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Institute of Systems Engineering and Informatics

USABILITY EVALUATION OF WEB-BASED GIS APPLICATIONS

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Zásady pro vypracování

The aim of the thesis is to propose a suitable procedure to evaluate the usability of chosen Web-based applications. Applications managed by public administration authorities will be included in the study. The basic concepts of web-based GIS applications and their usability will be described.

Outline

Concepts of web-based GIS applications.
Usability evaluation of Web-based GIS applications – methods and approaches.
Proposal of procedure of usability evaluation of choseb Web-based GIS applications.
Usability evaluation of the chosen Web-based GIS applications and recommendations.

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KOMARKOVA, J., SEDLAK, P., HABRMAN, J., CERMAKOVA, I., 2017. Usability evaluation of Web-based GIS by means of a model. *2017 international conference on information and digital technologies (idt)*. 2017. P. 191-197.
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AUTHOR'S STATEMENT

I declare:

I developed the work entitled **USABILITY EVALUATION OF WEB-BASED GIS APPLICATIONS** on my own. All literary sources and information that I used in my work are listed in the list of used literature.

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ANNOTATION

This thesis focuses on usability evaluation for web-based GIS applications. The aim is to propose a suitable evaluation procedure to evaluate the usability of web-based GIS applications managed by public administration authorities. In effect, ten public administration geoportals were selected, that is, Czech Republic, Poland, Germany, Slovakia, and Austria, along with their respective capital cities, Prague, Warsaw, Berlin, Bratislava and Vienna. Through extensive literature reviews, practical criteria were set and through a multicriteria decision making, suitable evaluation methods were chosen. A mixed methodology approach as well as a combination of user testing, think-aloud, and questionnaire were employed for the usability evaluation. The findings revealed critical issues, such as limited functionality, findability problems, English translation issues and inactive features. The geoportal of Berlin demonstrated the least usability, while that of Vienna emerged as the most usable among the evaluated geoportals.

KEYWORDS

usability evaluation, usability, user testing, web-based gis, geoportal, public administration

ANOTACE

Tato práce se zaměřuje na hodnocení použitelnosti pro webové GIS aplikace. Cílem je navrhnout vhodný postup hodnocení pro hodnocení použitelnosti webových GIS aplikací spravovaných orgány veřejné správy. Ve skutečnosti bylo vybráno deset geoportálů veřejné správy, tedy Česká republika, Polsko, Německo, Slovensko a Rakousko, spolu s jejich hlavními městy Prahou, Varšavou, Berlínem, Bratislavou a Vídní. Prostřednictvím rozsáhlého přehledu literatury byla stanovena praktická kritéria a prostřednictvím multikriteriálního rozhodování *byly vybrány vhodné metody hodnocení. Pro hodnocení použitelnosti byl použit smíšený metodologický přístup a také kombinace uživatelského testování, myšlení nahlas a dotazníku. Zjištění odhalila kritické problémy, jako je omezená funkčnost, problémy s nalezením, problémy s anglickým překladem a neaktivní funkce. Nejméně využitelnost vykázal geoportál Berlín, jako nejpoužitelnější se z hodnocených geoportálů ukázal Vídeňský.*

KLÍČOVÁ SLOVA

hodnocení použitelnosti, použitelnost, uživatelské testování, webový gis, geoportál, veřejná správa

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INTRODUCTION

Before the age of digitalization and the internet, geographical information was primarily tied to static paper maps. In this alpha generation, however, the power of the internet could be said to have fully penetrated every economic sector including all aspects and walks of life. The geographical sector also, has had its fair share of the internet. In effect, technological advancement like Web-based GIS applications, have brought geographical information even to the doorstep of the average individual.

In the 1960s, the world of GIS experienced significant breakthrough when the first fully operational vector-based GIS was developed in Canada, which is, the Canadian Geographic Information System (CGIS) (Waters 2017). The CGIS was used to reserve geospatial data for Canada Land Inventory and aid in development of governing processes for land-use management and resource supervision in Canada. As the years progressed, and the internet evolved, GIS evolved along with it. The first web-based map, the PARC Map Viewer by Xerox was launched in 1993 (Peterson 2021). As more improved versions were introduced to the internet in the subsequent years, the userbase of these web-based applications also increased. The report of Statistica in 2018 indicates about 154.4 million monthly users and over a billion searches of Google Maps alone (Roetman 2020). The increment in the client base has given rise to variety of user preferences which in effect has brought about issues of usability. It therefore behoves on developers to ensure that the software or applications serve the needs of the user adequately with little or no errors.

There exists several approaches and methodologies to usability evaluation. Many researchers have contributed their quota of knowledge when it comes to usability and its evaluation. The choice of any usability evaluation method depends on the application or software under study. To obtain effective usability evaluation, it is important to select a suitable methodology in other to attain desirable results. The performance of usability evaluation is of extreme importance because it is what helps to detect user acceptance. That is, it provides an indication of denial or approval by the user and also helps in the improvement of the application design.

Hence, this thesis aims to propose a suitable and qualitative procedure to evaluate the usability of chosen Web-based applications. Applications managed by public administration authorities will be included in the study.

1. IN-DEPTH STUDY OF WEB-BASED GIS APPLICATIONS

The patronage of web-based GIS applications has within the past decades heightened immensely. Many of these web-based GIS applications now happen to be even more sophisticated with several advanced functionalities including speed and precision, outdoing certain fundamental capabilities of some desktop GIS applications (Baker 2015). These web-based applications have potent mapping and analytical functions that are embodied in a web browser. It enables the presentation of geographic information effectively. A Geographic Information System can be defined as an application for capturing, managing, and analyzing spatial data (Kuria et al. 2019).

According to Kong, Zhang, Stonebraker (2014), a web-based GIS refers to an internet-based application that incorporates a map and enables users to search for and analyze spatial data, as well as generate personalized maps. Web-based GIS applications are often considered to be operating in a web browser, however, this explanation neglects systems that have desktop and mobile clients.

Web-based GIS applications, therefore, uses web technologies with its communication among its components. It can also be described as a form of distributed information system, consisting of at least a server and a client, whereby the server is a GIS server, and the client could be a web browser, desktop application, or mobile application (Kuria et al. 2019). The desktop client, however, should not be confused with Desktop GIS application whereby the software is physically installed on the hard drive or storage of the computer, and all the program files and data are stored on that machine.

Although the use of GIS applications can be dated back to about six decades, it was the advent and vast use of the World Wide Web that boosted the GIS applications and has now made the Web-based GIS applications popular (Düren, Bartoschek 2013).

The timelines are shown in figure 1 below.

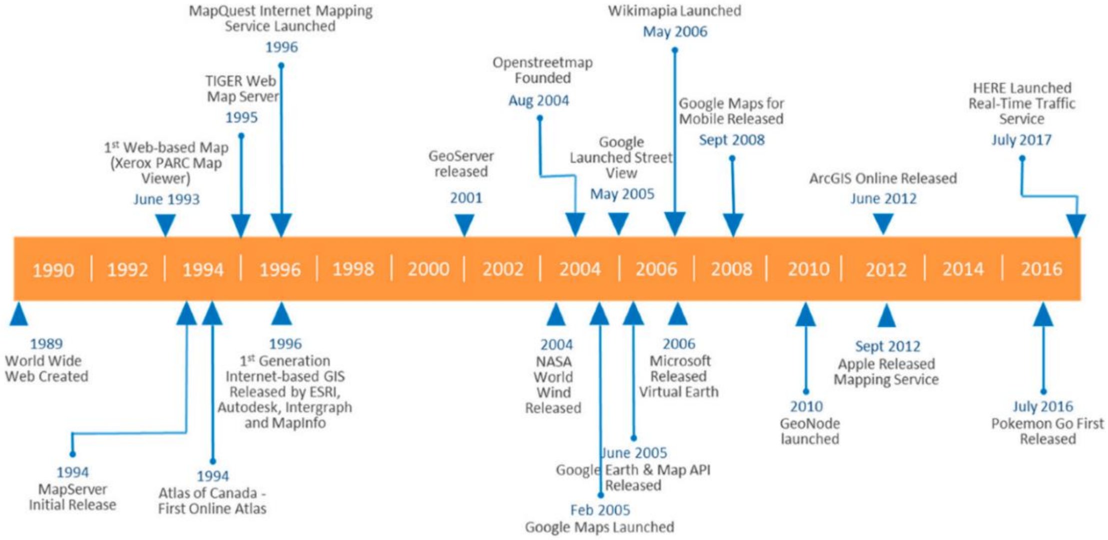


Figure 1: Some Major Mapping Events

*Source:(*Veenendaal, Brovelli, Li 2017)

After Tim Berners-Lee, the British scientist, developed the WWW in 1989, Steve Plutz at the Xerox's Corporation Palo Alto Research Centre, built the Xerox Parc Viewer in 1993. This was an experimental viewer map that permitted interactive information retrieval instead of just access to static files on the WWW (Mushonga, Banda, Mulolwa 2017). The Map Viewer made use of a custom-made CGI server module that was written in Perl. When an interaction was made with the interface, it would request a map from its server, and the server would in turn respond with a new map that was inserted in a new web page. This site is however no longer functional (Peterson 2021). The 1990s saw a release of more advanced applications like Atlas of Canada in 1994, which was the first ever online atlas (Murodilov, Alisherov 2023). MapQuest Internet Mapping Service was launched in 1996 and subsequently, the release of the 1st generation internet-based GIS by ESRI also in 1996 (Veenendaal, Brovelli, Li 2017).

Applications like Geoserver, released in 2001, was a GIS web server with an open-source platform that provides services like Web Coverage Service, Web Feature Service, Web Map Service and Web Feature Service Transaction Protocols (Agrawal, Gupta 2014). It has a fully featured web administration interface and can work with large range of data formats like Shapefile, Oracle Spatial and so on (Agrawal, Gupta 2014). It also allows for interoperability. Other open platform applications released in the early 2000s include Google in 2005, Wikimapia in 2006 and Microsoft's Virtual Earth also released in 2006, and Google again launched its Maps for mobile in 2008 (Veenendaal, Brovelli, Li 2017).

In 2010, the Global Facility for Disaster Reduction and Recovery (GFDRR) introduced GeoNode, which is a web framework and platform based on an open-source software technology that enabled institutions to develop geospatial information systems and deploy public spatial data infrastructures (SDI) and open geospatial data catalogues (Corti et al. 2019). Afterwards, ESRI released ArcGIS Online in June 2012 which was followed by Apple also launching their Mapping Service in September 2012 (De Miguel González, De Lázaro Torres 2020). Even more recent web-based GIS applications include Pokemon Go First, released in 2016 and Real-Time Traffic Service launched by HERE Technologies in 2017 (Veenendaal, Brovelli, Li 2017).

1.1 Design Principles of Web-Based GIS Applications

Since Web-based GIS applications in recent years have become increasingly popular and provides a more convenient way to access and visualize geospatial data and information over the internet, it is therefore very crucial for a well-designed web-based GIS application to be usable, instinctive and effective in presenting geospatial information to its users.

The following are few essential elements the design principle of a web-based GIS application could be based on;

- **User-centered design** – This principle focuses on user feedback and furthers the utility and usability of interactive masking contained by the Web GIS (D. Morgan 2016). The application should be designed considering the preferences, needs and goals of the users in mind. This involves understanding the users, their tasks and the information they need to complete those tasks and designing the application to support them. The main objective here is to develop an intuitive and usable interface that allows for easy access and interaction with the needed information.
- **Map-centric design** – Interactive maps nowadays, serve as the principal attraction and desirability for countless web-based applications, owing the enriched context added to map-centric applications encouraging user exploration (Antoun 2018). In web-based GIS applications, the map is a central and critical component that should be the focus of the application's design. A map-centered design should be easy to use, with clear labelling and tools for user interaction. The map should be the pivot of the application, with all other features revolving around it.

- **Responsiveness** – This is another important design principle, which refers to the ease of adaptation of the web-based GIS application to different screen sizes and devices. In the broad sense, responsiveness is defined as the ability of the application to adjust to various devices and types of definition (Horbiński, Cybulski, Medyńska-Gulij 2021). That is, designing it to effortlessly work on desktops, laptops, tablets and other mobile devices. This enables users to access needed information irrespective of the device being used or their location.
- **Data Visualization** – This principle is to present the geospatial data effectively and efficiently visually such as through graphs, charts and maps. This involves incorporating suitable colours, labels and symbology to clearly convey the information that is being displayed. In data visualization, abstract data such as categorical data and quantities are converted into visual attributes like colours, sizes and shapes and illustrated on an interactive screen (Brath, Banissi 2016). The design of the application should therefore provide a wide range of visualization options such as different map projections to accommodate distinct data types and user preferences.
- **Accessibility** – Web-based GIS applications should be designed to be accessible to all users, including those with disabilities. This means following accessibility guidelines, such as those provided by the World Wide Web Consortium (W3C), to ensure that the application can be used by users with visual impairment or suffer from limited muscle movement (Dimech 2022). This also includes providing alternative methods of accessing the information, such as through keyboard navigation or audio descriptions.
- **Scalability** – The design principle is based on the fact that the application should be designed to handle large amounts of data and handle high levels of traffic, ensuring that it is scalable and can grow and adapt to meet the changing needs of its users. Scalability allows the software to operate on a small number of data up to a large number and new data can be added on demand without downtime (Krämer, Senner 2015).
- **Performance** – The performance can be categorized into several factors, such as user perceived system response time, system reliability, system extensibility, and system service quota (Yang, Evans 2017). Users expect fast and responsive applications, and so it's important to optimize the application for performance. This includes using efficient algorithms and using caching and other techniques to reduce load times. Performance is particularly important for web-based GIS applications, as they often

involve processing large amounts of data, and a slow application can greatly impact the user experience.

- **Security** – There must be the formulation of adequate necessary and also sufficient conditions to ensure the security of every part of the system providing mechanisms to ensure the integrity of GIS information sharing (Burlov, Gryzunov, Tatarnikova 2020). The application should therefore be secure, with robust authentication and authorization mechanisms in place to protect sensitive data and information. It should also be designed with privacy of the user in mind, ensuring that personal data is protected and not shared without the user's consent.

1.2 System Architecture

The system architecture of a web-based GIS application usually comprises of several components that work together to provide the functionality and performance required for a successful execution of a task. According to Kumar (2019) the client-server system architecture is classified into four groups; the one-tier, two-tier, three-tier and N-tier architecture. The one-tier or standalone system architecture has all the layers in a singular software package. The two-tier architecture comprises of the client tier which manages both the presentation and application tier, and the second part consists of the data tier. The three-tier architecture is categorized into three parts, the presentation tier, the application tier and data tier.

This client-server architecture are mostly three-tier, and their components usually comprises:

- **Presentation Tier** – This is the user interface or internet client which provides the user with the interface which is used to select certain criteria or make requests and also structures and displays the results of the queries made (Abdalla 2016). It allows the end user to communicate with the GIS application and all of its features. This interface is usually usable and is embedded in a web page.
- **Application Tier** – Also called the logic tier is the central component of the three-tier system architecture in a web-based GIS application. This tier is usually sandwiched between the user interface and the database, and it is responsible for handling and processing the interactions between the user interface (presentation tier) and the database (data tier). It encompasses the client-side components, and it sends requests to the server and displays the corresponding results in terms of input and output. The application tier performs several functions, including data processing (Jayakumar

2018). That is, it manipulates the data received from the database and delivers it to the presentation tier in a layout that can be simply displayed to the user. The tier also contains the business logic of the application, which includes rules and algorithms that control how the data is processed. In addition, the application tier enhances the security of the system by regulating direct access to the database, which helps to lessen the risk of data breaches and other security threats.

- **Data Tier** – This tier stores, manages and provides access to all the geospatial data and metadata used by the application. It consists of a database server, that mobilizes required information from a repository (Abdalla 2016). The data tier in general consists of a Database Management System (DBMS) which manages the geospatial data and metadata stored in the database. A Database Server that hosts the database management system and provides access to the data stored in the database. Data Storage component of this tier stores the geospatial data and metadata in a structured and organized manner. And the Data Access and Management Layer is responsible for providing access to the geospatial data stored in the database.

Figure 2 below is a representation of a representation of a three-tier client server system architecture.

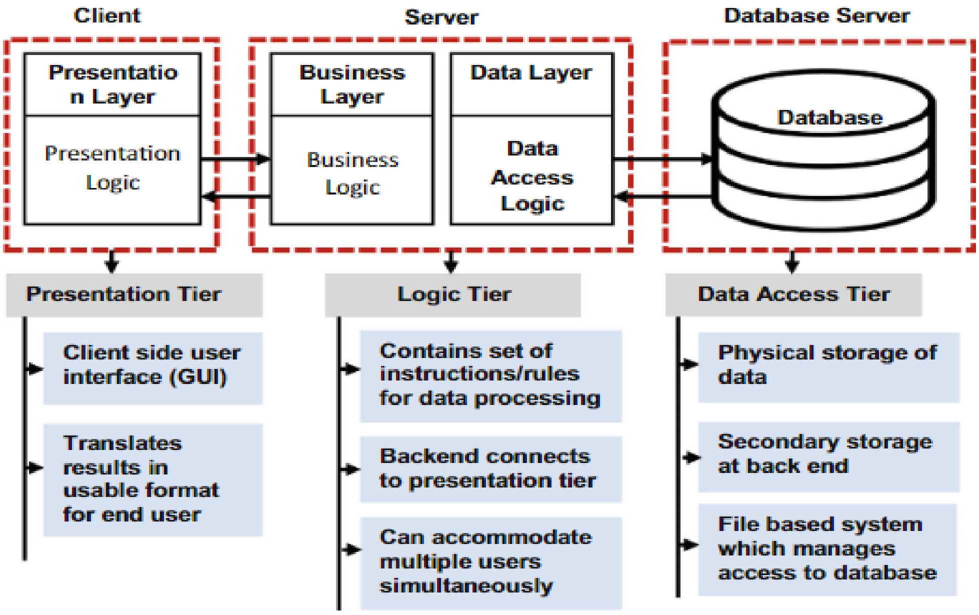


Figure 2: Three-tier Client-server System Architecture

Source: (Dhiman et. al, 2020)

The three-tier system architecture is known to have high efficiency in its performance. However, in the research of Che Mat et al. (2013) titled, "A Comparison between four-tier framework and three-tier framework for online applications of 3D GIS visualization," it was established that the performance of the four-tier system architecture comprising of the client tier, logic tier, visualization process tier and the database tier was superior to the three-tier.

The fourth system architecture is the N-tier application. This is similar to the three-tier system architecture, but the number of application tiers are increased to distribute the business logic. The basic architecture of a web-based GIS application is typically the client-server architecture because it requires a map server in addition to the web server and a database with geodata (Kuria et al. 2019). These components function together to provide a complete web-based GIS solution, allowing users to access and manipulate geographic data through a web browser. In a nutshell, however, there exists web applications which have a multi-tier or has several tiers, and this ensures flexibility and reusability of software (Huang, He, Miao 2014).

1.3 Types of Web-based GIS Applications

There exists several types of web-based GIS applications in the world today. Some of these include:

- **Mapping Applications** – Mapping applications are a type of GIS web-based applications which allows its users to visualize and interact with maps and spatial data. These applications makes use of web technologies to provide maps on the internet, allowing its users to gain access to and work with spatial data from anywhere there is an internet connection. They can display a wide range of spatial data, including roads, buildings, satellite imagery, and other areas of interests. Users interact with these maps by zooming in and out, panning, and clicking on map features to display more information. Mapping applications often have additional features such as search, routing, and geolocation, which allow users to find specific locations or plan routes. They are widely used in industries such as urban planning, transportation, environmental management, and many others (Brown, Reed, Raymond 2020). Example is Google Maps.
- **Geocoding applications** – These types of GIS web-based application takes textual address or place name inputs and converts them into geographical coordinates, usually latitude and longitude. The process involves converting an address or location into

geographic coordinates that can be used to create maps and analyze spatial data. Geocoding applications are used to provide location-based services, such as finding nearby points of interest, mapping locations, or routing directions. These applications can be used in a variety of industries, including transportation, real estate, marketing, and public safety. For example, a geocoding application can be used to map the locations of disease outbreaks, environmental hazards, and health care facilities (Monir et al. 2021). An example includes OpenStreetMap Nominatim.

- **Spatial analysis applications-** These are a type of GIS web-based application that allows users to perform spatial analysis on geospatial data. Spatial analysis involves analyzing the relationships between spatial data, such as identifying patterns, trends, and associations. Spatial analysis can be used to support decision-making, planning, and resource management and have become increasingly important in environmental science (Franch-Pardo et al. 2020). These tools can be used to map and analyze environmental data, such as land cover, water quality and air pollution. These applications can also generate visual outputs, such as maps, charts, and graphs, to help users understand and interpret the results of their analysis. An example is ArcGIS Online.
- **Routing applications** – Web-based GIS routing applications are online platforms or software tools that enable users to plan and optimize travel routes using GIS data. These applications use digital map data to find a path through a network of streets and roads, considering factors such as traffic, road closures, and other routing constraints. Routing applications can be used for a variety of purposes, such as planning a road trip, optimizing delivery routes, or finding the best route for emergency vehicles (Zeng, Tong, Chen 2019). These applications can also provide turn-by-turn directions, estimated travel times, and real-time traffic information to help users navigate to their destination. They usually integrate with other geospatial data sources, such as weather data or point of interest data, to provide more accurate and relevant routing information. One example is MapQuest.

1.4 Comparison of Advantages Between Web-based GIS And Desk-top GIS

Several literature exist between desktop and web-based GIS application and several advantages exist between them as well. Principally, one of primary focus of web-based GIS is on end users, that is, users that may not necessarily have the technical know-how in web-based GIS applications. On the other hand, Desktop GIS applications are usually for the educated, or workers who are experienced in the use of GIS and its applications. Because they are both targeted towards somewhat different users, there exists some differences between the functionalities possessed by these applications. Therefore, in usability evaluation, it is important to take into account the target group of users.

Table 1 below is a summary of their advantages from different researchers;

Advantage	Web-based GIS	Desktop GIS	Source
Accessibility	Can be accessed from anywhere with an internet connection using various devices, allowing for real-time collaboration and data sharing	Limited to specific machines where software is installed, which can limit access and collaboration	(De Miguel González, De Lázaro Torres 2020)
Ease of Use	Typically have usable interfaces and are easy to navigate, requiring minimal technical expertise	Requires specialized technical expertise to operate and may be challenging for beginners	(Rowland, Folmer, Beek 2020)
Cost-effectiveness	Can be more cost-effective due to reduced hardware and software costs, reduced IT infrastructure, and lower maintenance costs	Requires significant hardware investments and may also require specialized IT infrastructure and staff to maintain, making it more expensive to operate and maintain over the long term	(Elwakil, Ibrahim, Hefny 2015)
Scalability	It is designed to be scalable, allowing for larger or more complex datasets and increasing numbers of users without requiring significant hardware and software upgrades	May require significant hardware investments to run efficiently and may also require specialized IT infrastructure and staff to maintain	(Rowland, Folmer, Beek 2020)
Functionality	Despite the many advantages the web-based GIS has limited functionality	Has more functionalities which enables advanced analysis as compared to the web-based GIS	(Fast, Hossain 2020)
Enhanced Data Security	Less security since data is transmitted over the internet	Provides data security since the data is stored locally and not transmitted over the internet, reducing the risk of unauthorized access or data breaches	(Elwakil, Ibrahim, Hefny 2015)

Table 1: Desktop GIS Vs Web-based GIS

Source: Author's own creation

2. USABILITY

The concept of usability is a subject matter that cannot be underrated by any user when it comes to the patronage of any product. As the features and functionalities of applications and software become more and more complex, it becomes very cardinal for experts responsible for product creation to design them in such a manner that consumers will find it easy to manipulate, in order to derive the utmost benefit from its use (Jordan 2020).

According to the International Organization for Standardization, ISO 9241-11, usability can be defined as the **effectiveness**, **efficiency** and **satisfaction** with which specified users can achieve specified goals under specified conditions (Gupta, Ahlawat 2019). The IEEE Std. 610.12-1990 also defines usability as the learnability as well as the input and output efficiency of a system, (Gupta et al. 2020). In addition, the same is explained as the ability of a software to be understood, learnt, used, and to be attractive to the user, when used under definite environments (Mkpojiogu, Hussain, Hassan 2018).

Undoubtedly, the above researchers are in a great deal of concord that the underlying factor for usability of any product or software is the "user-friendliness". That notwithstanding, this may differ from product to product, software to software and application to application. Even customer perception of usability may vary from one end user to the other (Gupta, Ahlawat 2019). Regardless, for any application to be considered usable it must possess certain basic components.

2.1 Basic Constituents of Usability

The general belief is that products are designed with the psyche and physique of the end user in mind. That is, usability design incorporates the type of users and their expected knowledge base. It also takes into consideration the ability of the users to quickly rectify an error committed while using the application. Some go further to provided adequate allowances for users that may be handicapped in one way or the other. Some generic constituents of usability according to ISO 9241-11 are; effectiveness, efficiency and satisfaction (Gupta, Ahlawat 2019). Also, (Nielsen 2012) in his article, Usability 101: Introduction to Usability includes, learnability, effectiveness, errors, memorability and satisfaction. Furthermore, Khan & Adnan (2010), include learnability, effectiveness, efficiency, memorability and satisfaction, which is an echo of both ISO 9241-11 definition and that of Jakub Nielsen. Below are the definitions of basic constituents spoken about by the afore mentioned authors;

- **Learnability** – This measures the speed with which a user can study about a product's usage and acquire knowledge through its use (Zamora-Musa, Velez, Paez-Logreira 2018). This is also further explained as the ability of users to easily accomplish tasks upon initial encounter (Alzahrani, Gay, Alturki 2022)
- **Effectiveness** – It is explained as the accuracy and completeness with which specific users are able to achieve specific results under definite conditions. Effectiveness can be said to have been achieved if targeted or intended goals get accomplished as previously planned (Kuswati 2019).
- **Efficiency** – Efficiency involves the degree of effort needed to complete a task and how quickly or the speed with goals can accurately be achieved (Alzahrani, Gay, Alturki 2022). It occurs when results are accurately obtained from minimum level of resources or effort at the optimal speed.
- **Memorability** – This highlights the depth of the ability of a person to be able to recall certain causes of action. (Wang, et. al., 2020). It measures the ease of re-establishing user proficiency with the interface after a period of non-use (Alzahrani, Gay, Alturki 2022).
- **Satisfaction** – It is mostly measured through the spectacle of the user's impressionistic decision, often indicating the fulfilment or realization of the end user's expectation and or desires (Afrashtehfar, Assery, Bryant 2020).
- **Errors** – The are explained as slips and mistakes. Slips occur when users perform an action other than the intended. Mistakes happen when users have inaccurate goals for their tasks (Laubheimer 2015).

Some researchers include other elements such as understanding, simplicity and performance, highlighting the process of execution of tasks, the speed of their performance and quantum of errors committed in process. Usability testing and evaluation are the means by which all these afore stated constituents and elements are measured (Unrau, Kray 2019).

2.2 ISO Standards

Software quality is a fundamental factor that plays a crucial role in the usability of any software. It encompasses various attributes and characteristics that determine the overall excellence and usability of software systems. An essential component of a software is in its evaluation, and to ensure the required quality, it is important to measure the characteristics that enable the determination of software quality (Djordjevic 2017). It goes beyond absence of defects and encompasses broader standards that translate to reliability, effective solution, and customer satisfaction.

