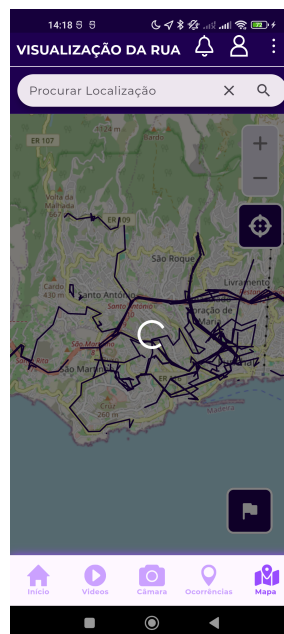
Only testers belonging to the professional user group performed this task. For this task, participants could either move the map manually to their current position or press the button which centers the map on their location. In general, most users who reported a moderate to high tech proficiency pressed the center on location button, while testers who reported a low tech proficiency

preferred to manually move to their location on the map. This can be due to not understanding the meaning of the chosen icon for this button, which was a crosshair.

One user mentioned there should be an icon indicating the user's current position on the map.

Some users suggested some form of feedback after pressing the center on location button. After the user presses this button, it takes a few moments before the map's center changes. The amount of time in-between pressing the button and the changing of the map's location varied between tests: while for some participants it took less than a second, for other participants it took a couple of seconds. This way, it would be positive to add some sort of feedback to the push of the button in order to let the user know their action was registered. This was approached by adding a circular loading indicator when the user pressed the button, as it is shown in figure 7.6.

Figura 7.6: New Behavior when Pressing Center on Current Location Button



7.1.4 Find the City of Funchal on the Map

Only testers belonging to the professional user group performed this task. Just like the previous one, users could perform this task by one of two options: either manually move the map to the city of Funchal, or use the search bar to search for Funchal, which would center the map on this city. However, there is no correlation between the choice the tester made and any other demographic data. Some users simply preferred to manually move the map to Funchal.

No particular issues or notable mistakes were noted for this task.

7.1.5 Visualize a Portion of a Street Timeline or Video

This task would vary between participants depending on which user group they were inserted into: if they were part of the professional user group, they would have to press one of the timelines

on the map and navigate said timeline by pressing the navigation arrows, while if they were part of the common citizen user group, they would have to select one video on their videos page, press the "see in the map" button, press the marker or polyline of the selected video and then navigate the video by pressing the navigation arrows.

In both user groups, there was some confusion on how to access a timeline or video on the map. However, all eventually discovered that they were accessed through pressing the polylines or markers on the map. Nevertheless, some analysis might be needed in order to tackle this aspect, even though users said that they would be capable of accessing other videos and timelines from the map after discovering the process.

In the case of the common citizen user group, however, there were additional issues to note. Testers became confused when asked to open their selected video on the map. Some pressed the map icon on the navigation bar, which opens the map component where their selected video would not be displayed in this version of the app, since timelines and videos are currently stored in different servers. Other users, instead of pressing the "see in the map" button, would press the play button on the video page.

These issues might be due to the size of the play button on the video page, which would draw the attention of the testers. In different devices, the play button would push the "see in the map" button down, making it hidden unless the tester scrolled down. One user mentioned they thought the play button would open the video on the map but they were misled. Solutions for these issues might range from decreasing the size of the play button and increasing the size and font size of the "see in the map" button while adding an icon, to removing the "see in the map" button altogether and making it so that pressing the play button on the video page would open the video on the map. A stable and satisfying solution still needs to be analyzed.

One common citizen user complained regarding the slow transition between frames of a video. However, this issue can be explained by two factors: similar frames and connection speed. At this moment, there is no analysis of recorded frames, therefore similar frames are not discarded, which might make it seem that there is little change between frames and make the video feel slow. A way to analyze frames in order to increase video quality and reduce redundancy needs to be considered. When it comes to connection speed, it will affect the rate at which images become available in the device, therefore slower connection speeds will lead to longer waiting periods between frame changes.

Another common citizen user also noted that there should be a marker indicating the position of the current frame on the map. This is to be considered a bug, as this aspect is fully functional on the map for the professional users. The root of this issue is still being evaluated.

7.1.6 Expand Map from the Current Timeline or Video

For this task, users would have to press the expand map button on the minimap.

Some users tried to expand the map through gestures, as in using their fingers to manually expand the map. Only after realizing this did not work would they notice the expand button. While the minimap is not dynamic in the sense of being able to manually change its dimensions,

this consideration might need to be further examined, as it could not only benefit the transition to the expanded map state, but to the expanded road viewer and split screen states as well.

Another tester commented that expanding the map should be accomplished simply by pressing the minimap. Pressing the map anywhere apart from the timelines or videos should expand it, and this behavior not working properly was considered a bug, and it should be investigated in order to be fixed in the future.

Finally, one common citizen user mentioned that viewing the video frames on the map and on the video play should be interchangeable, as in, when a user changed the current displayed frame on the video play, that frame should be the currently displayed frame if the user decides to open the video on the map and vice-versa.

7.1.7 Split Screen from Expanded Map

This task generated a great deal of confusion among participants, with almost half of them not being able to finish it. In order to split the screen in half from the expanded map state, users had to press the expand button on the street image box. Several participants complained of the lack of intuitiveness on how to achieve the split screen state. The main issues consisted of the low visibility of the button and the fact that using the same button in the same position as the one used to expand the map made it seem that the button would expand the viewer instead of splitting the screen. This would explain why the most common error made for this task was expanding the timeline, as the transitions between screen states seem not to be too clear.

Testers provided some suggestions in order to improve this. Some mentioned a similar proposal to one mentioned for expanding the map, as in the dimensions of the viewer should be dynamic, and sliding it to one of the sides of the device should automatically set the state to split screen. Others mentioned reworking the current solution, by changing the icon, its color and position. One participant also mentioned adding a caption to the button in order to explain its function.

Changing the chosen icon and its color is a very simple and quick fix at the code level, however it could not solve the current issue. Turning the road viewer dynamic on the expanded map state would be a more complex solution, and there is no guarantee that users would find it more intuitive to access the split screen state when dealing with the street management component for the first time. Although the split screen is fully functional, some more considerations and analysis are needed in order to guarantee that accessing this screen is a seamless and intuitive experience.

7.1.8 Expanded Timeline or Video from Split Screen

In order to complete this task, users would have to press the road viewer on the split screen state, which would expand either the timeline or their video, depending on what user group they were part of.

While no particular recurring errors were recorded, one user mentioned that similar tasks having different associated gestures made navigation a little confusing, and gave the example of how pressing the timeline would expand the timeline but pressing the map would not expand the map.

Pressing the map anywhere apart from the timelines or videos should expand it, as previously mentioned, and this bug will need to be addressed in the future.

7.1.9 Change Between Timelines

Only testers belonging to the professional user group performed this task, and in order to complete it, they would have to press the timeline dropdown and select a different timeline from the current one being displayed.

