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USABILITY AND ACCESSIBILITY CONSIDERATIONS AS AN APPROACH OF GEOPORTALS IMPROVEMENT

Master Thesis

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Zásady pro vypracování

The aim of this thesis is to examine how usability and accessibility concerns can support geoportals improvement, stressing the significance of user-centred design principles and accessibility standards. Two geoportals will be compared from the point of view of their usability using a suitable method, and their usability problems will be identified.

Outline:
– Foundation of geospatial information.
– Usability and its evaluation and testing methods.
– Proposal of usability evaluation procedure for usability evaluation of selected geoportals.
– Conduction of the usability evaluation, obtained results interpretation and improvement proposal.

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Coetzee, S., Plews, R., Brodeur, J., Hjelmager, J., Jones, A., Jetlund, K., Grillmayer, R., & Wasström, C. (2019). Standards—Making Geographic Information Discoverable, Accessible and Usable for Modern Cartography (pp. 325–344). https://doi.org/10.1007/978-3-319-72434-8_16.
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Piovan, S. E. (2020). Principles and Techniques of Cartography. In The Geohistorical Approach: Methods and Applications (pp. 39–88). Springer International Publishing. https://doi.org/10.1007/978-3-030-42439-8_3.

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V Pardubicích dne 1. září 2023

DECLARATION STATEMENT

I declare:

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ANNOTATION

The thesis focuses on the usability and accessibility considerations as an approach of geoportals improvement. The aim of this thesis is to examine how usability and accessibility concerns can support geoportals improvement, stressing the significance of user-centred design principles and accessibility standards. The study evaluated two web-GIS applications, Lithuania and Estonia, using heuristic assessment. The assessment involved experts examining the systems against predefined usability principles. The results showed significant differences between the two applications. Estonia had superior usability, with a more flexible scalebar feature, while Lithuania had a routing feature. Both applications had shortcomings in legend presentation, with Estonia having a broader range of layers and Lithuania's orthophoto layer offering up-to-date imagery.

KEYWORDS

Heuristic assessment, usability, accessibility, web-based gis, spatial data

ANOTACE

Práce se zaměřuje na úvahy o použitelnosti a přístupnosti jako přístupu ke zlepšování geoportálů. Cílem této práce je prozkoumat, jak mohou otázky použitelnosti a dostupnosti podpořit zlepšování geoportálů, s důrazem na význam principů návrhu zaměřeného na uživatele a standardů přístupnosti. Studie hodnotila dvě webové aplikace GIS, Litvu a Estonsko, pomocí heuristického hodnocení. Do hodnocení byli zapojeni odborníci, kteří zkoumali systémy podle předem definovaných zásad použitelnosti. Výsledky ukázaly významné rozdíly mezi oběma aplikacemi. Estonsko mělo vynikající použitelnost s flexibilnější funkcí měřítka, zatímco Litva měla funkci směrování. Obě aplikace měly nedostatky v prezentaci legendy, přičemž Estonsko mělo širší škálu vrstev a litevská ortofoto vrstva nabízí aktuální snímky.

KLÍČOVÁ SLOVA

Heuristické hodnocení, použitelnost, dostupnost, webový gis, prostorová data

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INTRODUCTION

Applications for Geographic Information Systems (GIS) on the web have grown in popularity because they are easily accessible and user-friendly. Through the use of web browsers, these user-friendly applications enable users to explore geographical data and do spatial analysis. Web-based GIS programs allow users to scale and pan the map to examine vast quantities of data, and they may show a variety of objects, including buildings, woods, roads, and traffic (Akram et al., 2023).

Web-based GIS applications are no different from other software products in that usability plays a critical role in their development. The effectiveness, efficiency, satisfaction, and learnability of usability measures are critical in assessing the usability of web-based GIS applications. Web-based GIS applications have been found to have usability issues through the use of usability assessment techniques such as user testing and heuristic evaluation (Abdulmonim, 2015)(Komárková et al., 2011).

An increasing number of people are interested in agent-oriented technology, which has led to the application of intelligent agents in GIS environments to improve user access to geospatial data and services that are made available through the Internet. This has affected the development of web-based GIS applications. Numerous sectors, including geography education, mapping flood inundation, and disaster management, have also made use of web-based GIS applications (Akram et al., 2023)(Obeidavi et al., 2019)(Komárková et al., 2011).

In conclusion, web-based GIS applications are essential tools for accessing and analyzing geospatial data. Their usability is crucial to ensure that users can effectively utilize these applications. Usability evaluation methods and usability metrics have been developed to identify and address usability issues in web-based GIS applications, ensuring that they remain user-friendly and accessible to a wide range of users.

Therefore, the aim of this thesis is to examine how usability and accessibility concerns can support geoportals improvement, stressing the significance of user-centred design principles and accessibility standards.

1. FOUNDATION OF GEOSPATIAL INFORMATION

1.1. Qualitative data

In the paper (Elwood & Cope, n.d.) qualitative data express differences in the kinds of information collected. Qualitative GIS incorporating non-cartographic spatial knowledge into conventional GIS. Qualitative GIS assumes that geographic phenomena, their relationships, and their meanings are produced and negotiated at many different moments in GIS development and application: in spatial data, in data structures, in spatial analysis techniques, in the meanings fostered or foreclosed in GIS-based maps and applications.

Qualitative data are not simply those data that are non-numerical. Rather, they argued that data may be qualitative in part by virtue of the rich contextual detail they provide about social and material situations. But it is not only the presence of rich contextual descriptive detail that constitutes data as qualitative. Rather, data may also be qualitative if they contain or provide interpretations of the situations or processes that they describe (Elwood & Cope, n.d.).

Qualitative GIS deal with spatially representable qualitative data analysed by means of qualitative data analysis. Originally, GIS have supported two main data models (vector and raster) for a simplified representation of the world. Unfortunately, these data models are often of only limited use for the analysis of qualitative data such as sketches, figures, and texts such as interview transcripts, diaries, or other textual documents. Qualitative GIS have extended the traditional GIS and confronts this problem using three main approaches that are transformations, hyperlinks, and software extensions (Jung & Elwood, 2010).

Transformations primarily consist of actions that enable the use of qualitative data in a geographic information system (GIS), such as the addition of coordinates to observations, such as photographs, texts, and sketches, or the classification of variables, such as interview transcripts or the reduction of nonnumeric variable values to a small number of categories. On the other hand, hyperlinks enable users to access unsupported GIS data formats (such text, video, or audio files) directly from inside a GIS by simply clicking on the relevant location, like the spot where a video was recorded or an interview took place (Jung & Elwood, 2010).

Software extensions might allow the usage of so-far unsupported data types. For example, pixels of the “imagined grid” display a photo from the raster cells' locations as opposed to the values of a continuous variable in the traditional raster data model. The space time cube is another qualitative GIS software extension. It displays people's trajectories in 3D with space as the x/y and time as the z-coordinates. Additionally, software extensions try to integrate qualitative data analysis and geoprocessing within a single environment (Martin & Schuurman, 2020).

1.2. Open data

Open data is information that is freely used, recycled, and shared by everyone with the exception of, at most, the need to give credit and share equally. To enumerate the key points,

- Access and Availability: Ideally, the data may be downloaded via the internet, and it must be available in its entirety for no more than a reasonable reproduction cost. Additionally, the data has to be accessible in a format that is both handy and editable (Ubaldi, n.d.).
- Reutilization and Redistribution: The information must be made available under conditions that allow for its repurposing and distributing, as well as combining it with other datasets (DIRECTIVE (EU) 2019/ 1024 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - of 20 June 2019 - on Open Data and the Re-Use of Public Sector Information, n.d.).
- Universal Participation: no one should be excluded from using, reusing, or redistributing something; everyone should be treated equally, regardless of their area of endeavour or other characteristics. For instance, "non-commercial" restrictions that would bar "commercial" usage are prohibited, as are limitations on use to certain domains (such as education only).

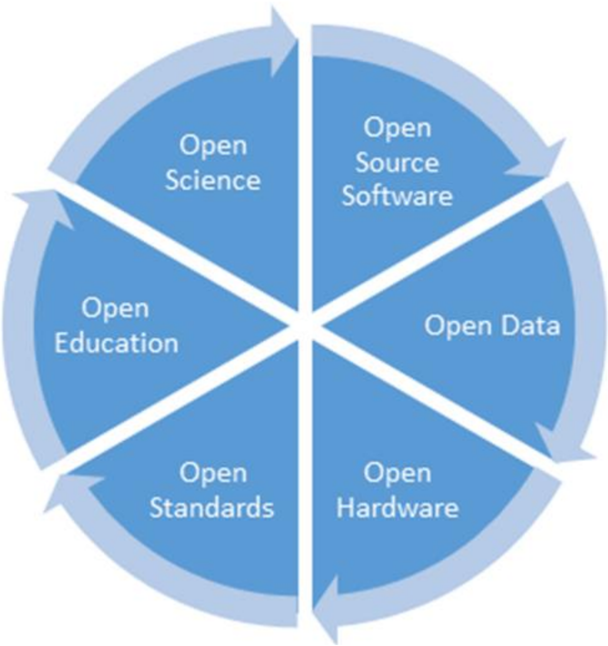


Figure 1: The components of openness

Source: (Coetzee et al., 2020)

Openness is a beneficial loop with several components. Each component benefits from the implementation and success of others, and the loop is not complete without one component (see Figure 1). There are three types of open geospatial data: authoritative data gathered and published by public administrations in the spirit of information freedom; data contributed by volunteers who band together into communities that gather and maintain geospatial data, like OpenStreetMap; and open scientific geospatial data where research findings are published to promote their reuse (Coetzee et al., 2020).

Geographic vector data that is usually gathered and kept up to date by governments for use in management and governance is included in the category of authoritative open geospatial data. Such authoritative data are increasingly being released under an open data license in keeping with the general practice of open public data, both to promote information freedom and for operational purposes. Additionally, satellite imagery is freely accessible under open licenses. Two such goods are the Landsat products, which are accessible through the USGS Earth Explorer (https://earthexplorer.usgs.gov/) and the Sentinel products, which are gathered through the European Union's Copernicus Earth Observation program and made available through the Copernicus Open Access Hub (https://scihub.copernicus.eu/).

The public sector has been referencing open data and its necessity more and more since the growth of the Web. The European Amended Public Sector Information (PSI) Reuse Directive, for instance, seeks to provide open, machine-readable formats and accompanying metadata for all appropriate public government data, therefore minimizing legal constraints on its reuse (Welle Donker & van Loenen, 2016). Transparent government is backed by the pledge to provide public data through open data portals. The European Data Portal serves as the entry point for public government data in accordance with the PSI Directive (https://data.europa.eu/en).

1.3. Spatial data and GIS

Spatial aspects of the Earth's surface are represented using raster and vector data formats (point, line, and polygon) (Kumar Dilipand Singh, 2019). The data is organised using layers, below (see Figure 2) which shows how the layers are represented.

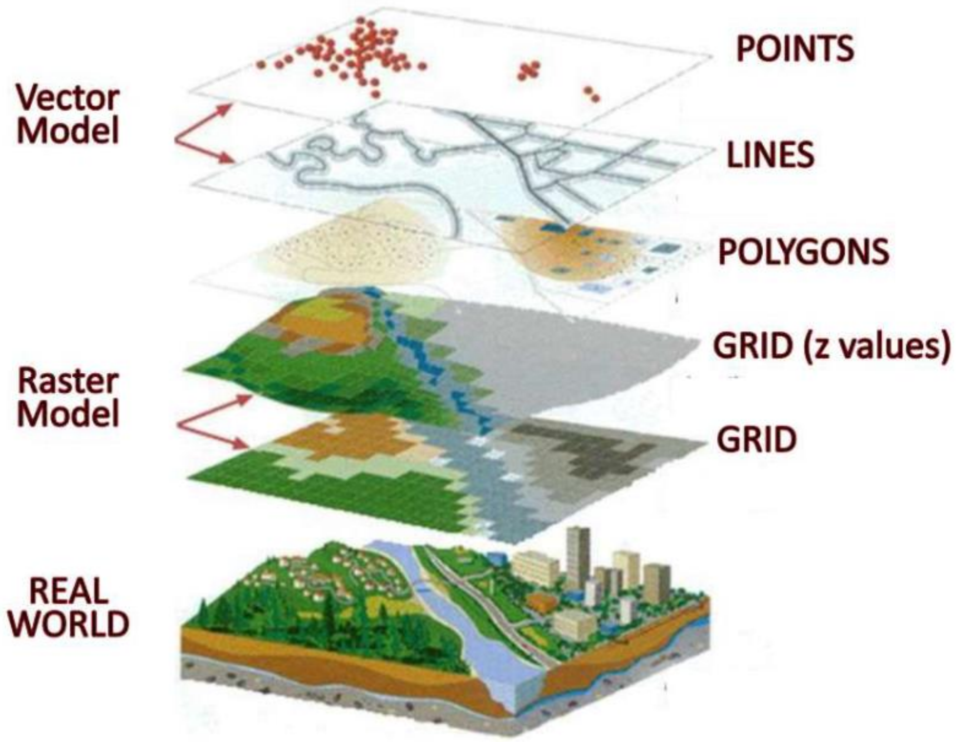


Figure **2***: Spatial data layers*

Source: (Characteristics of Geospatial Data Workshop 2: Technical Issues Towards Effective Applications of Geospatial Technologies and Data in DRM, n.d.)