ISO standards are globally established guidelines developed by the International Organization for Standardization that provide guidance on best practices in various sectors, including quality management systems, environmental management, health, risk, and safety. These standards are regularly reviewed to ensure their applicability and relevance in a changing globalized environment (Majernik et al. 2017). The goal of ISO standards is to promote consistency, efficiency, and quality in products, services, and processes across different countries and industries.

The SQuaRE (Systems and software Quality Requirements and Evaluation) series, defined by ISO/IEC, comprises international standards that provide a comprehensive framework for measuring and evaluating quality. This framework, known as ISO/IEC 25000 SquaRE series, offers a set of objective and standardized criteria applicable to various domains and products. It encompasses essential quality characteristics, measurement values, and evaluation methods, enabling organizations to assess and improve quality effectively across their products and services (Tsuda et al. 2019).

Some of the several ISO/IEC standards concerning usability and usability evaluation include:

- **ISO 9241-11** – This standard by far is the most popular when it comes to usability testing and evaluation. It defines usability as the **effectiveness, efficiency** and **satisfaction** with which specified users can achieve specified goals under specified conditions (Gupta, Ahlawat 2019). As earlier mentioned, usability mainly comprises of attributes which include efficiency, effectiveness, satisfaction, learnability, memorability, and errors, however, according to Arthana, Pradnyana, Dantes (2019), errors, learnability and memorability are already embedded in efficiency, effectiveness and satisfaction.
- **ISO 9241-210** – It is an international standard that provides guidelines for the human-centered design of interactive systems. The purpose of ISO 9241-210 is to ensure that interactive systems are designed with the needs and capabilities of users in mind. The standard defines user experience (UX) as a range of user emotions, perceptions, and

behaviours that occur before, during, and after the use of a system, product, or software (Mirnig et al. 2015). It consists of general principles of human-centered design and activities section which provides specific guidelines for each stage of the design process.

- **ISO 9241-220 –** This is a standard that outlines processes for enabling, executing, and assessing human-centered design within organizations. It builds on ISO 9241-210, which provides a framework for human-centered design. The standard offers a comprehensive description of the processes required to support human-centered design activities (Bevan et al. 2016). These processes help organizations to develop products, systems, and services that meet users' needs and preferences.
- **ISO/IEC 9126 –** Software engineering — Product quality, outlines a comprehensive set of quality characteristics that can be used to evaluate the quality of software products The main objective of this ISO/IEC standard is to address common human tendencies that can have a negative impact on the delivery and perception of software development projects (Dragoljub Pilipović 2021).
- **ISO/IEC 25010** – The standard published by the International Organization for Standardization (ISO) and is titled "Software engineering – Software product Quality Requirements and Evaluation (SquaRE). It specifically addresses issues concerning systems and software quality. The standard consists of five divisions which includes Quality Management, Quality Model, Quality Measurement, Quality Requirements Division, and Quality Evaluation Divisions (Fukuzumi, Geis, Earthy 2022).
- **ISO/IEC 25062** – This is a standard for reporting the results of usability evaluations. It focuses on the evaluation of software documentation, such as user manuals, help files and evaluates the usability of software documentation in terms of these main criteria; accuracy, completeness, comprehensibility, and usability. The standard follows the CIF (Common Industry Format) components and format, which align with the ISO 9241-11 definition of usability, which is the ability of a product to be used by defined users to achieve specific objectives with effectiveness, efficiency, and satisfaction (Moumane, Idri, Abran 2016).

2.3 Usability Evaluation

The pivot of usability evaluation is to gather an overall assessment on how adeptly a software, application or device produces desired results and how users are pleased with that process.

Usability evaluation largely encompasses the testing of the accessibility of software or application from the users' standpoint with regard to the diverse features of the application and functionalities (Hussain et al. 2017). According to EL-firjani, Elberkawi, Maatuk (2017), it can also be defined as the way of measuring the extent to which an interactive system is simplified and pleasant to use with the aim of pinpointing the usability problems associated with it. It is important for applications to be designed to handle problems and errors in such a way that does not frustrate the user because satisfaction can be regarded as a paramount win for any software or web-based application (Mwangi, Kimani, Mindila 2019).

Usability evaluation is an iterative process, and multiple rounds of evaluation may be necessary to be conducted to continually improve the design of the software or product (Sharfina, Santoso 2016). By incorporating usability evaluation into the design process, designers can create products that are more user-centered and more effective at meeting the needs of their users. Usability evaluation can help to identify usability problems such as difficulties with navigation, confusing layouts, unclear instructions, and slow performance. By identifying and addressing these problems, the design of the system or product can be improved to enhance the user experience, increase user satisfaction, and improve overall effectiveness and efficiency.

Sizable number of researchers, including Barnum (2020), have proposed that the general steps involved in usability evaluation include the following;

- **Define the evaluation goals and research questions** – The first step is to define the goals of the evaluation and the research questions that need to be answered. This includes defining the target user group, the tasks that users will perform, and the context of use.
- **Select a usability evaluation method** – Depending on the research goals and objectives as well as the research questions, the appropriate evaluation method is to be selected. This could be one or more usability evaluation methods.
- **Recruit participants** – Participants should be representative of the intended user population and be willing to participate in the evaluation. Depending on the method, a sufficient number of participants should be recruited.
- **Develop evaluation scenarios and tasks** – Evaluation scenarios and tasks should be designed to assess the usability of the product or system. Tasks should be realistic, relevant, and challenging enough to elicit meaningful feedback from participants.

- **Conduct the evaluation** – This involves administering the evaluation method and collecting data from participants. The evaluator should ensure that participants understand the evaluation process and are comfortable with the tasks.
- **Analyze the data** – The collected data should be analyzed using appropriate statistical and qualitative methods. The evaluator should identify usability issues and prioritize them based on their severity and impact.
- **Report the results** – The results of the evaluation should be reported to the stakeholders, including the design team and management. The report should include a summary of the evaluation process, the findings, and recommendations for improvement.
- **Iterate and refine** – The findings of the evaluation should be used to improve the design of the product or system. The design team should iterate and refine the design based on the feedback received from the evaluation

2.4 Testing and Evaluation Methods

The objective of conducting usability testing and evaluation is usually to ascertain problems related to the design of the product, discover opportunities for product improvement and also to obtain information about the preferences of users (Moran 2019). There are two main types that usability testing or evaluation that could be conducted depending on and the objective of the study. They are; Formative and Summative evaluation (Generosi et al. 2022).

- Formative evaluation involves testing the usability of a system during its development phase. It is conducted to identify and address usability issues usually before the system is released to the end-users.
- Summative evaluation on the other hand involves testing the usability of a system after it has been developed and released to the end-users. The aim is to measure the effectiveness, efficiency, and satisfaction of the system in meeting user needs and expectations.

Methods of evaluation are series of structured activities aimed at gathering information on how end-users interact with a software product and the specific characteristics of the product that contribute to achieving a certain level of usability. Despite the existence of various classification schemes for usability evaluation methods, these methods according to (Lyzara et al. 2019), can be broadly divided into three main categories Usability Inspection, User-based Testing and Usability Inquiry.

- **Inspection-Based Methods** – Inspection(expert) methods involve expert evaluators or designers who assess the usability aspects of the software, typically user interfaces, without the involvement of real end-users. These methods are based on evaluating the conformance of the software with a set of predefined guidelines or standards to detect potential usability issues (Lyzara et al. 2019). Examples of inspection-based evaluation methods include;
    - **Heuristic Evaluation** – Heuristic evaluation is guided by heuristic principles to detect user interfaces that are contrary to these principles by assessing its compliance with a list of pre-established principles (Khajouei, Zahiri Esfahani, Jahani 2017). Heuristic evaluation is a quick and cost-effective method of identifying usability issues, but it usually does not involve actual users and therefore might not reveal real usability problems.
    - **Cognitive Walkthrough** – A cognitive walkthrough is a usability evaluation method that assesses the ease of completing tasks with a system by analyzing the actions and goals required to complete each task (Khajouei et. at., 2017). It typically involves evaluators who work through scenarios step-by-step and assess the ease of use, effectiveness, and efficiency of the product or system. During the walkthrough, the evaluators try to anticipate the user's thought processes and decision-making and identify any obstacles or confusing aspects of the design. The cognitive walkthrough method can provide valuable insights into the user experience and help improve the overall usability of the software.
    - **Expert Review** – Expert review involves a UX expert inspecting a system to identify potential usability issues. While the line between expert reviews and heuristic evaluations can be indistinct in some organizations, an expert review can be considered a broader form of a heuristic evaluation (Harley, 2018).
    - **Pluralistic Walkthrough** – A pluralistic walkthrough is an inspection method used for evaluating the usability of a product. The method involves a group of stakeholders with varying competence, such as users, management, and developers, who gather together to review the design. The main objective of the pluralistic walkthrough is to identify usability issues and gather diverse perspectives (Thorvald et. al., 2015).

- **Feature Inspection** – It evaluates both the function and design of a system to ensure it meets the needs of intended users. This method involves listing the sequences of features used to complete tasks and checking for issues such as cumbersome steps and steps that are unnatural for users. The goal is to assess the usability of the proposed features and identify areas for improvement (Aziz et. al., 2021).

- **User-Based Methods** – These methods involve observing or testing the product with actual users to evaluate its usability. The methods involve the collection and analysis of usage data from actual end-users. During testing, the end-users utilize the software product or prototype to accomplish a predetermined set of tasks while the tester records the results of their actions. Examples of user-based methods include;
  - **User testing** – According to Moran (2019), user testing, often interchangeable with usability testing, can be explained as a usability-testing session where a researcher, also known as a facilitator or moderator, requests participants to perform tasks on a user interface. The researcher closely observes and records the participant's behaviour and attentively listens for their feedback while they carry out each task. This method enables the researcher to gain insights into the participant's experience with the interface and identify any usability issues that may arise. The study of Jakub Nielson suggests that not more than five participants are needed for user testing as this number, according to his analysis is enough to disclose about 85% of usability issues (Susanto et. al., 2018).
  - **Think aloud** – The think-aloud method, according to Alhadreti, Mayhew (2018), is a commonly used protocol for evaluating website usability. Users are prompted to voice their experiences, thoughts, actions, and feelings as they interact with the interface. This allows for direct observation of user cognitive processes, which can be used to inform usability improvement strategies.
  - **Eye tracking** – Wang et al. (2019) explains the eye tracking method as a psychophysiological technique employed to gain deeper insights into the user's attentional and cognitive processes during usability testing. The researcher further pointed out that the eye-mind hypothesis is the central assumption behind the use of eye tracking in usability research, as it posits that visual attention patterns can provide valuable information about the cognitive

strategies utilized by individuals. This method is expensive and therefore not widely used.

- **Card Sorting** – This method involves presenting named cards, containing features of a system to groups of users, and asking them into categorize them in groups sensible to them. Card sorting can be conducted in three main ways: **open**; where users group cards into unnamed categories and then name them, **closed**; where groups of cards with predefined categories are provided, or **hybrid**; where groups of cards are presented with predefined categories, but users are allowed to make modifications (De Lima Salgado et al. 2019).

- **Usability Inquiry** – This a form of a user-based method, however, participants are not necessarily given predefined tasks to accomplish. It involves gathering feedback from users by directly monitoring their interactions with the system in real environment as they work (Lyzara et al. 2019). This approach aims to understand how users interact with the system, identify any real-time issues or challenges they encounter, and gather insights on how to improve the system's usability. Examples of this method of evaluation include;
    - **Questionnaires** – This can be explained as documented inquiries posed to participants with the aim of gathering feedback, insights, and observations regarding the usability of a product, service, or system. They are used for the evaluation of satisfaction, user acceptance, and quality (Hajesmaeel-Gohari et al. 2022). These questions are carefully crafted to assess the user's experience, identify shortfalls, and uncover areas for improvement. The questions can be closed or open ended and can cover a range of topics, including ease of use, clarity of instructions, navigation effectiveness, visual design, and overall user satisfaction. By asking targeted questions, it can help researchers and designers understand how well the product meets user needs and expectations to obtain valuable user-centred insights that can be used to enhance usability.
    - **Surveys** – A survey is a research method can also be used to collect usability information from participants. It involves systematically gathering information by asking a series of questions to assess opinions, behaviours, preferences, or characteristics. Surveys can be conducted through various mediums, such as questionnaires, online platforms, phone interviews, or in-person interactions (Kaipio et al. 2017). The findings obtained from surveys can greatly assist

decision makers to greatly assess current state of usability of systems and provide valuable information for enhancements.

- **Focus groups** – A focus group is a group interview format where participants engage in discussions on a specific topic, typically selected by the researcher or evaluator. It provides researchers with access to shared meanings, perceptions, opinions, and interactions in a collaborative atmosphere (Onocko-Campos et al. 2017). Focus groups present an avenue for users to express their judgements, preferences, and challenges openly. Through interactive discussions, participants can elaborate on their user experiences, highlight usability issues, suggest improvements, and engage in collective problem-solving. The group dynamic allows for the exploration of diverse perspectives, enabling researchers to gain a deeper understanding of the usability strengths and weaknesses of the system.

Other researchers also include a fourth usability evaluation method namely;

- **Model-based Methods –** In model-based usability testing also referred to as analytical modelling, participants are presented with these prototypes or models and are asked to perform specific tasks or scenarios that simulate real-world usage. The focus is on evaluating the user experience, ease of use, and effectiveness of the design based on the model. Analytical models are valuable in both design and usability evaluation due to the inherent complexity of the usability problem (Komarkova et al. 2017).

  In the field of human-computer interaction some commonly used techniques employed to analyze and understand user interactions with computer systems according to research of Struška (2017) include;

  - **GOMS Model** – It involves cognitive modelling to break down tasks into sub-parts and analyze the sequence of actions. The KLM-GOMS variant is particularly popular, estimating task times based on empirical values for operators like keystrokes and mouse movements.
  - **Design analysis** – This involves detailed descriptions of the user interface design, representing the user's knowledge at different levels of abstraction.
  - **Knowledge analysis** – It utilizes formal assessments and grammars to identify and transform the knowledge used in the design and development of user interfaces. These techniques aid designers in creating effective and user-friendly interfaces.

2.5 Web-Based GIS Applications Managed By Public Administration Authorities

There has been a growing interest in evaluating the usability of web-based applications even in the domain of public administration.

Some notable research include one conducted by Verkijika, De Wet (2018) on A Usability Assessment Of E-Government Websites In Sub-Saharan Africa. The researchers used heuristic evaluation and automated testing for its study, and it was discovered that e-government websites in Sub-Saharan Africa (SSA) have poor usability with respect to the dimensions of online services, user-help and feedback, navigation, and content. Additionally, it was identified that there is a need for improvement in the provision of accessibility features and mobile device compatibility on SSA e-government websites.

Another study by Milosz, Chmielewska (2020) titled, Usability Testing Of E-Government Online Services Using Different Methods–A Case Study was performed employing the methods of usability testing i.e., user testing and eye tracking, and usability inquiry i.e., questionnaire. This research, on the e-government online services in Poland identified several usability issues such as low visibility of the help function, confusing navigation, and lack of clear and concise information on the website

Web-based GIS applications have become increasingly important tools for public administration, providing access to important geographic data and analysis tools for its users. However, the usability of such applications is crucial for their effective use, and yet there has been relatively little research on usability evaluation specifically for web-based GIS applications managed by public administrations. Given the importance in supporting decision-making processes for public administration, it is imperative to ensure that these applications are very usable. Therefore, this research incorporates Web-Based GIS Applications managed by public administration authorities in its study to add to the body of knowledge in this domain.

3. MATERIALS, METHODS AND PROPOSED PROCEDURE

The aim of this thesis is to propose a suitable procedure to evaluate the usability of chosen Web-based GIS applications incorporating applications managed by public administration authorities. The world of web-based GIS applications is teeming with a multitude of options, each offering unique features and functionalities. However, for this study, the researcher chose to focus on geoportals as a specific representative of web-based GIS solutions.

The rationale behind this choice stems from the researcher's interest in exploring the geoportals within the context of Central Europe. That is, Czech Republic and its neighbouring countries: Poland, Germany, Austria, and Slovakia, along with their respective capital cities: Prague, Warsaw, Berlin, Vienna, and Bratislava. Critical aspects that justify the focus on these geoportals are that not much study has been conducted to assess the usability of these selected public administration geoportals.

Also, they are comparable because they are all in Central Europe and part of the European Union therefore subject to similar governmental regulations. Furthermore, they cater to a similar target group of end users and examining its usability can inform the development and enhancement of effective, efficient and user-centric web-based GIS applications for public administration in the region.

The rest of this chapter outlines the objectives of the research and the planned methodology, procedure and conduction of the test, excluding the analysis of the results which is detailed in chapter 4. Chapter 5 focuses on discussing the obtained results and providing recommendations, while chapter 6 presents the conclusion of the study.

3.1 Research Objectives

With respect to the aforementioned aim, the research objectives and questions were formulated as follows:

1. To identify key criteria based on literature review that is necessary for the usability evaluation of selected public administration geoportals.
2. To design an effective and qualitative procedure for evaluating the usability of selected public administration geoportals.
3. To implement the designed procedure to ascertain key usability issues associated with the chosen public administration geoportals.

4. To learn and recommend solutions to the identified usability issues with the selected public administration geoportals.

   In setting these objectives, the researcher aims to design a procedure that is cost-effective, with respect to time efficiency and simplicity, ultimately leading to the identification of key usability issues and recommendations. This proposed procedure when adopted by public administration authorities will help to identify key usability issues provide and provide recommendations that will significantly improve the usability of web-based GIS applications resulting more user-centric design and enhanced user satisfaction.

3.2 Research Design

The research design serves as a systematic plan, outlining the approach and methods for the study. Acting as a blueprint, it guides data collection, analysis, and interpretation of the results, ensuring effective achievement of the set research objectives. Building on the study of Barnum (2020) as discussed in section 2.4 of this research, the methodology of this study shall adhere to the following sequence.

It follows essential steps to evaluate the selected public administration geoportals. It begins with a summary state of art, develops key evaluation criteria, and employs the necessary testing methods. A well-structured test design guides the data collection process is employed. Then, analysis of the data which provides insights into user experiences and identifies usability issues. Practical recommendations are offered to address these issues. Finally, provision of meaningful insights for improving the understudied web-based GIS applications and then a conclusion of the study.
This is depicted in figure 4 below;

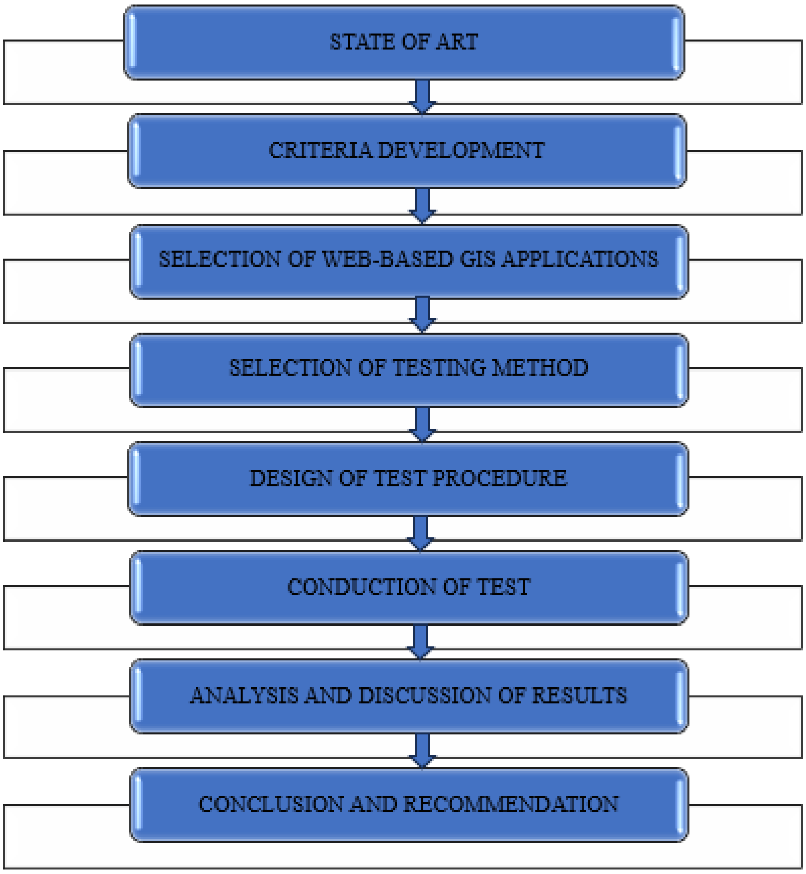


Figure 3: The Methodology Of this Study

Source: Author's own creation

3.3 State of Art

The researcher meticulously examined relevant scholarly materials from reputable digital sources such as IEEE, ACM, Web of Science, and Science Direct, among others. There was enormous and insightful information gathered, that enlightened the researcher and aided this the conduction study. Outlined below is a summary of some key lessons learned.

According to the study of Komarkova et al. (2019) on Usability Evaluation the Prague Geoportal Comparison of Methods, it was revealed that user testing is more effective in identifying severe and critical usability problems compared to heuristic evaluation. That is, while heuristic evaluation may highlight relatively minor "cosmetic" usability issues, user testing provides a deeper understanding of critical problems that significantly impact the overall user experience.

In the study of Milosz, Chmielewska (2020) on Usability Testing Of E-Government Online Services Using Different Methods- A Case Study, an important identified approach that is crucial to the study of usability evaluation conducted was the utilization of user personas that allowed the researchers to represent the end users and simulate real-world scenarios effectively. By testing with these identified personas, the research gained valuable insights into practical usability issues and their impact on user experience.

Also, in the research of Momenipour et al. (2021) on Usability of State Public Health Department Websites for Communication During a Pandemic: A Heuristic Evaluation, it was highlighted that heuristic evaluation is reliant on experts and may be perceived as subjective. Nonetheless, a combination of methods, including user testing, highlights more realistic usability issues, providing a more comprehensive and objective assessment of the system's usability.

Furthermore, the study of Nugraheni, Oktakhania, Noranita (2023) concerning the Usability Evaluation of Prakerja Card Website discovered that, age is a critical factor to consider in software development, as usability issues may vary across different age categories. What might be usable and intuitive for one age group could present challenges or be less effective for another.

Additionally, in the research of (Benaida 2023) on E-Government Usability Evaluation: A Comparison between Algeria and the UK, it was highlighted that user satisfaction is a key criterion and is critical to web design irrespective of the domain, therefore it is vital for expectations of users to be met by every developer.

These gained insight contributed immensely to the progress of this study.

3.4 Development of Criteria

To obtain the criteria for this study, the researcher put together and reviewed twenty-six selected research articles published over a period of ten years, that is, from 2013 to 2023. These research articles were primarily focused on usability studies concerning web-based GIS applications, geoportals, e-government websites, and other applications mainly associated with public administration. This was aimed to comprehend the evolving trends of usability evaluation methods within the public administration domain, and also to gain insight about the most discussed and key usability criteria used in their research.

Moreover, much emphasis was placed on recent studies to gather knowledge on the key criteria used in the evaluation and usability issues observed. In effect, six out of the twenty-six were research articles published from the period of 2013 to 2018, and to focus on more recent study, twenty out of the twenty-six research articles were from the period 2019 to 2023.

In the comprehensive study of these twenty-six articles, the narrative review approach was employed to identify, select, and synthesize these relevant articles and to chronologically spell out existing research on usability evaluation and its methods. This is depicted in Appendix A. The narrative review method involves qualitatively summarizing previously published articles and conducting a chronological, or thematic analysis with the primary objective of providing readers with an updated understanding of the existing knowledge pertaining to a particular topic (Ansari, Barati, Martin 2022)

These articles provided a wealth of knowledge, resulting in the identification and compilation of over one hundred usability issues and criteria. Through careful analysis, this extensive list was subsequently narrowed down to fifty key criteria which was then grouped into five major criteria that best encapsulated their main essence as shown in the Appendix B. This was done by eliminating all duplicate criteria to extract the most informative features and reduce the dimensionality of the data for easy analysis.

This principle was employed to condense multiple variables into a smaller set of principal components, making the data more manageable. The original variables are not discarded but rather reorganized and represented in a reduced form (Dugger et al. 2022). The analysis reduced the usability criteria into five major categories which were selected as the parameters to be used to perform usability evaluation for the selected web-based GIS applications. The derived five criteria to be used for this usability evaluation for the selected geoportals include:

i) Functionality
ii) Performance
iii) Cognizability
iv) User-centric Design
v) User Experience

- **Functionality** – The concept of functionality holds significant importance, and it is often equated to usability by many computer designers. Functionality is the quality and the degree to which an application operates according to its intended structure and performs as users' desire (Tandon, Kiran, Sah 2016). It encompasses a list of desired features aimed at fulfilling the needs of end users. Khan, Adnan (2010) emphasizes that functionality goes beyond the availability of necessary functions and also entails simplicity, enabling even non-experts to utilize the system effectively. These researchers further explain that functionality directly correlates with effectiveness which measures the accuracy functionality of in achieving goals considering the error proneness of the system. In the context of this research, functionality encompasses both effectiveness and errors as key considerations.
- **Performance** – System performance encompasses various factors, including user perceived system response time, reliability, extensibility, and service quota (Yang & Evans, 2017). The focus definition, for the purpose of this study is the user perceived system response time. It refers to the ability of a system to efficiently deliver accurate results with minimal resource utilization and at optimal speed. Implicit in this definition is the concept and measurement of efficiency, which pertains to how quickly goals can be accurately achieved.
- **Cognizability** – Cognizability by definition, refers to the ability of something to be knowable by the mind (Przybyslawski 2016). It refers to how well a product or system can be clearly identifiable, perceived and understood by users. Cognizability is connected to learnability, which involves how users easily accomplish tasks upon initial encounter, and memorability, which is how users quickly reengage with the system effortlessly after a break. (Alzahrani, Gay, Alturki 2022). A highly cognizable system leads to improved learnability and memorability, enhancing the overall user experience.
- **User Centric Design** – The philosophy of user-centric design serves as a pathway to creating a more effective system. It revolves around shaping the system's interface to align with the capabilities and needs of the users. This approach integrates a layout that supports the goals and tasks of the end users, ultimately leading to improved user acceptance and satisfaction (Endsley 2016).
- **User Experience** – One widely recognized definition of user experience is provided by ISO 9241-210, which is explained as an individual's perception and response that arises from the actual or anticipated use of a product, system, or service. It emphasizes that

user experience encompasses various aspects, including emotional, cognitive, and physical reactions, whether they occur before, during, or after the use of the product, system, or service (Hinderks et al. 2019). Thus, user experience is viewed as a comprehensive concept that encompasses the entirety of the user's engagement and interaction with the product.

It is noteworthy that, the definition and constituents of the five developed criteria in this study tally with definition of usability evaluation according to the definition of usability by both ISO 9241-11, which is effectiveness, efficiency and satisfaction and that of Nielsen (2012), which is learnability, effectiveness, errors, memorability and satisfaction. These definitions constituents have been earlier discussed in Chapter 2 of this study. This is depicted in figure 4 below.