While most participants managed to change the timelines using the dropdown, several first tried to change timelines by manually pressing a different location on the minimap.

One tester mentioned that the dropdown seemed unintuitive as they would prefer to manually select a different timeline through the minimap. A more seamless way to allow to change the timelines might need to be considered, as the dropdown's function was not clear from the get-go.

Some testers mentioned that they had not noticed the dropdown at first, and that changing its size and/or position on the screen might help.

During the performance of this task with another participant, a bug was discovered. If a user uses the navigation arrows too quickly in a row, the dropdown becomes unavailable for a few seconds. The more the user changes their location on the expanded viewer screen, the longer will the dropdown be disabled. While this bug is still under investigation, it should probably be related to the chosen communication package, as it does not easily allow to cancel requests once they are sent. A different communication package might be in order in the future.

7.1.10 Mark Zone with "place of interest"Flag

Only testers belonging to the professional user group performed this task. In order to complete this task, users would have to press the button with a flag in order to access the area flag mode, zoom in on a zone on the map with few street timelines and then press the flag button again in order to flag that area.

Some testers were confused on how to effectively flag an area. While accessing the area flag mode did not raise many issues, flagging an area proved more challenging. Some users tried pressing the map in order to flag an area around the location they pressed, while others became puzzled and left the area flag mode at first, only later managing to correctly flag an area.

One user mentioned that although flagging an area was not an intuitive process at first, it was a matter of learning the process, and they would feel comfortable flagging certain areas in the future with some practice.

One user mentioned the lack of intuitivity of the process, and suggested flagging be done by pressing the map, while another user mentioned that having to press the flag button twice seemed annoying and suggested flagging be done directly by pressing the flag button just once.

Some users mentioned that there was a lack of feedback when pressing the button, as there should be some sort of shadow or highlight indicating the button had been pressed.

Although the ideal solution is not yet clear, changing the way in which areas are flagged will need to be further analyzed and changed in the future.

7.2 NASA Task Load Index (NASA-TLX)

Users rated the perceived workload on a scale from 1 to 10. In the case of the common citizen user group, participants deemed the workload of the street management component as significantly low, with an average score of 2.72, a mode of 1 and a median of 2.5. The standard deviation was 1.67, which means there was a moderate amount of variation of perceived workload for users performing the common citizen tasks. In the case of participants belonging to the professional user group, the perceived workload was higher but still low overall, with an average score of 3.8, a mode of 3 and a median of 3.5. The standard deviation for this user group was 1.67 as well, meaning that the variation in perceived workload for users in this user group was moderate too.

In the common citizen group, the average workload perceived by user varied between a minimum score of 1 and a maximum score of 5.6. In the case of the professional user group, perceived workloads varied between a minimum of 1.6 and a maximum of 5.8. This suggests that even though the workload is perceived as higher for the tasks aimed for the professional users, it is not excessive for either user group.

The results for each of the dimensions evaluated on the NASA-TLX are the following:

- **Mental Demand:** For the common citizen user group, participants reported a low mental demand, with an average of 2.8, a mode of 2, a median of 2.5 and a standard deviation of 1.55. This indicates that although the overall mental demand was low, there was some variance in the perceived mental workload.

For the professional user group, the mental demand was higher, with an average score of 4.1, a mode of 3, a median of 3.5 and a standard deviation of 1.79. This indicates that although sharing a similar variance in mental load, the features aimed for the professional user seemed more mentally demanding.

- **Temporal Demand:** The common citizen user group expressed a low time load, with an average score of 2.8, a mode of 3, a median of 3.5 and a standard deviation of 1.62. Users performing the common citizen tasks reported a low temporal demand although there is some variance in the results.

In the case of the professional user group, temporal demand was higher, with an average score of 4, a mode of 5, a median of 4.5 and a standard deviation of 1.7. The tasks aimed for the professional users were more demanding on average, even though the standard deviation suggesting there being some variance in results.

- **Performance:** The performance dimension reported the highest average score for the common citizen user group, with an average score of 3.6, mode of 3, median of 3 and standard deviation of 1.9. Although seemingly the most demanding workload dimension for this user

group, the higher standard deviation value suggests significant variance in self-perceived performance.

The reported performance of the professional user group was overall better, with an average score of 3.4, mode of 3, median of 3 and standard deviation of 1.07. The performance was improved for this user group, and variance was lower, meaning there was more overall consensus on the noted performance.

- **Effort:** Participants belonging to the common citizen user group reported low required effort, with an average score of 2.6, a mode of 1, a median of 2 and a standard deviation of 1.9. The average participant disclosed low effort, however, the standard deviation value indicates variance in the sample group is somewhat significant.

The professional user group expressed significant required effort in order to complete the task, with an average score of 4.2, a mode of 6, a median of 4.5 and a standard deviation of 1.87. This way, the tasks aimed for professionals were deemed as requiring more effort on average, even with the moderate variance being considered.

- **Frustration:** Users from the common citizen group reported close to no frustration when performing their tasks, with an average score of 1.8, a mode of 1, a median of 1.5 and a standard deviation of 1.03. For this user group, there is an overall consensus on the low frustration the tasks induce.

Frustration was higher on the professional user group, with an average score of 3.3, a mode of 2, a median of 2.5 and a standard deviation of 1.89. The median of 2.5 indicates that half of the users felt no significant frustration when performing their assigned tasks, while the meaningful standard deviation indicates considerable variability on the user's frustration level.

We can take some conclusions from these findings. For each dimension tested, the common citizen user group reported lower workloads overall, with the average scores and median values being lower for each dimension when compared to the accounts of the professional user group. While worth mentioning the increased complexity and capacity of the features available for professional users, the higher mental and temporal demand, effort and frustration, and lower perceived performance, might lead to an overall lower user satisfaction. However, the standard deviation values were only significantly constrained on the frustration dimension for the common citizen user group and on the performance dimension of the professional user group, meaning there is moderate to significant variability in satisfaction in user experience.

In order to determine the correlation between each dimension of the NASA-TLX, a correlation matrix was developed for each user group, which are shown in tables 7.1a and 7.1b. We can establish that, overall, all dimensions have significant positive correlations, which mean that the increase in one dimension will lead to the increase in other dimensions. For example, higher mental demand scores will lead to increases of temporal demand, performance, effort and frustration.

From these results, we can conclude that tackling one of the dimensions in order to improve their results will improve the component in other areas.