Models of social processes, natural processes, and dynamic simulation models are examples of data models, which represent how the world is thought to function. The spatial resolution of a model determines its level of detail, which is highly significant. Key elements of models are their spatial and temporal resolution. When it comes to recording changes, the smallest distance is known as spatial resolution, and the shortest time is known as temporal resolution.

Spatial data is one of the main drivers of technological and economic development across many sectors of government, industry, and society. Spatial data is central to ongoing advancements in critical domains including health, finance, transportation, navigation, environmental management, and many others. Spatial data holds immense value for a range of stakeholders including government institutions, private companies, public groups, First Nations, non-profit organizations, and individuals.

Nevertheless, using and sharing spatial data comes with challenges of the quality of the data and providing confidence in its fitness for use (Basiri et al., 2019). For example, management and maintenance of physical road transport infrastructure typically require spatial data with much higher precision and positional accuracy than is required for, say, routing or navigation. Such issues present challenges even within an organization and are only magnified when attempting to share spatial data.

Another key barrier to sharing spatial data can be location privacy. Location privacy concerns a person's right to control the information about their location as personal and sensitive data. Considerations such as quality and privacy, as well as issues such as transparency, equity, inter-operability, can present impediments to sharing of spatial data (Durrant et al., 2021)(Stalla-Bourdillon et al., 2020).

Technology alone cannot overcome all the barriers to sharing, effective mechanisms for data governance also play a crucial role in managing, handling, and protecting spatial data to promote sharing. Such governance becomes even more critical in an era of artificial intelligence and machine learning, where big data algorithms may inadvertently present new risks by reinforcing biases, lacking transparency, and issues with accountability (Janssen et al., 2020).

The governing of spatial data has been and continues to be an ongoing challenge for governments and industries alike. This is due to the heterogeneous nature of spatial data production, resulting in differing types and quality of spatial data. Historically, National Mapping and Cadaster Agencies (NMCAs) have been one of the primary spatial data governance approaches globally. One of the main roles of an NMCA is collecting, managing, and sharing authoritative spatial data for greater socioeconomic benefits, including urban planning, construction, environmental management, and other public purposes

(Seifert Markus and Salzmann, 2022).

The spatial data governance model of an NMCA can be seen as a top-down approach, managed by spatial professionals, and driven by structural instruments with full control over spatial data (i.e., collection, quality assessment, protection, and distribution). More recent times have also witnessed the rapid expansion of corporate spatial data governance, such as by Google, Meta, Amazon, and 1spatial, with increasing commercial revenue the overriding priority. In governments and NMCAs, Spatial Data Infrastructures (SDIs) have been the common approach to facilitate data discovery, access, and use of multi-source spatial data (Crompvoets et al., 2018).

As the quantity and quality of spatial data have grown significantly, so discourse around spatial data and SDI governance has evolved in response. Another increasingly common variant of SDIs that emphasize the more technical aspects of spatial data sharing is digital infrastructures like Digital Earth (DE). A DE similarly functions as a platform or ecosystem for sharing, analyzing, and visualizing spatial data for improved insight and decision-making with a clear mandate to provide a public benefit (Nativi et al., 2021). However, in addition to large volumes of dynamic spatial data, DE platforms often combine repositories of big data with capabilities for machine learning, artificial intelligence, and spatial analysis.

Geographic information systems are, in one understanding, digital technologies for storing, managing, analyzing, and representing geographic information. Typically, such a system consists of data models; structures for representing geographic entities and their characteristics in digital form; data structures for storing these data; the data themselves (together with the ontologies, categorization schemes, and other elements that are part of these representations); software for query, retrieval, analysis, and mapping; and the hardware used to support these functions.

1.4. Location and coordinate systems

Coordinate systems are essential for creating spatial data, including points, lines, polygons, rasters, and annotations. They can be specified in various units like decimal degrees, feet, meters, or kilometers. Data is defined in both horizontal and vertical dimensions, with horizontal coordinate systems based on a three-dimensional ellipsoidal or spherical surface and locations defined using angular measurements. Vertical coordinate systems provide a reference for z-coordinates, which measure the height or depth of features. Georeferencing is the process of assigning locations, and they should be constant over time for their usefulness. The geographic system of coordinates based on the earth's rotation about its center of mass is the most comprehensive system for georeferencing, providing fine spatial resolution and allowing for distance computation. Longitude and latitude define location on the earth's surface, and the coordinates are transformed into cartesian coordinates using the Mercator projection, maintaining the correct distance between points and the equator. Universal Transverse Mercator (UTM) coordinates are in meters for accurate calculations (Longley et al., 2010).

Although the distortions of the UTM system are small they are nevertheless too great for some purposes, particularly in accurate surveying. Many countries adopt their own coordinate systems in order to support high-accuracy applications. Transforming between coordinate systems and projections is a very effective use case for GIS. More difficult conversions, however, arise when converting place names to geographic coordinates. The reason GPS (https://www.gps.gov) technology is so appealing is that it enables users to instantly obtain their accurate UTM coordinates or latitude and longitude with a single button press (Longley et al., 2010).

The Global Navigation Satellite System (GNSS) provides the positioning and navigation services for end users through the radio-navigation signals sent by the navigational satellites from space. There are four main global GNSS systems, namely Global Positioning System (GPS) in the United States, GLONASS in Russia, BeiDou Navigation Satellite System (BDS) in China, and Galileo in the European Union (Lu, 2021) . World Geodetic System (WGS) 84, Parametry Zemli 1990 (PZ-90), Galileo Terrestrial Reference Frame (GTRF), and China Geodetic Coordinate System (CGCS) 2000 are reference frames of GPS, GLONASS, Galileo, and BeiDou, respectively. Each system has its unique time scale, as well (Kazmierski et al., 2018)

1.5. Spatial data infrastructure standards

In the paper (Coetzee et al., 2019),an SDI comprises individuals, organizations, and systems that collect, process, disseminate, or act on geographic information, and includes the information itself. Below (see Figure 3) is an example of a fundamental notion supporting an SDI:

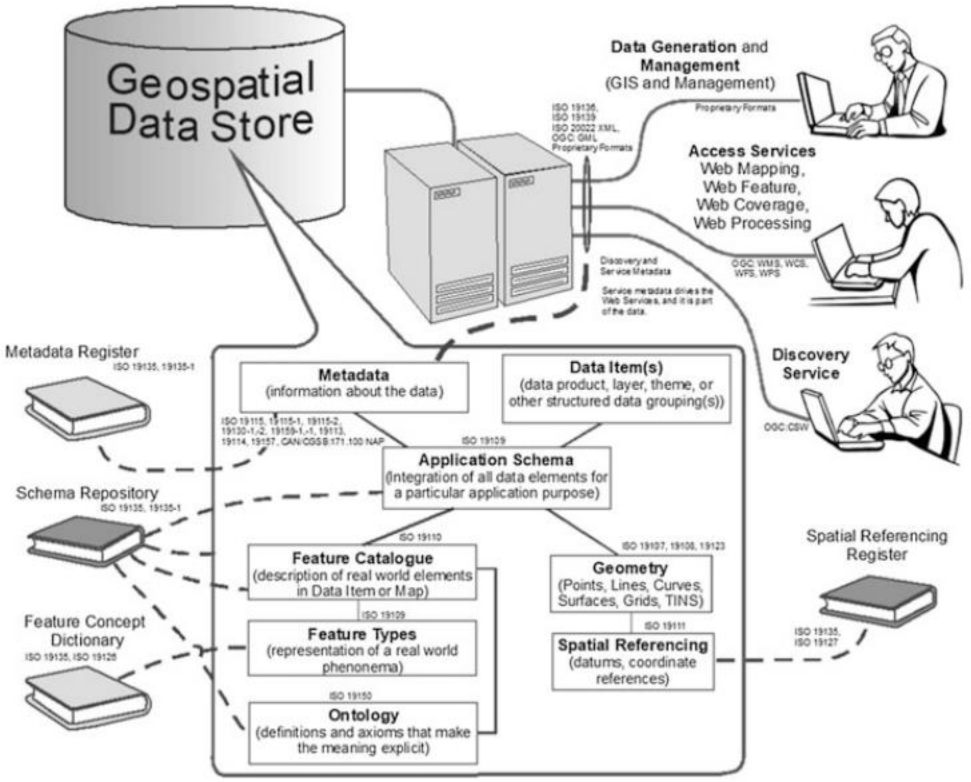


Figure 3: Spatial data infrastructure environment.

Source: (Coetzee et al., 2019)

In spatial data infrastructure (SDI) standards are the foundation and building blocks for harmonization and interoperability of geographic information. Through the implementation of standards, an SDI provides the fundamental facilities, services and systems that make geographic information available, accessible, and usable.

ISO/TC 211, Geographic information/Geomatics, is the technical committee of the International Organization for Standardization (ISO) and is responsible for the standardization of geographic information. Established in 1994, its work aims at establishing a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. ISO/TC 211 covers semantic, syntactic, and service issues, as well as procedural standards, at various levels of abstraction.

The Open Geospatial Consortium (OGC) is a voluntary consensus standards organization, also established in 1994. The focus of OGC work is to define, document, and test implementation specifications for use with geospatial content and services. OGC specifications leverage the abstract standards defined by ISO/TC 211. OGC and ISO/TC 211 have a long history of collaboration and development of joint standards.

Collaboration with other standards developing organizations ensures that geographic information and services are aligned with state-of-the-art technologies in the era of modern cartography. For example, the Internet Engineering Task Force (IETF) develops and promotes standards for the Internet, which are widely used. Some of these, e.g. IETF RFC 3986, Uniform Resource Identifier (URI): Generic Syntax, are referenced in standards for geographic information. Similarly, standards by the World Wide Web Consortium (W3C) are referenced, such as editions of the W3C Recommendation, Extensible Markup Language (XML).

Web services, web-based GIS

Nowadays, printed maps have mostly been replaced by digital maps or digital data, which are both accessible online and downloadable via services on the Internet. Relevant web service standards include the Catalogue Service for the Web (CSW) for data discovery by the way of metadata; Web Map Service (WMS) for delivering image maps via the Internet; Web Feature Service (WFS) for delivering (vector based) geographic feature data via the Internet; Web Coverage Services (WCS) for delivering images and other kinds of coverage data via the Internet; and Web Processing Service (WPS) for processing geospatial data, e.g. converting data from one encoding format to another, or transforming it from one projection to another (Coetzee et al., 2019).

The availability of spatial information online has grown exponentially and has led to the rapid transition of GIS technologies from stand-alone GIS systems for the GIS expert to networked systems supported by distributed client-server applications. These distributed applications, also known as web mapping applications or web GIS in the Cloud, are defined by Esri, the leading commercial provider of GIS technologies, as any GIS interface which makes use of web technology to communicate between a client and server and is available as a web browser, desktop application or mobile application.

These distributed web mapping applications allow users to access, interact and visualise spatial information dynamically from a range of often heterogeneous data sources and communicate effectively with other users based on this information. Web GIS allows for the retrieval of spatial information over the web and user interaction with this information in the form of data browsing, manipulation or spatial analysis depending on the interface.