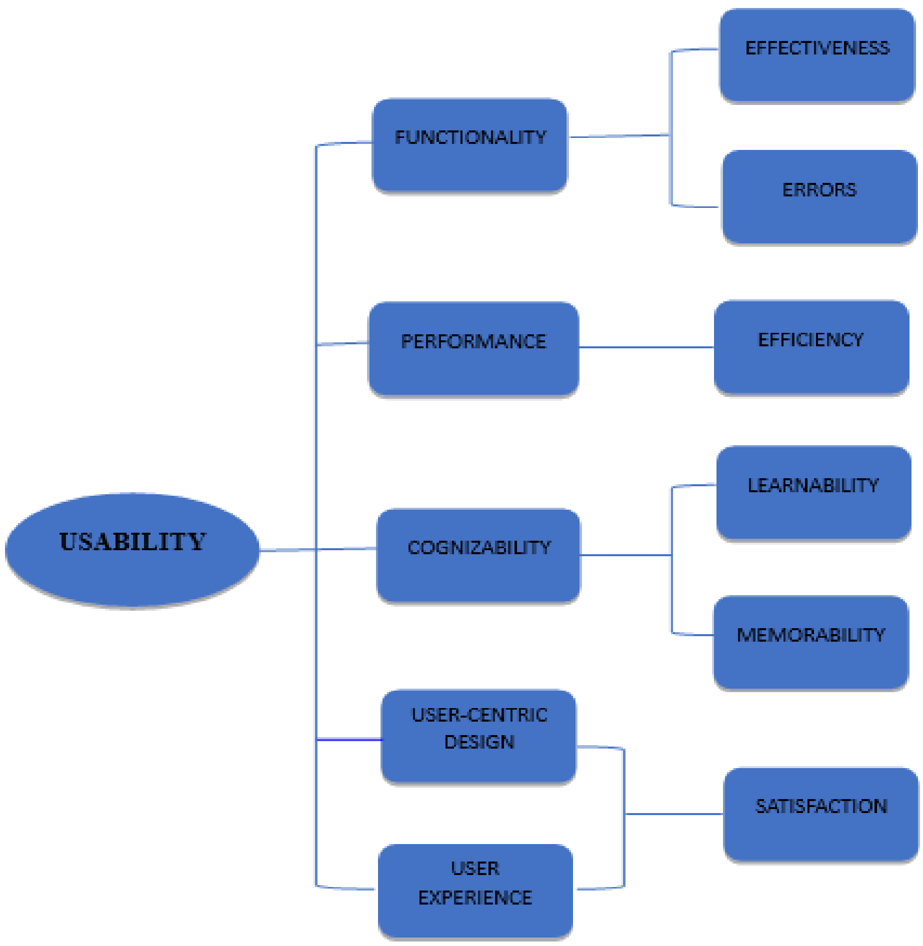


Figure 4: Relationship Between Developed Criteria And ISO/ Nielsen

Source: Author's own creation

3.4 Selection Of Web-based GIS Applications

Public administration authorities have the crucial responsibility of providing quality geospatial information to the public including foreigners, considering especially their reliance on such data for navigation, tourism and other businesses. Geoportals, equipped with comprehensive maps and spatial data, play a pivotal role in fulfilling these responsibilities. A geoportal is a specific type of web portal that serves as a centralized platform for locating, accessing, and utilizing geospatial information and related geographic resources. It provides users with a range of functionalities such as data visualization, editing capabilities and other tools and services specific to geospatial data (Singh, Mukherjee, Mukherjee 2021).

Geoportals are designed to cater to a wide range of end users, especially for users that are non-experts in GIS. While geoportals do provide more advanced tools and functionalities beyond applications like Google Maps, they also aim to the platform usable and accessible to a broader audience, including individuals from various disciplines without a GIS background, by offering usable interfaces, intuitive map viewers, and simplified tools to explore and interact with geospatial data (Singh, Mukherjee, Mukherjee 2021). These portals often provide basic functionalities such as searching for specific locations, viewing maps, and downloading data without requiring extensive GIS knowledge.

The researcher chose ten geoportals managed by public administrations, which are that of the Czech Republic and its four neighbouring countries including their capital cities, to perform a usability evaluation and comparative analysis. The focus on these geoportals is justified by the lack of extensive usability studies conducted on these selected public administration platforms. Additionally, their comparability lies in their location within Central Europe and membership in the European Union, making them subject to similar governmental regulations. Moreover, these geoportals cater to a common target group of end users, emphasizing the significance of examining their usability.

The objective is to ascertain the key usability problems associated with their maps that are encountered by foreigners and recommend suitable solutions. This was to be achieved by designing a qualitative procedure that is cost effective with respect to simplicity, timesaving, and is efficient and effective, that could be adopted by public administration authorities for usability evaluation to reveal key usability issues.

Taking into account these central European countries, it is paramount for the adherence of the Infrastructure for Spatial Information in Europe (INSPIRE) directive, enacted by the European

Union, to be imperative to ensure the provision and sharing of high-quality and reliable geospatial information in terms of spatial data infrastructure (Tavana et al. 2023). The responsibility of public administration in this regard stems from the understanding that foreigners heavily depend on accurate and up-to-date geospatial information for navigating unfamiliar territories and maximizing their tourism experiences and for any other related purpose.

In accordance with stages of consumption in tourism, applications used for tourism can be categorized into three groups. Firstly, pre-consumption, which involves planning and destination decision making. Secondly, consumption which involves it being used for connection, navigation and other decisions in the short-term. The third stage, which is the post consumption stage, is used for documentation, sharing and reexperience (Garcia-Lopez et al. 2021).

By delivering reliable maps and geospatial data that satisfy these consumption needs, public administrations can contribute to the seamless navigation and exploration of their region by foreigners. This does not only enhance their satisfaction but also positively impacts the country and promotes its' image as a visitor-friendly destination.

The list of selected web-based GIS applications are contained in table 2 below;

COUNTRY	**GEOPORTAL**	**CAPITAL**	**GEOPORTAL**
Czech	https://geoportal.gov.cz/web/guest/home	Prague	https://www.geoportalpraha.cz/en
Germany	https://www.geoportal.de/	Berlin	https://www.berlin.de/
Poland	https://www.geoportal.gov.pl/	Warsaw	https://warszawa.e-mapa.net/
Slovakia	https://www.geoportal.sk/en/	Bratislava	https://geoportal.bratislava.sk/
Austria	https://www.geoland.at/	Vienna	https://www.wien.gv.at/stadtplan/en/

Table 2: A list of selected Web-based GIS Applications And Their Hyperlinks

Source: Author's own creation

It is worth noting that, all the above listed websites are the official government geoportals for the selected countries and their respective capital cities expect for Warsaw, whose official geoportal https://mapa.um.warszawa.pl/ is not functional. A search for alternatives resulted in two geoportals, https://warszawa.e-mapa.net/ and https://geoportal360.pl/14/warszawa/. The first geoportal, https://warszawa.e-mapa.net/ was chosen and the second geoportal https://geoportal360.pl/14/warszawa/ was rejected because its functions are to limited to conduct any meaningful study.

3.5 Selection of Testing Method

Following a thorough review of literature, the researcher faced the decision to select the most appropriate evaluation method among four commonly used options that is, user testing, heuristic evaluation, questionnaire, and analytical models. In effect a Multi-Criteria Decision Making (MCDM) was employed to make a well-informed decision.

Multi-Criteria Decision Making (MCDM) is a systematic approach to solving problems that involve several criteria. It aims to evaluate and compare different solutions, taking into account various conflicting criteria. MCDM involves a rigorous analysis using mathematical and analytical methods, such as the Analytic Hierarchy Process (AHP), to assess the outcomes systematically and objectively (Kumar et al. 2017). This method, rooted in mathematics and psychology, ranks and prioritizes alternatives in complex scenarios, enabling well-informed and rational choices through pair-wise comparisons. By organizing and evaluating alternatives based on multiple criteria, it enhances decision accuracy and reliability. (Tavana et al. 2023).

The method consists of three parts, namely, the goal, which is the problem statement that needs solution, alternatives which is the lists of all possible answers or solutions, and lastly, the criteria, which is used for the judgement of the alternatives.

In this MCDM, our goal is to select a suitable usability evaluation method to effectively analyze selected web based GIS applications for public administrations. Our criterial include functionality, performance, cognizability, user-centric design and user experience. Our alternatives are user testing, heuristic evaluation, questionnaire, and analytical models.

Below in figure 6 is a diagram depicting the goal, criteria and alternatives for this study;

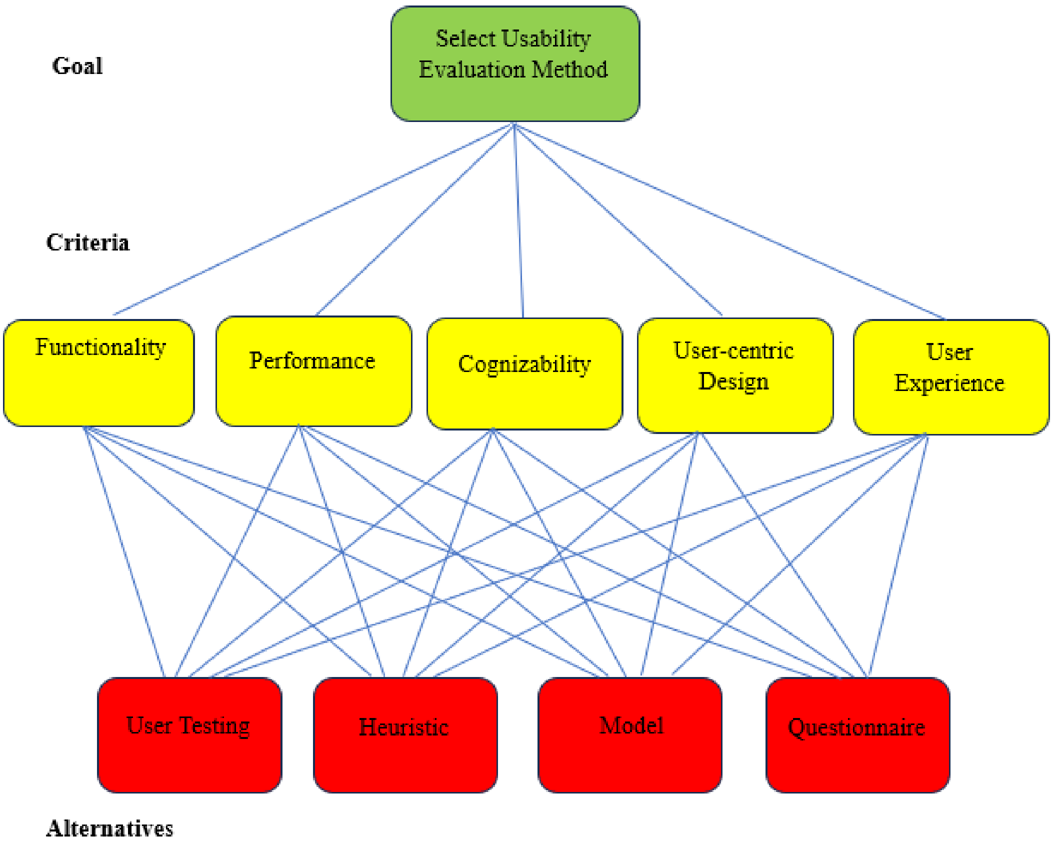


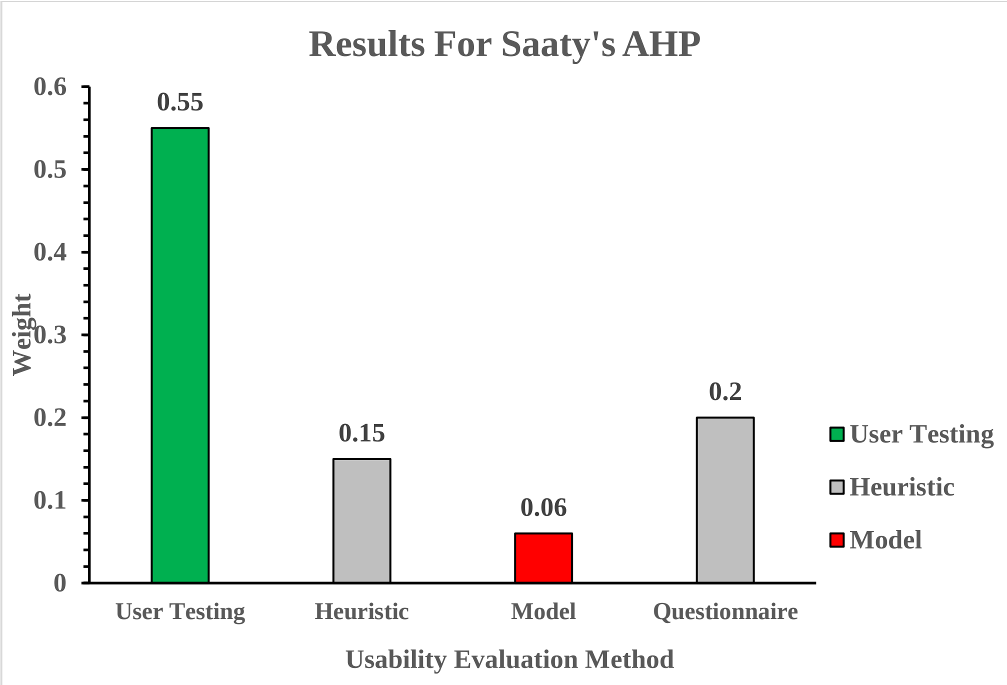
Figure 5: MCDM Process Using Saaty's AHP

Source: Author's own creation

After conducting the MCDM analysis using Saaty's AHP. It was determined that user testing emerged as the most suitable method for evaluating the usability of the system.

User testing, as a usability evaluation method, involves observing and gathering feedback from users while they interact or perform tasks with the system (Moran 2019). This method provides valuable insights into how users perceive and navigate through the interface, identify any usability issues they encounter, and measure their overall satisfaction with the system. By selecting user testing as the preferred usability evaluation method, the study aims to directly involve users in the evaluation process, gaining first-hand feedback and understanding their perspectives. This approach uncovers specific usability problems, assesses the effectiveness and efficiency of the system to gain insights for potential improvements.

Below in graph 1 is a representation of the results from the Multi Criteria Decision Making using Saaty's Analytical Hierarchy Process



Graph 1: Results Of Saaty's AHP MCDM

Source: Author's own creation

From the graph above it can be seen that the results show that User Testing method is the most appropriate method with a suitability of about 0.55 or 55% a model-based method is the least suitable with a suitability of 0.06 or 6%.

The findings of many researchers including (Momenipour et al. 2021) illustrate that a combination of methods, which is a combination of methods including user testing highlights more realistic and key usability issues. Because one of our objectives for this research is to identify key usability issues of the selected geoportals, the researcher adopted a combination of evaluation methods by infusing the user testing method with the think aloud protocol and questionnaire for a more robust evaluation and to help achieve this objective.

Also in this study, the researcher adopted a mixed methodology that involved both qualitative and quantitative methods. The qualitative results were primarily obtained from the literature review, while both quantitative and qualitative data were collected through questionnaires, think-aloud sessions, and user testing observations. Although the study utilizes both approaches, the focus is placed primarily on the qualitative study as the main emphasis (Khan, Adnan 2010).

3.6 Selection of Participants

According to research conducted by Jakob Nielsen and Tom Landauer, it has been found that testing a system with just five users can reveal approximately 85% of usability issues. In the study it was discovered that the most effective results are often obtained by conducting testing with a small number of users, preferably not more than five. Adding more participants will result in identifying menial problems similar to the ones already discovered by the five participants (Susanto, Prasetyo, Astuti 2018). This is shown in figure 8 below;

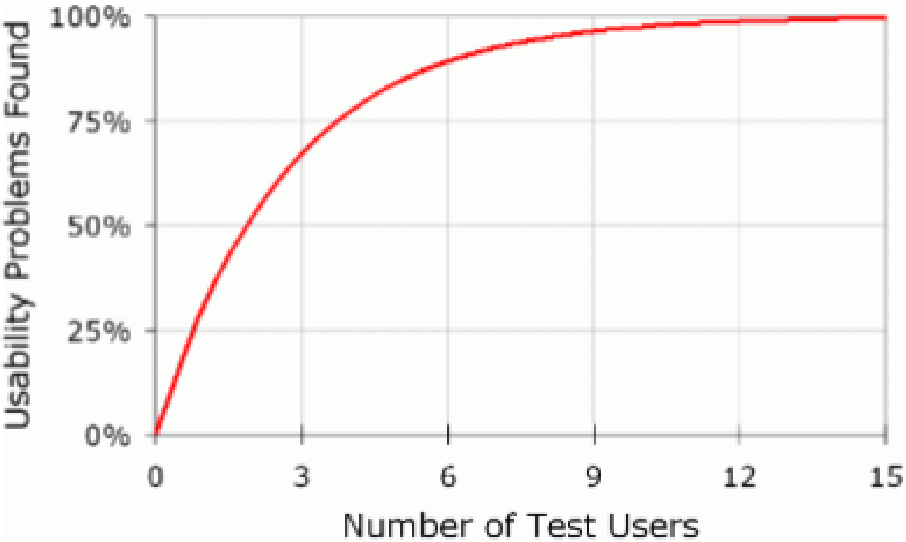


Figure 6: Number Of Testers And Their Corresponding Usability Problems

Source: (Susanto, Prasetyo, Astuti 2018)

From figure 8 above, it can be seen that zero testers lead to zero usability problems found while five testers depict about 85% of usability issues discovered. In light of this, and for the purpose of this study, six participants that are foreigners were recruited with the expectation of uncovering close to 90% of the usability issues associated with the chosen public administration geoportals. The selection of participants was random and based on their availability.

The participants were selected from the Faculty of Economics and Administration and the Faculty of Arts and Philosophy at the University of Pardubice, encompassing a range of educational levels from Bachelor to PhD. All of participants are foreign students. One participant did not have a GIS background but was familiar with similar applications like Google maps and Mapy.cz.

Table 3 below is a representation of the demographics of the participants;

PARTICIPANT	GENDER	FACULTY	EDUCATIONAL LEVEL	NATIONALITY
A	Male	Economics and Administration	Bachelor	Ghanaian
B	Female	Economics and Administration	Master	Ethiopian
C	Male	Economics and Administration	Master	Ethiopian
D	Female	Economics and Administration	Master	Burmese
E	Female	Economics and Administration	Master	Zimbabwean
F	Female	Arts and Philosophy	PhD	Azerbaijani

Table 3: The Demographics Of The Participants

Source: Author's own creation

3.7 Design Of The Test Procedure

The procedure of the test was designed inspired by the concept of the researchers (Khan, Adnan 2010). This was adopted because it is specifically designed for evaluating web-based GIS applications, aligning with the researcher's objectives and aims. This procedure was deemed suitable to facilitate the achievement of the research objectives effectively. The proved invaluable in identifying critical issues related to the geoportals and provided the researcher with the opportunity to observe the interaction of different user types, including those with and without a GIS background.

3.7.1 Tasks and Scenarios

The tasks for the evaluation of the geoportals were carefully crafted based on extensive study of relevant literature and designed to effectively measure the selected criteria, namely Functionality, Performance, Cognizability, User-Centric Design, and User Experience. These criteria served as the foundation for creating tasks to effectively assess the usability of the chosen public administration geoportals.

A total of 15 tasks were prepared each for the geoportals of the selected countries and also for the geoportals of the selected capital cities. The 15 scenarios were crafted specifically to test the criteria Functionality, Performance and Cognizability. All 15 tasks were used to assess the

Functionality of the geoportals while 5 tasks each from the 15 were used to assess Performance (highlighted in green) and Cognizability (highlighted in blue). Because of the limited functionality of the geoportal of Berlin, tasks 5 and 6 were used to test both for Performance and Cognizability. Table 4 and 5 below depict tasks and scenarios for the geoportals of selected countries and their capital cities respectively;

	ALL TASKS FOR GEOPORTALS OF SELECTED COUNTRIES
	Use the web search engine to find each country's Geoportal
1	Launch the Application
2	Convert to English version
3	Locate and load the online map
4	Scroll to locate the capital city of the country
5	Switch map to Orthophoto/aerial map
6	Zoom to any landmark within the country
7	Measure the distance between any two points
8	Display a specific point of interest of your choosing
9	Turn on/off administrative boundaries
10	Display coordinates of any location within the country
11	Locate scale and change to a measurement of your choice
12	Locate the legend of the map
13	Locate the print button
14	Bookmark or highlight any location for future reference
15	Create link/Share/Export map
	End of Tasks

Table 4: A table depicting tasks for user testing of selected countries

Source: Author's own creation

	ALL TASKS FOR GEOPORTALS OF SELECTED CAPITAL CITIES
	Use the web search engine to find each capital city's Geoportal
1	Launch the Application
2	Convert to English version
3	Locate and select the online map
4	Zoom to any street within the capital city
5	Display a specific point of interest of your choosing
6	(Browse the address of any hospital) use search field to locate it on the map
7	Measure the distance between two any points
8	Display coordinates of any location within the city
9	Turn on/off administrative boundaries
10	Switch map to Orthophoto/aerial map
11	Locate the print button
12	Bookmark or highlight any location for future reference
13	Locate scale and change to a measurement of your choice
14	Locate the legend of the map
	Create link/Share/Export map
	End of Tasks

Table 5: A table depicting tasks for user testing of selected capital cities

Source: Author's own creation

3.7.2 Measurability of Criteria

In accordance with the definitions of the selected criteria discussed in section 3.4 of this study, the following metrics were set as a means of measurability for these criteria:

- **Functionality** – The metrics that were used for the measurement of this criterion include the available features of the selected geoportal, the time taken to all complete tasks, the success rate, the error rate of tasks and the accuracy of task outcome.
- **Performance** – The metrics that were used for the measurement of this criterion include user perceived response time with respect to the load times of the geoportals in response to functions executed. These included time taken for the application to launch, time

taken for the map to load and also time taken for selected layers within the application to display.

- **Cognizability** – The two dimensions of this criterion are learnability and memorability. For learnability, which is how users easily accomplish tasks upon initial encounter the metrics of measurability used include initial time taken to complete selected tasks, success rate, the error rate of tasks. And for memorability, which is how users quickly reengage with the system effortlessly after a period of non-use, participants had to retake some chosen tasks to test their memorability. The metrics of measurability used include time taken to redo selected tasks, success rate, the error rate of tasks.
- **User-centric Design and User Experience –** These criteria in our study measures user satisfaction of the selected geoportals. User satisfaction is a latent variable, which means it is a type of variable that cannot be directly measured or observed but is instead inferred from other observable variables (Sinha, Calfee, Delucchi 2020). They are usually categorical very subjective, therefore a questionnaire consisting of 10 questions for each country and city, utilizing a 5-point Likert Scale (strongly agree-5, to strongly disagree-1) was employed to measure these two criteria.

3.7.3 Testing Equipment

The usability test was conducted in a controlled setting, utilizing an HP Laptop with AMD Athlon Silver 3050U processor and Radeon Graphics running at 2.30 GHz, equipped with 8.00 GB of RAM and system type being 64-bit operating system, x64-based processor. Installed on the laptop was Windows 11 Home, Version 22H2. The participants were also provided with a Logitech mouse M185 for interaction with the laptop. Chrome was the web browser used to launch all geoportals.

3.7.4 Testing Environment

The test was meticulously conducted the same controlled environment to eliminate any potential disturbances or interruptions so as to enable the full concentration of the participants. Consistency was ensured by utilizing the same control room for each of the six participants. Additionally, each participant was separately tested, primarily due to the implementation of the think-aloud protocol so as to allow the researcher to specifically capture and note the thoughts and concerns expressed by each participant regarding the geoportals.

3.7.5 Questionnaire

The user-centric design and the user experience criteria of this research represent the satisfaction of our users, in this case the participants. Here, user-centricity encapsulates user-centeredness of the layout or presentation and overall ergonomics of the selected web-based GIS applications, user experience encompasses the entirety of the users engagement and interaction with the geoportals.

The questionnaire consisted of ten questions, each utilizing a 5-point Likert scale (strongly agree-5 to strongly disagree-1) based on the System Usability Scale (SUS). SUS is regarded as a quantitative example of a qualitative user experience (Saeidnia et al. 2022). This scale allowed the participants to rate their perceptions and experiences regarding the User-centric Design and overall User Experience of the geoportals. By incorporating the questionnaire, valuable subjective feedback was obtained to complement the data collected during the usability test.

The questionnaire was prepared using Google Forms and was sent to the participants' email addresses. They were instructed to fill out the questionnaire after the completion of the test. The first five questions of the questionnaire ascertained participants perception concerning the User-centric Design of the geoportal and the subsequent five question tests their Experience with the systems. The set of questions for the questionnaire are shown in section 3.7.1 of this study.

3.7.6 Pilot Study

Prior to conducting the main testing phase, a pilot study was carried out involving two participants, the results, however, are not included in this study. The purpose of the pilot study was to assess the feasibility of tasks and scenarios and to uncover any potential shortcomings that could impact participants in taking the actual test. Although the results of the pilot testing are not specifically discussed in the main results, they greatly aided the authors in putting certain parameters in place.

These included the preparation of a participant's guide to be read by all participants before commencing the test. It informed the participants to on what to do which included utilizing the help button of the geoportals if need be, and also to skip tasks they found too difficult or too long to carry out. The time limit set here was three minutes.

Through the pilot study, the researcher also came to a realization to allow the participants a time period of up to five minutes for the participants to familiarize themselves with tasks and environment, and also ask questions before commencing. This ensured understandability, so that the participants in the actual testing phase encounter minimal difficulties.

The researcher gained insights from the pilot study, recognizing that participants improved in task performance as they progressed through the multiple geoportals. To prevent biasness in the actual test, the order of the geoportals was systematically rotated. This approach was implemented to ensure a fair and unbiased evaluation during the main testing phase.

3.8 Conduction Of The Test

Prior to the test, the researcher verbally and meticulously explained the procedure involved in carrying out the tasks. The participants were given a five-minute period to familiarize themselves with the procedure and tasks at hand. There were also given a participants guide to help them adequately prepare for the tasks. They were encouraged to employ a “think aloud” protocol, which involved expressing their thoughts and impressions about the geoportals.

There was a total number of fifteen tasks to be performed on each country and each capital city geoportal by the participants. In effect each of the six participants completed a total of ninety tasks across all ten selected public administration geoportals aside the tasks retaken for the measurement of memorability aspect of the cognizability criteria.

The duration of each task execution was measured using a timer to assess the period it takes for task execution. In addition to the usability test, the participants were also requested to complete and submit a questionnaire, shown in Appendix I. The time taken averagely by each participant to complete the tasks for each geoportal was approximately 13 minutes. In effect, each participant spent an average of about 2.2 hours to complete all tasks and fill questionnaire for both the countries and the cities.

4. ANALYSIS OF RESULTS

According to this study, usability of the selected public administration geoportals are being assessed through the lenses of the criteria; Functionality, Performance, Cognizability, User-centric Design and User Experience. Tasks prepared for the participants were on the basis of these parameters. A total of 15 tasks were to be completed by six participant for each country and city. This brings to a total of ninety questions for each geoportal by all participants put together.

After the tasks were completed, the results recorded were taken for further analysis. Content analysis were conducted to highlight the key usability issues associated with the geoportals. This method provides a versatile approach that accommodates both inductive and deductive strategies of analysis, making it suitable for integrating qualitative and quantitative analyses seamlessly (Michaela Gläser-Zikuda 2020).

Descriptive statistics specifically the median was also employed to describe the main characteristics of the dataset and questionnaire obtained and to give a clear and concise overview. Descriptive statistics refers to a concise summary of key information that describes the fundamental characteristics of a dataset. It involves providing a brief overview of the data by calculating measures such as the mean, median and standard deviation (Mishra et. al., 2019). The median was specifically chosen because of the small sample size and the median value is robust and not influenced by outliers (Berger, Kiefer 2021).