Tabela 7.1: Correlation Matrices of NASA-TLX Dimensions

	MD	TD	Perf	Effort	Frust
MD	1				
TD	0.7352	1			
Perf	0.7636	0.8028	1		
Effort	0.7258	0.8752	0.5988	1	
Frust	0.6667	0.8371	0.7485	0.5784	1

(a) Common Citizen User Group

	MD	TD	Perf	Effort	Frust
MD	1				
TD	0.8755	1			
Perf	0.6691	0.6081	1		
Effort	0.8868	0.9768	0.7281	1	
Frust	0.3841	0.4846	0.6458	0.5777	1

(b) Professional User Group

7.3 System Usability Scale (SUS)

For the SUS, participants rated each one of the 10 questions on a scale of 1 to 5, depending on their level of agreement with the provided templates. From the gathered responses, the scores were calculated as such:

- For each of the odd numbered questions (Q1, Q3, Q5, Q7, Q9), subtract 1 from the participant's score;
- For each of the even numbered questions (Q2, Q4, Q6, Q8, Q10), subtract the participant's score from 5;
- Add all scores of each participant together and multiply the result by 2.5 in order to obtain the overall SUS score of each user.

Scores for the SUS can range from 0 to 100, and the results can be fit into certain brackets as such:

- **0-49: Poor Perceived Usability** - Scores in this bracket signify an urgent need to make usability a top priority; the system is likely frustrating for users and may significantly hinder their ability to complete tasks effectively;
- **50-69: Fair Perceived Usability** - Scores in this bracket signify the need for a careful analysis of the current perceived usability and identification of areas for improvement; while the system is usable, it likely causes some discomfort or inefficiency for users;

- **70-84: Good Perceived Usability** - Scores in this bracket signify a positive perceived usability, although still with some room for improvement; users generally find the system effective and satisfying, but there may be minor issues that could enhance the experience further;
- **85-100: Excellent Perceived Usability** - Scores in this bracket signify a very high level of usability, indicating that users find the system to be intuitive, efficient, and highly satisfying to use. Little to no changes are needed, as the system is meeting or exceeding user expectations.

The overall SUS scores and their average are displayed in table 7.2.

Tabela 7.2: Overall Participant SUS Scores

ID	Overall SUS Score
1	80
2	85
3	80
4	95
5	85
6	80
7	82.5
8	72.5
9	97.5
10	95
average	85.25
median	83.75

(a) Common Citizen User Group

ID	Overall SUS Score
p1	85
p2	80
p3	77.5
p4	77.5
p5	77.5
p6	65
p7	75
p8	35
p9	70
p10	70
average	71.25
median	76.25

(b) Professional User Group

From the obtained results, we can conclude that in the case of the common citizen user group, usability falls between the Excellent and Good usability brackets. Half of the participants from this user group rated usability with a score of 83.75 or higher. Out of all 10 common citizen participants, 5 rated the street management component with an "Excellent Perceived Usability" and 5 rated it with a "Good Perceived Usability".

In the case of the professional user group, scores were overall lower, with the average and median values falling within the bottom of the Good usability bracket. With the median being 76.25, this means that half of testers rated usability of the professional component of the street management component with an equal or higher score. Out of the 10 testers falling on the professional user group, 1 rated it with an "Excellent Perceived Usability", 7 with a "Good Perceived Usability", 1 with a "Fair Perceived Usability" and 1 with a "Poor Perceived Usability". Although the score given by user p8 is concerning and further analysis is in order, it should be noted that the provided rating is an outlier when compared to the remainder of scores.

In the case of the common citizen user group, the questions with the lowest average rating were questions "Q1: I think that I would like to use this system frequently" and "Q9: I felt very

confident using the system", both of them with an average score of 3, and the question with the highest average rating was "Q6: I thought there was too much inconsistency in this system", meaning that although users weren't exceptionally confident while using the system and showed no intentions of using it frequently, the system was perceived as consistent overall.

In the case of the professional user group, the question with the lowest average rating was question "Q1: I think that I would like to use this system frequently" with an average score of 2.3, and the highest was "Q4: I think that I would need the support of a technical person to be able to use this system." We can conclude that, overall, users do not seem too interested on frequently using the street management components of the Theia application.

7.4 Questionnaire for User Interface Satisfaction (QUIS)

The QUIS results show different yet not too different levels of satisfaction for the common citizen and professional user groups. For the common citizen user group, the average score was 8.35 out of 9, which displays a good outlook on the component's usability, appearance and functionality. For the professional user group, the average rating was somewhat lower at 7.13 out of 9. Nevertheless, it's still a solid and positive perception.

The median score given by common citizen users was 9 while for the professional users it was 7. Although both results are promising, the outlook is more positive for the common citizen user group, as half of the testers rated the interface very positively, while professional users, though still satisfied, believed there was still room for improvement.

The standard deviation for the common citizen user group was 0.78 while for professional users it was 1.53, which indicates that the perception of the user interface for common citizens was mostly unanimous, while for the professional user group there were varying degrees of satisfaction, although with only moderate variability.

The QUIS ratings show two distinct results for the tasks aimed for the common citizen and professional users. While common citizens showed extreme satisfaction when regarding the interface they were exposed to for their tasks, the professional user group, while still overall content with their user interface, believed there was still some room to improve the general usability, functionality and appearance. This way, it is necessary to keep monitoring the provided feedback in order to improve the component in interface aspects where it is lacking. For the common citizen, the lowest average score was the visual score with an average of 8, while for the professional users, the lowest average score was the learnability with an average score of 6.5. However, it is worth noting that the highest average score for professional users, which was the overall functionality with a 7.5, is still lower than the lowest average for the common citizen. Therefore, efforts should be made in order to ameliorate the perceived user interface satisfaction for the features intended for the professional user, as these seem to require the most amount of fine tuning.

With the employment of these quantitative tools for the evaluation of the street management component, it is possible to ascertain some general results in the case of functionality, usability and satisfaction.

In the case of the NASA-TLX, SUS and QUIS, the project developed for the common citizen performed somewhat better than the one developed for the professional user.

There are still some considerations to be had in the professional user section regarding system usability, where one user gave a score of 35 out of 100, and also efforts should be made in order to reduce the perceived workload for this user group, as well as increase user satisfaction with the interface.

In the case of the common citizen user group, results were overall better. Only minor fixes and considerations are needed in order to reduce variability of results and to improve system usability.

When considering the formulated research question, we can conclude that Theia's street management component had an overall positive impact on the street and urban management. 9 out of the 10 common citizen participants considered using this application instead of other street navigation methods for street maintenance and documentation, while for the professional user group, 8 out of 10 participants responded positively. Despite some challenges surging, especially for professional users, the component was favored by users, and participants provided valuable feedback for future developments of the Theia street management component.

Capítulo 8

Conclusions and Future Work

With the conclusion of this dissertation, a street management component for the Theia mobile application has been developed. This project's objective was to allow for street imagery to assist in making the urban administration process easier and more seamless. The developed product proved to be a satisfactory way of connecting both spacial and temporal data regarding street imagery on a map.