To develop and implement these Web GIS applications, as well as to send and receive the data which supports these applications, both the consumer web mapping applications and those geared towards professionals in the field make use of web technologies. Primarily, Web GIS clients and servers generally communicate through the HTTP protocol, where the simplest form a Web GIS can be in is one server and one or more clients. In general, however, Web GIS architectures are designed in a three-tier system, which includes a data tier and can be completely distributed across the internet and interact with each other using web services (Rowland et al., 2020).

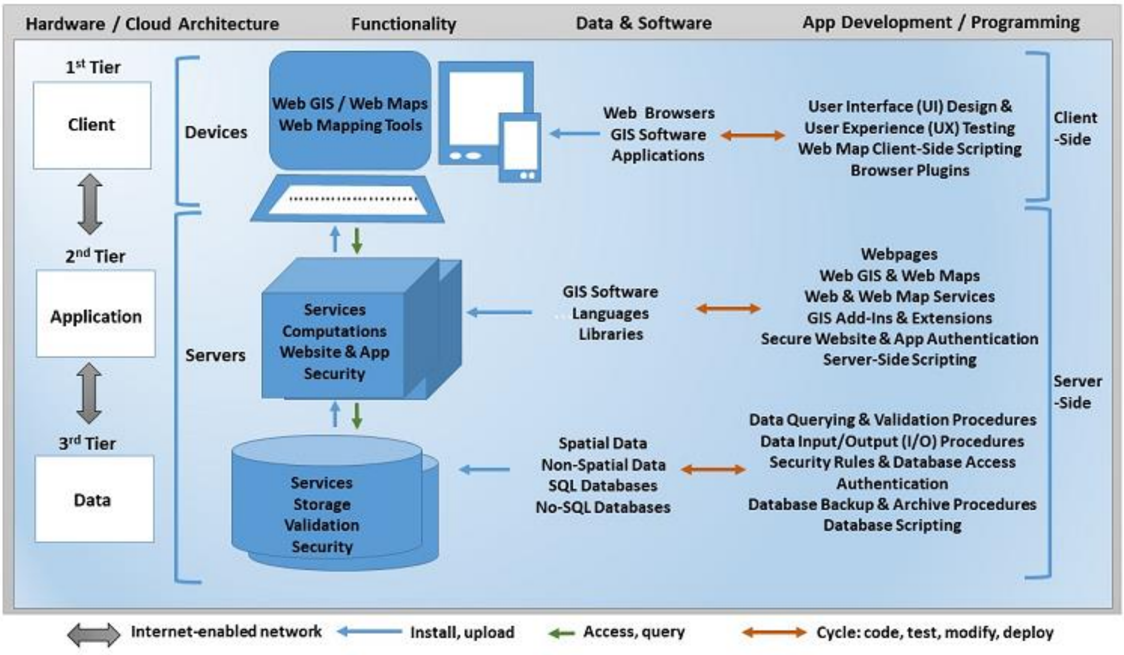


Figure 4: Web GIS Architecture

Source: (Swift & Goldberg, 2019)

1.6. Cartography

Cartography is the science and art of map making, it involves the creation and interpretation of maps to represent spatial information. Various elements are essential to the design and effectiveness of maps. Below are some key cartography elements (Lapaine, 2019):

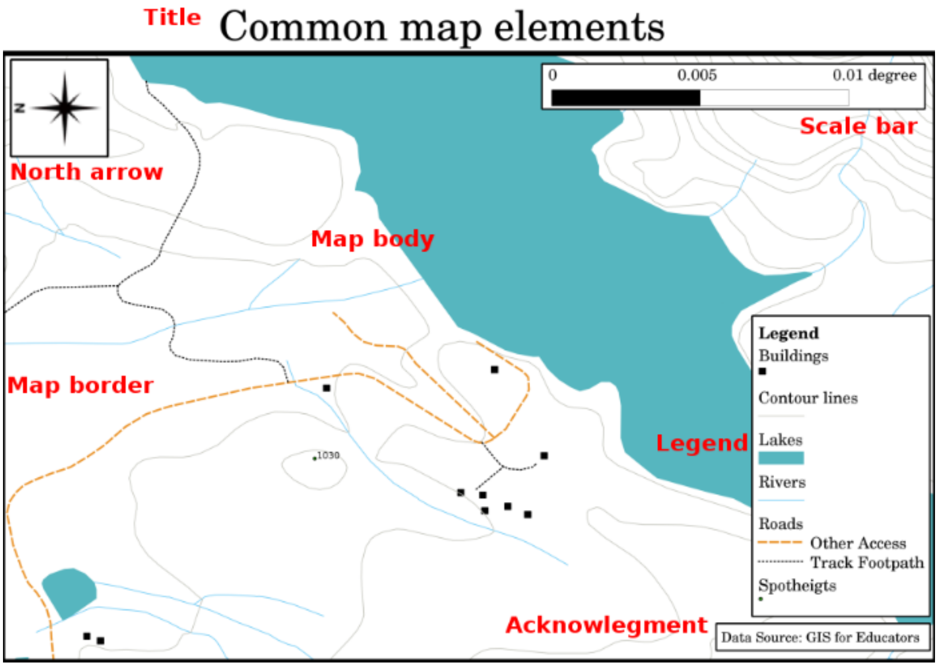


Figure 5: Common map elements

Source: (QGIS Documentation, 2024)

- Map field (map itself)
- Title: provides a clear and concise description of the map's purpose.
- Legend: explains the symbols, colours, and other map elements used to represent features.
- Scale and scale bar: The map scale indicates the distance between the map and the earth's surface, while the scale bar provides a graphical representation, aiding in accurate distance estimation.
- Source, date, author (so called imprint): indicates the data sources used for creating the map and the date the data was collected or map created.
- North arrow: shows the direction of north and aiding map orientation.
- Symbols and icons: represent various features like roads, rivers using standardized symbols.

In cartography symbolization is the coding of features to communicate meaning. To accomplish the communication purpose of a map, the symbolization should be clear, concise, and easily understood by the user, even if the map can take on a range of functions(Piovan, 2020) .

The cartography process comprises several critical phases and is a complex technique as shown in (**Error! Reference source not found.**. The cycle is never-ending and begins with a setting rich in geographical data. Advanced technologies are used to collect data, and then pattern recognition based on knowledge and map purpose is used. After that, cartographers compile this data, choosing a depiction based on factors like scale and topic. Before being created for its audience, data is altered via symbolization and may be generalized for clarity throughout the encoding process. After that, map users analyze and decode the symbols to glean information. Travel and urban development decisions are influenced by these maps. They also influence how we behave in space and how we perceive our surroundings. The fundamental idea is map abstraction, which skilfully reduces complicated reality (Habib & Okayli, 2023).

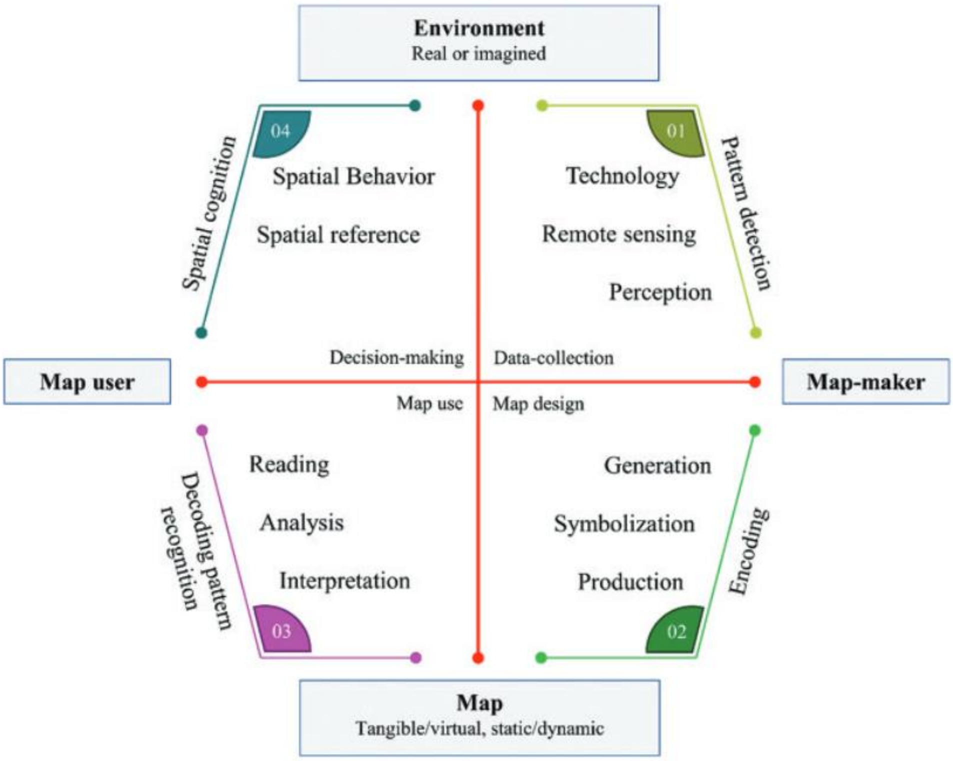


Figure 6: Cartography process.

Source: (Habib & Okayli, 2023)

2. USABILITY

The simplicity with which a user can learn to operate, set up inputs for, and interpret outputs from a system or component is known as its usability. A key component of good software is its usability. Functionality, dependability, usability, efficiency, maintainability, and portability are the six major areas of software quality that the software quality model discusses. According to ISO/IEC 9126, usability is a collection of characteristics that affect the amount of work required to use and the subjective evaluation of that usage by a group of users, either explicitly expressed or inferred (Sagar & Saha, 2017).

Usability bridges the gap between people and machines. During the past few decades several standards and models which consist of different usability attributes for assessing usability have been proposed which include:

- McCall's model (1976)
- Boehm's model (1978)
- Boehm's model (1978)
- Shackel's model (1991)
- Nielsen's model (1993)
- ISO 9241 part 11 (1998)
- ISO 9126-1 (2001)
- The QUIM model (2006)

An essential task to guarantee a high standard of user experience is usability evaluation. Transactional online applications may be evaluated using a variety of Usability Assessment Methodologies (UEMs); the challenge is determining which UEM will yield the most information. Research indicates that the following methods are frequently used in usability assessments: usability testing, heuristic assessments, questionnaires, and automated usability methods (Sagar & Saha, 2017) (Aboulomania, n.d.).

Usability method	Limitations	Requirements	Equipment	Output	Qualitative/ Quantitative
Heuristic evaluation	Limited to expert evaluators. May miss user specific issues.	Usability experts. 1-3 people required.	Computer and expertise in GIS and usability. List of heuristics.	List of usability issues.	Qualitative
User testing	Time consuming and expensive. Small sample sizes may not show user diversity.	5-15 participants, facilitator, and observation room.	Computer, task scenarios and usability lab.	User performance data, task completion time.	Quantitative/ Qualitative
Questionnaires / Surveys/ Interview	Limited to self-reported information. May not capture in-depth user related problems	Survey, questionnaire and more than 50 participants are required.	Computer and distribution method (online/mail)	User satisfaction scores.	Quantitative/ Qualitative

Table 1: Comparison of usability methods

Processing: own, based on the resources: (Abulfaraj Anas and Steele, 2020)

Web applications accessibility

Web technologies are growing as a result of the rapid advancement of digital advances. Ensuring website usability and navigability for all users, including those with impairments, is contingent upon online accessibility (Dror et al., 2021). To encourage accessibility in online design, a number of standards and principles have been created. Web accessibility refers to the process of designing and developing tools, websites, and technologies such that users may use them unsupervised or with little to no assistance. People can perceive, comprehend, navigate, and engage with the web, to be more precise(Hortizuela, 2022).

3. METHODS AND PROCEDURE

The previous chapters provided an in-depth analysis of the current state of the art on the usability and accessibility theories required in the designing of web-based GIS applications, emphasizing significant theories and discoveries that have influenced the comprehension of web applications. Building upon this foundation, the methodology and procedures chapter will now outline the framework through which aim to address the research questions posed in this study and the framework is depicted below (see Figure 7).