4.1 Functionality

According to this study, this criterion assesses the effectiveness and error tolerance of our selected geoportals, and therefore, this criteria can be said to have been achieved if targeted or intended goals get accomplished as previously planned, (Kuswati 2019), taking into consideration slips and mistakes (Laubheimer 2015). It embraces all functionalities and features incorporated into the geoportal to make the application operable. It further shows how easily accessible these functions are and how easily they can be used to complete tasks. The available features of the selected geoportal, the time taken to complete tasks, the success rate, the error rate of tasks and the accuracy of task outcome.

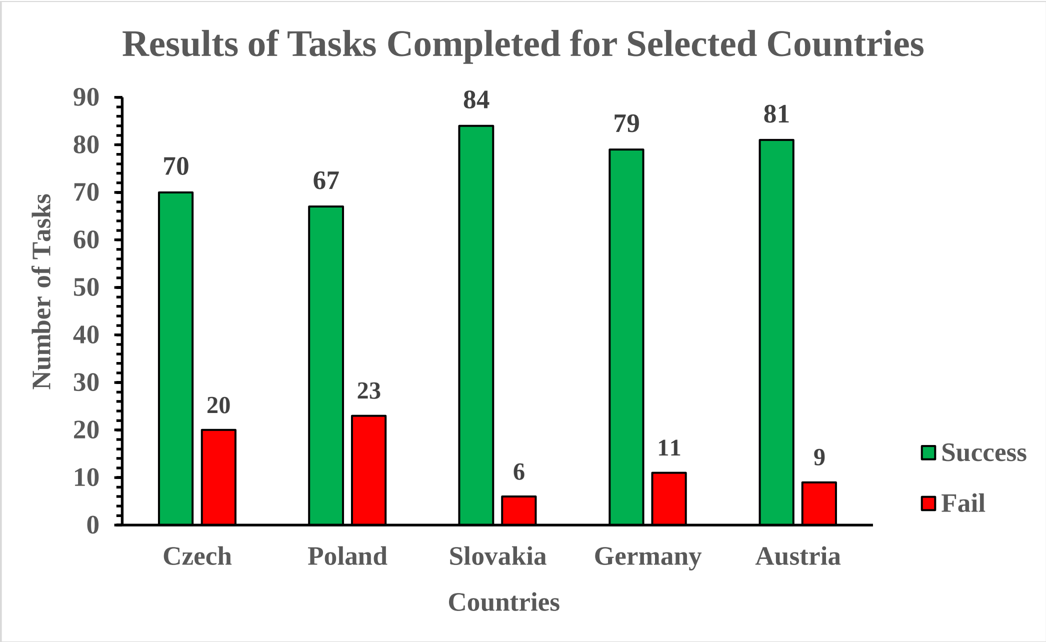
Table 6 and 7exhibited in Appendix U is a summary of the number of unsuccessful participants of the tasks executed for the geoportals of both selected countries and their capital cities respectively;

From the tables above, the most challenging tasks, listed in order of importance according to the participants, are as follows:

- **Display points of interest** – The geoportals of Berlin and Slovakia does not offer this functionality. Participants found it challenging to locate it on other geoportals.
- **Bookmark** – Poland, Prague, and Warsaw lacked dedicated icons for this feature. Participants encountered difficulty in finding this functionality on other geoportals as well.
- **Create link/Share/Export map** – This feature for the geoportals of Poland, Austria, Prague were too concealed for the participants. The geoportal of Czech does not have a dedicated feature for this functionality.
- **Legend** – The legend button on the geoportal of the Czech Republic was extremely difficult for participants to find, as it was too small and hidden.
- **Turning on/off administrative boundaries** – Participants found this functionality hidden and difficult to locate. The geoportal of Berlin lacks this feature.
- **Locate print button** – To the participants this functionality was too out of sight and difficult to find. The geoportal of Berlin lacks this feature.
- **Locate and load map** – The participants encountered difficulty in finding this feature on the geoportal of Berlin, as it was hidden at the bottom of the homepage.
- **Switch to orthophoto/aerial map** – Participants found this functionality concealed and difficult to locate. The geoportal of Berlin does not have this feature.
- **Distance measurement and display of coordinates** – The participants found this functionality hidden and challenging to find initially. However, learnability improved over time on other geoportals. The geoportal of Berlin does not have this feature.

Geoportals Of The Selected Countries

Graph 2 below depicts the goals achieved or task completion rate by participants in the user testing. It shows both the total number of successfully completed tasks and unsuccessfully completed tasks for the geoportals of the selected countries.



Graph 2: Successful And Failed Number Of Tasks For geoportals of selected Countries

Source: Author's own creation

From graph 2 above, Poland exhibits a relatively lower number of successfully completed tasks that is, 67 out of 90, representing 74.4% and a relatively higher number of unsuccessfully completed tasks of 23 out of 90 representing a rate of 25.6%. Also, the total number of successfully completed tasks for Czech Republic, is 70 out of 90, representing a rate of 77.8%. These figures imply that though these countries have a good enough functional geoportal, there are some areas where could be made more functionable to achieve higher success rates.

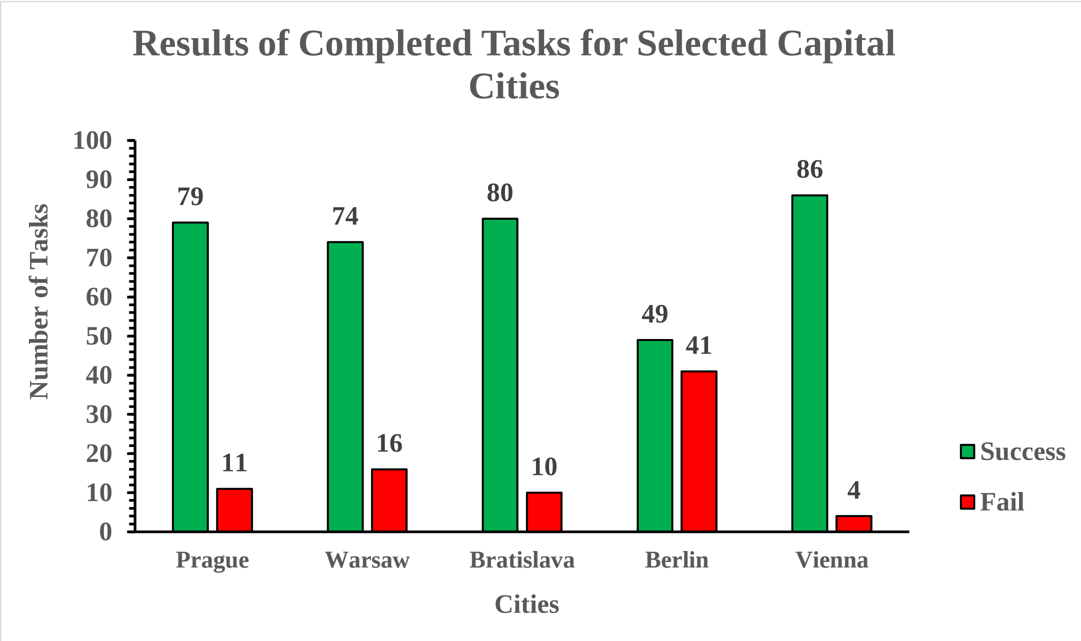
Furthermore, it can be observed that Germany shows successful tasks of 79 out of 90, representing a rate of 87.8%. Austria's geoportal recorded 81 out of 90 of successful tasks, representing a rate of 90% and a low failure rate of 10%. These geoportals have very good functionality.

Among the analyzed countries, Slovakia stands out with the highest number of successful tasks, that is, 81 out of 90 tasks representing a rate of 93.3% and the lowest failure rate of 6.7%. This suggests that Austria's geoportal is the most functionally usable compared to the other countries.

In conclusion, it can be inferred that, based on the functionality of the geoportal of Austria, one has a 93.3% chance of successfully accomplishing a task using the geoportal of Austria but an 74.4% chance of completing that same goal with the geoportal of Poland.

Geoportals Of The Selected Capital Cities

Graph 3 below depicts the goals achieved or task completion rate by participants in the user testing. It shows both the total number of successfully completed tasks and unsuccessfully completed tasks for the geoportals of the selected city capitals.



Graph 3: Successful And Failed Number Of Tasks For Selected Capital Cities

Source: Author's own creation

From graph 3 represented above, both Bratislava, Prague and Warsaw exhibit a number of 80, 79, and 74 tasks respectively that were successfully completed, representing a success rate of 88.9%, 87.8% and 82.2%. These capital cities appear to have an acceptable functionality of geoportals applications and are comparatively higher than the other tested capital cities except for Vienna.

On the other hand, Vienna demonstrates the highest number of successful tasks that is, 86 out of 90, representing success rate of 95.6% and the lowest failure rate of 4.4%. These findings indicate that Vienna's geoportal exhibits the highest level of functional usability compared to the other countries' geoportals.

With comparatively the lowest success rate of 54.4% indicating 49 out 90 successfully completed tasks, and a significantly highest failure rate of 45.6%, representing a total number 41 failed tasks out of 90 tasks, Berlin's statistics underscore the urgent need for substantial improvements in its geoportal. Improvement in the functionality of the geoportal is essential for Berlin to achieve higher success rates and optimize its overall usability.

In summary, it can be inferred that, one has an 95.6% chance of successfully accomplishing a task in geoportal of Vienna but a 54.4% chance of completing that same goal in the geoportal of Berlin.

4.2 Performance

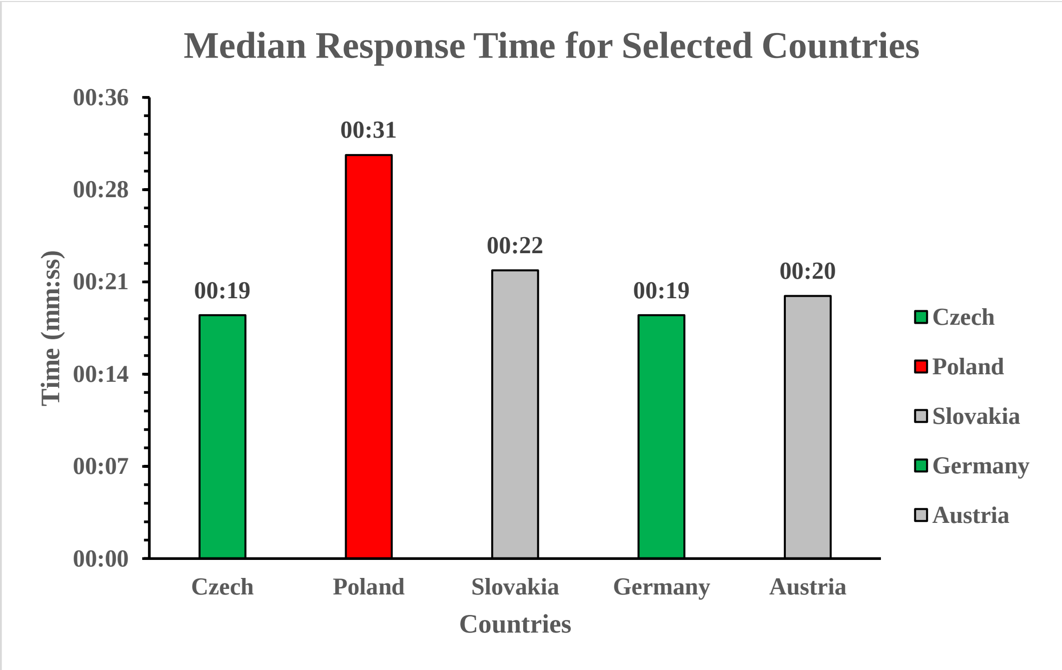
Per the definition of this criterion as earlier explained in section 3.4 of this study, a critical aspect of this evaluation is the user perceived response time of the system, which determines how quickly goals can be accurately achieved. The load time for the geoportals in response to functions executed were used to measure this criterion. This user perceived response time was based on three themes, and represents the time taken for the software to launch, map to load and also time taken for pages and layers within the application to display.

Five tasks were therefore set to cover these three themes as shown in section 3.7.1 of this study, and the following results were obtained.

Geoportals Of The Selected Countries

The total time taken for the tasks to be accomplished were recorded for the countries of the selected public administration geoportals. This is shown in Appendix E. However, the median response time for each geoportal was calculated and the results are shown in the graph below.

Graph 4 below displays the median user perceived response time of the geoportal of the selected countries during the user testing. The results are as follows;



Graph 4: Median Response Time Of Performance Test For The Geoportals Of Chosen Countries

Source: Author's own creation

From graph 4 above, Germany and Czech demonstrated the fastest load time of 19 seconds, indicating a high user response time of these geoportals. This result suggests that the geoportals of Germany and Czech are optimized for efficient data retrieval and prompt user access comparatively.

Austria and Slovakia follow closely with a load time of 20 seconds and 22 seconds respectively, demonstrating efficient speed in delivering the geoportal content. These countries also showcase respectable speed in their geoportal performance, providing users with a relatively swift and a commendable experience.

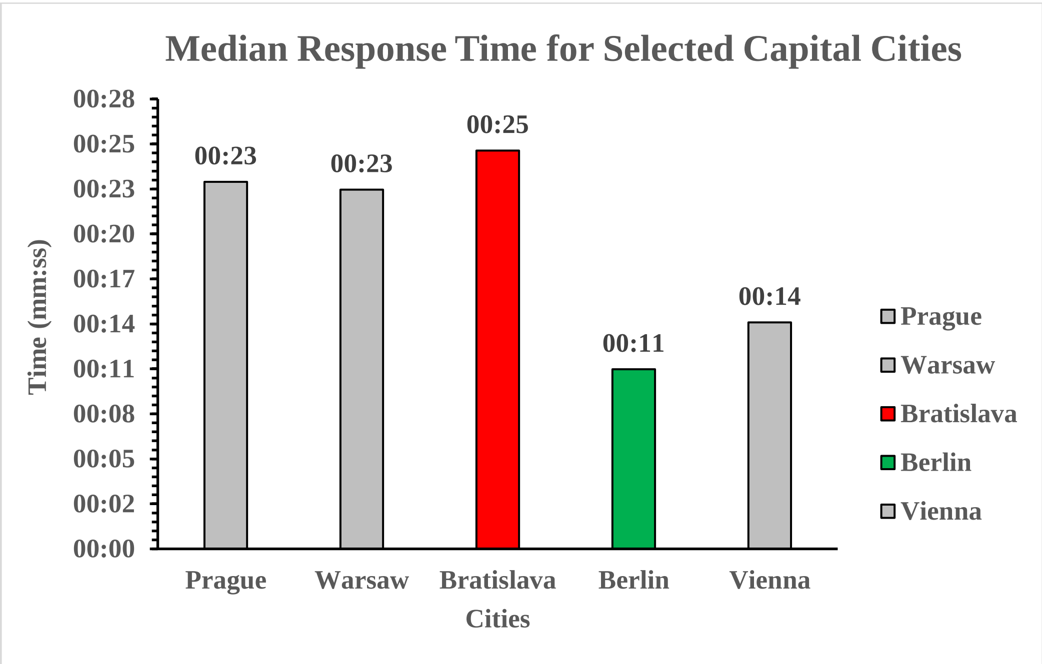
Poland on the other hand exhibited the longest load time of 31 seconds, indicating a relatively slower speed compared to the other analyzed countries.

In brief, it can be said that, completing a task such as launching the application, loading the map and displaying layers, it will take about 31 seconds using the geoportal of Poland while it will take 19 seconds to do same with the geoportal of Germany and Czech. However, these observed differences in performance are not critical as it did not affect the execution of tasks.

The Geoportals Of The Selected Capital Cities

The total time taken for the tasks to be accomplished were recorded for the capital cities of the selected public administration geoportals. This is shown in Appendix F. However, the median response time for each geoportal was calculated and the results are shown in graph 5 below.

The graph below displays the median user perceived response time of the geoportal of the selected countries during the user testing. The following results were obtained;



Graph 5: Median Response Time Of Performance Test For The Chosen Capital Cities

Source: Author's own creation

It can be observed from the graph above that, Bratislava had the longest load time of 25 seconds. This indicates the slowest speed in delivering the geoportal content to users in comparison to the other cities under study. Prague and Warsaw follow closely with load times of 23 seconds each. These cities demonstrated moderately efficient speed in their geoportal performance, in comparison with the other cities.

Berlin exhibited the fastest user perceived load time of 11 seconds followed by Vienna with 14 seconds. These cities showcase relatively quicker speed in delivering the geoportal content, resulting in a prompt user experience.

Summarizing, it can be said that, completing a task such as launching the application, loading the map and displaying layers, it takes about 25 seconds using the geoportal of Bratislava while it takes 11 seconds to do same with the geoportal of Berlin. However, these observed differences in performance are not critical as it did not affect the execution of tasks.

4.3 Cognizability

This is the criterion that measures learnability and memorability as discussed in section 3.7.2 of this study. In sum, It measures the ease of quickly accomplishing a task upon an initial encounter with a system and of re-establishing user proficiency with the interface after a period of non-use (Alzahrani, Gay, Alturki 2022). The metrics of measurability used include time taken to redo selected tasks, success rate, the error rate of tasks. After the last task of each set of tasks, participants were retested on selected tasks to measure the memorability aspect as shown in section 3.7.1of this research.

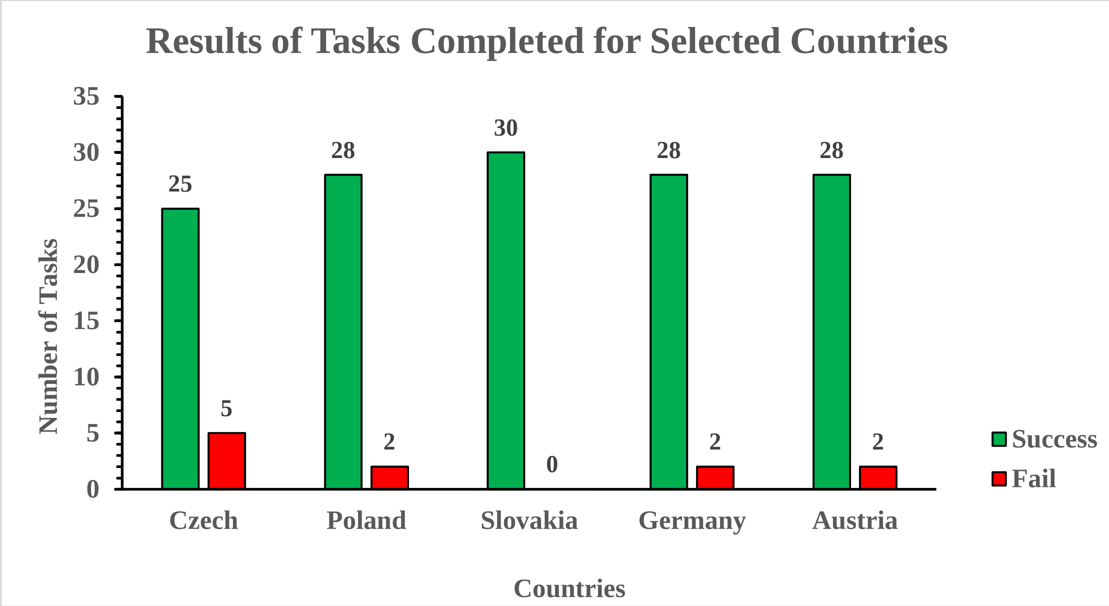
The tasks that the participants found challenging include;

- **Locate the legend** – Regarding the learnability aspect, some of the participants faced difficulty finding the legend for the geoportals of Austria and the Czech Republic upon initial use.
- **Locate the print button** – Similarly, some participants struggled to locate the print button for Poland geoportal during their first encounter.
- **Turn on/off administrative boundaries** – For the memorability aspect, some participants were not able to remember how to locate and turn on/off administrative boundaries for the geoportals of Czech Republic and Germany when they retook the tasks.

Geoportals Of The Selected Countries

While evaluating this criterion, it became apparent that not all participants successfully completed all tasks. Additionally, variations in the time taken to perform these tasks were observed, indicating participants' struggles in recalling the necessary steps. The specific time durations for the Cognizability test can be found in the Appendix G.

Below in graph 6 is a graphical representation of the successfully and unsuccessfully completed tasks of the geoportals for selected countries;



Graph 6: Tasks Completed For Cognizability Test For Chosen Countries

Source: Author's own creation

After the test, it was observed that Slovakia demonstrated the best Cognizability results with all tasks being successfully completed by all participants, representing a 100% success rate. This suggests that participants found it easier to learn and relatively simpler to re-establish familiarity and proficiency with the system.

Austria, Germany and Poland also performed similarly well with 28 out of 30 successfully completed tasks and 2 unsuccessfully completed tasks for each of the geoportals, representing a success rate of 93.3%.

The geoportal of Czech Republic had the least Cognizability results with 25 out of 30 successfully completed tasks and 5 unsuccessfully completed tasks, representing a success rate of 83.3%. This implies that one has a 100% chance of learning and easily re-establishing proficiency after a period of non-use with the geoportal of Slovakia as compared to the geoportal of Czech Republic which stands at a rate of 83.3%.

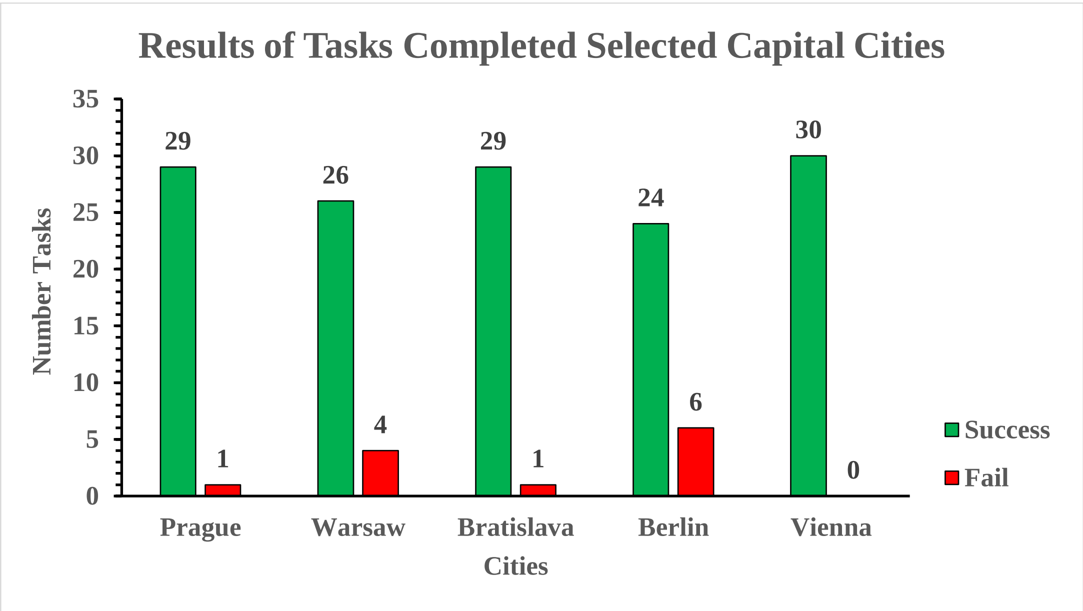
Geoportals Of The Selected Capital Cities

Similarly, with the geoportals of selected capital cities, successful and failed tasks together with observed variations in task completion times suggested that participants encountered difficulties in recalling the necessary steps for some of the geoportals, thus affecting their cognitive experience. This aspect served as a measure of Cognizability, highlighting the ease and speed with which participants could learn and retain the required tasks within the geoportals. The specific time durations for the Cognizability test were recorded and is provided Appendix H.

The tasks that the participants found challenging include;

- **Locate the legend** – With respect to the learnability aspect, some participants initially struggled to locate the legend for Warsaw and Berlin during their first encounter with the geoportals.
- **Display points of interest** – For the memorability aspect, some participants were not able to recall how to locate and display points of interest within the geoportals of Prague and Bratislava.

Graph 7 below represents the Cognizability results for selected geoportals of the capital cities;



Graph 7: Tasks Completed For Cognizability Test For Chosen Capital Cities

Source: Author's own creation

The above graph shows that, Vienna exhibited the best Cognizability results with all tasks successfully completed by all participants representing a 100% success rate. This suggests that participants found it easier to learn and relatively less sophisticated to re-establish familiarity and proficiency with the system.

Prague and Bratislava also performed equally well with 29 out of 30 successfully completed tasks and 1 unsuccessfully completed task for each of the geoportals, representing a success rate of 96.7%. This was followed by Warsaw with 26 out of 30 successfully completed tasks and 4 unsuccessfully completed tasks representing a success rate of 86.7%.

The geoportal of Berlin showed the lowest Cognizability results, with 24 out of 30 tasks successfully completed and 6 unsuccessfully completed, resulting in an 80.0% success rate. Notably, all failed tasks in the Cognizability test for the Berlin geoportal are attributed to the learnability aspect, as some functionalities are not available. However, the memorability test yielded a 100% success rate, indicating that participants could easily recall how to perform tasks in this geoportal even after a period of non-use. This results can be seen in Appendix H.

4.4 User-Centric Design

The User-centric Design of this research represents one of the criteria that measures the satisfaction of users, in this case the participants, of the geoportals. Here, user-centricity encapsulates user-centeredness of the layout or presentation and ergonomics of the selected web-based GIS applications. As a latent variable, a questionnaire consisting of 10 questions, utilizing a 5-point Likert Scale (strongly agree-5, to strongly disagree-1) was employed to measure this criteria.

Geoportals Of The Selected Countries

Outlined below are the participants perceptions concerning the user-centric design of the geoportals of the selected countries;

- **Slovakia** – In Slovakia's geoportal, the majority of participants were highly impressed with the overall layout, finding it well-organized, neat, and properly labelled contents, which facilitated easy findability of features. The excellent use of colour, contrast, font, and icon placement contributed to an enhanced overall user satisfaction, meeting their expectations. However, a notable concern was the absence of a title for the map. That notwithstanding, most participants strongly agreed that the geoportal followed a User-centric Design, as indicated in the questionnaire responses.

- **Austria** – This geoportal the participants were equally impressed with, like that of Slovakia. They expressed satisfaction with the layout, pointing out its neat organization and proper categorization of contents, which made it easy to locate features. The questionnaire results showed that most participants strongly agreed with the user-centric design of this geoportal.
- **Germany** – With respect to Germany's geoportal, participants expressed contentment with the layout, approving of the colour theme and font, as well as appreciating the consistency across all layers. However, they were dissatisfied with the default map loading with other European countries, and the faint demarcations of borders sometimes led to accidental zooming out without realization. Additionally, some features, such as points of interest, were perceived as hidden and difficult to find. Despite these concerns, participants were satisfied with the design of the geoportal overall.
- **Czech** – With this geoportal, participants observed that it offered numerous data tools and functionalities for analysis. However, they expressed that the interface appeared too professional and seemed unapproachable to non-experts. Some features were also perceived as hidden, making them difficult to locate. Additionally, participants found it challenging to remember how to execute tasks within the geoportal.
- **Poland** – In the case of Poland's geoportal, participants expressed the lowest level of satisfaction with its interface. They described it as clumsy, with poor content organization, poor colour contrast and font size. The map's appearance with other European countries and clumsy border demarcations were noted as concerns. In the questionnaire, most participants gave neutral ratings to the geoportal.

Table 8, exhibited in Appendix V is a representation of the questionnaire responses for User-centric Design of the selected countries

The table illustrates that a significant portion of the participants responses, 63.3% strongly agreed with the user-centric design of the geoportal of Slovakia. Additionally, 23.3% of the participants agreed with the design, and 13.3% provided neutral responses.