The motivation for the development of this project, being the need for a more efficient and comprehensive method to document and manage changes in urban street environments, led to an analysis of the current market for SVI projects. It was discovered that although Google Street View dominates the research and user market, there are smaller VSVI services available whose qualities would go more in line with the project at hand. The limitations and trade-offs between regular SVI and VSVI services were also noted.

During the implementation phase, an intensive development process was undergone, using current tools in order to achieve the product goal. While several challenges and missteps were faced, they were all overcome, which resulted in a module with the wants and needs of users in mind.

Feedback was extracted from a sample of users through qualitative and quantitative methods, in order to guarantee the set goals had been met and that users were satisfied with the product. In these tests, it was discovered that while the functionalities aimed for the common citizen were solid and mostly satisfactory, there is still some need for some improvement on workload perception, user interface and system usability. Although feedback was overall positive, some of the provided scores raise some concern, especially the one "Poor Usability" score in system usability.

While with promising results, some improvements are acknowledged. The street images visualization component was tested only on Android devices, making it impossible to prove its cross-platform capabilities. There is also the issue of user demographics, as actual professional users should be employed for future testing.

The future for the Theia street management module could be promising. If user's feedback continues to be considered for development, and dataset limitations are addressed, this tool could

become crucial for urban and road administration, as a way to increase the speed and quality of the oversight and documentation of the streetspace.

In conclusion, Theia's street management is a way of showing the capabilities of combining digital technologies with the urban governance process. With an user-oriented development, it proves itself as a promising tool which can positively influence the oversight of urban spaces in a way that satisfies the community.

8.1 Future Work

There are considerations for the future regarding the street management module.

The management module needs to be carefully tested on the iOS operating system in order to guarantee that all of the implemented features work, as intended, on these devices.

After implementing the remaining user stories and the mentioned improvements and bug fixes have been integrated, the new version of the street operations component should go through another round of user tests so that it is possible to make sure these new features work properly and seamlessly.

In the future, the street images visualization module should be tested with more users who could be considered actual professional users. This way, the road operations component could be improved taking into account their needs, suggestions and feedback, as there is a significant number of components created specifically for them. This street management module should also be tested on both Android and iOS devices instead of only on Android phones.

The developed module should also allow for street captures by the common citizen to be displayed in the street operations portion of the app. Due to the current employment of two different servers for the common citizen operations and the road operations, this coupling will have to be postponed until both servers have been merged.

There are also some considerations to be had when it comes to the timeline dataset. This dataset consists of images captured mostly by cameras mounted on the dashboard of vehicles, and therefore it is prone to several issues, as discussed in Chapter 2. While the issues of spacial quality and heterogeneity are somewhat addressed with area flags, there are still issues regarding image quality, logical consistency, metadata accuracy and redundancy. This way, the project's dataset would benefit from some sort of quality assurance. This could be achieved through various methods, such as the implementation of a artificial intelligence model in order to determine and prune redundancy and increase image quality by removing faulty images, or as suggested by (author?), through the assignment of a score to reflect trustworthiness to each contributor.

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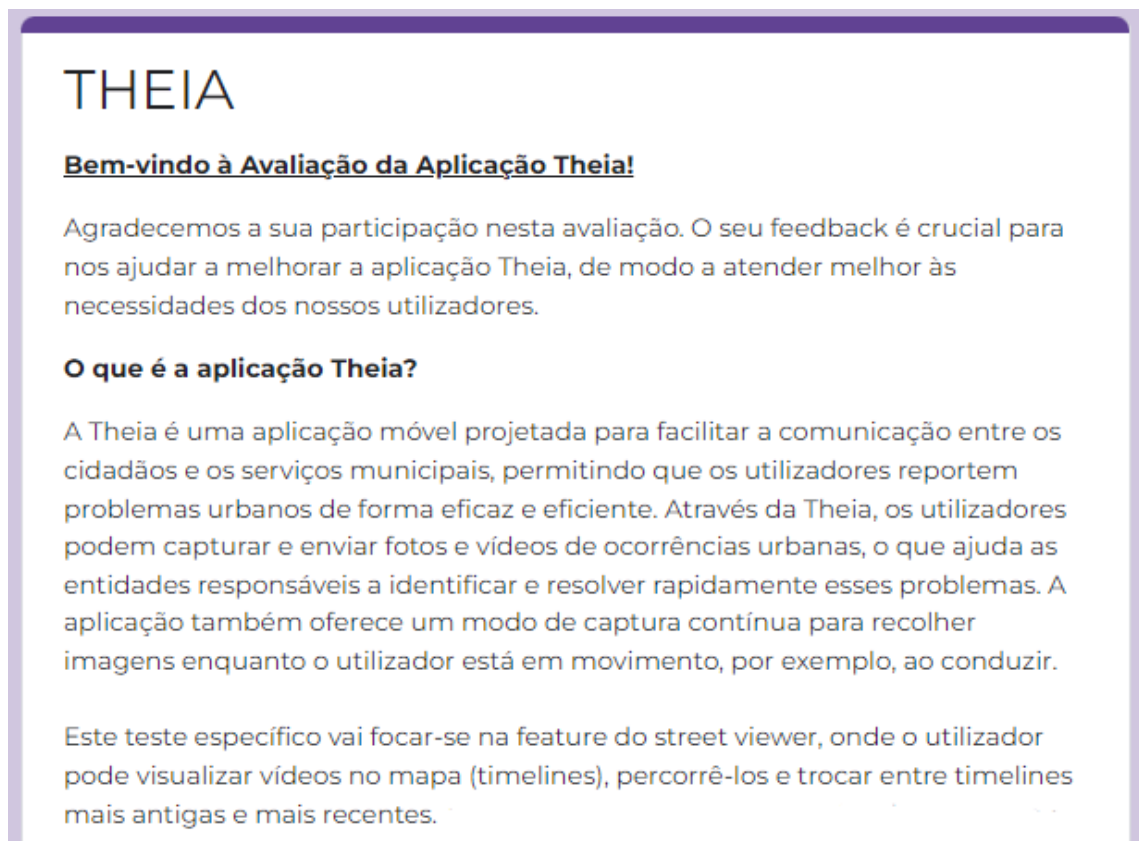
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Anexo A

Forms

Figura A.1: Google Forms Questionnaire for the User - Part 1



THEIA

Bem-vindo à Avaliação da Aplicação Theia!

Agradecemos a sua participação nesta avaliação. O seu feedback é crucial para nos ajudar a melhorar a aplicação Theia, de modo a atender melhor às necessidades dos nossos utilizadores.

O que é a aplicação Theia?

A Theia é uma aplicação móvel projetada para facilitar a comunicação entre os cidadãos e os serviços municipais, permitindo que os utilizadores reportem problemas urbanos de forma eficaz e eficiente. Através da Theia, os utilizadores podem capturar e enviar fotos e vídeos de ocorrências urbanas, o que ajuda as entidades responsáveis a identificar e resolver rapidamente esses problemas. A aplicação também oferece um modo de captura contínua para recolher imagens enquanto o utilizador está em movimento, por exemplo, ao conduzir.