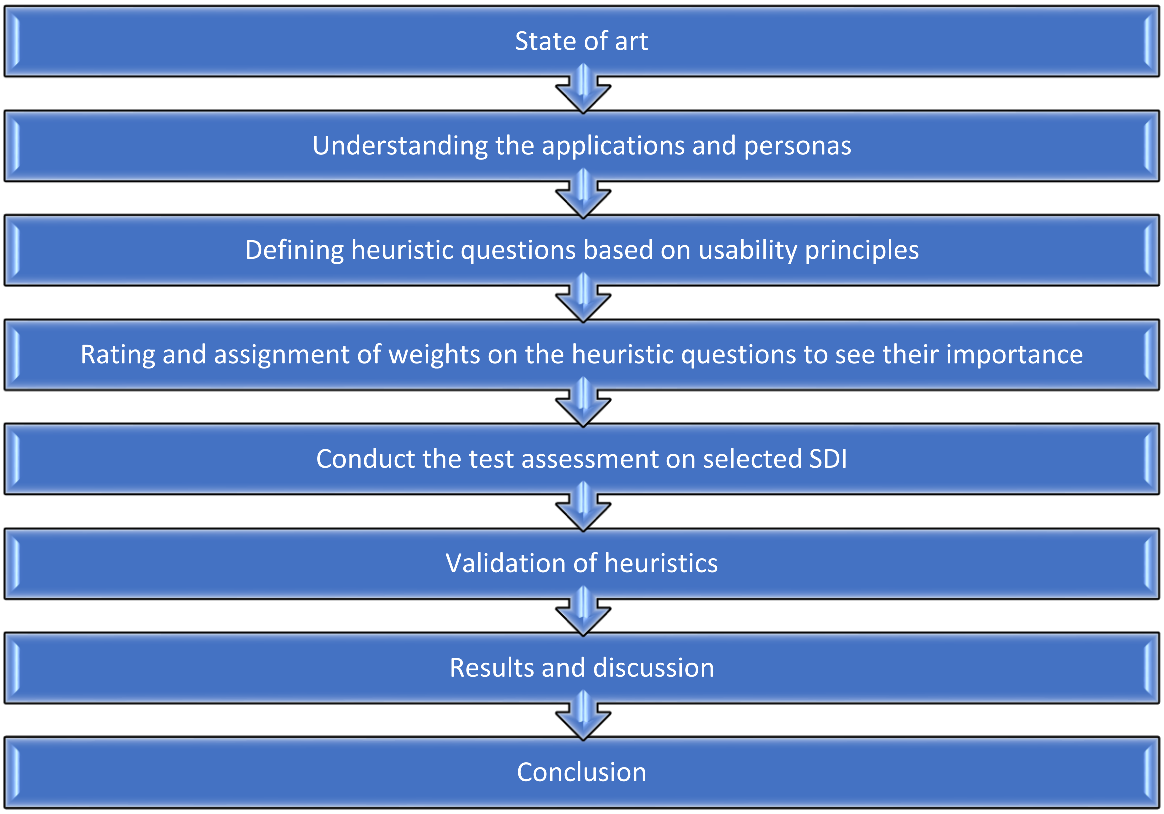


Figure 7: Research Methodology

Source: Author's own creation

3.1. Understanding the applications and personas

Geoportal applications

Geoportals are web-based solutions that enable open spatial data sharing and online geo-information management. They provide a consolidated platform for accessing Earth observation data and geo-information, offering functionalities like maps, data discovery, and online analysis. Driven by scientific projects, international organizations, governmental agencies, and commercial interests, geoportals address challenges related to big Earth data by providing access to diverse datasets (Jiang et al., 2020).

The applications to be evaluated are as follows:

- Estonia geoportal https://xgis.maaamet.ee/xgis2/page/app/maainfo
- Lithuania geoportal https://www.geoportal.lt/map/?lang=en

The purpose of choosing these applications in my research is that I can access a wealth of information that is freely available to the public, can help in enhancing innovation, and promotes progress in academia and beyond.

There are various strategic benefits to selecting Estonia as one of my geoportals for heuristic assessment. Within the European Union, Estonia is recognized as a leader in technology and an innovator due to its progressive views on digital infrastructure and governance. English is a language that is widely spoken, which makes it easier for people to collaborate and communicate easily while doing assessments, the availability of English language is also another benefit of choosing Estonia. Learning from Estonian geoportals' best practices can also help you develop your own geoportal by providing guidance and improvement. All things considered, utilizing Estonia's knowledge and assets can greatly improve the quality and efficiency of other geoportal services (Arta et al., 2023)(Lilkov, 2023).

According to Rogers' diffusion theory, Lithuania's relationship with Estonia makes it essential to include it in the geoportals for my heuristic evaluation. This theory emphasizes how innovations spread through social systems over time, using Estonia's technological achievements as an example. Diffusion dynamics, usability, user experience, and implementation strategies can all be better understood by contrasting the geoportals of Lithuania and Estonia. Diffusion is largely due to Lithuania's quick innovation and development of digital infrastructure, especially in e-government services. Significant investment in research and development is indicated by the medium R&D intensity in the knowledge-intensive business services sector. I also selected the Lithuanian geoportal because of its English language accessibility, which is comparable to that of its Estonian equivalent. Furthermore, the increasing use of e-governance in Lithuania, especially in small states with youthful populations, suggests a social structure that is conducive to the adoption of innovations (Ziemba & Becker, 2019)(Stephany, 2020).

Personas

A persona in user experience design is a fictional character that represents certain traits and qualities of real users. It is a crucial tool for understanding and empathizing with the target audience. Personas are typically documented visually, including text, icons, graphics, and sometimes a face, based on facts and data about real users obtained through research methods like user interviews and behavioural data analysis. They help designers make user-focused decisions, shape product direction, and communicate user understanding effectively. Personas include details like the persona's name, image, experience level in the product area, goals, concerns, a quote reflecting their attitude, and context for how they would interact with the product. Ultimately, personas serve to capture user research visually, build empathy, prioritize user needs in design processes, and facilitate communication of user research findings with others (Huynh et al., 2021)(Louise Bruton, 2022; Rikke Friis Dam and Teo Yu Siang, 2022).

The author considered various user demographics and contexts. Firstly, focusing on user expertise entails assessing both end users, who might have limited or no experience in GIS, and expert users. Understanding how these different groups interact with the interface can help tailor the application to cater to varying levels of familiarity with GIS tools. Geographical location is another pivotal aspect, as users from different regions may have unique needs and expectations.

By testing the application across diverse locations, developers can ensure it remains effective and accessible across different environments. Age groups also play a significant role, with variations in literacy and preferences among young adults and older users. Lastly, considering the range of devices users might utilize, from smartphones to desktop computers, is essential for ensuring compatibility and seamless usability across different equipment. By addressing these factors comprehensively, developers can enhance the overall usability and accessibility of web-GIS applications.

The aim of the evaluation is to develop a set of heuristics based on Nielsen's principles, accessibility principles and use the set of heuristics to find usability and accessibility problems in the applications.

3.2. Defining heuristic questions based on usability principles

To create heuristics from usability research, no systematic methodology has been put out. I was inspired to create my usability guidelines by a strategy employed by Nielsen. Based on predetermined heuristics or usability principles, measuring heuristics entails evaluating the effectiveness, efficiency, and satisfaction of a user's engagement with a system. Table 2 shows the set of heuristics which l developed using Nielsen’s usability principles and some accessibility principles.

Heuristic questions based on principles	**Rating**
Visibility of system status	
Are the symbols used on the map easily recognizable?	3
Are the labels used on the map representative of real-world geographic features?	3
Do the styles used for different types of features (e.g., water bodies, roads, buildings) match users' real-world expectations?	3
Do the colors used for different types of features on the map match users' real-world expectations?	3
Match between system and the real world	
Can you easily recognize the meaning of map labels without having to rely on memory?	3
Can you easily interpret the meaning of map symbols without having to rely on memory?	3
Are there clear legends available to help you understand the meaning of different map features?	3
User control and freedom	
Is it clear what geographic area you are currently viewing on the map?	3
Can you easily identify which layers are currently visible?	3
Can you easily identify which layers are currently active?	3
Consistency and standards	
Is it simple to pan the map?	3
Is it simple to zoom on the map?	3
Is it possible to easily change the layers that are displayed?	2
Can users click the scalebar to perform actions, such as changing the map scale?	3
Error prevention	
Are map interactions consistent throughout the application?	2
Are labelling styles consistent throughout the application?	2
Is the symbology consistent throughout the application?	3
Recognition rather than recall	
Does the interface provide clear feedback if you attempt an invalid action?	3
Flexibility and efficiency of use	
Is the interface easy to use for users with varying levels of GIS expertise?	3
Aesthetic and minimalist design	

Heuristic questions based on principles	Rating
Does the map interface have an eye-catching design?	2
Is the map interface clutter-free?	2
Help users recognize, diagnose, and recover from errors	
Are there clear error messages available to help users understand mistakes?	3
Are there prompts available to help users correct mistakes?	2
Does the interface provide guidance on how to recover from errors without losing progress?	3
Help and documentation	
Are user-friendly help documents available for the application?	3
Does the application have contextual assistance features?	3
Does the application have tooltips?	3
Feedback and response	
Is the response time for loading map tiles sufficiently fast and without noticeable delays?	3
Are queries executed promptly without any noticeable delays?	3
Responsiveness and operability	
Can users navigate the interface using only a keyboard?	3
Can users interact with the interface using only a keyboard, without relying on a mouse?	3
Does the interface reflect user feedback?	2
Does the website function smoothly on mobile devices?	3
Is the website designed with responsive design?	3
Is the website optimized for touchscreen interactions?	2

Notice: 1 represents less importance, 2 represents moderate importance,3 represents high importance

Table 2: Heuristic questions

Processing: Author's own processing

3.3. Rating and assignment of weights on the heuristic questions to see their importance

Since the author's study is mostly qualitative and mainly dependent on expert opinion, the heuristic questions were rated using Fuller's technique. Without the requirement for in-depth quantitative analysis, it enables professionals to judge the significance of heuristic questions based on their domain expertise and qualitative comprehension of the issue.

Making decisions is an essential process that includes determining options, obtaining data, weighing options, and deciding on the best course of action. Depending on how complicated the choice is and how much cooperation is needed, several decision-making methods can be used.

By utilizing the weighted scoring method, I was able to score the heuristic questions in an efficient manner, which allowed for a methodical and organized approach to decision-making. Three signifies high level of importance whereas two signifies moderate level of importance and one signifies low level of importance of the heuristic questions (see Table 2).

3.4. Conducting the test assessment on selected SDI

Choice of participants

In keeping with the research's aim, preference is given to participants for the heuristic evaluation who have a solid foundation in cartography and Geographic Information Systems (GIS). The individuals who were selected have a deep knowledge of the fundamentals of spatial data processing and visualization and have a remarkable degree of GIS education and experience. These participants, who are specifically drawn from the Faculty of Economics and Administration, where GIS is a very important subject, offer a special synthesis of scholarly understanding and real-world experience.

Furthermore, because they are IT students in an English language program, they have a diverse skill set that combines linguistic competency with technical acumen, which is crucial for efficient evaluation and reporting of results. Three individuals were chosen for the assessment, all with this specific educational background. This targeted cohort provides a comprehensive grasp of the complexities of GIS and allows for meaningful criticisms and ideas for interface design and usability enhancements. Table 3 shows a list of the characteristics of the participants which were chosen for the research.

Participant	Gender	Age	Level of Education	Country
1	Female	29	Master	Myanmar
2	Male	27	Master	Syria
3	Female	28	Master	Ghana

Table 3: Participants characteristics

Processing: Author's own processing

Briefing the participants

It was my responsibility as the author to make sure the participants understood why the study was being done. Participants received thorough briefings that gave them the information they needed to participate actively in the study and make a valuable contribution. Participants gained the ability to understand the importance of their participation and the wider influence of the study by being given clear communication about the goals, methods, and possible outcomes. In order to create a successful research that produces insightful discoveries and advances in knowledge, transparent communication is essential to building trust and fostering teamwork.

Tools and equipment

To assure the accuracy and dependability of my results, a range of instruments and equipment will be used throughout the test for my research. To evaluate the applications' cross-platform interoperability, this will involve devices running a variety of operating systems, including Windows, iOS, and Android. Additionally, the usefulness and performance of the research on various browsers will be evaluated using a variety of online browsers, including Microsoft Edge, Mozilla Firefox, Safari, and Google Chrome (see Table 4). In addition, several assistive technologies were tested to guarantee accessibility for all users, with a particular focus on people with visual impairments. By employing a diverse range of tools and equipment, the aim is to comprehensively evaluate the effectiveness of my research and create a user-friendly experience for all individuals.