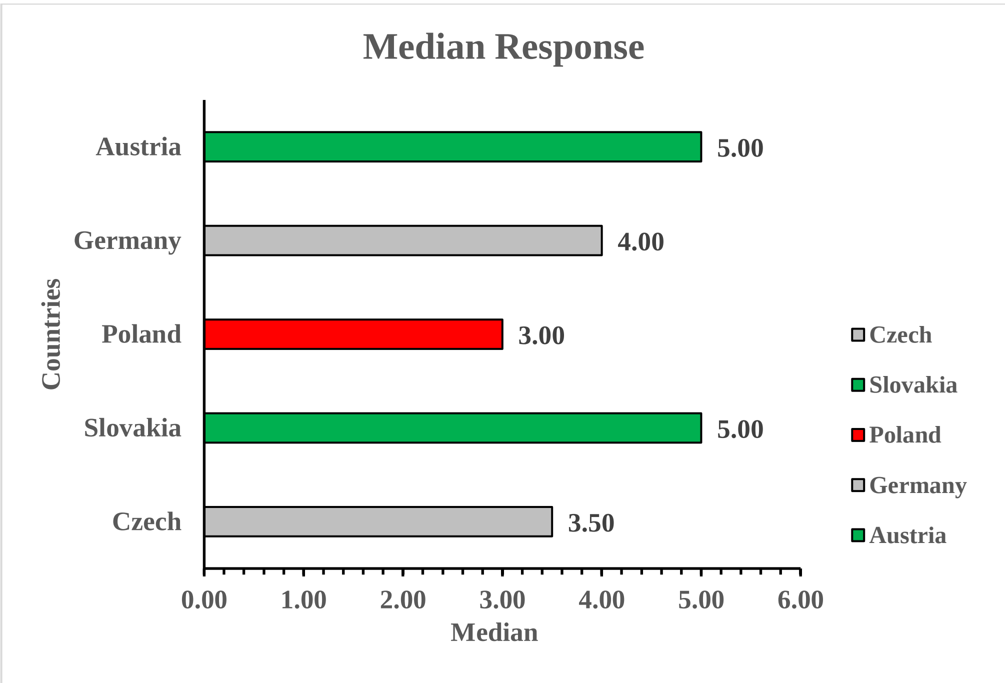
In the evaluation of the Czech geoportal, 6.7% of the participants responses was in strong agreement to its user-centric design, 43.3% agreed, 36.7% provided neutral responses, and 13.3% disagreed with the design.

For the Polish geoportal, 6.7% of the participants strongly agreed with its user-centric design, 16.7% agreed, 43.3% were neutral, 23.3% disagreed, and 10.0% strongly disagreed with User-centric Design of the geoportal.

In the case of the German geoportal, 20.0% of the participants strongly agreed with its User-centric Design, 46.7% agreed, 10.0% were neutral, 16.7% disagreed, and 6.7% strongly disagreed.

With respect to the Austrian geoportal, the majority of participants, 53.3% strongly agreed with its user-centric design, 30.0% agreed, and 16.7% provided neutral responses.

Below in graph 8 is a graphical representation of the results of the questionnaire indicating the median responses of the participants with respect to the user-centricity of the applications' interface of the selected countries. The results obtained were as follows;



Graph 8:Median Responses Of Questionnaire For User-centric Design Of Geoportals The Selected Countries

Source: Author's own creation

The diagram above shows the median of the responses from the questionnaire concerning the user centricity of the interface design of the geoportals. It can be inferred from above that the majority of the average response of the respondents in terms of a user-centric design was in favour of the geoportal of Slovakia, and Austria was a median value of 5.00. This suggest a very strong agreement to the user-centric design of the geoportals interface.

Germany and Czech had median values of 4.50 and 4.00 respectively. This also suggest a strong enough agreement by the participants to the User-centric Design of the geoportals interface.

The least was Poland with a median of 3.00. This demonstrates that the participants were more impressed with the overall layout of the geoportal of Slovakia but were neutral about that of Poland.

Geoportals Of The Selected Capital Cities

The participants' perceptions regarding the User-centric Design of the geoportals in the selected capital cities are as follows:

- **Vienna** – The participants were highly impressed with the geoportal of Vienna. They found the layout to be excellent, the interface appealing, and the icons and features to be well-placed. Going beyond the typical north, south, east, and west directions and adding scroll directions for northeast, northwest, southeast, and southwest, were appreciated by the participants. Overall, the geoportal was commended for its highly User-centric Design.
- **Prague** – The participants found the geoportal of Prague acceptable, but they provided feedback that the map interface was too blurry. They suggested that using a different colour for the map would improve its legibility. Overall, despite the minor issue, the participants were satisfied with the geoportal's interface.
- **Berlin** – The participants liked Berlin's geoportal interface. However, they identified these issues; difficulty in finding the map and limited functionality for executing tasks. Despite the limitations, the geoportal still demonstrated elements of User-centric Design with well-placed and arranged icons for the features that were available.
- **Bratislava** – The participants had a neutral view regarding the geoportal of Bratislava. They expressed that the map appeared too bright and colourful, making it seem busy and overwhelming. They suggested that improving the colour contrast could bring more clarity to the map.
- **Warsaw** – Among the geoportals of the selected capital cities, the participants were least impressed with the geoportal of Warsaw. They found it to be clumsy and blur.

Despite having good functionality, some features are difficult to locate, and the overall appearance was not appealing to them.

Table 9, exhibited in Appendix V is a representation of the questionnaire responses for User-centric Design of the selected capital cities;

The table presents the participants' questionnaire responses regarding the user-centric design of the geoportals of the chosen capital cities.

With the geoportal of Prague, 16.7% of participants strongly agreed, 43.3% agreed, 23.3% were neutral, 16.7% disagreed, and there were no strong disagreements for the User-centric Design of the interface of the geoportal.

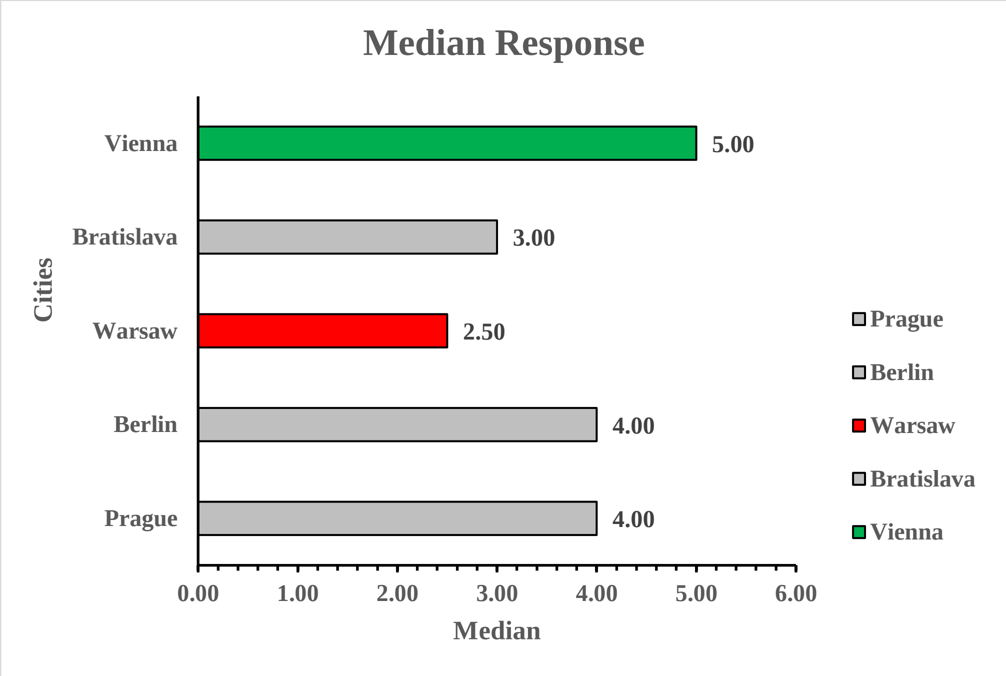
For Warsaw's geoportal, 10.0% of participants agreed, 40.0% disagreed, 40.0% were neutral, and 10.0% strongly disagreed to its User-centric Design.

Concerning the User-centric Design of the geoportal of Bratislava, 23.3% of participants strongly agreed, 23.3% agreed, 36.7% were neutral, 10.0% disagreed, and 6.7% strongly disagreed.

Berlin had 13.3% of participants strongly agreeing, 46.7% agreeing, 16.7% neutral, 6.7% disagreeing, and 16.7% strongly disagreeing to the User-centric Design of the geoportal.

Finally, in Vienna, 56.7% of participants strongly agreed, 36.7% agreed, 6.7% were neutral, and there were no disagreements. These results highlight a strong positive response by the participants' concerning the User-centric Design of the geoportal of Vienna.

Graph 9 below is of the results of the questionnaire demonstrating the preferences of the participants with respect to the User-centricity of the design of the Geoportals of the selected cities. The results were obtained as follows;



Graph 9:Median Questionnaire Responses For User-Centric Design Of The Geoportals Of Selected Countries

Source: Author's own creation

The diagram above illustrates that the participants' responses showed a more favourable agreement for the geoportal of Vienna with a median value of 5.00, which represents a strong agreement to the User-centric Design of the geoportal.

Berlin and Prague followed with median values of 4.00, which represents "agree" on the scale of the questionnaire. The participants gave a neutral response of 3.00 with respect to the User-centric Design of the geoportal of Bratislava.

Warsaw had the least, with a median response of 2.50, depicting that the participants were of the view that the interface of the geoportal of Warsaw was not User-centric enough.

4.5 User Experience

The user experience criterion is a comprehensive measure that assesses participants' overall satisfaction and perception of the geoportals, based on their interactions and experiences. It encapsulates the collective impact of the various usability aspects evaluated throughout the study, including Functionality, Performance, Cognizability, and User-centric Design, As a latent variable, it represents a hidden construct that cannot be directly observed but can be inferred. Therefore, the results of this criterion were obtained from the responses to the administered questionnaire.

Geoportals Of The Selected Countries

Table 10 exhibited in Appendix V is a representation of the questionnaire responses for User Experience for the selected countries.

The table reveals that for the geoportal of Slovakia, the majority of participants, that is, 60.0% of the responses strongly agreed to have had a great user experience with this geoportal, and an additional 33.3% agreed with it. 6.7% of the responses were neutral.

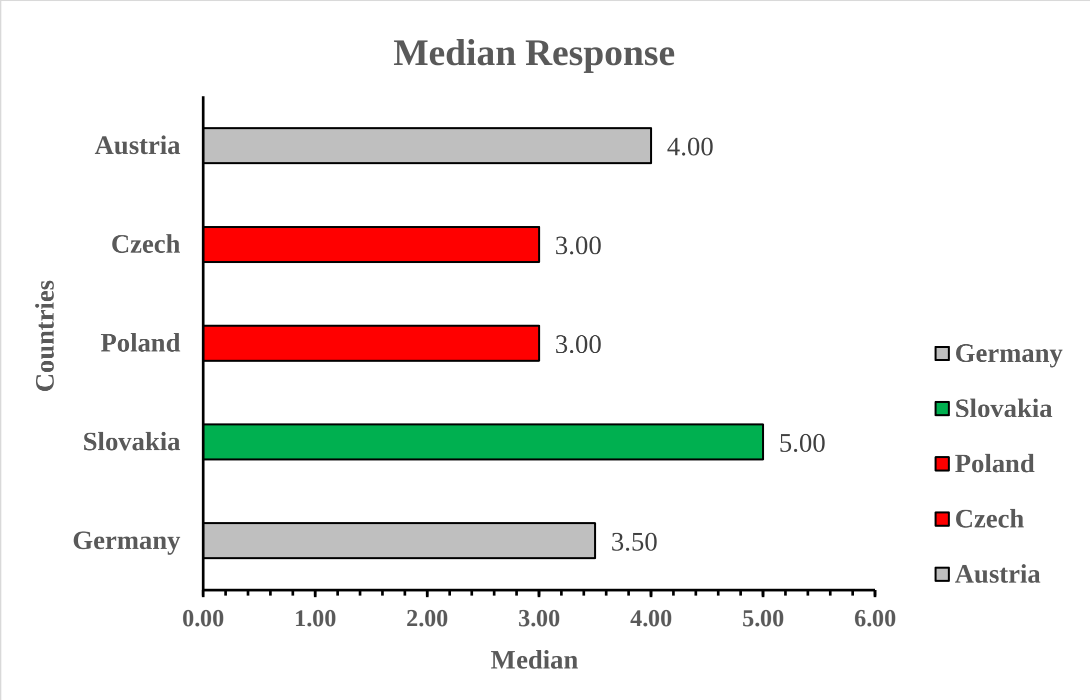
Similarly for Austria, 50.0% strongly agreed that user experience with this geoportal was very good, and an additional 33.3% agreed with it. However, 20.0% of the participants maintained a neutral position on the geoportal.

In the context of Germany's geoportal, 33.3% of the responses of the participants strongly agreed to have had a good user experience, while an additional 30.0% agreed with it. Moreover, 16.7% of the participants had a neutral response, and 16.7% disagreed with the a good user experience. A percentage of 3.3% provided a strongly disagree response to this criterion.

With the Czech Republic's geoportal, 10.0% of the responses of the participants geoportal strongly agreed to a good user experience, and 20.0% agreed. Additionally, 36.7% had a neutral response, 26.7% disagreed, and 6.7% strongly disagreed.

For the geoportal of Poland, only 3.3% strongly agreed and 13.3% agreed to having a good user experience. Also, 36.7% had a neutral response, while 16.7% disagreed, and 30.0% strongly disagreed.

Graph 10 below represents the results of the questionnaire, indicating the stand of the participants with respect to their overall user experience of the applications for the selected countries. The median for the responses were calculated and the results obtained are as follows;



Graph 10: Median Questionnaire Responses For User Experience Of The Geoportals Of Selected Countries

Source: Author's own creation

The above graph of the participants' responses shows their overall best user experience was in favour of the geoportal of Slovakia with a median value of 5.00, representing "strongly agree" to a great user experience. This was followed by Austria with a median of 4.00 indicating "agree" to a good user experience. Closely followed by this is the geoportal of Germany with a median of 3.50.

Czech Republic and Poland followed with median 3.00 each, depicting a neutral overall user experience for these geoportal.

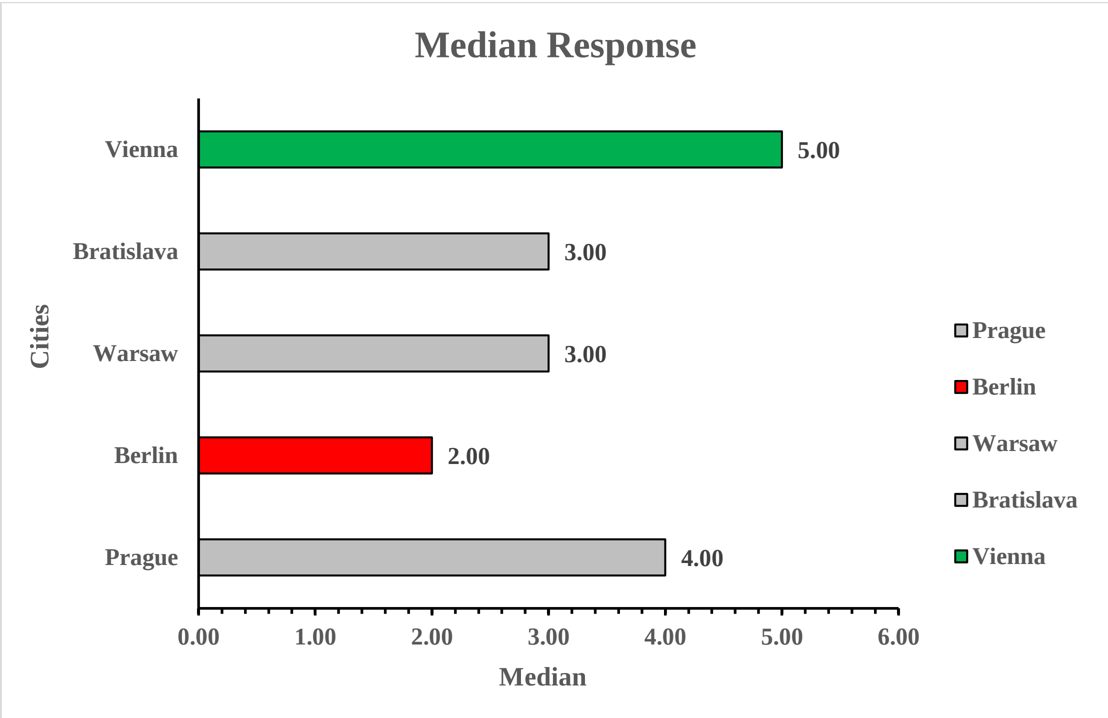
Geoportals Of The Selected Capital Cities

Table 11 exhibited in Appendix V is a representation of the questionnaire responses for User Experience of the geoportals for the selected capital cities.

The table presents the participants responses regarding the user experience criterion for the geoportals of the selected capital cities. The geoportal of Vienna received the highest number of "Strongly Agree" responses of 76.7%, indicating a high positive overall user experience. The geoportal of Prague had a significant number of "Agree" responses of 60.0%, while that of and Bratislava had 40% reflecting satisfactory user experiences.

On the other hand, Warsaw and Berlin had a higher percentage of "Disagree responses" with Warsaw having 36.7% and Berlin having the worst of 40.0% responses of the participants strongly disagreeing, indicating some dissatisfaction with their user experiences.

The graph below represents the results of the questionnaire, indicating the position of the participants with respect to their overall user experience for the geoportal of the various selected cities. The median for the responses were calculated and the results obtained are as follows;



Graph 11: Median Questionnaire Responses For User Experience Of Geoportals Of Selected Capital Cities

Source: Author's own creation

From the Graph above, the participants' best user experience was with Vienna's geoportal, the median score of 5.00, followed by Prague, with a median score of 4.00, with a good user experience. Bratislava and Warsaw had neutral user experience with median of 3.00. Berlin's geoportal received the lowest score of mean: 2.00 indicating a poor user experience.

5. DISCUSSION

The researcher conducted a thorough analysis of the results obtained from the usability test, think-aloud and questionnaire administered. This analysis proved instrumental in uncovering a range of usability issues specific to the selected web-based GIS applications. This study adopted a combination of method approach that is, user-based method (user testing, think aloud) and usability inquiry (questionnaire). The discussion of the results obtained are from the implementation of these methods based on the five selected criteria, that is, Functionality, Performance, Cognizability, User Centric Design and User Experience.

- **Functionality** – Khan, Adnan (2010) and Tandon, Kiran, Sah (2016) explain functionality to ensure the availability of all necessary features for a system to meet users' needs, simple to be used by non-experts and should be effective enough to deliver accurate results while minimizing error susceptibility.

  Outlined below are the functionality issues with respect to the geoportals of the selected countries:

  - **Czech Republic**
    - When switched to the English version the button for orthophoto/aerial sometimes become inactive**.**
  - **Poland**
    - There is no dedicated bookmark functionality.
    - When switched to English, some of the layers, example the legend, does not translate to English.
  - **Slovakia**
    - There is no title on the map of the geoportal.
    - There are no points of interest within the geoportal to be displayed.
  - **Germany**
    - When switched to the English version the scale become static and does not change when the map is zoomed in or out.
    - There is no in-built English functionality so foreign users have to depend on translation tools like google translate.
    - There is no help functionality, and tutorial videos are only in German.

- **Austria**
    - When switched to English not all the layers of the map translate.

Outlined below are the functionality issues with respect to the geoportal of selected capital cities:

- **Prague**
    - There is no dedicated functionality for users to bookmark.
- **Warsaw**
    - There is no dedicated bookmark functionality.
    - There is no in-built English functionality.
    - When switched to the English version not all the layers translate**.**
- **Berlin**
    - The map button of the geoportal is placed at the very bottom of the homepage making findability very difficult.
    - There are no tools for measurements within the geoportal.
    - There are no coordinates display for the map.
    - There is no option to change the default map view to orthophoto/aerial.
    - The is no data on administrative boundaries.
    - There is no print button.
    - There is no help functionality.
    - There is no in-built English functionality.
- **Bratislava**
    - There is no in-built English functionality.
    - When switched to the English not all the layers translate.
    - The is no dedicated help button.
- **Vienna**
    - The link/bookmark and print features appear in text and not as icons.

The participants stated that these issues of functionality with these geoportals affected their overall usability experience of the geoportals. This aligns with the assertion of Tandon, Kiran, Sah (2016) that functionality affects the usability of the whole system.

- **Performance** – According to Yang, Evans (2017) system performance encompasses various factors, including user perceived system response time, reliability, extensibility, and service quota. The focus for the purpose of this study definition is user perceived system response time. In effect, the metric used to measure this criterion was the load and response time of the geoportals.

It was observed that the geoportals of Germany, Czech and Berlin had the fastest response time followed by Slovakia, Warsaw, Prague and Vienna with moderate response time. Poland and Bratislava had the longest response time in relation the to all the other geoportals.

Though there were variations in the response time of the geoportals, there are not of critical issues of usability because the variations did not affect or prevent the execution of the tasks within the geoportals. This issue is trivial and should be given little consideration, in line with Gonçalves et al. (2021) that, minor usability problem should be given low priority in terms of fixing, as it has little impact on users' tasks and they can recover quickly from it.

- **Cognizability** – As defined by Przybyslawski (2016), it refers to the ability of a thing to be knowable by the mind, which is connected to learnability and memorability. As earlier stated, two tasks were used to test the learnability aspect while three tasks were used to test the memorability aspect. From the analysis above it was observed that all tasks were successfully completed, for the geoportal of Slovakia.

  On the other hand, Berlin recorded the least for this criterion. It is, however, important to note that all unsuccessful tasks of this criterion for the geoportal of Berlin were due to the learnability aspect, as the functionalities are not present in the geoportal. However, the memorability test for the geoportal of Berlin resulted in a 100% success rate, demonstrating that if the features are available, the participants could effortlessly remember how to perform tasks in this geoportal even after a period of non-use.
- **User-Centric Design** – According to Endsley (2016), it is a way of creating a more effective system by aligning the interface with the capabilities and needs of the users, through the integration of a layout that supports the goals and tasks of the end users.

  The participants found the layout for the geoportals of Slovakia, Austria and Vienna more user-centric and more presentable.

  The participants pointed out that the interface of the Czech and Poland geoportals looked too professional and less approachable. Coupled with a lot of features and metadata, it caused confusion as they tried to locate the features making them feel overburdened with many features. On the other hand, the geoportals of Bratislava, Warsaw, and Poland were perceived as clumsy, with a busy appearance and unbalanced color scheme, which makes them unappealing to the participants. This negatively this negatively affected findability of features with these geoportals. This agrees with the findings of Alzahrani, Gay, Alturki (2022) that, unstandardized application design may result in applications that have user interfaces and functionality that makes it more challenging for end users to find features and use them.

- **User Experience** – ISO 9241-210 defines user experience as an individual's perceptions and responses arising from using or anticipated use of a product, system, or service (Alzahrani, Gay, Alturki 2022). It encompasses the overall impressions and satisfaction derived from the interaction with the system.

  The questionnaire showed that the participants were overall highly satisfied and had the best experience with the geoportals of Slovakia and Vienna, the participants also had very good experience with the geoportals of Austria and Prague and subsequently Germany. They were, however, neutral with the geoportals of Czech, Poland, Warsaw and Bratislava, and least satisfied with the geoportals of Berlin. They were quick to remark that the geoportal of Berlin was overall below their expectation, and they would not like to reuse it. This confirms the finds according to the research of Portz et al. (2019) which says that, user experience directly affects the acceptability and adoption of a system.

5.1 Usability Issues of The Geoportals

Usability can be termed as the quality of the software. It plays a crucial role in the success of software systems by ensuring that they meet the needs and expectations of their users. A well-designed program should not only fulfil its intended purpose but also provide a seamless and satisfactory user experience (Alzahrani, Gay, Alturki 2022). This section of the research sets out to highlight the prevalent usability issues that were observed and encountered in the geoportals as the participants performed the tasks with the applications. The usability problems of the geoportals are summarized below;

5.1.1 Major Usability Issues

- **Limited Functionality** – Geoportal of *Berlin* lacks certain crucial features such as distance measurement, coordinate display, help button and print button. Participants resorted to the print function from the drop down menu when they right clicked on the map. The map view could also not be changed to orthophoto/aerial or any other.

The geoportals *Warsaw*, *Prague* and *Poland*, lack a dedicated bookmark functionality to enable users make references for future use.

The geoportals of *Germany*, *Berlin* and *Bratislava* have no functional help features for assistance.

Slovakia's geoportal has no point of interest for users to display and utilize essential landmarks.

- **Issues of Findability** – Locating the map of *Berlin* proved to be particularly challenging. Participants expected it to be prominently displayed but instead found the map of Berlin at the bottom of the homepage.

  The legend for the geoportals of *Czech* and *Berlin* are concealed and were too difficult to find by the participants.

  The administrative boundaries for the geoportals of *Poland*, *Czech*, *Bratislava*, *Vienna* and *Warsaw* seemed too obscure for the participants to locate.
- **No Built-In English** – The geoportals of *Germany*, *Berlin*, *Bratislava* and *Warsaw* have no built-in English functionality. The absence of an English language setting hampers the usability of the geoportal for foreign users. As a consequence, the participants were compelled to rely on external translation tools, such as Google Translate, to interact with the system. These machine translation tools have the potential of translation inaccuracies that can lead to misinterpreting vital information or instructions, which may in turn hamper their ability to fully comprehend the functionality and features of the geoportal.
- **Incomplete English Translation** – The language barrier extends beyond the initial interface translation. This was increasingly problematic because certain layers within the geoportals of *Poland*, *Austria*, *Bratislava*, and *Warsaw* fail to switch to English, requiring users to continually translate content as they navigate through different sections. Also, the actual maps could not be translated into English, participants encountered difficulty in locating cities due to the absence of English labels. Some aspects could not be translated to English at all, like the legend of the *German* geoportal.
- **Navigation Issues** – The maps of the geoportals for *Poland* present some navigational challenges when participants attempt to undo actions. One notable issue is that doing a measurement on the map is the delete button is not easily identifiable and the inactive

undo and redo buttons to navigate back and forth within the interface hinders users' ability to backtrack and revert unintended changes. Additionally, when users rely on the undo button on the web browser to go back, the map restarts, resulting in the loss of all previously completed work.

- **Inactive Features** – Certain features of some of the geoportals become inactive when switched to English. For instance, the scale and coordinate display and user notice on the map of the geoportal of *Germany* becomes static and unchangeable irrespective of scrolling or zooming when translated to the English version.
  The orthophoto/aerial button on the geoportal of *Czech* also becomes inactive when switched to English. It sometimes requires several clicks before it gets reactivated.

5.1.2 Minor Usability Issues

- **Poor Interface Design** – The geoportals *of Bratislava*, *Warsaw*, and *Poland* were deemed clumsy and unappealing by participants due to their busy appearance and unbalanced color schemes. The overwhelming display of map features negatively impacted findability, hindering users from easily locating the desired features within these geoportals.
- **Poor Border Demarcation** – The absence of clear and well-defined borders for the default displayed maps of the geoportals of Germany, *Warsaw*, *Berlin* and *Prague*, distinguishing them from its neighbours, created confusion during navigation. This led to accidental zooming and scrolling into surrounding countries or cities hindering the participants intended exploration within the application.
- **Slow Response Time** – The participants encountered minor delays when loading the geoportal application for *Poland* and *Bratislava*. These load times were comparatively slower than the other geoportals under study, and took longer for application to launch, load the map, and display the desired layers. This, however, is the least among the minor issues and did not affect the execution of the tasks.