Este teste específico vai focar-se na feature do street viewer, onde o utilizador pode visualizar vídeos no mapa (timelines), percorrê-los e trocar entre timelines mais antigas e mais recentes.

Figura A.2: Google Forms Questionnaire for the User - Part 2

Avaliação da Aplicação

Este questionário é parte de um processo de avaliação abrangente, que inclui completar tarefas específicas e avaliar a experiência utilizando o índice de carga de trabalho NASA (NASA Task Load Index). A avaliação é composta por quatro partes principais:

1. Protocolo Think-Aloud

Nesta secção, será solicitada a conclusão de algumas tarefas específicas na aplicação Theia.

2. Volume de Trabalho - Task Load Index (NASA-TLX)

Nesta secção, será avaliado o volume de trabalho necessário para a utilização da aplicação em cinco das seis dimensões do NASA-TLX, nomeadamente: exigência mental, quantidade de tempo, desempenho, esforço e frustração sentida.

3. Usabilidade - Escala de Usabilidade do Sistema (SUS)

Nesta secção, irá avaliar a sua experiência geral com a aplicação com base em dez afirmações. Cada afirmação deve ser classificada numa escala de 1 (Discordo Totalmente) a 5 (Concordo Totalmente). A SUS ajudar-nos-à a entender quão eficaz, eficiente e satisfatório é o desempenho da aplicação no seu ponto de vista.

4. Interface do Utilizador - Questionário de Satisfação da Interface do Utilizador (QUIS)

Esta secção consiste num conjunto de perguntas que medem a sua satisfação com a interface de utilizador da aplicação. Irá avaliar cada item numa escala de 1 (Muito Insatisfeito) a 9 (Muito Satisfeito). O QUIS é projetado para nos fornecer feedback detalhado sobre a acessibilidade, aparência e experiência geral do utilizador da aplicação.

Figura A.3: Google Forms Questionnaire for the User - Part 3

Instruções:

- Por favor, responda a todas as questões tendo em conta a sua experiência na utilização da aplicação Theia.
- Não existem respostas certas ou erradas, estamos interessados nas suas opiniões e experiências genuínas.
- Se encontrar alguma dificuldade ou tiver sugestões, por favor mencione-as nas secções de comentários opcionais fornecidas.

As suas respostas serão mantidas confidenciais e serão usadas apenas para melhorar a aplicação Theia. Agradecemos o seu tempo e esforço para nos ajudar a melhorar a aplicação para todos os utilizadores.

Vamos começar!

Figura A.4: Google Forms Questionnaire for the User - Part 4

Dados Pessoais

Para fins de análise estatística e para entender melhor os diferentes perfis dos utilizadores, por favor, forneça as seguintes informações. A sua resposta será anónima e confidencial.

Número de Participante *

A ser dado pelo(a) investigador(a)

Your answer

Idade *

☐ 18-30

☐ 31-45

☐ 46-60

☐ 60+

Figura A.5: Google Forms Questionnaire for the User - Part 5

Gênero *

- ☐ Feminino
- ☐ Masculino
- ☐ Prefiro não dizer
- ☐ Other: _____

Nível de Competência Digital *

- ☐ Baixo (Uso básico de Telemóvel)
- ☐ Moderado (Uso regular de aplicações e serviços de internet)
- ☐ Alto (Uso avançado de tecnologia, confortável com resolução de problemas)

Figura A.6: Google Forms Questionnaire for the User - Part 6

Área

Your answer _____

Nível de Escolaridade

- ☐ Ensino Básico
- ☐ Ensino Secundário
- ☐ Ensino Superior
- ☐ Other: _____

Figura A.9: Google Forms Questionnaire for the User - Part 9

Secção 3: Escala de Usabilidade do Sistema (SUS)

Por favor, avalie as seguintes afirmações:

Acho que gostaria de usar esta aplicação frequentemente.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei a aplicação desnecessariamente complexa.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei a aplicação fácil de usar.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Figura A.10: Google Forms Questionnaire for the User - Part 10

The image shows a Google Forms questionnaire with three questions, each followed by a five-point Likert scale. The questions are in Portuguese. The first question is 'Acho que precisaria do suporte técnico para conseguir usar esta aplicação.' with a scale from 1 (Discordo Totalmente) to 5 (Concordo Totalmente). The second question is 'Achei que as várias funções desta aplicação estavam bem integradas.' with the same scale. The third question is 'Achei que havia muita inconsistência nesta aplicação.' with the same scale. All five radio buttons in each scale are currently unselected.

Acho que precisaria do suporte técnico para conseguir usar esta aplicação.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei que as várias funções desta aplicação estavam bem integradas.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei que havia muita inconsistência nesta aplicação.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Figura A.11: Google Forms Questionnaire for the User - Part 11

Imagino que a maioria das pessoas aprenderiam a usar esta aplicação muito rapidamente.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Achei a aplicação muito complicada de usar.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Senti-me muito confiante a usar a aplicação.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Precisei de aprender muitas coisas antes de conseguir usar a aplicação.

1 2 3 4 5

Discordo Totalmente ☐ ☐ ☐ ☐ ☐ Concordo Totalmente

Figura A.14: Google Forms Questionnaire for the User - Part 14

Secção 5: Comentários Finais

Agradecemos a sua participação e feedback! Por favor, utilize o espaço abaixo para quaisquer comentários adicionais ou sugestões que gostaria de compartilhar, sobre a sua experiência com a aplicação Theia.

A sua opinião é fundamental para o aprimoramento da aplicação Theia. Muito obrigado pelo seu tempo e colaboração!

Consideraria utilizar esta aplicação para manutenção e documentação do estado das ruas em vez de outros modos de navegação de rua digital? *

☐ Sim

☐ Não

Comentários Adicionais

Your answer

Figura A.15: Google Forms Questionnaire for the Investigator - Part 1

Número do participante *

Your answer _____

Tarefa 1 - Abrir a funcionalidade do mapa ou abrir a funcionalidade dos videos

Prep work - login

question asked *

☐ open map

☐ open video

Steps

☐ User presses the map feature button

☐ User presses the video feature button

Erros Cometidos

☐ User presses any button apart from the map/video feature button

☐ Other: _____

Completoou a tarefa *

☐ Sim

☐ Não

Comentários

Your answer _____

Figura A.16: Google Forms Questionnaire for the Investigator - Part 2

Tarefa 2 - Centrar o mapa na posição geográfica atual (ignore if participant is common citizen)

Steps

- ☐ user presses the center on current position button
- ☐ user manually moves to current position

Erros cometidos

- ☐ user leaves the map feature
- ☐ user presses the searchbar
- ☐ user presses a street timeline
- ☐ user presses the area flag button
- ☐ Other: _____