Device	Operating System	Browser version
Asus VivoBook S14, Processor: 11th Gen Intel(R) Core (TM) i5-1135G7 @ 2.40GHz 2.42 GHz, RAM: 8GB	Windows 11 Home	Google Chrome Version 123.0.6312.106 (Official Build) (64-bit) Microsoft edge Version 123.0.2420.81 (Official build) (64-bit)
Galaxy S20 Ultra 5G	Android Version 13	Chrome Version 123.0.6312.99
iPhone 11	iOS Version 17.3.1	Safari

Table 4: Detailed list of used tools and equipment

Processing: Author's own processing

Carrying out the experiment

In this experiment, participants will engage in a structured task aimed at evaluating the usability and accessibility of various applications across different platforms. Each participant will receive a checklist of questions which can be found in Appendix C designed to guide their interaction with the applications, with assistance from the author. Depending on their device, participants will use either a Windows operating system with browsers such as Chrome, Microsoft Edge, or Firefox on laptops, iOS with Safari browser on iPhones, or Android on Samsung phones. Upon completing the task, participants will fill out a questionnaire focusing on their experience with the applications, assessing aspects of usability and accessibility. This experimental setup allows for a comprehensive evaluation of user experience across multiple platforms, providing valuable insights for application development and optimization.

To give an organized framework for evaluating the chosen applications, usability principles are frequently divided into many areas for heuristic assessment tests. By carefully examining different elements of usability, these categories assist assessors in identifying possible problems and prioritizing changes. Based on their practical applicability and thematic similarity, I categorized the usability principles into several groups for the heuristic evaluation exam. By providing a defined framework for evaluating usability difficulties, these categories hope to expedite the assessment process (see Figure 8).

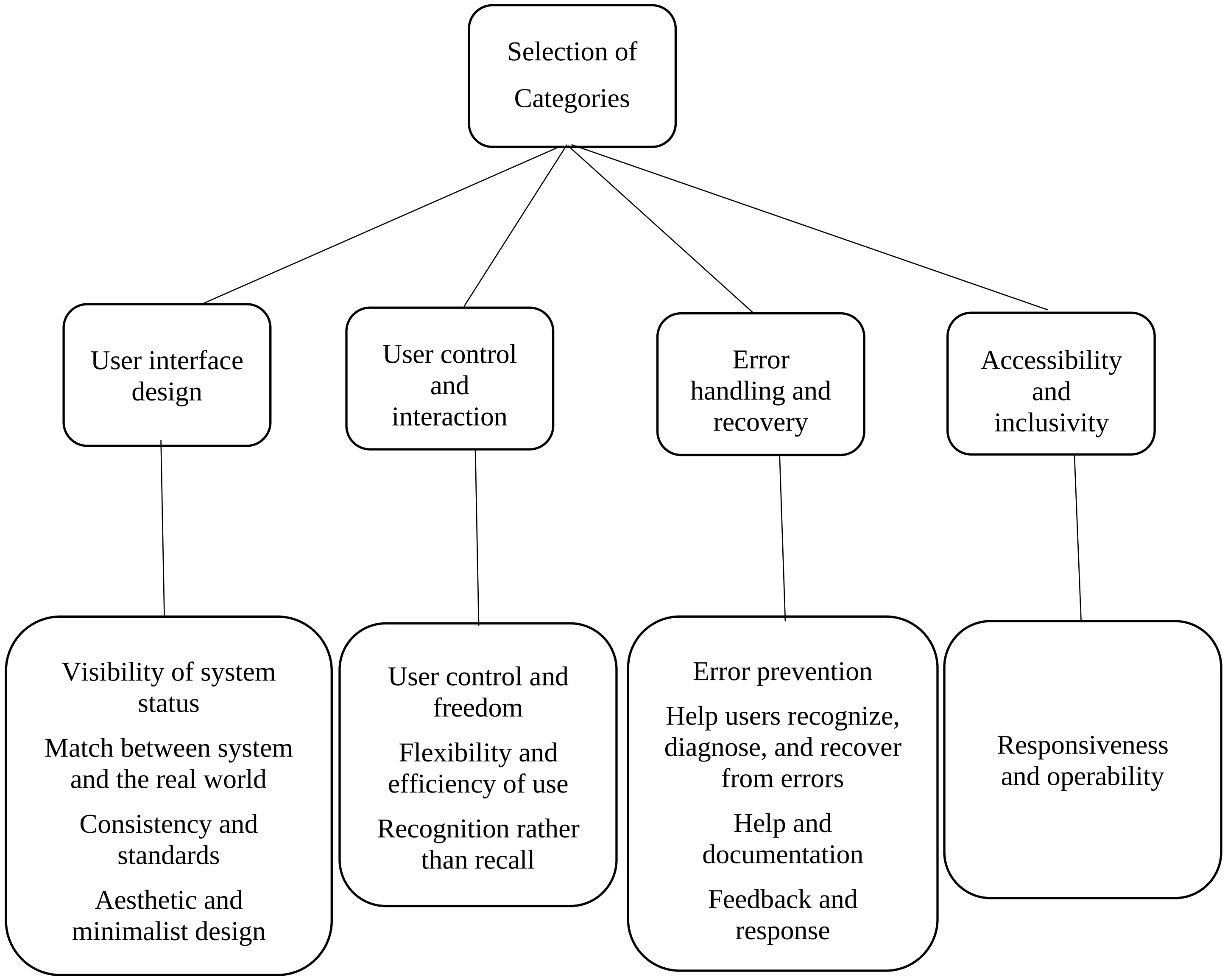


Figure 8: Categories of the heuristic principles

Processing: Author's own processing

3.5. Validation of heuristics

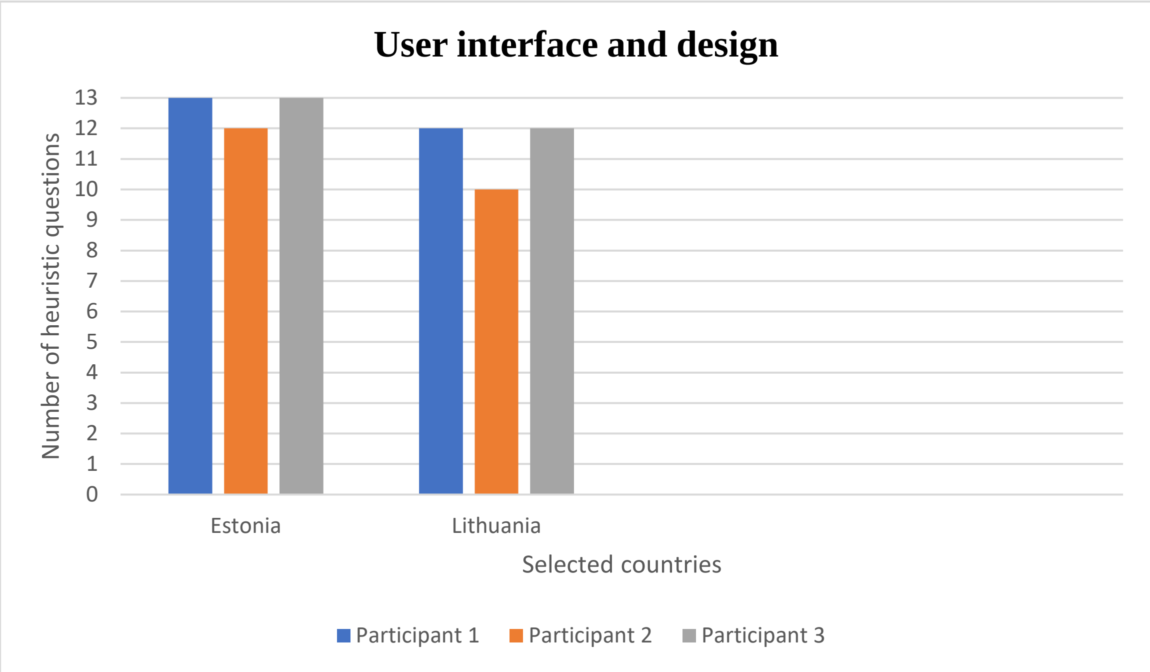
Ensuring the accuracy and dependability of my findings requires the validation of heuristic assessment results for the geoportals of Lithuania and Estonia. In addition to offering useful insights into the usability and user experience of these digital platforms, this procedure is crucial for validating the efficiency of the heuristic evaluation criteria. Error handling and recovery, user interaction and control, accessibility and inclusivity, and user interface design were the four main areas of focus for me in this validation project. These criteria play a crucial role in evaluating the geoportals' overall usability, functionality, and inclusivity as well as providing insightful information about their advantages and shortcomings.

To inform my strategy, I carried out a pilot study for the geoportals' heuristic evaluation. Initially, the pilot research sought to confirm that the selected heuristic assessment criteria was a good fit for evaluating the geoportals' usability and user experience. After evaluating the feedback and responses section, it became clear that there was a mismatch between the intended interpretation of the questions and the meaning expressed by the answers. In particular, when asked *"Is there a noticeable delay in response time for loading map tiles?"* and *"Is there a noticeable delay in response time for executing queries?"*, a "Yes" response was meant to suggest that there was no difficulty, but a "No" response indicated that there was. However, this caused uncertainty, as delays are undesired in the tested applications. As a result, l reevaluated the question format (see *Table 2*) and response possibilities to guarantee future evaluations are clear and consistent.

The pilot research also offered the chance to evaluate the viability of the assessment approach, which included methods for gathering data and conducting analyses. The objective of the pilot project was to provide a solid framework for the heuristic evaluation that can be systematically used to the geoportals of Estonia and Lithuania, eventually producing insightful findings and doable suggestions for enhancing their usefulness and user experience.

Three participants were asked to carefully review an extensive checklist with 35 questions divided into various categories. Thirteen insightful questions were used to examine several aspects of user interface design, which are crucial in determining the user experience. A targeted set of five questions was utilized to evaluate user interaction and control, which are essential for smooth navigation. Eleven queries were used to thoroughly examine error handling and recovery procedures, which are essential for system resilience. In conclusion, accessibility was assessed using six distinct checkpoints to guarantee inclusiveness and usability for all users. This methodical technique made it possible to analyze the system in detail and gave insightful information about many aspects of the applications under examination.

4. RESULTS, PROPOSALS AND DISCUSSION

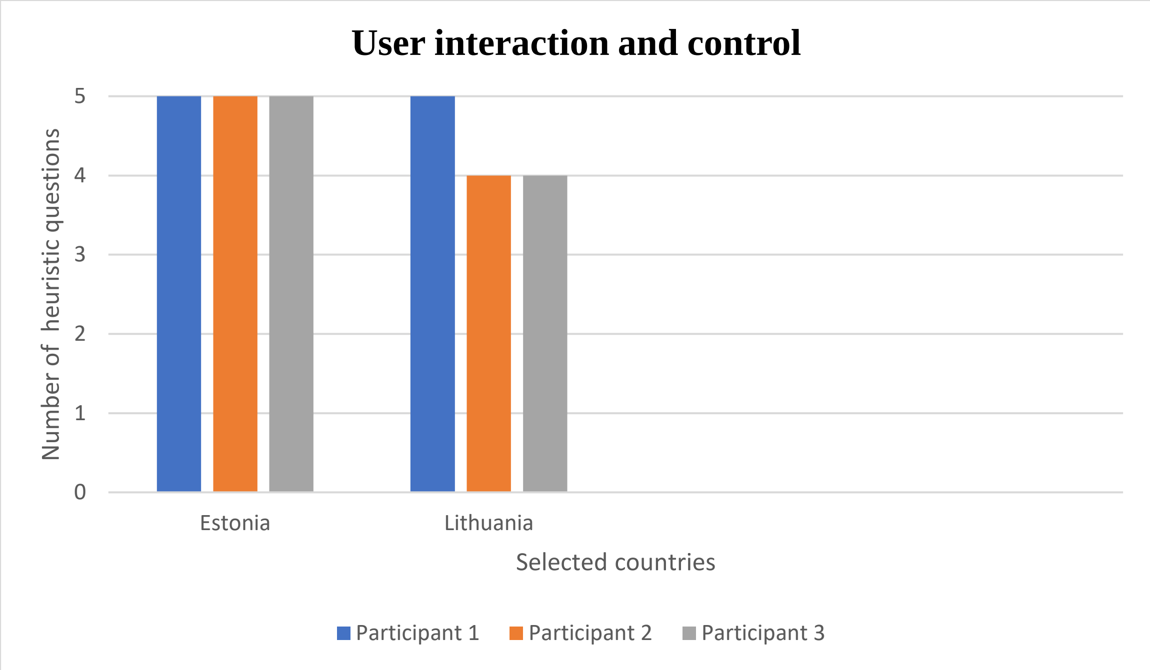


Graph 1: User interface and design results

Source: Author's own creation

The comparative evaluation of Estonia and Lithuania's user interface and design revealed that Estonia received a remarkable score of 97%, surpassing Lithuania's score of 87%. However, there is still room for improvement in both countries as some usability issues were identified, accounting for 3% and 13% of the total score for Estonia and Lithuania, respectively. Specifically:

- The design of the map interface for both countries appear cluttered and may cause difficulty for users trying to navigate and understand the information on it.
- The symbols on the Lithuanian map are not easily recognizable, leading to confusion and misinterpretation of spatial data.
- Lithuanian map labels lack clarity and readability, making it difficult for users to quickly understand their meaning without relying on memory. Enhancements to the label design could help improve user comprehension.