5.2 Recommendations

The following are the recommendations to the public administration authorities of the geoportals of selected countries and capital cities, to manage the afore mentioned usability issues;

Recommendations for the issues of Limited Functionality

- **Poland, Warsaw, Prague**
  - Public administration authorities should incorporate dedicated bookmark functionality to the geoportal to improve user experience and enable users to save and revisit specific locations or maps.
- **Slovakia**
  - Authorities should also ensure the incorporation of points of interest within the geoportal to allow users to explore and provide valuable information about significant locations or landmarks.
  - Public administration authorities for the geoportal of Slovakia should ensure the addition of a clear title to the map to provide users with a clear context and understanding of the geographical area they are viewing.
- **Germany, Bratislava**
  - Public administration authorities should add a help functionality in English to guide foreign users on how to navigate and utilize various functionalities effectively.
- **Berlin**

  Public administration authorities responsible for the geoportal of Berlin should:
  - Integrate tools for measurements within the geoportal to enhance functionality and provide users with necessary tools for analysis.
  - Implement a coordinates display feature to enable users to access location information and improve navigational capabilities.
  - Provide an option to switch to orthophoto/aerial view to enable users to have access to different map views.
  - Include data on administrative boundaries to provide users with comprehensive information about different regions within the city.
  - Introduce a print button functionality to enable users to generate hard copies of maps or data as needed.
  - Implement a help functionality to offer users guidance and support in navigating the geoportal effectively.

Recommendations for the Issues of Findability

- **Berlin**

- Public administration authorities should improve the visibility and prominence of the map on the homepage of the Berlin geoportal to make it easily accessible to users.
- Public administration authorities should also enhance the discoverability of the legend in the geoportals of Berlin, by using more conspicuous icons and positioning the it in a more accessible location.

- **Czech, Bratislava, Vienna, Warsaw**
  - Make the administrative boundaries more apparent and easily locatable on the geoportals of Poland, Czech, Bratislava, Vienna, and Warsaw by using distinct colors or labels to highlight them.
  - Public administration authorities should also enhance the discoverability of the legend in the geoportal of Czech, by using more conspicuous icons and positioning it in a more accessible location.
  - Public administration authorities in charge should enhance the link/bookmark and print features of the geoportal of Vienna by using easily recognizable icons instead of text, to make these functions more intuitive and easier to recognize.

Recommendations for No Built-In English

- **Germany, Berlin, Bratislava, Warsaw**
  - It is recommended for public administration authorities to implement an in-built English version of the geoportal to cater to foreign users and eliminate the need for external translation tools like Google Translate.

Recommendations for Incomplete English Translation

- **Germany, Poland, Austria, Bratislava, Warsaw**
  - Public administration authorities of these geoportal should ensure that all layers consistently switch to English to create a more coherent experience for users.

Recommendations for Navigational Issues

- **Poland**
  - The public administration authorities responsible for the geoportal for Poland should implement an active undo and redo functionality, and make delete

features visible, allowing users to backtrack and revert unintended changes during measurements or other actions.
    - Additionally, an auto-save or restore feature can be considered to safeguard users' work in case of accidental refresh or browser closure.

Recommendations for Inactive Features

- **Czech Republic**
    - To ensure a smooth user experience for English-speaking users, it is crucial for public administrative authorities to investigate and fix the problem with the orthophoto/aerial button becoming inactive when the geoportal is switched to the English version to improve accessibility of features of the geoportal to foreigners.
- **Germany**
    - It is recommended to public administration authorities to incorporate a language-independent design approach that ensures essential features, such as the scale and coordinate displayand user notice remain functional and responsive regardless of the language selected.
    - Also, public administration authorities should implement a comprehensive multilingual support for all features and content, to ensure that translations do not interfere with the functionality of the geoportals.

Recommendations for Poor Interface Design

- **Bratislava, Warsaw, Poland**
    - Public administration authorities should consider streamlining the interface design of the geoportals of Bratislava, Warsaw, and Poland. This can be achieved by reducing clutter, balancing color schemes and organizing content to simplify accessibility.

Recommendations for Poor Border Demarcation

- **Germany, Warsaw, Berlin, Prague**
    - The public administration authorities should implement bold outlines for the borders of these geoportals to enhance the visibility and clarity of borders for

their default displayed maps, making it easier for users to distinguish them from neighboring regions.

Recommendations for Slow Response Time

- **Poland and Bratislava**
    - Public administration authorities for these geoportals should employ a strategy to prioritize the loading of essential components and features of the geoportal. Loading critical elements first and then fetching secondary components, and ensuring users can start interacting with the application as soon as possible.

5.3 Limitation of The Study

- One limitation of this test is that the participants were solely foreign students at the University of Pardubice with educational backgrounds ranging from Bachelor to PhD degrees. The set is not fully representative as other foreign users under different categories were not included.
- The findings of this study are subject to the limitation of a sample size comprising six participants. Therefore, caution should be exercised when generalizing the results to a larger population or drawing definitive conclusions.

5.4 Future Study

- Future research should explore in-depth persona identification of the end users of these geoportals, including tourists and foreigners with diverse backgrounds, to gain insights into the usability of geoportals from their perspectives.
- For future studies, increasing the number of participants can lead to the discovery of a broader range of usability issues. This expansion allows for a more robust statistical analysis.
- Exploring the compatibility of these geoportals with mobile applications presents an interesting and insightful avenue for further research.

CONCLUSION

Usability evaluation is of utmost significance, serving as a crucial factor in detecting user acceptance and providing insights into users' opinions of the application. It also plays a pivotal role in facilitating the improvement of the application's design based on valuable user feedback.

The aim of the thesis is to propose a suitable procedure to evaluate the usability of chosen Web-based applications incorporating applications managed by public administration authorities. This research is essential because usable web-based applications are paramount for public administration authorities since they have the responsibility to provide efficient services to the public including citizens, foreigners, and various stakeholders. Although INSPIRE is a spatial data infrastructure initiative for sustainable development within the European Union, there are no imposing regulations for the provision of services to the public concerning these geoportals. Therefore, a usability evaluation allows us to obtain valuable insights into how well these applications cater to the needs of users and whether they effectively facilitate users in accomplishing their tasks.

Ten web-based GIS applications, including geoportals of Czech Republic, Poland, Germany, Slovakia, and Austria, along with their capital cities, Prague, Warsaw, Berlin, Vienna, and Bratislava, were selected for the study. **Suitable and key criteria were set through the thorough review of twenty-six relevant literatures on usability evaluation on public administration applications.** These were articles were separately reviewed to help identify and develop key and suitable criteria to guide the usability evaluation of this study.

Thorough review of literature and the utilization of Saaty's Analytic Hierarchy Process for multicriteria decision making was employed to select a suitable testing method for the evaluation. **User testing, in combination with think aloud protocol and questionnaire were adopted for the design and implementation of the proposed procedure**. Furthermore, a mixed methodology was employed to ensure a comprehensive and well-rounded assessment of the system's usability. Also, based on literature, six participants were recruited for the user testing. It took approximately 13 hours to complete the conduction of testing and for the participants to fill out the questionnaire.

The usability evaluation of selected geoportals revealed critical issues, such as limited functionality, findability problems, issues with English translation and inactive features. In addition, the procedure also uncovers minor issues such as poor interface design, which can be addressed based on the financial standing of the public administration once the key problems have been tackled effectively.

The key findings of the study highlight significant differences in usability among the evaluated geoportals. Notable is the geoportal of Berlin which demonstrated the least usability among the evaluated geoportals, due to its limited functionality. On the other hand, the geoportal of Vienna stood out as the most usable among the evaluated geoportals, offering almost all necessary functionalities and featuring an excellent user-centric interface design and rating very high in terms of user satisfaction.

Recommendations for each geoportal were proposed based on the usability issues ascertained from the test results.

This proposed procedure for usability evaluation is cost-effective with respect to time-efficiency because it is fast and also utilizes a reasonable number of participants. When adopted by public administration authorities, it will help to identify key usability issues and provide recommendations that will significantly improve the usability of web-based GIS applications. leading to the development of user-centric and inclusive solutions, enhancing user overall user satisfaction.

REFERENCES

1. ABDALLA, Rifaat, 2016. *Introduction to geospatial information and communication technology (GeoICT)*. Springer. ISBN 3319336037.
2. AFRASHTEHFAR, Kelvin I, ASSERY, Mansour K A and BRYANT, S Ross, 2020. Patient satisfaction in medicine and dentistry. *International journal of dentistry*. Vol. 2020.
3. AGRAWAL, Sonam and GUPTA, Rajan Dev, 2014. Development and comparison of open source based Web GIS Frameworks on WAMP and Apache Tomcat Web Servers. *The international archives of the photogrammetry, remote sensing and spatial information sciences*. Vol. 40, pp. 1–5.
4. ALHADRETI, Obead and MAYHEW, Pam, 2018. Rethinking thinking aloud: A comparison of three think-aloud protocols. In : *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery. 20 April 2018. ISBN 9781450356206. DOI 10.1145/3173574.3173618.
5. ALZAHRANI, Adel, GAY, Valerie and ALTURKI, Ryan, 2022. The Evaluation of the Usability in Mobile Applications. *Proceedings of the 40th International Business Information Management Association (IBIMA), Seville, Spain*. pp. 23–24.
6. ANSARI, Bahareh, BARATI, Mehdi and MARTIN, Erika G., 2022. Enhancing the usability and usefulness of open government data: A comprehensive review of the state of open government data visualization research. *Government Information Quarterly*. Vol. 39, no. 1. DOI 10.1016/j.giq.2021.101657.
7. ANTOUN, Jo-Anne, 2018. *Cartographic Design and Interaction: An Integrated User-Centered Agile Software Development Framework for Web GIS Applications*. . University of Southern California.
8. ARTHANA, I K R, PRADNYANA, I M A and DANTES, G R, 2019. Usability testing on website wadaya based on ISO 9241-11. In : *Journal of Physics: Conference Series*, p. 012012. . IOP Publishing. 2019. ISBN 1742-6596.
9. BAKER, Thomas R, 2015. WebGIS in education. *Geospatial technologies and geography education in a changing world: Geospatial practices and lessons learned*. pp. 105–115.
10. BARNUM, Carol M, 2020. *Usability testing essentials: Ready, set... test!* Morgan Kaufmann. ISBN 0128169435.

11. BENAIDA, Mohamed, 2023. e-Government Usability Evaluation: A Comparison between Algeria and the UK. *International Journal of Advanced Computer Science and Applications*. Vol. 14, no. 1.
12. BERGER, Alexander and KIEFER, Markus, 2021. Comparison of different response time outlier exclusion methods: A simulation study. *Frontiers in Psychology*. Vol. 12, p. 675558.
13. BEVAN, Nigel et al., 2016. New ISO standards for usability, usability reports and usability measures. In : *Human-Computer Interaction. Theory, Design, Development and Practice: 18th International Conference, HCI International 2016, Toronto, ON, Canada, July 17-22, 2016. Proceedings, Part I 18*, pp. 268–278. . Springer. 2016. ISBN 3319395092.
14. BRATH, Richard and BANISSI, Ebad, 2016. Using typography to expand the design space of data visualization. *She Ji: The Journal of Design, Economics, and Innovation*. Vol. 2, no. 1, pp. 59–87.
15. BROWN, Greg, REED, Pat and RAYMOND, Christopher M, 2020. Mapping place values: 10 lessons from two decades of public participation GIS empirical research. *Applied Geography*. Vol. 116, p. 102156.
16. BURLOV, V G, GRYZUNOV, V V and TATARNIKOVA, T M, 2020. Threats of information security in the application of GIS in the interests of the digital economy. In : *Journal of Physics: Conference Series*, p. 012023. . IOP Publishing. 2020. ISBN 1742-6596.
17. CHE MAT, Ruzinoor et al., 2013. A Comparison between four-tier framework and three-tier framework for online applications of 3D GIS visualization. *Life Science Journal*. Vol. 10, no. 3, pp. 1534–1540.
18. CORTI, Paolo et al., 2019. *GeoNode: an open source framework to build spatial data infrastructures*. . PeerJ Preprints.
19. D. MORGAN, John, 2016. A User-centered Design for the Addition of Interactive Masking Capability within an existing Web GIS. *Transactions in GIS*. Vol. 20, no. 5, pp. 807–816.
20. DE LIMA SALGADO, André et al., 2019. Smart toys and children's privacy: Usable privacy policy insights from a card sorting experiment. In : *SIGDOC 2019 - Proceedings of the 37th ACM International Conference on the Design of Communication*. Association for Computing Machinery, Inc. 4 October 2019. ISBN 9781450367905. DOI 10.1145/3328020.3353951.

21. DE MIGUEL GONZÁLEZ, Rafael and DE LÁZARO TORRES, Maria Luisa, 2020. WebGIS Implementation and Effectiveness in Secondary Education Using the Digital Atlas for Schools. *Journal of Geography*. Vol. 119, no. 2, pp. 74–85. DOI 10.1080/00221341.2020.1726991.
22. DIMECH, Karen, 2022. Investigating Browser-Based Map Accessibility for Visually Impaired Users. *Applied Geomatics Approaches*. p. 181.
23. DJORDJEVIC, Nebojsa, 2017. Evaluation of the usability of web-based applications. *Vojnotehnicki glasnik*. Vol. 65, no. 3, pp. 785–802. DOI 10.5937/vojtehg65-11319.
24. DRAGOLJUB PILIPOVIĆ, Dejan Simeunović, 2021. View of The Quality of Software Metrics. .
25. DUGGER, Zachary et al., 2022. Principal Component Analysis in MCDM: An exercise in pilot selection. *Expert Systems with Applications*. Vol. 188. DOI 10.1016/j.eswa.2021.115984.
26. DÜREN, Martin and BARTOSCHEK, Thomas, 2013. Assessing the Usability of WebGIS for Schools. In : *GI_Forum 2013 – Creating the GISociety*, pp. 388–398. Vienna : Austrian Academy of Sciences Press. 2013. ISBN 978-3-87907-532-4. DOI 10.1553/giscience2013s388.
27. EL-FIRJANI, Naser F M, ELBERKAWI, Ebitisam K and MAATUK, Abdelsalam M, 2017. METHOD FOR WEBSITE USABILITY EVALUATION: A COMPARATIVE ANALYSIS. .
28. ELWAKIL, Maged M., IBRAHIM, Romani Farid and HEFNY, Hesham A., 2015. New Architecture for Mobile GIS Cloud Computing. *IJARCCE*. Vol. 4, no. 10, pp. 1–7. DOI 10.17148/ijarcce.2015.41001.
29. ENDSLEY, Mica R, 2016. *Designing for situation awareness: An approach to user-centered design*. CRC press. ISBN 1420063588.
30. FAST, Victoria and HOSSAIN, Fahim, 2020. An Alternative to Desktop GIS? Evaluating the Cartographic and Analytical Capabilities of WebGIS Platforms for Teaching. *Cartographic Journal*. Vol. 57, no. 2, pp. 175–186. DOI 10.1080/00087041.2019.1631514.
31. FRANCH-PARDO, Ivan et al., 2020. Spatial analysis and GIS in the study of COVID-19. A review. *Science of the total environment*. Vol. 739, p. 140033.
32. FUKUZUMI, ichi, GEIS, Thomas and EARTHY, Jonathan V, 2022. *What Is the Difference between Usability in ISO 25000 and ISO/IEC 9241-11?-The Term*

“usability” as Part of the Product Quality Model Used in the SQuaRE Series in Contrast to the Term Usability in ISO 9241-11. .

33. GARCIA-LOPEZ, Eva et al., 2021. An Experiment to Discover Usability Guidelines for Designing Mobile Tourist Apps. *Wireless Communications and Mobile Computing*. Vol. 2021. DOI 10.1155/2021/2824632.
34. GENEROSI, Andrea et al., 2022. A Test Management System to Support Remote Usability Assessment of Web Applications. *Information*. Vol. 13, no. 10, p. 505.
35. GONÇALVES, Mateus Carvalho et al., 2021. End-user development of smart home rules using block-based programming: a comparative usability evaluation with programmers and non-programmers. *Behaviour & Information Technology*. Vol. 40, no. 10, pp. 974–996.
36. GUPTA, Deepak and AHLAWAT, Anil K, 2019. Taxonomy of GUM and usability prediction using GUM multistage fuzzy expert system. *Int. Arab J. Inf. Technol.* Vol. 16, no. 3, pp. 357–363.
37. GUPTA, Deepak et al., 2020. Feature selection and evaluation for software usability model using modified moth-flame optimization. *Computing*. Vol. 102, pp. 1503–1520.
38. HAJESMAEEL-GOHARI, Sadrieh et al., 2022. The most used questionnaires for evaluating satisfaction, usability, acceptance, and quality outcomes of mobile health. *BMC Medical Informatics and Decision Making*. Vol. 22, no. 1. DOI 10.1186/s12911-022-01764-2.
39. HINDERKS, Andreas et al., 2019. Developing a UX KPI based on the user experience questionnaire. *Computer Standards & Interfaces*. Vol. 65, pp. 38–44.
40. HORBIŃSKI, Tymoteusz, CYBULSKI, Paweł and MEDYŃSKA-GULIJ, Beata, 2021. Web map effectiveness in the responsive context of the graphical user interface. *ISPRS International Journal of Geo-Information*. Vol. 10, no. 3, p. 134.
41. HUANG, Dong, HE, Bingsheng and MIAO, Chunyan, 2014. A survey of resource management in multi-tier web applications. *IEEE Communications Surveys and Tutorials*. Vol. 16, no. 3, pp. 1574–1590. DOI 10.1109/SURV.2014.010814.00060.
42. HUSSAIN, Azham et al., 2017. A usability evaluation of Lazada mobile application. In : *AIP Conference Proceedings*. . AIP Publishing. 2017. ISBN 0094-243X.
43. JAYAKUMAR, K., 2018. Managing mangrove forests using open source-based webgis. In : *Coastal Management: Global Challenges and Innovations*, pp. 301–321. Elsevier. ISBN 9780128104736. DOI 10.1016/B978-0-12-810473-6.00016-9.
44. JORDAN, Patrick W., 2020. *An Introduction To Usability*. CRC Press.

45. KAIPIO, Johanna et al., 2017. Usability problems do not heal by themselves: National survey on physicians' experiences with EHRs in Finland. *International Journal of Medical Informatics*. Vol. 97, pp. 266–281. DOI 10.1016/j.ijmedinf.2016.10.010.
46. KHAJOUEI, Reza, ZAHIRI ESFAHANI, Misagh and JAHANI, Yunes, 2017. Comparison of heuristic and cognitive walkthrough usability evaluation methods for evaluating health information systems. *Journal of the American Medical Informatics Association*. Vol. 24, no. e1, pp. e55–e60. DOI 10.1093/jamia/ocw100.
47. KHAN, Zulfiqar Ali and ADNAN, Muhammad, 2010. *Usability evaluation of web-based GIS applications: A comparative study of Google Maps and MapQuest*.
48. KOMARKOVA, Jitka et al., 2017. *Usability Evaluation of Web-Based GIS by means of a Model*. .
49. KOMARKOVA, Jitka et al., 2019. *Usability Evaluation the Prague Geoportal Comparison of Methods* . Online. Retrieved from : http://www.geoportalpraha.cz/en/map-
50. KONG, Ningning, ZHANG, Tao and STONEBRAKER, Ilana, 2014. Common metrics for web-based mapping applications in academic libraries. *Online Information Review*. Vol. 38, no. 7, pp. 918–935. DOI 10.1108/OIR-06-2014-0140.
51. KRÄMER, Michel and SENNER, Ivo, 2015. A modular software architecture for processing of big geospatial data in the cloud. *Computers & Graphics*. Vol. 49, pp. 69–81.
52. KUMAR, Abhishek et al., 2017. *A review of multi criteria decision making (MCDM) towards sustainable renewable energy development*. Elsevier Ltd. Renewable and Sustainable Energy Reviews 69. DOI 10.1016/j.rser.2016.11.191.
53. KUMAR, Santosh, 2019. A review on client-server based applications and research opportunity. *International Journal of Recent Scientific Research*. Vol. 10, no. 7, pp. 33386–33857.
54. KURIA, Ezekiel et al., 2019. *A Framework for Web GIS Development: A Review General Terms*. .
55. KUSWATI, Yeti, 2019. Motivation role in improving work effectiveness. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*. Vol. 2, no. 4, pp. 281–288.
56. LANGEVIN, Raina, LORDON, Ross and AVRAHAMI, Thi, 2021. Heuristic evaluation of conversational agents. In : *Conference on Human Factors in Computing*

Systems - Proceedings. Association for Computing Machinery. 6 May 2021. ISBN 9781450380966. DOI 10.1145/3411764.3445312.

57. LAUBHEIMER, Page, 2015. Preventing User Errors: Avoiding Unconscious Slips. . Online. 2015. Retrieved from : https://www.nngroup.com/articles/slips/ [accessed 20 June 2023].
58. LYZARA, Ria et al., 2019. E-Government Usability Evaluation: Insights from A Systematic Literature Review. In : *ACM International Conference Proceeding Series*, pp. 249–253. Association for Computing Machinery. 10 January 2019. ISBN 9781450366427. DOI 10.1145/3305160.3305178.
59. MAJERNIK, Milan et al., 2017. Design of integrated management systems according to the revised ISO standards. *Polish Journal of Management Studies*. Vol. 15, no. 1, pp. 135–143.
60. MICHAELA GLÄSER-ZIKUDA, Gerda Hagenauer & Melanie Stephan, 2020. View of The Potential of Qualitative Content Analysis for Empirical Educational Research. .
61. MILOSZ, Marek and CHMIELEWSKA, Magdalena, 2020. Usability testing of e-government online services using different methods–a Case Study. In : *2020 13th International Conference on Human System Interaction (HSI)*, pp. 142–146. . IEEE. 2020. ISBN 1728173922.
62. MIRNIG, Alexander G et al., 2015. A formal analysis of the ISO 9241-210 definition of user experience. In : *Proceedings of the 33rd annual ACM conference extended abstracts on human factors in computing systems*, pp. 437–450. . 2015.
63. MKPOJIOGU, Emmanuel O C, HUSSAIN, Azham and HASSAN, Fa'alina, 2018. A systematic review of usability quality attributes for the evaluation of mobile learning applications for children. In : *AIP Conference Proceedings*. . AIP Publishing. 2018. ISBN 0094-243X.
64. MOMENIPOUR, Amirmasoud et al., 2021. Usability of state public health department websites for communication during a pandemic: A heuristic evaluation. *International Journal of Industrial Ergonomics*. Vol. 86. DOI 10.1016/j.ergon.2021.103216.
65. MONIR, N et al., 2021. Address Geocoding Services in Geospatial-based Epidemiological Analysis: A Comparative Reliability for Domestic Disease Mapping. *International Journal of Geoinformatics*. Vol. 17, no. 5.
66. MORAN, Kate, 2019. Usability Testing 101. . . 1 December 2019.

67. MOUMANE, Karima, IDRI, Ali and ABRAN, Alain, 2016. Usability evaluation of mobile applications using ISO 9241 and ISO 25062 standards. *SpringerPlus*. Vol. 5, pp. 1–15.
68. MURODILOV, Kh T and ALISHEROV, Sh M, 2023. WEB CARTOGRAPHY AT THE CURRENT STAGE OF DEVELOPMENT OF GEOINFORMATION RESOURCES. *Galaxy International Interdisciplinary Research Journal*. Vol. 11, no. 4, pp. 166–171.
69. MUSHONGA, Hilary Takudzwa, BANDA, Faustin and MULOLWA, Augustine, 2017. Development of a web based GIS for health facilities mapping, monitoring and reporting: A case study of the Zambian Ministry of health. *South African Journal of Geomatics*. Vol. 6, no. 3, pp. 321–332.
70. MWANGI, E, KIMANI, Stephen and MINDILA, Agness, 2019. A Review Of Web-Based GIS Usability Elements. *J. Inform. Technol*. Vol. 4, pp. 2–13.
71. NIELSEN, Jakob, 2012. Usability 101: Introduction to Usability. . Online. 2012. Retrieved from : https://www.nngroup.com/articles/usability-101-introduction-to-usability/ [accessed 23 April 2023].
72. NUGRAHENI, Dinar Mutiara Kusumo, OKTAKHANIA, Yolanda and NORANITA, Beta, 2023. Usability evaluation of Prakerja card website. In : *AIP Conference Proceedings*. . AIP Publishing. 2023. ISBN 0094-243X.
73. ONOCKO-CAMPOS, Rosana Teresa et al., 2017. Desafios metodológicos para o uso de grupos focais com pessoas com doença mental grave. *Cadernos de Saude Publica*. Vol. 33, no. 6. DOI 10.1590/0102-311X00187316.
74. PETERSON, Michael P, 2021. MapQuest and the beginnings of web cartography. *International Journal of Cartography*. Vol. 7, no. 2, pp. 275–281.
75. PORTZ, Jennifer Dickman et al., 2019. Using the technology acceptance model to explore user experience, intent to use, and use behavior of a patient portal among older adults with multiple chronic conditions: descriptive qualitative study. *Journal of medical Internet research*. Vol. 21, no. 4, p. e11604.
76. PRZYBYSLAWSKI, Artur, 2016. Cognizable Object in Tshad ma rigs gter According to Go rams pa. *Journal of Indian Philosophy*. Vol. 44, no. 5, pp. 957–991.
77. ROETMAN, James, 2020. Using WiFi Signals in Combination with GPS to Track Human Traffic in a Space. *EasyChair*. No. 3902.

78. ROWLAND, Alexandra, FOLMER, Erwin and BEEK, Wouter, 2020. *Towards self-service gis—combining the best of the semantic web and web gis*. MDPI AG. ISPRS International Journal of Geo-Information 9. DOI 10.3390/ijgi9120753.
79. SAEIDNIA, Hamid Reza et al., 2022. Usability Evaluation of the Mask Mobile Application: The Official Application of the Iranian Government. *Iranian Journal of Medical Microbiology*. Vol. 16, no. 1, pp. 49–55. DOI 10.30699/ijmm.16.1.49.
80. SHARFINA, Zahra and SANTOSO, Harry Budi, 2016. An Indonesian adaptation of the system usability scale (SUS). In : *2016 International conference on advanced computer science and information systems (ICACSIS)*, pp. 145–148. . IEEE. 2016. ISBN 1509046291.
81. SINGH, Malini, MUKHERJEE, Sudipta and MUKHERJEE, Madhumita, 2021. Recent Development in Geospatial Platform and its significance in Tourism Planning. In : *Proceedings of 2021 2nd International Conference on Intelligent Engineering and Management, ICIEM 2021*, pp. 40–45. Institute of Electrical and Electronics Engineers Inc. 28 April 2021. ISBN 9781665414500. DOI 10.1109/ICIEM51511.2021.9445373.
82. SINHA, Pratik, CALFEE, Carolyn S. and DELUCCHI, Kevin L., 2020. *Practitioner's Guide to Latent Class Analysis: Methodological Considerations and Common Pitfalls*. Lippincott Williams and Wilkins. Critical Care Medicine. DOI 10.1097/CCM.0000000000004710.
83. STRUŠKA, Stanislav, 2017. *Univerzita Pardubice Fakulta ekonomicko-správní*. .
84. SUSANTO, Tony Dwi, PRASETYO, Anisa Ingesti and ASTUTI, Hanim Maria, 2018. Web usability evaluation on BloobIS website by using hallway usability testing method and ISO 9241:11. In : *Journal of Physics: Conference Series*. Institute of Physics Publishing. 22 March 2018. DOI 10.1088/1742-6596/974/1/012043.
85. TANDON, Urvashi, KIRAN, Ravi and SAH, Ash N, 2016. Customer satisfaction using website functionality, perceived usability and perceived usefulness towards online shopping in India. *Information development*. Vol. 32, no. 5, pp. 1657–1673.
86. TAVANA, Madjid et al., 2023. Analytic hierarchy process and data envelopment analysis: A match made in heaven. *Expert Systems with Applications*. Vol. 223. DOI 10.1016/j.eswa.2023.119902.
87. TSUDA, Naohiko et al., 2019. WSQF: Comprehensive Software Quality Evaluation Framework and Benchmark Based on SQuaRE. In : *Proceedings - 2019 IEEE/ACM 41st International Conference on Software Engineering: Software Engineering in Practice, ICSE-SEIP 2019*, pp. 312–321. Institute of Electrical and Electronics

Engineers Inc. 1 May 2019. ISBN 9781728117607. DOI 10.1109/ICSE-SEIP.2019.00045.