Completou a tarefa *

- ☐ Sim
- ☐ Não

Comentários

Your answer _____

Figura A.17: Google Forms Questionnaire for the Investigator - Part 3

Tarefa 3 - Encontrar o Funchal no mapa (ignore if participant is common citizen)

Steps

- ☐ user moves to Funchal manually
- ☐ user searches Funchal in the searchbar

Erros cometidos

- ☐ user leaves the map feature
- ☐ user presses a street timeline
- ☐ user presses the center on current location button
- ☐ user presses the area flag button
- ☐ Other: _____

Completo a tarefa

- ☐ Sim
- ☐ Não

Comentários

Your answer _____

Figura A.18: Google Forms Questionnaire for the Investigator - Part 4

Tarefa 4 - Visualizar porção do video no mapa/timeline das ruas

Prep work - explicar conceito de timeline

Steps

- ☐ user opens video on the map (only if participant is common citizen)
- ☐ user presses one of the lines on the map in order to access that street timeline
- ☐ user presses the arrow pointing up in order to see the next street image
- ☐ user presses the arrow pointing down in order to see the previous street image

Erros cometidos

- ☐ user opens the map feature instead of viewing video on the map (only if participant is common citizen)
- ☐ user plays video instead of viewing video on the map (only if participant is common citizen)
- ☐ user leaves the map feature
- ☐ user presses the searchbar
- ☐ user presses the center on current location button
- ☐ user presses the area flag button
- ☐ user presses the close timelines dropdown
- ☐ user presses the expand map button
- ☐ user changes between timelines
- ☐ Other: _____

Completo a tarefa *

- ☐ Sim
- ☐ Não

Comentários

Your answer

Figura A.19: Google Forms Questionnaire for the Investigator - Part 5

Tarefa 5 - A partir da timeline da rua, expandir o mapa

Steps

☐ user presses the expand map button

Erros cometidos

☐ user leaves the map feature

☐ user presses a street timeline

☐ user presses the next/previous street image button

☐ user presses the close timelines dropdown

☐ Other: _____

Completoa tarefa *

☐ Sim

☐ Não

Comentários

Your answer

Figura A.20: Google Forms Questionnaire for the Investigator - Part 6

Tarefa 6 - Dividir o mapa ao meio, com o mapa e a timeline a ocupar o mesmo espaço no ecrã

Steps
☐ user presses the splitscreen button

Erros cometidos
☐ user leaves the map feature
☐ user presses the searchbar
☐ user presses a street timeline
☐ user presses the next/previous street image button
☐ user presses the center on current location button
☐ user expands the timeline
☐ user presses the close timelines dropdown
☐ Other: _____

Completou a tarefa *
☐ Sim
☐ Não

Comentários

Your answer _____

Figura A.21: Google Forms Questionnaire for the Investigator - Part 7

Task 7 - A partir do ecrã dividido, focar na timeline outra vez

Steps
☐ user presses on the current street image

Erros cometidos
☐ user leaves the map feature
☐ user presses the searchbar
☐ user changes the current timeline
☐ user presses the next/previous street image button
☐ user presses the center on current location button
☐ Other: _____

Completou a tarefa *
☐ Sim
☐ Não

Comentários

Your answer

Figura A.22: Google Forms Questionnaire for the Investigator - Part 8

Task 8 - A partir da timeline atual mudar entre timelines próximas diferentes (ignore if participant is common citizen)

Prep work - mover para mapa expandido e selecionar uma timeline com outras timelines próximas

Steps

- ☐ user presses the street timelines dropdown
- ☐ user chooses a different street timeline from the current one

Erros cometidos

- ☐ user leaves the map feature
- ☐ user presses the searchbar
- ☐ user selects the same timeline as the current one
- ☐ user changes the timeline through the map box
- ☐ user presses the next/previous street image button
- ☐ Other: _____

Completo a tarefa

- ☐ Sim
- ☐ Não

Comentários

Your answer _____

Figura A.23: Google Forms Questionnaire for the Investigator - Part 9

Task 9 - Assinalar zona com poucas timelines como lugar de interesse (ignore if participant is common citizen)

Prep work - explicar conceito de flags e mover para mapa expandido

Steps

- ☐ user accesses the area flag mode
- ☐ user zooms in on an area with few street timelines
- ☐ user presses the flag button

Erros cometidos

- ☐ user leaves the map feature
- ☐ user presses the return to expanded map button
- ☐ user presses a street timeline
- ☐ Other: _____

Completo a tarefa

- ☐ Sim
- ☐ Não

Comentários

Your answer _____

Anexo B

Results

Tabela B.1: Demographic Data of Participants.

ID	Type	Age Group	Gender	Tech Proficiency	Occupation	Field	Education
1	Common Citizen	46-60	Male	Moderate	Professional	Engineering	Higher Education
2	Common Citizen	18-30	Male	High	Student	Engineering	Higher Education
3	Common Citizen	46-60	Female	Low	Professional	Education	Higher Education
4	Common Citizen	18-30	Non-Binary	Moderate	Student	Fine Arts	Higher Education
5	Common Citizen	18-30	Female	High	Professional	Consulting	Higher Education
6	Common Citizen	18-30	Female	High	Student	Engineering	Secondary Education
7	Common Citizen	46-60	Female	Moderate	Professional	Education	Higher Education
8	Common Citizen	46-60	Male	Moderate	Professional	Education	Higher Education
9	Common Citizen	18-30	Female	High	Unemployed	Fine Arts	Higher Education
10	Common Citizen	18-30	Female	Moderate	Student	Graphic Design	Higher Education
p1	Professional User	18-30	Male	High	Student	Engineering	Higher Education
p2	Professional User	46-60	Male	Moderate	Professional	Engineering	Higher Education
p3	Professional User	46-60	Female	Low	Professional	Education	Higher Education
p4	Professional User	31-45	Male	Low	Unemployed		Secondary Education
p5	Professional User	18-30	Female	Moderate	Professional	Consulting	Higher Education
p6	Professional User	18-30	Female	Moderate	Unemployed	Fine Arts	Higher Education
p7	Professional User	18-30	Female	Moderate	Student	Graphic Design	Higher Education
p8	Professional User	18-30	Female	High	Student	Multimedia Art	Higher Education
p9	Professional User	18-30	Male	Moderate	Unemployed	Multimedia Art	Higher Education
p10	Professional User	31-45	Male	Moderate	Professional	Fine Arts	Secondary Education

Tabela B.2: NASA Task Load Index (NASA-TLX) Scores

ID	Mental Demand	Temporal Demand	Performance	Effort	Frustration
1	2	4	3	5	2
2	3	3	3	3	1
3	6	6	6	6	4
4	2	1	2	1	1
5	3	2	3	1	2
6	1	3	4	1	2
7	4	3	5	4	1
8	4	4	7	3	3
9	1	1	1	1	1
10	2	1	2	1	1
p1	3	3	2	3	2
p2	6	6	3	6	3
p3	7	6	4	6	2
p4	5	5	5	6	4
p5	2	2	3	2	1
p6	3	3	3	3	2
p7	2	1	2	1	2
p8	6	5	5	6	7
p9	3	5	3	5	5
p10	4	4	4	4	5