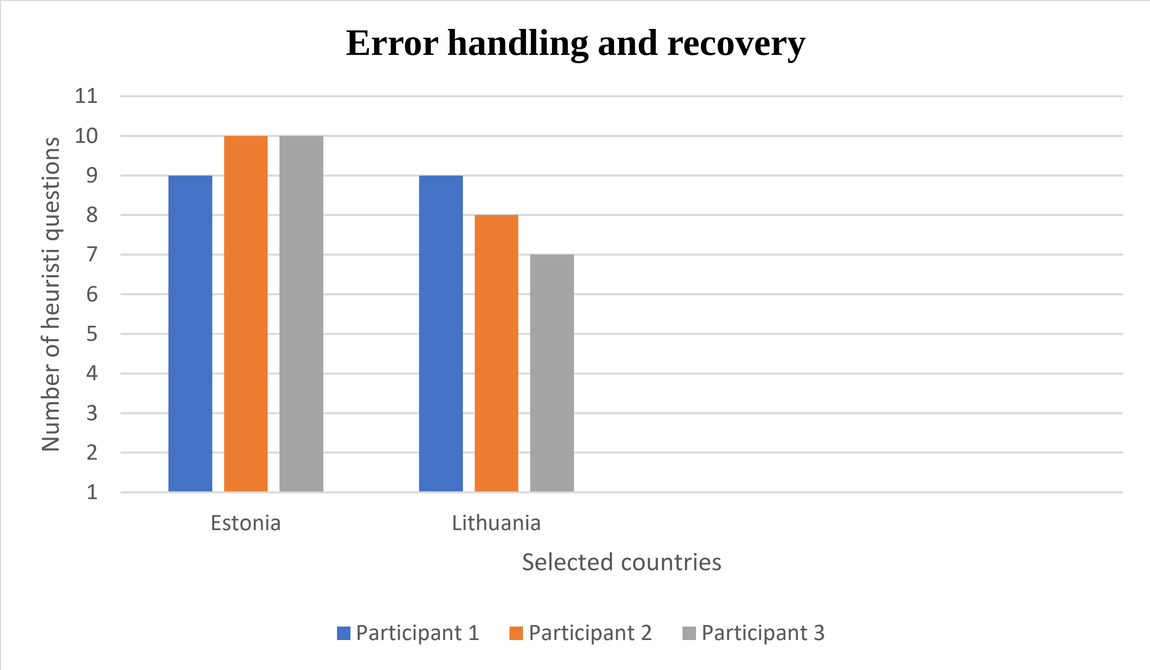


Graph 2: User interaction and control results

Source: Author's own creation

In the comparison of user interaction and control between the geoportals of Estonia and Lithuania, Estonia achieved a perfect score of 100%, while Lithuania received a score of 87%. The following problems indicates the remaining 13% for Lithuania:

- The geographic area being viewed on the map is not always clearly displayed, which can lead to confusion for users.
- The interface may not be as user-friendly for individuals with varying levels of GIS expertise, potentially limiting its accessibility.

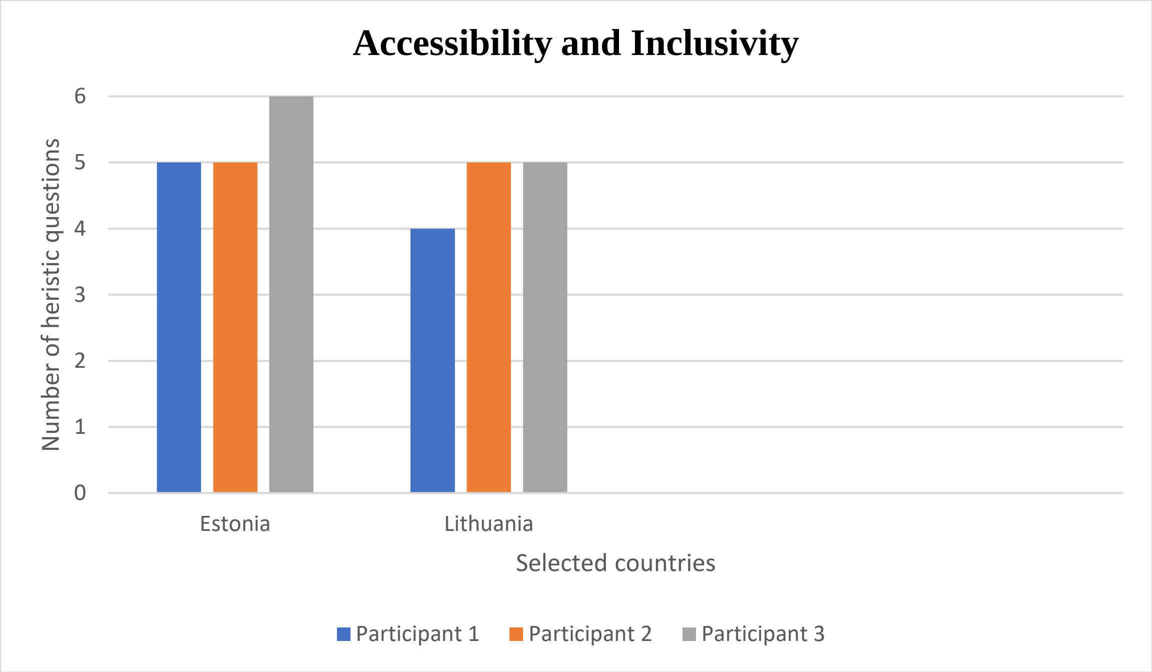


Graph 3: Error handling and recovery results

Source: Author's own creation

During the evaluation of error handling and recovery, Estonia scored 88%, while Lithuania scored 73%. The remaining 12% and 27% for Lithuania and Estonia, respectively, emphasize the necessity of strengthening error-handling systems and speeding up response times to guarantee a more seamless and effective user experience across both geoportals. Below are the reasons for the remaining 12% and 27%:

- Both Estonia and Lithuania lack clear error messages to help users understand their mistakes. This can lead to confusion and frustration for users.
- Neither country geoportal provides guidance on how to recover from errors without losing progress. This can hinder user efficiency and productivity.
- Lithuania experiences slow response times when loading map tiles, resulting in noticeable delays that may affect user experience and workflow.
- Lithuania experiences noticeable delays in query execution, which may impede user tasks and data analysis.



Graph 4: Accessibility and inclusivity

Source: Author's own creation

Both Estonia and Lithuania have been assessed for accessibility and inclusivity, with Estonia achieving a commendable score of 89%, while Lithuania attained a score of 78%. However, both countries still have room for improvement to ensure a more inclusive user experience.

- In Estonia, 11% of users face difficulty in navigating the interface using just a keyboard, which limits accessibility for individuals with mobility impairments.
- Similarly, in Lithuania, 22% of users face the same issue. Moreover, the geoportals of both countries are not fully keyboard-accessible, which poses challenges for users with certain disabilities, as they cannot complete all tasks without relying on a mouse.
- Additionally, the Lithuania geoportal does not effectively incorporate user feedback to address accessibility concerns and enhance inclusivity. This indicates a potential gap in responsiveness to user needs and preferences, which can hamper the overall user experience.

Proposals and Discussion

This section of my thesis delves deeply into the usability challenges identified within geoportals, offering comprehensive insights into the issues encountered. By meticulously analyzing the usability shortcomings, this thesis not only highlights the complexities but also presents innovative solutions to address these challenges effectively. Through a structured approach and detailed examination, this thesis not only identifies the problems but also offers practical and actionable recommendations to enhance the usability of geoportals, contributing significantly to the field of geospatial technology and user experience design.

User Interface and Design

- **Is the map interface clutter-free? -** For both countries the issue of a cluttered interface can be solved by the following:
  - Users should be able to personalize the interface based on their preferences. This could involve the ability to rearrange panels, adjust the size of elements, or save custom map views.
  - Implement browser-based storage to retain user preferences across sessions.
  - Additionally, include links to FAQs for users seeking more detailed information.
  - Integrate a search bar that enables users to locate specific layers, tools, or features.
  - Furthermore, allow users to tailor the interface to their requirements by providing options to modify the layout, colour scheme, or default settings.
- **Are the symbols used on the map easily recognizable? –** For Lithuania the symbols on the map are not easily recognizable and can be solved by:
  - Implement interactive features allowing users to click symbols for additional information or context, such as pop-up windows with detailed descriptions or links to relevant resources just like in the Estonia application (see Figure 9).

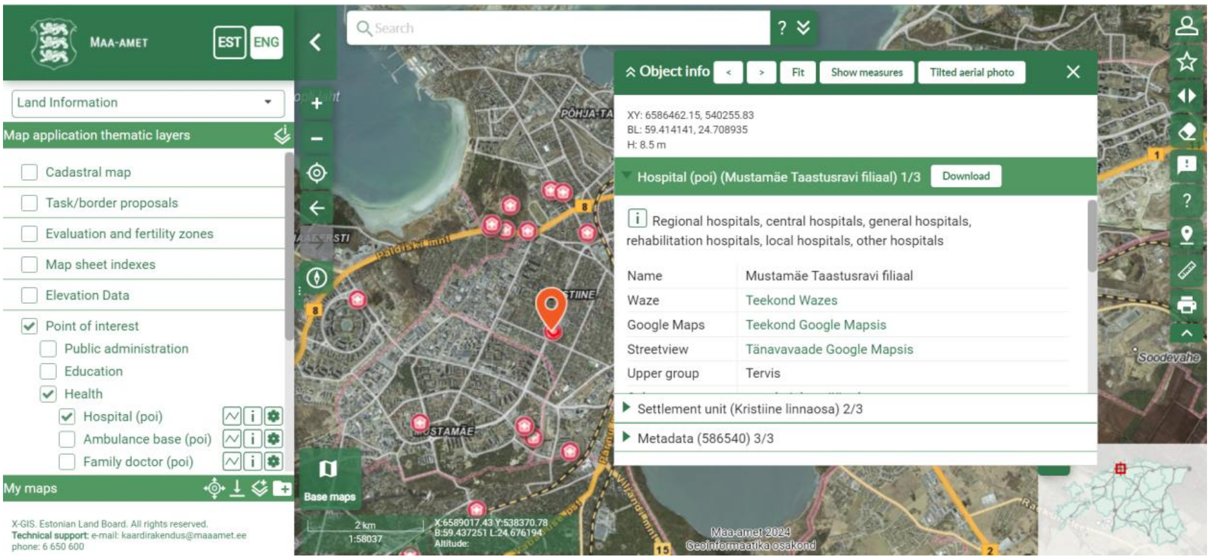


Figure 9: Estonia's interactive detailed features

Source: [*https://xgis.maaamet.ee/xgis2/page/app/maainfo*](https://xgis.maaamet.ee/xgis2/page/app/maainfo)

- Allowing users to toggle symbols on and off in the legend, allows users to focus on the most important information without being overwhelmed by unnecessary visual elements.