88. UNRAU, René and KRAY, Christian, 2019. Usability evaluation for geographic information systems: a systematic literature review. *International Journal of Geographical Information Science*. Vol. 33, no. 4, pp. 645–665.
89. VEENENDAAL, Bert, BROVELLI, Maria Antonia and LI, Songnian, 2017. Review of web mapping: Eras, trends and directions. *ISPRS International Journal of Geo-Information*. Vol. 6, no. 10, p. 317.
90. VERKIJIKA, Silas Formunyuy and DE WET, Lizette, 2018. A usability assessment of e-government websites in Sub-Saharan Africa. *International Journal of Information Management*. Vol. 39, pp. 20–29. DOI 10.1016/j.ijinfomgt.2017.11.003.
91. WANG, Jiahui et al., 2019. Exploring Relationships Between Eye Tracking and Traditional Usability Testing Data. *International Journal of Human-Computer Interaction*. Vol. 35, no. 6, pp. 483–494. DOI 10.1080/10447318.2018.1464776.
92. WATERS, N M, 2017. History of GIS. *International Encyclopedia of Geography: People, the Earth, Environment, and Technology; Richardson, D., Castree, N., Goodchild, MF, Kobayashi, A., Liu, W., Marston, R., Eds*. pp. 1–12.
93. YANG, Chaowei Phil and EVANS, John D, 2017. *Network GIS Performance.*. . Citeseer.
94. ZAMORA-MUSA, Ronald, VELEZ, Jeimy and PAEZ-LOGREIRA, Heyder, 2018. Evaluating learnability in a 3D heritage tour. *Presence*. Vol. 26, no. 4, pp. 366–377.
95. ZENG, Yuxiang, TONG, Yongxin and CHEN, Lei, 2019. Last-mile delivery made practical: An efficient route planning framework with theoretical guarantees. *Proceedings of the VLDB Endowment*. Vol. 13, no. 3, pp. 320–333.

APPENDIX

Appendix A: A table of 26 selected scholarly articles for criteria development

Year	Study	Usability Method	Number of People	Criteria	Usability Issues	Findings/ Limitations/ Recommendations
2013	Vipin Kumar, K. U., & Subramoniam, S. (2013). Usability analysis of an Indian e-governance software. Electronic Government, An International Journal, 10(2), 211-221.	Questionnaire survey	112	Suitability of task, self-descriptiveness, controllability, conformity with user expectation, error tolerance, suitability for individualisation, suitability for learning	The e-governance Software does not meet the ergonomic quality	IsoMetricsS ISO:9241 contains several dozens of such factors which can be tested more elaborately before making concluding remark.
2014	Venkatesh, V., Hoehle, H., & Aljafari, R. (2014). A usability evaluation of the Obamacare website. *Government information quarterly*, *31*(4), 669-680	Heuristic , Survey, Questionnaire	374	Access, Content and content organization, Graphs, Hardware and Software, Headings titles and labels, Home page, Links, List, Navigation, Page layout, Screen, Scrolling and Paging Search Text User experience	Poor Interface design, Slow load time, Poor user experience	User experience content organization, navigation and screen graphs and list were the top six usability dimension that contributed most to the overall satisfaction of citizens
2015	Delopoulos, H. N. (2015). A usability evaluation of e-government services: the case of e-deliberation service of Greece. International Journal of Electronic Governance, 7(2), 93-112.	Nielsen's heuristic, cognitive walkthrough, inspection, questionnaire, expert testing, policy analysis, web usability guidelines and standards	4	Nielsen's heuristic, ISO 9241-11 web usability guidelines, HHS web usability guidelines, ISO 9241-151 web usability guidelines	Experts discovered: System was not interactive because No feedback after user input or actions, the service provides no user Poor navigation Because the back navigation, causes a restart of the whole process, Problem of readability and clarity because Confirmation pages are not clear,	User testing is recommended for a comprehensive view usability problems

					Problem of error prevention No help and no documentation	
2016	Hub, M., & Musilová, B. (2016). 90omparison of usability evaluation of public administration webpages by user testing and by analytical models. Scientific papers of the University of Pardubice. Series D, Faculty of Economics and Administration. 37/2016.	User Testing And By Analytical Models	7	Total time for task completion Total waiting time	The comparison of results showed deviation therefore, the model did not reflect the reality.	Not generic for all public administration
2017	Komarkova, J., Sedlak, P., Habrman, J., & Cermakova, I. (2017, July). Usability evaluation of web-based gis by means of a model. In 2017 international conference on information and digital technologies (idt) (pp. 191-197). IEEE.	Analytical model, NGOMSL, User testing	12	Findability, Clearness of arrangements Utilization Understandability Pleasantness of a user interface Response time of an application Design Necessity of plug-ins	Major problem was findability as user could not identify tools to display street names measure distances and couldn't utilize search tools	Pardubice region required utilization of Java applet, which made utilization of the application impossible because it requires users to allow dangerous plug-ins in web-browser
2018	VERKIJIKA, Silas Formunyuy and DE WET, Lizette. A usability assessment of e-government websites in Sub-Saharan Africa. International Journal of Information Management, [s. l.], v. 39, p. 20-29, 2018. ISSN 0268-4012.	Heuristic evaluation and automated testing		Online services, user help, Navigation, Legitimacy, Information architecture, Accessibility	Need up to date user-help and feedback capabilities Poor navigation for most countries Poor legitimacy scores for most countries indicating low trust in the government website to users. Poor organization of information for effective use Lack of simplicity leading to smaller range of accessibility	User-based method was recommended to identify issues relatable to actual users However, automated testing allows for the testing of more websites (279 in this study) as compared to user testing.

2019	Komarkova, J., Sedlak, P., Struska, S., & Dymakova, A. (2019, June). Usability Evaluation the Prague Geoportal: Comparison of Methods. In 2019 International Conference on Information and Digital Technologies (IDT) (pp. 223-228). IEEE.	Heuristic evaluation, user testing, survey	24-user 3-experts	Accessibility, display and application launch, Design, user interface look, Moving and zooming in map, Utilization of scale, Work with data layers, Distance measurement and searching, Printing and exporting maps,	Identification of functions e.g., measurement tool, GPS coordinates, Poor arrangements of features, Long load time, Slow response time	Severe problems are identified by means of the user testing compared to heuristic Heuristic evaluation typically identifies “cosmetic” usability problems, which are relatively minor in nature compared to critical usability issues Better placement and highlighting of tools and icons for easier identification
	Alexandru, A., Gheorghe-Moisii, M., Iordache, D. D., & Tîrziu, E. (2019, June). A case study in the usability evaluation of an online public service used by seniors. In 2019 11th International Conference on Electronics, Computers and Artificial Intelligence (ECAI) (pp. 1-4). IEEE.	Usability Inspection	4	Prompting Feedback Information architecture Grouping / distinction Consistency Cognitive workload Minimal actions Explicit user actions User control Flexibility Compatibility with the user Task guidance and support Error management Help and documentation	Major problems with how interactive was in terms of prompting and feedback Major problems with respect to user effort, user control and user freedom	Language variety embedded in the application is important for the benefit of international beneficiaries
	Zeain, A. (2019). Usability evaluation of Iraq government websites (Master’s thesis).	Heuristic Evaluation	30	Nielsen’s usability heuristics evaluation	Difficulty in understanding information provided Poor load times Difficulty in finding information Poor clarity of information	User testing is recommended with participants with diverse IT background to ascertain practical usability issues
	Gkonos, C., Iosifescu Enescu, I., & Hurni, L. (2019). Spinning the wheel of design: evaluating geoportal Graphical	User Testing, Questionnaire	30	Complexity/ Simplicity Need for technical support Functionality	Too many steps(clicks) to execute a task	Participants were only allowed to hight usability problems but not their constructive feedback

	User Interface adaptations in terms of human-centred design. International Journal of Cartography, 5(1), 23-43.			Consistency Learnability Dependability	Poor navigation causing increased mental pressure to complete task Poor content organization Limited functionalities	
2020	Milosz, M., & Chmielewska, M. (2020, June). Usability testing of e-government online services using different methods–A case study. In 2020 13th International Conference on Human System Interaction (I) (pp. 142-146). IEEE.	User testing, questionnaire, survey	24	User tasks to depict content organization, Interaction, Navigation, Consistency, Simplicity	Difficulties identification and recognition of features Poor navigation Not interactive enough for multi-step tasks Inadequate visibility of system status Formatting issues and inconsistencies	User personas was used to reflect real-world scenarios Testing with these identified personas provided valuable insights into practical usability issues
	Chang, C., & Almaghalsah, H. (2020). Usability evaluation of e-government websites: A case study from Taiwan. International Journal of Data and Network Science, 4(2), 127-138.	Heuristic Evaluation	100	Nielsen's usability heuristics evaluation	Links or subject did not match required information Many different colour of links obstruct users colour vision resulting in confusion and difficulty in information identification The system did not fully utilize the users' language hence did no match the real world Poor recognition and visibility	Certain criteria associated with multiple heuristics were grouped together under a single heuristic. It is recommended to assess, taking into account not only the perspective of local users but also that of foreigners.
	Polasanapalli, S. L., & Buggareddy, P. (2020). Usability Evaluation to design a user interface by implementing HCI design principles.	Heuristic evaluation, expert review, survey	100	Nielsen's usability heuristics evaluation	Repetition of data Unattractive layout Poor navigation Poor visibility	Speech recognition and voice search be implemented for disabled people by following all the HCI design principles
	Sukmasetya, P., Setiawan, A., & Arumi, E. R. (2020, April). Usability evaluation of university website: a case study. In Journal of Physics: Conference Series (Vol. 1517, No. 1, p. 012071). IOP Publishing.	Questionnaire	95	Learnability Efficiency Memorability Error Satisfaction.	User encountered errors in the execution of tasks due to difficulty in menu identification Some menu did not work according to function	Other users should be incorporated in the study for better usability analysis. E.g., prospective students
2021	Momenipour, A., Rojas-Murillo, S., Murphy, B., Pennathur, P., & Pennathur, A. (2021). Usability of state public health department websites for	Heuristic Evaluation	5	User experience, Hardware and software requirements, homepage usability, Homepage layout,	Poor content organization Poor search functionality,	Heuristic evaluation is expert dependent and may be construed as subjective.

	communication during a pandemic: A heuristic evaluation. *International journal of industrial ergonomics*, *86*, 103216.			website navigation, text and graphics, Content organization, Search functionality	Poor navigation Design inconsistencies	However, combination of methods including user testing highlights more realistic usability issues.
	Garcia-Lopez, E., Garcia-Cabot, A., de-Marcos, L., & Moreira-Teixeira, A. (2021). An experiment to discover usability guidelines for designing mobile tourist apps. Wireless Communications and Mobile Computing, 2021, 1-12.	Heuristic Evaluation	4 experts	Nielsen's Severity Ranking Scale (SRS) Visibility of system status and findability of the mobile device Match between system and the real world Consistency and mapping Good ergonomics and minimalist design Ease of input, screen readability, and glanceability Flexibility, efficiency of use, and personalization Aesthetic, privacy, and social conventions	Unreadable font size of street names Names did not match read world Advertisements covered bigger portion of the interface Confusing and inconsistency of layout and design Display of only one point of interest at a time	Tourists are from different countries therefore personalization of units should be considered (such as currency or distance measurements) An efficient search for attractions should be provided, not only listing them but the tourist must be able to search by name
	Prayoga, A., Ferli, I., Absor, M. U., & Al Ayyubi, M. S. (2021, December). Evaluation of the pesawaran regency government website using the method usability testing. In Proceeding International Conference on Information Technology and Business (pp. 90-92).	User Testing, Questionnaire	34	Content, Organisation And Readability Navigation and Links User Design Interface Performance and Effectiveness	Users were dissatisfied with these criteria at an average degree of 0.324	The 32.4% usability issues were ignored and not reported because the research conclusion that 67.6% was above average
	Alshira'h, M. (2021). Usability evaluation of learning management systems (LMS) based on user experience. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(11), 6431-6441.	Questionnaire	350	Interaction and feedback User manipulation and control Display of update information Appearance and layout Text and graphics	Poor user control as users found difficulties in the manipulation of software to make submissions.	Language inclusion should be incorporated in the software considering the number of foreign students
2022	Ilyas, A., Wajid, S. H., & Muhammad, A. (2022). Usability Evaluation of E-Government Website: A Use of System Usability Scale. *Pakistan Journal of*	System usability scale	19	Ease of use Consistency Functionality Learnability	Poor user interface design Low user satisfaction	Technical expertise of tested participants highly affects the results of usability evaluation as it may not

	Engineering and Technology, *5*(1), 11-15.					represent the problems of the average users
	Saeidnia, H. R., Karajizadeh, M., Mohammadzadeh, Z., Abdoli, S., & Hassanzadeh, M. (2022). Usability evaluation of the mask Mobile application: the official application of the Iranian government. Iranian Journal of Medical Microbiology, 16(1), 49-55.	Heuristic evaluation, user testing, System usability scale	5 experts 124 users	Jacob Nielsen's 10 general principles	Poor error prevention Weak flexibility and efficiency	The heuristic evaluation pointed out the specific usability problems. However, the SUS recorded a mean of 89% which according to the researchers was excellent, hence the 11% errors were ignored and not reported.
	Dahri, N. A., Vighio, M. S., Al-Rahmi, W. M., & Alismaiel, O. A. (2022). Usability Evaluation of Mobile App for the Sustainable Professional Development of Teachers. International Journal of Interactive Mobile Technologies, 16(16).	Heuristic Evaluation	3 experts	Design standards Convention for hyperlinked text in the main text Navigational standards Findability Readability Multi-language option Mobile device compatibility Information architecture	Errors, e.g., empty links Not enough content Poor content organization and layout	Ministries should enforce usability evaluation and accessibility as part of quality assurance
	Asemi, A., & Asemi, A. (2022). A judgment-based model for usability evaluating of interactive systems using fuzzy Multi Factors Evaluation (MFE). Applied Soft Computing, 117, 108411.	Fuzzy, Analytical Model	10	Effectiveness Efficiency Error protection Learnability Utility	The system exhibited poor usability in terms of error protection, efficiency, and effectiveness	Tested participants were individuals with speech impediment, other users must be included in usability analysis for better results
2023	Benaida, M. (2023). E-Government Usability Evaluation: A Comparison between Algeria and the UK. International Journal of Advanced Computer Science and Applications, 14(1).	Expert evaluation, Questionnaire	7	Page layout, Text appearance, Graphics, Images, Multimedia	Poor page layout Poor content organization	User satisfaction is critical to web design irrespective of the domain; thus, expectations must be met by the developer
	Nugraheni, D. M. K., Oktakhania, Y., & Noranita, B. (2023, June). Usability evaluation of Prakerja card website. In AIP Conference Proceedings (Vol. 2738, No. 1). AIP Publishing.	User testing, Questionnaire	15	Effectiveness Efficiency Satisfaction.	Difficulty in manipulation resulting in low efficiency and satisfaction of software Identification problems due to small-sized words and colour with no contrast.	Age is a critical factor to consider in software development as issues of usable may be prevalent in an age category but not in another

	Piccoli, F., Locatelli, S. G., Schettini, R., & Napoletano, P. (2023). An Open-Source Platform for GIS Data Management and Analytics. Sensors, 23(8), 3788.	Survey, System usability scale	20	Effectiveness Ease of use	Zoom levels were unsatisfactory Unsatisfactory ease of use for non-expert users	Technical assistance for this Geoportal was necessary for non-expert user.
	Toolaroud, P. B., Nabovati, E., Mobayen, M., Akbari, H., Feizkhah, A., Farrahi, R., & Jeddi, F. R. (2023). Design and usability evaluation of a mobile-based-self-management application for caregivers of children with severe burns. International wound journal.	Cognitive walkthrough, Questionnaire	38	Functionality Screen design, Terminology Educational content Learning capabilities	This study was a participatory design which involved engagement of all stakeholders in the design of the application and evaluation process, hence usability evaluation for all criteria proved to be good.	The study did not cover or evaluate the individual and clinical impacts of the application

Source: Author's own creation

Appendix B: A summary of the 26 scholarly articles

STANDARD	CRITERIA	METRIC
Effectiveness Errors	**Functionality**	Menu functionality and features, Operability, Suitability Work with data layers Multi-language option, Accuracy, Robustness, Pop-up directives, Error tolerance Error management
Efficiency	**Performance**	Navigation, Promptness, Load time Wait time, Zooming Panning, Scrolling Smoothness of transition Links, Click times
Learnability Memorability	**Cognizability**	Self-descriptiveness of icons, Understandability, Legibility Simplicity, Consistency Findability, Conformity with user expectation, Match between system and the real world, Recognizability
Satisfaction	**User-centric Design**	Design and user interface look, Headings, titles, and labels Text appearance, Graphics, Multimedia Content organization, Visual appeal, Clearness of arrangements, Contrast Appearance and layout, Ergonomics
	User Experience	Flexibility, User control, Manipulation , Personalization Interaction , Feedback, Prompting, Minimal actions Ease of Use Utility

Source: Author's own creation

Appendix C: Time Taken By Participants For Functionality Test For Selected Countries

MEASURABILITY OF FUNCTIONALITY FOR SELECTED COUNTRIES	MM:SS																													
	CZECH						POLAND						SLOVAKIA						GERMANY						AUSTRIA					
	PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Launch the Application	00:03	00:02	00:02	00:02	00:03	00:03	00:06	00:05	00:04	00:06	00:06	00:06	00:06	00:04	00:05	00:05	00:06	00:05	00:03	00:02	00:02	00:03	00:02	00:02	00:04	00:03	00:02	00:02	00:03	00:02
Convert to English version	00:03	00:06	00:02	00:03	00:02	00:05	00:04	00:05	00:07	00:02	00:03	00:04	00:03	00:05	00:05	00:05	00:07	00:06	00:04	00:05	00:02	00:05	00:06	00:03	00:04	00:03	00:03	00:02	00:02	00:01
Locate and load the online map	00:12	00:04	00:08	00:06	00:02	00:05	00:13	00:07	00:12	00:17	00:18	00:33	00:13	00:09	00:03	00:19	00:17	00:07	00:14	00:05	00:13	00:07	00:02	00:08	00:11	00:06	00:05	00:04	00:04	00:07
Scroll to locate the capital city of the country	00:10	00:05	00:06	00:04	00:09	00:08	00:11	00:04	00:03	00:02	00:02	00:04	00:06	00:05	00:09	00:07	00:09	00:08	00:15	00:12	00:09	00:17	00:12	00:13	00:08	00:09	00:12	00:11	00:16	00:06
Switch map to Orthophoto/aerial map	00:13	00:04	00:12	00:08	00:07	X	00:25	00:16	X	X	X	X	00:06	00:05	00:06	00:04	00:11	00:02	00:05	00:07	00:18	00:22	00:34	00:02	00:04	00:004	00:11	00:07	00:13	00:15
Zoom to any landmark within the country	00:08	00:07	00:09	00:07	00:07	00:10	00:05	00:08	00:06	00:04	00:06	00:06	00:06	00:07	00:04	00:02	00:06	00:02	00:05	00:06	00:07	00:04	00:07	00:04	00:05	00:07	00:06	00:04	00:07	00:07
Measure the distance between any two points	X	00:07	00:20	00:15	00:19	00:04	00:12	00:13	1:00	00:19	X	00:11	00:05	00:10	00:11	00:08	00:16	00:05	00:24	00:08	00:10	00:07	00:05	00:07	00:07	00:08	00:13	00:10	00:09	00:13
Display any point of interest of your choosing	X	00:21	02:00	X	X	01:02	X	00:17	00:12	00:28	00:26	X	X	X	X	X	X	X	X	00:54	X	X	X	00:29	00:07	00:10	00:15	00:11	00:17	00:19
Turn on/off administrative boundaries	X	00:20	00:40	X	X	00:45	X	00:22	00:24	X	X	X	00:20	00:17	00:05	00:15	00:25	00:20	X	00:39	00:32	X	X	00:07	00:13	00:15	00:08	00:13	00:17	00:30
Display coordinates of any location	00:06	00:14	00:17	00:7	X	00:23	00:19	00:15	00:19	X	00:06	00:17	00:09	00:04	00:02	00:02	00:16	00:14	00:13	00:09	00:23	00:07	00:20	X	00:07	00:10	00:13	00:08	00:12	00:11
Locate scale and change to a measurement	00:12	00:03	00:4	00:08	00:05	00:04	00:15	00:07	00:11	00:11	00:10	00:06	00:11	00:03	00:08	00:07	00:11	00:02	00:13	00:5	00:07	00:08	00:09	00:07	00:11	00:02	00:06	00:07	00:06	00:03
Locate the legend of the map	X	00:47	X	00:25	00:29	X	00:17	00:06	00:13	00:06	00:07	00:16	00:13	00:04	00:05	00:07	00:11	00:05	00:02	00:03	00:06	00:05	00:08	00:02	00:12	00:19	00:13	00:25	X	X
Locate the print button	00:16	00:08	00:22	00:23	00:09	00:09	X	00:07	00:08	00:11	X	00:09	00:10	00:04	00:06	00:06	00:05	00:09	00:11	00:04	00:06	00:05	00:10	00:013	00:09	00:12	00:14	00:09	00:14	00:05
Bookmark or highlight any location for future reference	X	00:09	1:01	00:23	X	00:31	X	X	X	X	X	X	00:25	00:08	00:10	00:09	00:20	00:13	X	00:10	X	X	01:04	00:13	X	00:10	X	00:12	00:25	X
Create link/Share/Export map	X	X	X	X	X	X	X	15	X	12	27	X	00:07	00:06	00:07	00:06	00:03	00:01	00:04	00:06	00:06	00:08	00:04	00:01	X	00:03	X	00:05	X	X

Source: Author's own creation

Appendix D: Time Taken By Participants For Functionality Test For Selected Capital Cities

MEASURABILITY OF FUNCTIONALITY FOR SELECTED CAPITAL CITIES	MM:SS																													
	PRAGUE						WARSAW						BRATISLAVA						BERLIN						VIENNA					
	PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Launch the Application	00:03	00:02	00:02	00:02	00:03	00:03	00:06	00:05	00:04	00:06	00:06	00:06	00:06	00:04	00:05	00:05	00:06	00:05	00:03	00:02	00:02	00:03	00:02	00:03	00:04	00:03	00:02	00:02	00:03	00:02
Convert to English version	00:07	00:08	00:07	00:01	00:03	00:2	00:14	00:12	00:25	00:14	00:07	00:05	00:03	00:04	00:03	00:05	00:07	00:03	00:07	00:04	00:06	00:02	00:05	00:04	00:03	00:04	00:07	00:06	00:07	00:07
Locate and select the online map	00:03	00:04	00:02	00:02	00:06	00:04	00:03	00:05	00:04	00:06	00:04	00:02	00:03	00:02	00:05	00:06	00:06	00:05	X	01:11	X	X	01:27	X	00:03	00:05	00:04	00:03	00:02	00:03
Zoom to any street within the capital city	00:06	00:05	00:08	00:02	00:07	00:04	00:04	00:03	00:03	00:03	00:07	00:05	00:05	00:06	00:02	00:11	00:07	00:08	00:04	00:03	00:03	00:04	00:02	00:02	00:02	00:05	00:04	00:02	00:01	00:06
Display a specific point of interest of your choosing	00:04	00:06	00:09	00:14	00:02	00:13	00:07	00:05	00:11	00:04	00:03	00:09	00:11	00:08	00:13	00:07	00:16	00:07	00:07	00:03	00:04	00:10	00:05	00:04	00:05	00:04	00:03	00:04	00:03	00:04
(Browse the address of any hospital) use search field to locate it on the map	00:08	00:04	00:05	00:07	00:05	00:05	00:11	00:09	00:08	00:12	00:10	00:11	00:09	00:06	00:08	00:06	00:07	00:06	00:07	00:05	00:08	00:06	00:06	00:04	00:08	00:05	00:07	00:06	00:08	00:03
Measure the distance between two any points	00:05	00:06	00:16	00:04	00:13	00:08	00:10	00:06	00:16	00:09	00:08	00:10	00:09	00:06	00:11	00;10	00:08	00:07	X	X	X	X	X	X	00:09	00:05	00:06	00:07	00:11	00:05
Display coordinates of any location within the city	00:16	00:13	00:27	00:10	00:27	00:13	X	00:07	X	00:11	X	00:13	X	00:19	00:21	00:32	X	X	X	X	X	X	X	X	00:13	00:11	00:20	00:16	00:10	00:16
Turn on/off administrative boundaries	X	00:40	00:60	X	X	X	X	00:11	X	00:23	X	00:06	X	00:13	X	00:22	X	00:29	X	X	X	X	X	X	X	X	00:59	00:43	X	X
Switch map to Orthophoto/aerial map	00:07	00:07	00:15	00:09	00:08	00:08	00:14	00:09	00:18	00:13	00:14	00:12	00;17	00:13	00:25	00:25	00:08	00:30	X	X	X	X	X	X	00:06	00:04	00:03	00:06	00:08	00:07
Locate the print button	00:03	00:04	00:05	00:10	00:06	00:01	00:05	00:03	00:04	00:06	00:02	00:03	00:05	00:3	00:02	00:02	00:04	00:03	X	X	X	X	X	X	00:11	00:13	00:12	00:11	00:16	00:13
Bookmark or highlight any location for future reference	X	X	X	X	X	X	X	X	X	X	X	X	X	X	00:33	X	X	00:29	X	00:06	00:10	X	X	00:09	00:13	00:19	00:09	00:10	00:07	00:19
Locate scale and change to a measurement of your choice	00:17	00:07	00:08	00:14	00:14	00:11	00:07	00:03	00:06	00:06	00:05	00:05	00:19	00:08	00:15	00:12	00:11	00:10	00:13	00:05	00:11	00:08	00:07	00:06	00:08	00:05	00:07	00:07	00:05	00:03
Locate the legend of the map	00:14	00:06	00:09	00:12	00:21	00:08	X	00:33	X	00:42	X	X	00:07	00:03	00:02	00:04	00:05	00:05	X	00:19	X	X	00:15	X	00:10	00:07	00:08	00:08	00:07	00:09
Create link/Share/Export map	00:02	00:03	00:03	00:02	X	00:06	00:4	00:04	00:08	00:06	00:09	00:08	00:05	00:04	00:02	00:04	00:03	00:08	00:12	00:06	00:11	00:05	00:06	00:04	00:02	00:03	00:05	00:03	00:02	00:02