Tabela B.3: System Usability Scale (SUS) Scores

ID	Q1: Likelihood of Use	Q2: Unnecessary Complexity	Q3: Ease of Use	Q4: Need of Tech Support	Q5: Integration	Q6: Inconsistency	Q7: Learning Speed	Q8: Cumbersome	Q9: Confidence	Q10: Required Knowledge
1	4	3	3	2	4	1	5	2	5	1
2	4	1	4	1	4	2	4	1	4	1
3	3	1	4	3	5	1	5	2	3	1
4	5	1	5	1	4	1	4	1	5	1
5	3	1	5	2	5	1	3	1	4	1
6	4	2	5	2	3	1	3	1	4	1
7	5	1	4	2	5	1	4	2	3	2
8	4	2	2	2	5	1	5	2	2	2
9	4	1	5	1	5	1	5	1	5	1
10	4	1	5	1	4	1	5	1	5	1
p1	4	1	4	1	5	3	3	1	5	1
p2	4	2	4	1	4	2	5	2	4	2
p3	5	3	4	3	5	1	5	2	4	3
p4	4	2	4	2	4	2	5	1	3	2
p5	3	1	4	2	3	1	4	2	4	1
p6	3	2	3	2	4	3	3	2	4	2
p7	3	2	4	1	3	3	4	1	4	1
p8	2	5	2	2	2	4	2	4	3	2
p9	2	3	4	1	4	2	4	2	3	1
p10	3	2	3	2	4	2	3	2	4	1

Tabela B.4: Questionnaire for User Interaction Satisfaction (QUIS) Scores

ID	Learnability	System Response Time	Navigation	Visual Layout	Consistency	Overall Functionality
1	8	9	7	8	8	8
2	8	8	7	9	9	9
3	8	7	9	8	8	9
4	9	8	9	9	7	8
5	8	9	9	7	8	8
6	8	9	7	9	9	8
7	8	9	9	7	8	9
8	7	9	9	9	9	8
9	9	9	9	6	9	9
10	9	9	9	8	9	9
p1	7	6	9	8	7	8
p2	8	9	7	7	7	8
p3	8	9	9	9	9	9
p4	7	9	8	7	8	8
p5	8	7	9	8	8	8
p6	6	8	6	6	7	8
p7	7	7	8	8	8	8
p8	3	5	4	2	5	4
p9	5	6	6	7	6	6
p10	6	7	7	6	9	8

Tabela B.5: User General Feedback on the Street Management Feature

ID	Would you consider using this feature for maintenance and documentation of the street state instead of other digital street navigation methods?	Comments
1	Yes	Application with potential if widely used, needs some adjustments in the interface and greater ease of use of some features.
2	Yes	
3	Yes	The icons should have a more contrasting color with the rest of the application, be larger, and have labels.
4	Yes	UI is very good and app is easy to use
5	Yes	
6	No	
7	Yes	
8	Yes	
9	Yes	The layout color doesn't make much sense being purple, I think it should be green.
10	Yes	I think the application's color palette is disconnected from its purpose; in my opinion, colors like blue, green, and yellow would be more coherent with the proposed objective.
p1	Yes	
p2	Yes	If there is investment in the application and an active community, this tool could be very useful for public road maintenance.
p3	Yes	
p4	Yes	
p5	Yes	
p6	No	
p7	Yes	
p8	No	
p9	Yes	Purple is not a color that symbolizes the purpose of the app.
p10	Yes	

Tabela B.6: Results of Think-Aloud for Task 1 - Open Map or Videos Feature

ID	Question Asked	Steps	Number of Errors Committed	Completed Task	Comments
1	Open video	User presses the video feature button	0	Yes	
2	Open video	User presses the video feature button	0	Yes	
3	Open video	User presses the video feature button	0	Yes	
4	Open video	User presses the video feature button	0	Yes	
5	Open video	User presses the video feature button	0	Yes	
6	Open video	User presses the video feature button	0	Yes	
7	Open video	User presses the video feature button	0	Yes	
8	Open video	User presses the video feature button	0	Yes	
9	Open video	User presses the video feature button	0	Yes	
10	Open video	User presses the video feature button	0	Yes	
p1	Open map	User presses the map feature button	0	Yes	
p2	Open map	User presses the map feature button	0	Yes	
p3	Open map	User presses the map feature button	0	Yes	
p4	Open map	User presses the map feature button	0	Yes	
p5	Open map	User presses the map feature button	0	Yes	
p6	Open map	User presses the map feature button	0	Yes	
p7	Open map	User presses the map feature button	0	Yes	
p8	Open map	User presses the map feature button	0	Yes	
p9	Open map	User presses the map feature button	0	Yes	
p10	Open map	User presses the map feature button	0	Yes	

Tabela B.7: Results of Think-Aloud for Task 2 - Center Map on Current Geographical Position

ID	Steps	Number of Errors Committed	Completed Task	Comments
p1	User presses the center on current position button	0	Yes	Add a circular loading indicator to show that the request has been made
p2	User presses the center on current position button	0	Yes	
p3	User manually moves to current position	1	Yes	
p4	User manually moves to current position	0	Yes	
p5	User presses the center on current position button	0	Yes	A bit slow and it's hard to tell if the app registered the button press
p6	User presses the center on current position button	0	Yes	
p7	User manually moves to current position	0	Yes	Took a while to move to location with the button. There should be some indication that it's processing. It should zoom in on the area.
p8	User manually moves to current position	0	Yes	
p9	User presses the center on current position button	0	Yes	A pin should appear at the user's current position
p10	User presses the center on current position button	0	Yes	

Tabela B.8: Results of Think-Aloud for Task 3 - Find the City of Funchal on the Map

ID	Steps	Number of Errors Committed	Completed Task	Comments
p1	User moves to Funchal manually	0	Yes	
p2	User searches Funchal in the se- arch bar	0	Yes	
p3	User moves to Funchal manually	1	Yes	
p4	User searches Funchal in the se- arch bar	0	Yes	
p5	User searches Funchal in the se- arch bar	0	Yes	
p6	User searches Funchal in the se- arch bar	0	Yes	
p7	User searches Funchal in the se- arch bar	0	Yes	
p8	User moves to Funchal manually	0	Yes	
p9	User searches Funchal in the se- arch bar	0	Yes	
p10	User searches Funchal in the se- arch bar	0	Yes	

Tabela B.9: Results of Think-Aloud for Task 4 - Visualize a Portion of a Street Timeline or Video