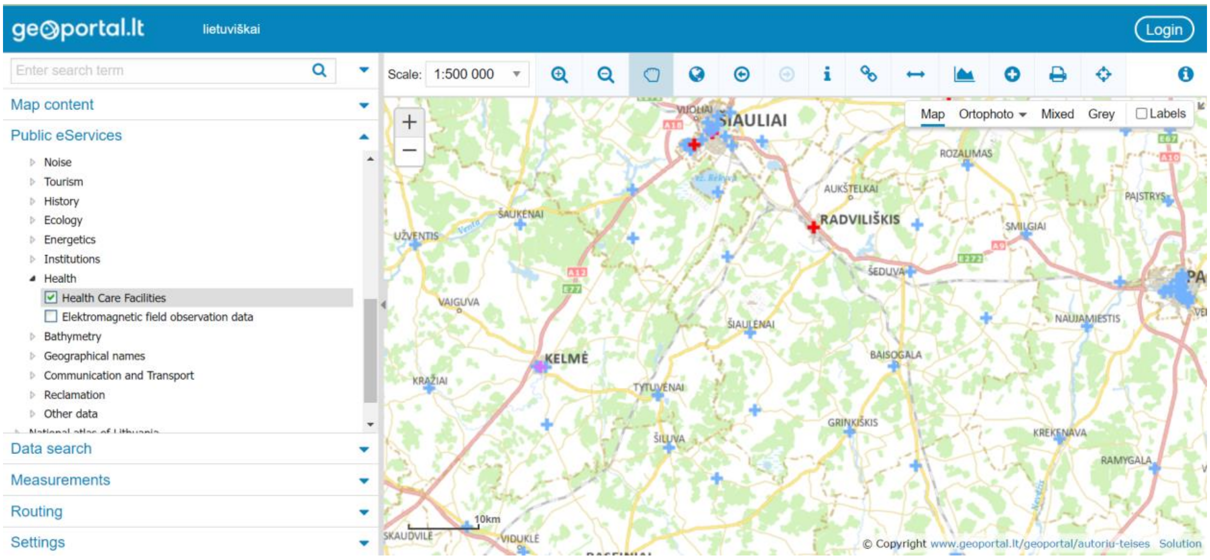


Figure 10: Lithuania symbols

Source: [*https://www.geoportal.lt/map/?lang=en*](https://www.geoportal.lt/map/?lang=en)

- Symbols used in the Lithuania Geoportal lack consistency in terms of colors, leading to potential confusion for users (see *Figure 10*).
- For example, in the case of health care facilities, the colors of symbols vary, which can be perplexing for users trying to interpret the map.

  - It's essential to ensure that symbols are clearly explained in the legend, including their meanings and variations in colors, to provide users with accurate information and prevent misinterpretation.
  - By enhancing consistency in symbol colors and providing detailed explanations in the legend, the Lithuania Geoportal can improve user comprehension and usability.

- **Can you easily recognize the meaning of map labels without having to rely on memory?** – For Lithuania:
  - Place map labels in relation to the appropriate geographic elements that they are meant to depict. Make sure that labels on the map don't cover up or hide any crucial information.
  - Provide interactive elements that let people examine more context or information by clicking on map labels. Pop-up windows that provide thorough explanations or connections to important resources are examples of this.

User interaction and control

- **Is it clear what geographic area you are currently viewing on the map?**

- **Is the interface easy to use for users with varying levels of GIS expertise?**
  - In the interface of Estonia, points of interest are grouped together in one place on the legend. This makes it easier for users with varying levels of GIS expertise to locate and identify them quickly, without having to navigate through the entire legend. As a result, the design approach enhances usability and efficiency.
  - On the other hand, in the Lithuanian interface, users may have to scroll through the entire legend to find specific points of interest. This can be time-consuming and less intuitive.
  - Estonia's interface showcases a user-centric design strategy by prioritizing the organization and accessibility of essential information. This contributes to a smoother user experience. If the Lithuanian interface implemented a similar approach to grouping points of interest in one place, it could improve usability and cater to users with different levels of GIS expertise more effectively.

Error handling and recovery

- **Are there clear error messages available to help users understand mistakes?**
    - Both Geoportals lack clear error messages to guide users in understanding their errors, leading to potential confusion and frustration.
    - One solution could be to add suggestions for words with different accents, particularly in languages where accents are common, such as Lithuanian and Estonian.
    - Since the English alphabet does not include letters with accents, providing suggestions for alternative spellings or variations with accents can assist users in correcting errors more effectively.
    - These suggestions can be incorporated into the error messages displayed to users when they encounter input errors, offering guidance on how to correct their mistakes.
    - By providing suggestions for words with different accents, the Geoportals can improve user experience by reducing the likelihood of input errors and facilitating smoother interactions.
- **Does the interface provide guidance on how to recover from errors without losing progress?**
    - Estonia's geoportal effectively uses bookmarks for error recovery and progress retention.
    - To enhance error recovery and user experience in Lithuania's geoportal, bookmarks can be implemented alongside features like inline validation and undo functionality.
    - Bookmarks allow users to save locations and states, making it easier for them to recover from errors without losing their progress in both geoportal applications.
    - By adding inline validation and undo functionality, users can effectively backtrack and correct errors while preserving their progress.
- **Is there a noticeable delay in response time for loading map tiles, executing queries?**
    - In the case of Lithuania, they can implement caching mechanisms to store frequently accessed map tiles and query results. This reduces the need to

generate tiles or execute queries repeatedly, resulting in faster response times for users.

Accessibility and inclusivity

- **Can users navigate the interface using only a keyboard, can users interact with the interface using only a keyboard, without relying on a mouse?**
    - Both geoportals have limited keyboard navigation options, which can make it difficult for users who rely on keyboard-only navigation to access all features.
    - To improve accessibility, it is recommended to provide a keyboard shortcut guide or help documentation within the interface.
    - Additionally, interactive controls such as sliders, checkboxes and dropdown menus should be operable using keyboard commands. It's important to use standard keyboard conventions for interacting with controls, such as using the Enter key to activate and the Spacebar to toggle checkboxes.
- **Does the interface reflect user feedback?**
    - Incorporating several feedback mechanisms, such surveys, user forums, and feedback forms, into the geoportal interface of Lithuania. It promotes involvement, making these techniques clearly visible and easily available to consumers.

Additional information

Lithuania

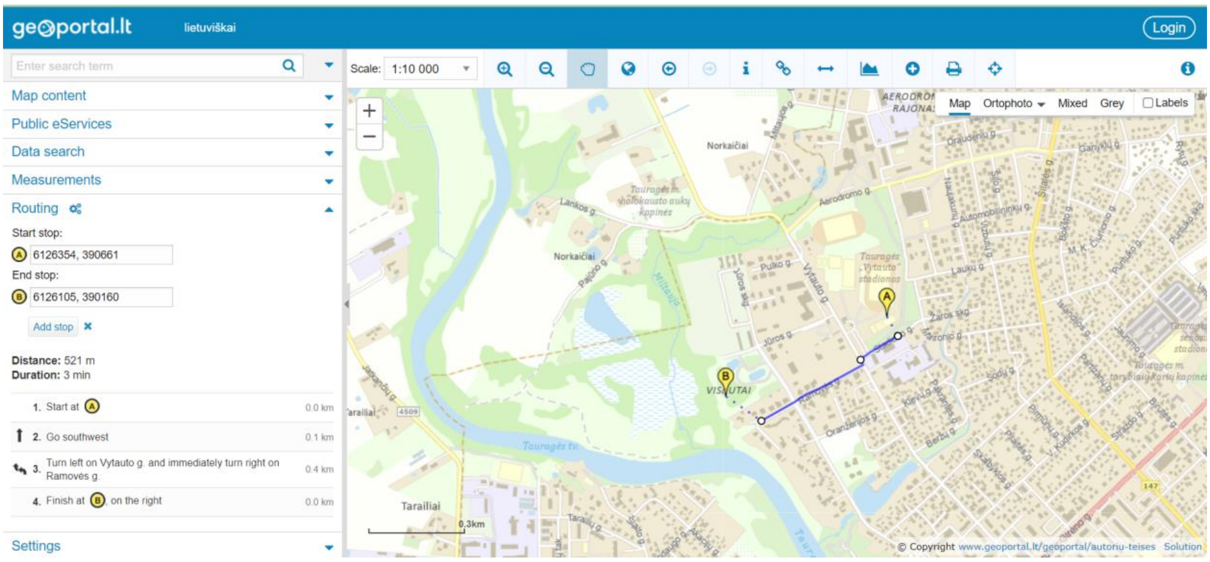


Figure 11: Routing feature for Lithuania

Source: https://www.geoportal.lt/map/?lang=en

- The Lithuanian geoportal offers a valuable routing feature (see Figure 11) that enhances users' navigation experience by providing detailed information on distance, direction, and estimated time of arrival for selected locations. This functionality empowers users to plan their journeys more effectively, whether for daily commutes or longer trips, by offering precise route guidance and valuable insights into travel times.
- Unlike its counterpart in Estonia, which lacks this feature, the Lithuanian geoportal stands out for its ability to streamline travel planning and optimize routes, catering to the diverse needs of users across the country.
- While the selection of layers on the Lithuanian geoportal may be comparatively limited, it boasts a significant advantage with its up-to-date orthophoto layers (see Figure 12). These layers provide users with accurate and current aerial imagery, offering a clear and detailed view of the landscape. This currency ensures that users have access to the most recent geographic information when utilizing the orthophoto layers for various purposes.
- In contrast, the Estonian geoportal may offer a broader range of layers (see *Figure 13)*, but its orthophoto layers lag behind in terms of currency, potentially impacting the precision and reliability of spatial analyses and decision-making processes.