Source: Author's own creation

Appendix E: Time Taken By Participants For Performance Test For Selected Countries

TASKS FOR MEASURABILITY OF PERFORMANCE FOE SELECTED COUNTRIES	MM:SS																													
	CZECH						POLAND						SLOVAKIA						GERMANY						AUSTRIA					
	PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
1. Launch the Application	00:03	00:02	00:03	00:02	00:03	00:03	00:03	00:04	00:02	00:02	00:02	00:03	00:03	00:02	00:03	00:03	00:03	00:02	00:07	00:06	00:06	00:05	00:05	00:05	00:03	00:03	00:02	00:03	00:02	00:02
2. Load the online map	00:06	00:05	00:05	00:05	00:05	00:06	00:09	00:12	00:12	00:13	00:12	00:14	00:08	00:07	00:06	00:05	00:07	00:06	00:03	00:01	00:02	00:01	00:01	00:02	00:05	00:05	00:04	00:04	00:04	00:05
3. Scroll to locate the capital city of the country	00:06	00:06	00:05	00:05	00:05	00:04	00:04	00:03	00:03	00:02	00:03	00:03	00:04	00:04	00:03	00:04	00:03	00:04	00:03	00:02	00:03	00:03	00:02	00:03	00:04	00:04	00:03	00:04	00:03	00:04
4. Switch map to Orthophoto/aerial map	00:03	00:02	00:02	00:02	00:02	00:02	00:09	00:09	00:10	00:08	00:09	00:08	00:07	00:05	00:06	00:05	00:06	00:05	00:06	00:05	00:05	00:05	00:06	00:05	00:07	00:05	00:06	00:05	00:06	00:05
5. Zoom to any landmark within the country	00:06	00:03	00:03	00:05	00:05	00:04	00:05	00:04	00:06	00:05	00:05	00:05	00:06	00:04	00:05	00:05	00:05	00:04	00:04	00:03	00:03	00:04	00:05	00:05	00:05	00:04	00:03	00:05	00:03	00:04

Source: Author's own creation

Appendix F: Time Taken By Participants For Performance Test For Selected Capital Cities

TASKS FOR MEASURABILITY OF PERFORMANCE FOR SELECTED CAPITAL CITIES	MM:SS																													
	PRAGUE						WARSAW						BRATISLAVA						BERLIN						VIENNA					
	PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
1. Launch the Application	00:03	00:02	00:02	00:02	00:03	00:03	00:06	00:05	00:04	00:06	00:06	00:06	00:06	00:04	00:05	00:05	00:06	00:05	00:03	00:02	00:02	00:03	00:02	00:02	00:04	00:03	00:02	00:02	00:03	00:02
2. Load the online map	00:07	00:07	00:06	00:06	00:05	00:06	00:02	00:02	00:02	00:02	00:02	00:02	00:03	00:03	00:03	00:03	00:03	00:03	00:02	00:01	00:02	00:01	00:01	00:02	00:05	00:05	00:04	00:04	00:04	00:05
3. Zoom to any street within the capital city	00:06	00:04	00:05	00:05	00:06	00:05	00:05	00:06	00:04	00:07	00:07	00:06	00:07	00:06	00:07	00:07	00:07	00:06	00:03	00:02	00:02	00:03	00:02	00:03	00:04	00:03	00:02	00:02	00:03	00:03
4. Display a specific point of interest of your choosing	00:08	00:04	00:04	00:07	00:06	00:06	00:06	00:04	00:05	00:06	00:06	00:06	00:07	00:05	00:06	00:06	00:06	00:05	00:03	00:03	00:02	00:03	00:04	00:03	00:02	00:02	00:02	00:01	00:02	00:01
5. (Browse the address of any hospital) use search field to locate it on the map	00:04	00:02	00:03	00:05	00:03	00:04	00:04	00:03	00:04	00:04	00:04	00:03	00:04	00:03	00:05	00:05	00:03	00:04	00:02	00:01	00:02	00:02	00:02	00:02	00:02	00:02	00:03	00:03	00:03	00:03

Source: Author's own creation

Appendix G: Time Taken By Participants For Cognizability Test For Selected Countries

TASKS FOR MEASURABILITY OF COGNIZABILITY FOR SELECTED COUNTRIES	MM:SS																													
	CZECH						POLAND						SLOVAKIA						GERMANY						AUSTRIA					
	PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Learnability																														
1. Locate scale and change to a measurement of your choice	00:12	00:03	00:4	00:08	00:05	00:04	00:15	00:07	00:11	00:11	00:10	00:06	00:11	00:03	00:08	00:07	00:11	00:02	00:13	00:5	00:07	00:08	00:09	00:07	00:11	00:02	00:06	00:07	00:06	00:03
2. Locate the print button	00:16	00:08	00:22	00:23	00:09	00:09	X	00:07	00:08	00:11	X	00:09	00:10	00:04	00:06	00:06	00:05	00:09	00:11	00:04	00:06	00:05	00:10	00:013	00:09	00:12	00:14	00:09	00:14	00:05
Locate the legend of the map	X	00:47	X	00:25	00:29	X	00:17	00:06	00:13	00:06	00:07	00:16	00:13	00:04	00:05	00:07	00:11	00:05	00:02	00:03	00:06	00:05	00:08	00:02	00:12	00:19	00:13	00:25	X	X
Memorability																														
4. Display coordinates of any location within the country	00:17	00:06	00:07	00:10	00:14	00:13	00:09	00:06	00:08	00:08	00:07	00:07	00:08	00:04	00:06	00:06	00:06	00:04	00:13	00:07	00:10	00:09	00:13	00:18	00:11	00:6	00:12	00:11	00:11	00:04
5. Turn on/off administrative boundaries	X	00:10	00:13	00:015	X	00:12	00:11	00:07	00:04	00:12	00:09	00:10	00:13	00:07	00:08	00:10	00:11	00:08	X	00:10	00:12	00:13	00:17	X	00:15	00:07	00:11	00:9	00:13	00:17

Source: Author's own creation

Appendix H: Time Taken By Participants For Cognizability Test For Selected Capital Cities

TASKS FOR MEASURABILITY OF COGNIZABILITY FOR SELECTED CAPITAL CITIES	MM:SS																													
	PRAGUE						WARSAW						BRATISLAVA						BERLIN						VIENNA					
	PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS						PARTICIPANTS					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Learnability																														
Locate scale and change to a measurement of your choice	00:17	00:07	00:08	00:14	00:14	00:11	00:07	00:03	00:06	00:06	00:05	00:05	00:19	00:08	00:15	00:12	00:11	00:10	00:13	00:05	00:11	00:08	00:07	00:06	00:08	00:05	00:07	00:07	00:05	00:03
Locate the legend of the map	00:14	00:06	00:09	00:12	00:21	00:08	X	33	X	42	X	X	00:07	00:03	00:02	00:04	00:05	00:05	X	X	X	X	X	X	00:10	00:07	00:08	00:08	00:07	00:09
(Browse the address of any hospital) use search field to locate it on the map	00:08	00:04	00:05	00:07	00:05	00:05	00:11	00:09	00:08	00:12	00:10	00:11	00:09	00:06	00:08	00:06	00:07	00:06	00:07	00:05	00:08	00:06	00:06	00:04	00:08	00:05	00:07	00:06	00:08	00:03
Memorability																														
Display a specific point of interest of your choosing	X	00:07	00:11	00:12	00:09	00:13	00:18	00:11	00:16	00:14	00:09	00:016	X	00:01	00:06	00:61	00:16	00:05	00:09	00:06	00:08	00:06	00:08	00:04	00:13	00:04	00:06	00:14	00:14	00:03
Create link/Share/Export map	00:13	00:07	00:09	00:11	00:08	00:07	00:06	00:03	00:05	00:04	00:04	00:03	00:09	00:05	00:07	00:08	00:05	00:06	00:08	00:04	00:07	00:05	00:06	00:04	00:05	00:03	00:04	00:04	00:05	00:03

Source: Author's own creation

Appendix I: Questionnaire For Participants

QUESTIONNAIRE FOR USABILITY EVALUATION OF SELECTED GEOPORTALS
Thank you for taking part in the usability test for the Geoportals. Your feedback is valuable in improving the user experience of the software. Please take a moment to answer the questionnaire below based on your personal experience during the usability test. As you proceed kindly; • Read each question carefully and reflect on your experience. • Provide your feedback based on your true experience. • Choose the rating that best represents your opinion for each question. If you have any additional comments or suggestions related to a specific question or any aspect of the geoportal's usability, please feel free to provide them in the space provided at the end of the questionnaire.

QUESTIONS	STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE
USER-CENTRIC DESIGN					
1. The content within the Geoportal is well-organized, with clear headings, and sections that help users locate and access the desired information.					
2. The labels, icons, and menus in the Geoportal are self-descriptive, allowing users to quickly understand their purpose and functionality.					
3. The Geoportal has good colour contrast leading to clarity and legibility of the map interface.					
4. The Geoportal is intuitive and has consistency of content organization across various layers of the map.					
5. The Geoportal's layout is overall pleasing and contributes to the overall user satisfaction.					
USER EXPERIENCE					
6. The Geoportal has the necessary features and functionality to complete all tasks.					
7. Users can personalize their workspace by saving and organizing their preferred layers and maps, by printing or bookmarking for easy access.					
8. Execution of task is easy and require minimal actions.					
9. The Geoportal is very flexible and interactive.					
10. The Geoportal meets my expectation and l am satisfied with it.					

Any additional comments……………………………………………………………………….

Source: Author's own creation

Appendix J: Participants' Guide for User Testing

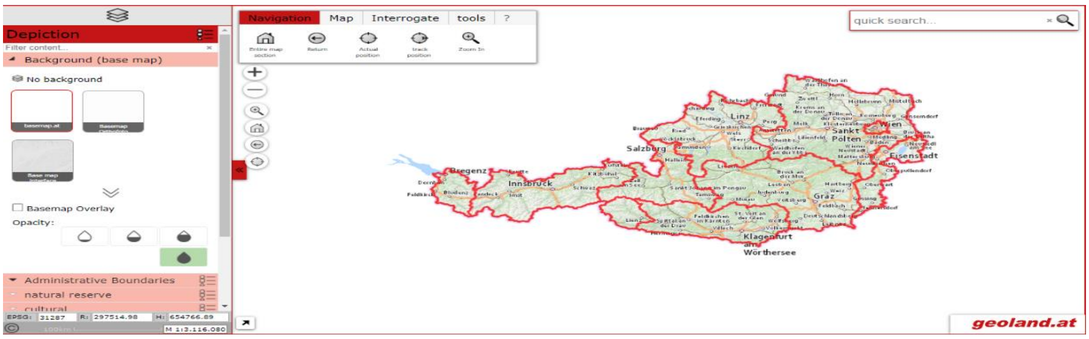
PARTICIPANT GUIDE
1. Familiarize yourself with the web-GIS portals and its interface
2. Read instructions carefully
3. Review the provided task scenarios and understand the goals and objectives of each task
4. Begin with the first task scenario and perform task step by step
5. Use the provided tools and features to complete the task as accurately as possible
6. Take note of any issues, difficulties, or confusing aspects encountered during the task
7. Verbalize your thoughts and actions as you complete the task scenario (think aloud)
8. Utilize the help button of the geoportals if need be
9. You can skip tasks you find too difficult or too long to carry out (after 3 minutes)
10. Provide feedback on the overall usability of the web-GIS portal based on your experience completing the tasks.
11. Complete questionnaire for additional information
12. Task completion

Source: Author's own creation

Appendix K: Interface for Geoportal of Slovakia

Source: Author's own creation

Appendix L: Interface for Geoportal of Austria

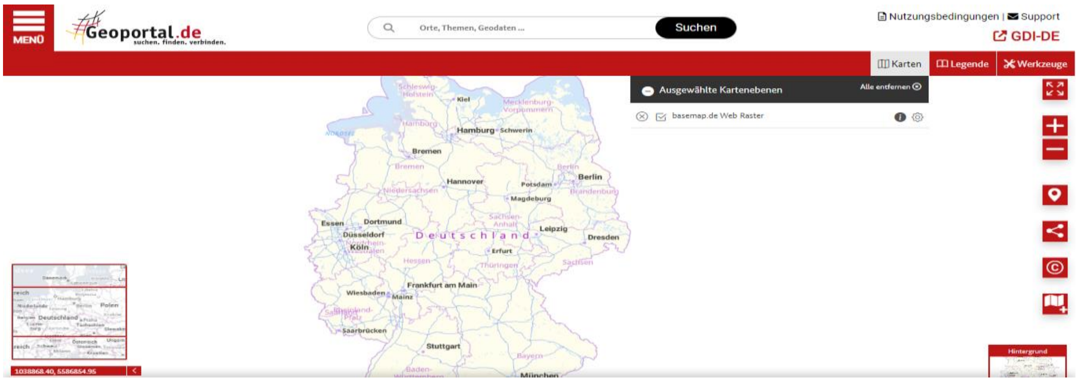


Source: Author's own creation

Appendix M: Interface for Geoportal of Poland

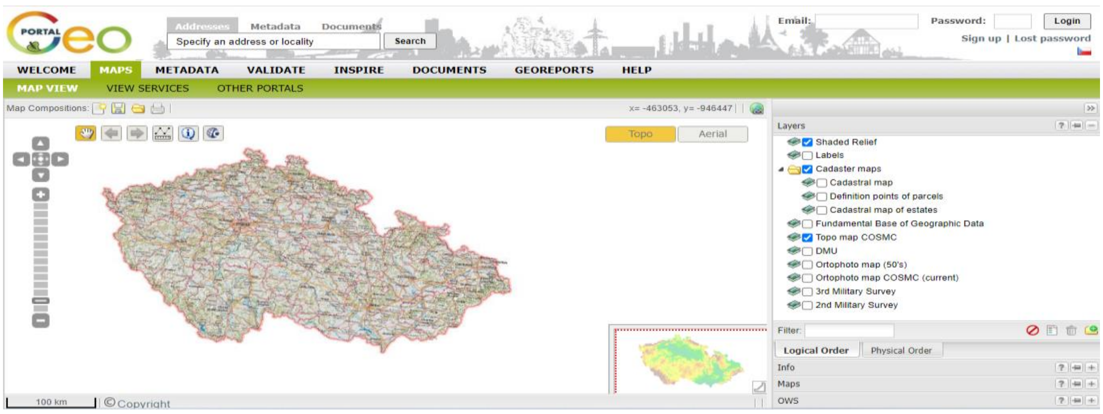
Source: Author's own creation

Appendix N: Interface for Geoportal of Germany



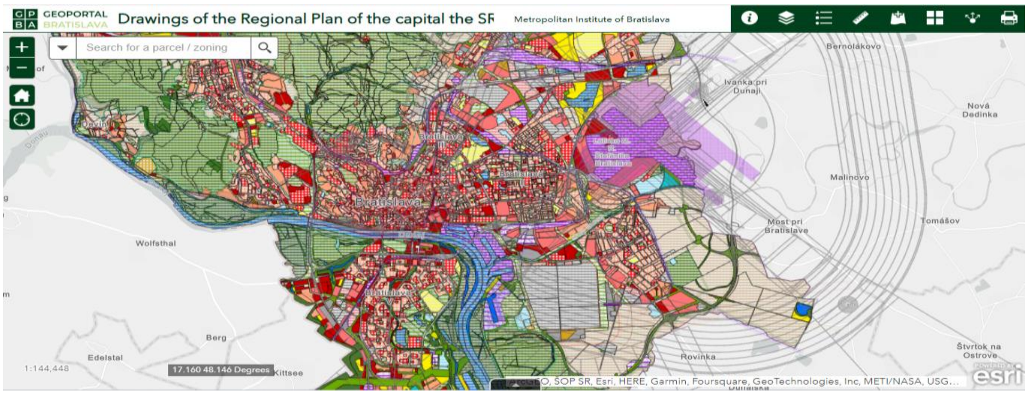
Source: Author's own creation

Appendix O: Interface for Geoportal of Czech Republic



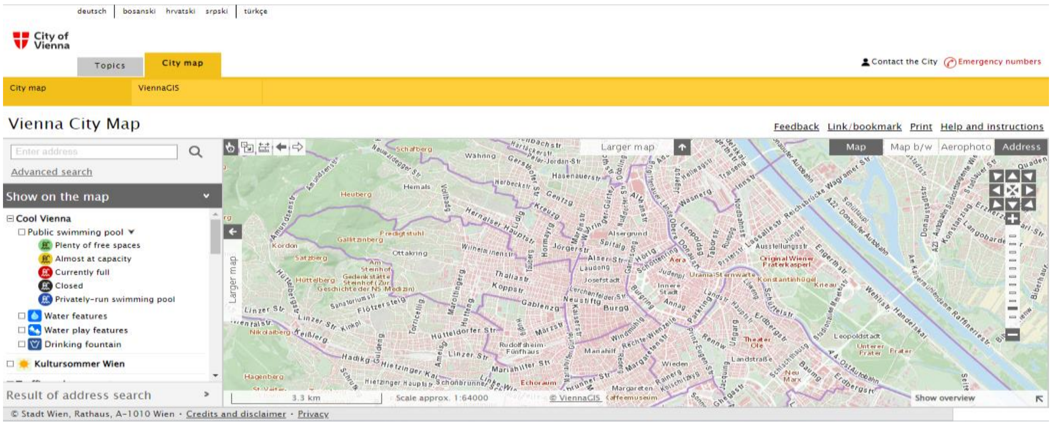
Source: Author's own creation

Appendix P: Interface for Geoportal of Bratislava



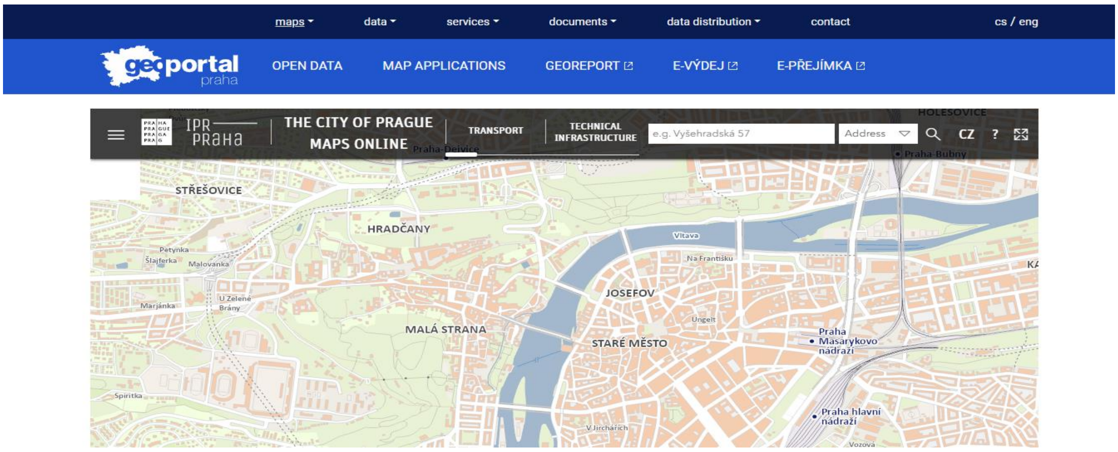
Source: Author's own creation

Appendix Q: Interface for Geoportal of Vienna



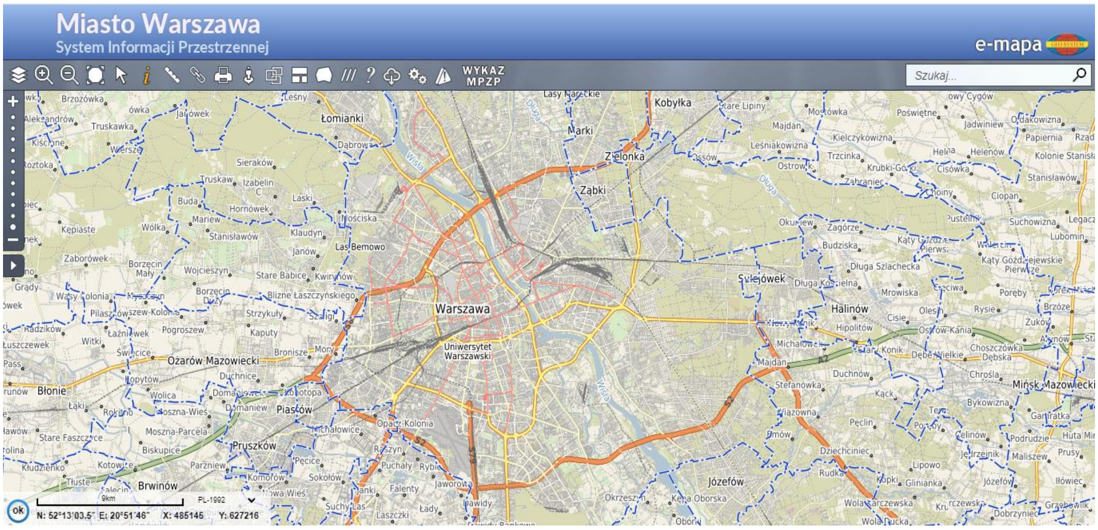
Source: Author's own creation

Appendix R: Interface for Geoportal of Prague



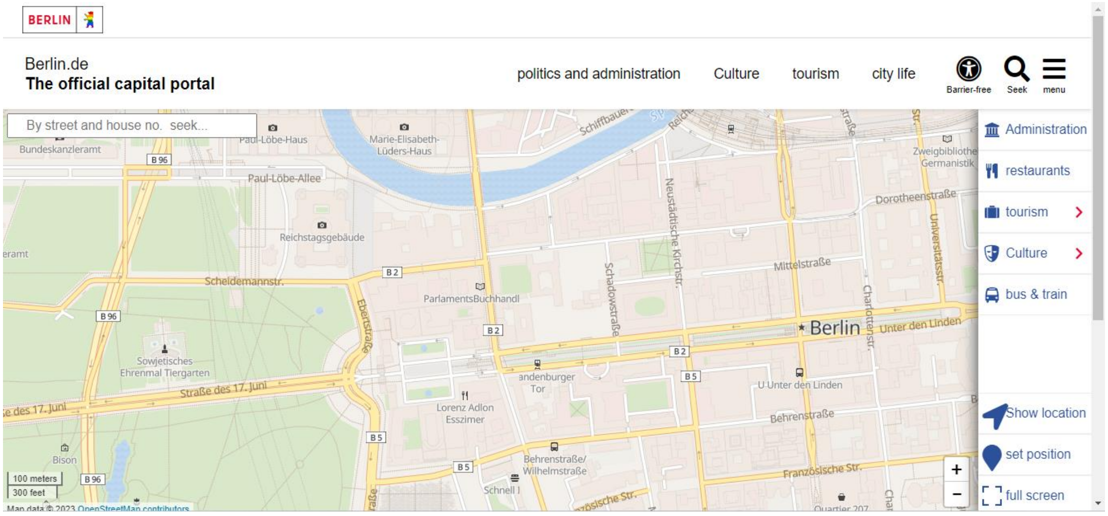
Source: Author's own creation

Appendix S: Interface for Geoportal of Warsaw



Source: Author's own creation

Appendix T: Interface for Geoportal of Berlin



Source: Author's own creation

Appendix U: Unsuccessful participants for geoportals of selected countries and cities

Table 6: Unsuccessful participants of tasks executed for the geoportals of selected countries

TASKS	NUMBER OF UNSUCCESSFUL PARTICIPANTS				
	CZECH	POLAND	SLOVAKIA	GERMANY	AUSTRIA
Switch to orthophoto/aerial map	1	4	-	-	-
Measure the distance between any two points	1	1	-	-	-
Display point of interest of your choice	3	2	6	4	-
Turn on/off administrative boundaries	3	4	-	3	-
Display coordinates of any location	1	1	-	1	-
Bookmark a location for future reference	2	6	-	3	3
Locate the legend of the map	3	-	-	-	2
Locate the print button	-	2	-	-	-
Create link/Share/Export	6	3	-	-	3

Source: Author's own creation

Table 7: Unsuccessful participants of tasks executed for the geoportals of selected capital cities

TASKS	NUMBER OF UNSUCCESSFUL PARTICIPANTS				
	PRAGUE	WARSAW	BRATISLAVA	BERLIN	VIENNA
Locate and load online map	-	-	-	4	-
Switch to orthophoto/Aerial map	-	-	-	6	-
Measure the distance between any two points	-	-	-	6	-
Turn on/off administrative boundaries	4	3	3	6	4
Display coordinates of any location	-	3	3	6	-
Locate the print button	-	-	-	6	-
Bookmark a location for future reference	6	6	4	3	-
Locate the legend of the map	-	4	-	4	-
Create link/Share/Export map	1	-	-	-	-

Source: Author's own creation

Appendix V : Tables Questionnaire Responses for Selected Countries and Capital Cities

Table 8: Questionnaire Responses For User-Centric Design Of The Geoportals Of Selected Countries

Scale	Czech		Poland		Slovakia		Germany		Austria	
	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%
Strongly Agree	2	6.7	2	6.7	19	63.3	6	20.0	16	53.3
Agree	13	43.3	5	16.7	7	23.3	14	46.7	9	30.0
Neutral	11	36.7	13	43.3	4	13.3	3	10.0	5	16.7
Disagree	4	13.3	7	23.3	-	-	5	16.7	-	-
Strongly Disagree	-	-	3	10.0	-	-	2	6.7	-	-
Total	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**

Source: Author's own creation

Table 9: Questionnaire Responses For User-Centric Design Of The Geoportals Of Selected Capital Cities

Scale	Prague		Warsaw		Bratislava		Berlin		Vienna	
	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%
Strongly Agree	5	16.7	-	-	-	-	4	13.3	17	56.7
Agree	13	43.3	3	10.0	7	23.3	14	46.7	11	36.7
Neutral	7	23.3	12	40.0	11	36.7	5	16.7	2	6.7
Disagree	5	16.7	12	40.0	10	33.3	2	6.7	-	-
Strongly Disagree	-	-	3	10.0	2	6.7	5	16.7	-	-
Total	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**

Source: Author's own creation

Table 10: Questionnaire Responses For User Experience Of The Geoportals Of Selected Countries

Scale	Czech		Poland		Slovakia		Germany		Austria	
	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%
Strongly Agree	3	10.0	1	3.3	18	60.0	5	16.7	9	30.0
Agree	6	20.0	4	13.3	10	33.3	10	33.3	15	50.0
Neutral	11	36.7	11	36.7	2	6.7	9	30.0	6	20.0
Disagree	8	26.7	5	16.7	-	-	5	16.7	-	-
Strongly Disagree	2	6.7	9	30.0	-	-	1	3.3	-	-
Total	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**

Source: Author's own creation

Table 11: Questionnaire Responses For User Experience Of The Geoportals Of Selected Capital Cities

Scale	Prague		Warsaw		Bratislava		Berlin		Vienna	
	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%	Frequency	Percent%
Strongly Agree	4	13.3	-	-	-	-	-	-	23	76.7
Agree	18	60.0	9	30.0	12	40.0	4	13.3	4	13.3
Neutral	5	16.7	10	33.3	11	36.7	9	30.0	3	10.0
Disagree	1	3.3	11	36.7	3	10.0	5	16.7	-	-
Strongly Disagree	2	6.7	-	-	4	13.3	12	40.0	-	-
Total	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**	**30**	**100%**

Source: Author's own creation