ID	Errors	Number of Errors Committed	Completed Task	Comments
1	user views video outside the map	1	Yes	
2	user presses video play	1	Yes	thought the video play would open the map but it was misleading
3	user presses video play	1	Yes	frame change is slow
4	user presses video play	1	Yes	add an indicator for the current frame position in the videos
5		0	Yes	
6		0	Yes	
7		0	Yes	
8	user leaves the map feature	1	Yes	
9		0	Yes	
10	user opens the map feature instead of viewing the video on the map	1	Yes	easy to understand that the line is the route
p1		0	Yes	
p2		0	Yes	
p3	user leaves the map feature	1	Yes	
p4	user leaves the map feature	1	Yes	
p5		0	Yes	lines are not very intuitive as timelines
p6		0	Yes	
p7		0	Yes	
p8		0	Yes	
p9		0	Yes	
p10		0	Yes	

Tabela B.10: Results of Think-Aloud for Task 5 - Expand Map from the Current Timeline or Video

ID	Errors	Number of Errors Committed	Completed Task	Comments
1	user leaves video tab	1	Yes	pressing play button and opening video on the map are confusing; when opening in map it should focus on the current frame on the video play (with a marker for the current position)
2		0	Yes	
3		0	Yes	
4		0	Yes	
5		0	Yes	
6		0	Yes	
7		0	Yes	Initially thought about using gestures to expand the map
8		0	Yes	tried to enlarge the map with gestures. Took a while to realize the button was there.
9		0	Yes	
10		0	Yes	
p1		0	Yes	
p2		0	Yes	instead of having a button to expand the map, the map should expand by just clicking on it
p3		0	Yes	
p4		0	Yes	
p5		0	Yes	
p6	User pressed on the map a couple of times before pressing the expand button	1	Yes	
p7		0	Yes	
p8		0	Yes	
p9		0	Yes	
p10		0	Yes	

Tabela B.11: Results of Think-Aloud for Task 6 - Split Screen from Expanded Map (Part A)

ID	Errors	Number of Errors Committed	Completed Task	Comments
1	user expands the video	1	Yes	splitting screen is not intuitive
2	user expands the video	1	Yes	thought the split screen button would expand the video because when the video is expanded, pressing the button in the same position takes you to the expanded map screen
3	user leaves the map feature; user expands the video	2	No	add a caption/information to explain the function of the split screen button, and change button colors to increase visibility
4		0	Yes	change the icon for the split screen; it's not intuitive, and identical buttons for expanding the map from the video and for the split screen cause confusion
5	user leaves the map feature; user expands the video	2	No	split screen icon was not visible and its function was not intuitive
6		0	No	It would make more sense to slide for split screen or change the icon to something easier to understand; having it identical to the expand map button causes issues.
7		0	No	The button is not very visible, and because it's identical to the map button, it's not immediately obvious that it splits the screen.
8	user leaves the map feature	1	No	The button is not visible. Since it's identical to the map button, it's not clear that it does more than just expand.
9		0	Yes	It would make more sense to allow dragging to split the screen.
10		0	Yes	

Tabela B.12: Results of Think-Aloud for Task 6 - Split Screen from Expanded Map (Part B)

ID	Errors	Number of Errors Committed	Completed Task	Comments
p1		0	Yes	
p2	user leaves the map feature; user expands the timeline; user presses the area flag mode	3	No	Accessing the splitscreen state is not intuitive
p3	user presses the center on current location button; user expands the timeline	2	Yes	
p4	user leaves the map feature; user presses a street timeline; user expands the timeline	3	No	find another way or another icon for splitscreen because the current icon's position is misleading
p5		0	Yes	
p6		0	Yes	It would make more sense to be able to slide to splitscreen
p7		0	Yes	
p8		0	Yes	The icon looks like it will expand everything instead of splitting the screen
p9		0	Yes	
p10	user expands the timeline	1	Yes	Button is not intuitive

Tabela B.13: Results of Think-Aloud for Task 7 - Expanded Timeline or Video from Split Screen

ID	Errors	Number of Errors Committed	Completed Task	Comments
1	user leaves the map feature; user presses timeline from expanded map	2	Yes	
2		0	Yes	
3		0	Yes	
4		0	Yes	
5		0	Yes	
6		0	Yes	
7		0	Yes	
8		0	Yes	Similar gestures for different actions cause some confusion (e.g., clicking on the timeline expands the timeline, but clicking on the map does not expand the map).
9		0	Yes	A marker indicating where the user is on the map would be useful.
10		0	Yes	
p1		0	Yes	
p2		0	Yes	
p3	user expands map	1	Yes	
p4		0	Yes	
p5		0	Yes	
p6		0	Yes	
p7		0	Yes	
p8		0	Yes	
p9		0	Yes	
p10		0	Yes	

Tabela B.14: Results of Think-Aloud for Task 8 - Change Between Timelines

ID	Errors	Number of Errors Committed	Completed Task	Comments
p1		0	Yes	
p2	user changes the timeline through the map box; user presses the next/previous street image button	2	Yes	
p3	user leaves the map feature; user changes the timeline through the map box	2	Yes	The video date display does not appear complete on all phones
p4	User changes the timeline through the map box	1	Yes	
p5	User changes the timeline through the map box	1	Yes	Not very intuitive, the dates do not suggest that there might be a slight change in location
p6	User changes the timeline through the map box	1	Yes	It seems more logical to go to the map to change. Didn't notice the dropdown. If it had a title, it might be easier to catch attention
p7	User changes the timeline through the map box	1	Yes	Moving the dropdown position up might help to see it at first
p8		0	Yes	
p9		0	Yes	The dropdown where it is located seems busy and cluttered
p10	User changes the timeline through the map box	1	Yes	

Tabela B.15: Results of Think-Aloud for Task 9 - Mark Zone with "place of interest"Flag

ID	Errors	Number of Errors Committed	Completed Task	Comments
p1	user presses the return to expanded map button;	0	Yes	
p2	user presses a street timeline	2	Yes	Marking areas is not very intuitive but it is a matter of practice
p3		0	Yes	
p4	User presses the return to expanded map button	1		The method of marking areas is not very intuitive; there should be another way to mark areas without clicking the same button used to access the area flag mode. Marking areas should happen by pressing a location on the map
p5		0	Yes	It should not be necessary to press the button twice to mark areas; pressing the button once should simply mark the area
p6	User presses a street timeline	1	Yes	The same symbol for marking and entering area flag mode is not very intuitive
p7	User presses a street timeline	1	Yes	The button to enter area flag selection and marking makes it seem like the user didn't click. Buttons don't have a shadow to indicate that the button was clicked.
p8		0		
p9		0	Yes	The same button for split screen and expanding the map causes confusion about where to click. The icon looks like it's meant to report something, a pin or a similar icon would be better. The same icon twice causes confusion.
p10	User presses a street timeline	1	Yes	