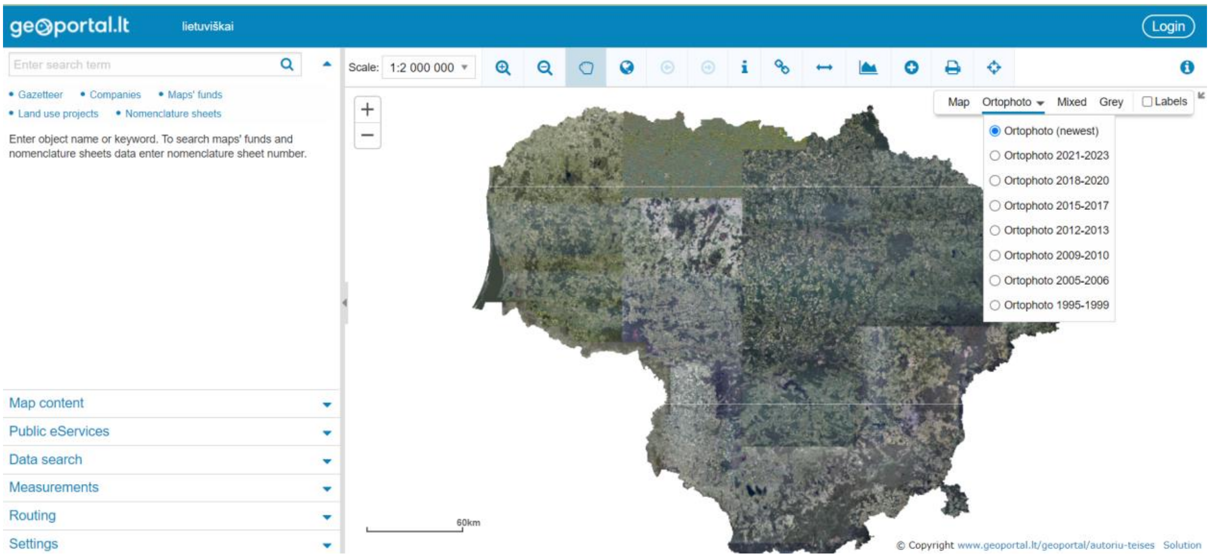


Figure 12: Lithuania layers

Source: https://www.geoportal.lt/map/?lang=en

Estonia

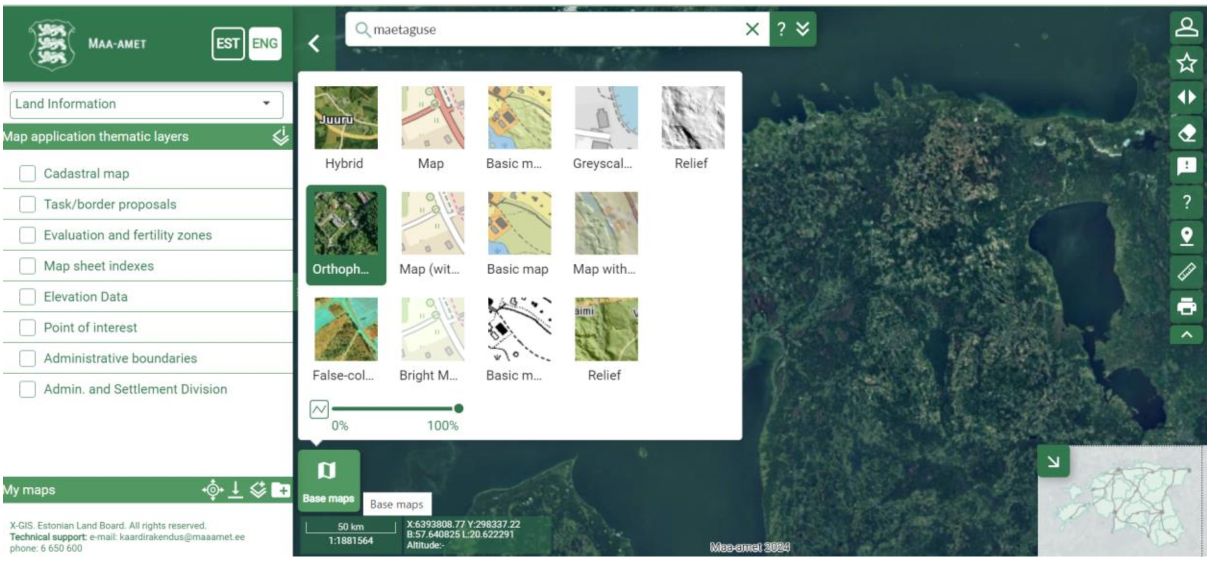


Figure 13: Estonia layers

Source: https://xgis.maaamet.ee/xgis2/page/app/maainfo

- Estonia geoportal offers a flexible scale bar feature allowing users to input custom values.
- Users can manually enter the desired scale value for precise measurements.
- Lithuania geoportal restricts users to selecting from predetermined scale options.
- In Estonia, the scale bar customization enhances user control and accuracy in map interpretation and analysis.

- Conversely, Lithuania's scale bar functionality limits user flexibility, potentially affecting the granularity of spatial measurements and analysis.
- The help documentation of Estonia is static and non-translatable
- Implementation of a dynamic content management system for the help documentation allows for easy updates and translations.

Limitation of the study

- The study only utilized personas representing master students with similar GIS expertise levels.
- Heuristic assessment provides a high-level evaluation of usability but lacks the depth needed to uncover complex usability challenges or interactions within the application.

Future study

- Incorporate personas representing a broader spectrum of GIS expertise levels, including novice users, intermediate users, and advanced professionals. This will provide a more comprehensive understanding of usability issues across different user groups.
- Combine heuristic assessment with other usability evaluation methods, such as user testing, cognitive walkthroughs, or eye-tracking studies, to gain a more holistic understanding of usability issues and their underlying causes.

CONCLUSION

The aim of this thesis is to examine how usability and accessibility concerns can support geoportals improvement, stressing the significance of user-centred design principles and accessibility standards

The topic holds paramount importance in fostering inclusive, user-centric design practices. By prioritizing usability principles and accessibility standards from design to deployment phases and employing heuristic assessments, developers ensure that their applications are intuitive, efficient, and accessible to all users, regardless of their abilities. This approach not only enhances the overall user experience but also promotes inclusivity, equal access to information, and user satisfaction. Ultimately, integrating usability and accessibility considerations throughout the development lifecycle ensures that geoportals meet the diverse needs and preferences of their users, leading to more impactful and widely adopted solutions.

In conducting the evaluation of two web-GIS applications, with a focus on the Lithuania and Estonia geoportals, heuristic assessment was chosen due to its structured and systematic approach, aligning with established principles and guidelines. This evaluation method involves experts examining the systems against a set of predefined usability principles or heuristics to pinpoint potential usability issues. A total of 35 heuristic questions, based on Nielson's usability principles, were created for this assessment. The Fuller's method was then employed to rate each heuristic question to determine their relevance in the applications. Drawing from relevant literature, three participants were selected for the assessment, provided with instructions and a checklist to guide them through the evaluation process.

The key findings of the study reveal notable differences between the usability of Estonia and Lithuania's web-GIS applications. Estonia demonstrated superior usability compared to Lithuania, particularly highlighted by its more flexible scalebar feature, allowing users to input desired values directly, unlike Lithuania's constrained selection options. Despite its overall lower usability score, Lithuania's inclusion of a routing feature, providing users with directions, distances, and travel times between points, offers valuable functionality absent in Estonia's application.

Both applications exhibited shortcomings in legend presentation, lacking labels accompanying appropriate geographic features. Estonia boasted a broader range of available layers, though Lithuania's orthophoto layer notably stood out for its up-to-date imagery. These findings underscore the nuanced strengths and weaknesses of each geoportal, informing potential areas for improvement in usability and feature offerings.

In my thesis contribution, I propose enhancements for both the Estonia and Lithuania geoportals to improve their usability and consistency. I recommend refining the legends on both platforms by aligning labels with geographic features and standardizing symbols and colors to reduce confusion. Additionally, Estonia could benefit from incorporating Lithuania's routing feature to enhance navigation capabilities. Similarly, Lithuania could adopt Estonia's flexible scale bar functionality to provide users with more precise measurement options. By implementing these improvements, both geoportals can offer more intuitive and user-friendly experiences for their respective users.

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APPENDIX A

The Web Content Accessibility Guidelines (WCAG), created by the World Wide Web Consortium (W3C) https://www.w3.org/WAI/fundamentals/accessibility-principles/ are the most commonly accepted set of recommendations. The following are important guidelines and precepts for online accessibility:

Perceivable information and user interface (Miniukovich et al., 2018)**:**

- Text alternatives convey the purpose of an image or function, providing an equivalent user experience. They can be read aloud, enlarged, or displayed on braille devices. Text alternatives serve as labels for controls, functionality, keyboard navigation, voice recognition, audio, video, files, and embedded applications on websites.
- Text transcripts with accurate auditory or visual information sequences offer basic accessibility and aid in creating captions and audio descriptions.
- To modify content presentation, users must mark-up headings, lists, tables, input fields, and content structures correctly, ensure information is independent of presentation, and use browsers and assistive technologies to customize presentation settings. This allows for reading aloud, enlarged, and adapted content, including page outlines and summaries.
- Distinguishable content is easier to see and hear, requiring colour combinations, text reflow, resizable images, adjustable audio volume, and low background audio to avoid interference. This ensures important information is easily distinguishable, especially for those without assistive technologies or those using assistive technologies. This includes people with colour blindness who rely on proper design for colour contrast, and those with text-to-speech or assistive listening devices.

Operable user interface and navigation:

- Functionality is available from a keyboard: Keyboard accessibility is crucial for users who rely on keyboards for web interaction, including form controls and input. It ensures all mouse functionality is available, keyboard focus isn't trapped, and web browsers and authoring tools support keyboard use, including alternative keyboards and voice recognition.
- Users have enough time to read and use the content: Some individuals require more time to read and use content, such as typing text or understanding instructions on a

website. Ensuring sufficient time includes adjusting time limits, pauses, postponing interruptions, and re-authenticating sessions without losing data.

Robust content and reliable interpretation:

- Content is compatible with current and future user tools: Robust content is compatible with various browsers, assistive technologies, and user agents by ensuring valid markup interpretation and providing names, roles, and values for non-standard user interface components, enabling assistive technologies to process content reliably and present it differently.

Understandable information and user interface:

- Text is readable and understandable: Content authors must ensure text is readable and understandable to a broad audience, including text-to-speech. This includes identifying the primary language of a web page, providing definitions for unusual words, and using the simplest language possible. This helps software process text, generate page summaries, and assist people with cognitive disabilities in understanding complex sentences and vocabulary.
- Content appears and operates in predictable ways: People often prefer predictable user interfaces, which can be achieved through repetition of navigation mechanisms, consistent labels, and user consent. This allows users to quickly learn website functionality and operate it according to their needs. Some users assign shortcut keys or memorize steps to access specific pages or processes.
- Users are helped to avoid and correct mistakes: Forms and interaction can be confusing or difficult for many users, leading to mistakes. To help avoid and correct mistakes, descriptive instructions, error messages, context-sensitive help, and the opportunity to review submissions are provided. These measures help those who don't understand or forget the functionality.

APPENDIX B

Rules for Heuristics

Heuristics are guidelines or rules of thumb that are applied while solving issues or coming to choices (Hjeij & Vilks, 2023). Usability heuristics refer to a collection of general guidelines that are used in the context of usability and user experience design to assess the effectiveness, efficiency, and user satisfaction of a user interface (Quiñones & Rusu, 2017a). These heuristics are frequently used in the stages of product or system design and assessment. The table below shows common usability heuristics, often attributed to Jakob Nielsen.

Principle	Definition
Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
Match between system and the real world	The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions
Error prevention	Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
Recognition rather than recall	Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Flexibility and efficiency of use	Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
Aesthetic and minimalist design	Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Processing: own, based on the resources:(Quiñones & Rusu, 2017b) (Miller et al., 2018)

APPENDIX C

Principle	Heuristic question	Status
	User interface design	
Visibility of system status	Are the symbols used on the map easily recognizable?	☐
	Are the labels used on the map representative of real-world geographic features?	☐
	Do the styles used for different types of features (e.g., water bodies, roads, buildings) match users' real-world expectations?	☐
	Do the colors used for different types of features on the map match users' real-world expectations?	☐
Match between system and the real world	Can you easily recognize the meaning of map labels without having to rely on memory?	☐
	Can you easily interpret the meaning of map symbols without having to rely on memory?	☐
	Are there clear legends available to help you understand the meaning of different map features?	☐
Consistency and standards	Is it simple to pan the map?	☐
	Is it simple to zoom on the map?	☐
	Is it possible to easily change the layers that are displayed?	☐
	Can users click the scalebar to perform actions, such as changing the map scale?	☐
Aesthetic and minimalist design	Does the map interface have an eye-catching design?	☐
	Is the map interface clutter-free?	☐
	User interaction and control	
User control freedom	Is it clear what geographic area you are currently viewing on the map?	☐
	Can you easily identify which layers are currently visible?	☐
	Can you easily identify which layers are currently active?	☐
Flexibility and efficiency of use	Is the interface easy to use for users with varying levels of GIS expertise?	☐

Recognition rather than recall	Does the interface provide clear feedback if you attempt an invalid action?	☐
	Error handling and recovery	
Error prevention	Are map interactions consistent throughout the application?	☐
	Are labelling styles consistent throughout the application?	☐
	Is the symbology consistent throughout the application?	☐
Help users recognize, diagnose, and recover from errors	Are there clear error messages available to help users understand mistakes?	☐
	Are there prompts available to help users correct mistakes?	☐
	Does the interface provide guidance on how to recover from errors without losing progress?	☐
Help and documentation	Are user-friendly help documents available for the application?	☐
	Does the application have contextual assistance features?	☐
	Does the application have tooltips?	☐
Feedback and response	Is the response time for loading map tiles sufficiently fast and without noticeable delays?	☐
	Are queries executed promptly without any noticeable delays?	☐
	Accessibility and inclusivity	
Responsiveness and operability	Can users navigate the interface using only a keyboard?	☐
	Can users interact with the interface using only a keyboard, without relying on a mouse?	☐
	Does the interface reflect user feedback?	☐
	Does the website function smoothly on mobile devices?	☐
	Is the website designed with responsive design?	☐
	Is the website optimized for touchscreen interactions?	☐

Table 5: Checklist

Processing: Author’s own processing

APPENDIX D

INSTRUCTIONS FOR PARTICIPANTS
• Spend some time getting to know the user interface you will be assessing. • Verify your comprehension of each heuristic's application to usability. • As you evaluate and communicate your ideas, feelings, and any problems you run into, think out loud. • Make a note of any heuristic violations that you find. • To evaluate the apps, utilize the checklist. • A checkmark on the checklist indicates YES if the heuristic question is answered correctly; if not, it indicates NO. • You can provide the procedure feedback after finishing the checklist.

Table 6: Instructions for participants

Processing: Author's own processing