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A CHANGE OF VIEW:

Usable interface design propositions for geoportals

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A change of view:

Usable interface design propositions for geoportals

by

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Abstract

Nowadays, lots of Geo-Information (GI) is openly available. The value of this information lies in its use. Geoportals play an important part in allowing users to discover and access suitable data for their use cases. However, the user-friendliness of these geoportals is not as it should be. As the communicational layer between a system and its users, a more user-friendly User Interface (UI) can result in a more user-friendly geoportal. The following research question covers this aim towards more user-friendly geoportal UIs:

"What user interface design elements determine the user-friendliness of physical and intellectual human-computer interaction with geoportals?"

In an explorative research methodology involving a literature study into UIs and geoportals, assessing existing geoportals, and a user requirements session, I developed a guideline for user-friendly geoportal UIs: the Geoportal User Interface Design Evaluator (GUIDE).

The elements captured in the GUIDE cover the different parts of the UI: the content presentation, the interaction with available services (system interaction, navigation, search mechanisms, access mechanisms, and communication mechanisms) and the enabling information (metadata and help mechanisms). Concrete implementation examples of these design elements are provided by implementing a mock-up in accordance to the GUIDE. The catalogue page of this mock-up, annotated with the corresponding design elements, is displayed in Figure 1.

Figure 1: Catalogue page of the mock-up designed in accordance to the GUIDE (see Annex G for a cheat sheet regarding the abbreviations and colour codes).

To assess whether or not the elements of the GUIDE result in an increase in user-friendliness, the results of a benchmark usability session are compared to the results achieved during a follow-up usability session with the mock-up. The tasks participants perform during these sessions are all related to the most important reasons why users would visit a geoportal: discovering data, assessing whether the discovered data is suitable for a specific use case, and accessing the data.

The comparison of the results of the two usability studies suggests that the elements listed in the GUIDE as implemented in the mock-up indeed result in a more user-friendly geoportal UI. In the adopted usability metric that covered 128 fields related to performance and self-reported metrics, the mock-up outperformed the benchmark in 95 fields. This improvement is confirmed by qualitative comments of the six participants of the usability sessions and by experts of Publieke Diensverlening Op de Kaart - “Public services on the map” (PDOK). Especially the increase in efficiency is appreciated.

Based on the foundation the GUIDE and the corresponding mock-up provide, there is room for more in-depth research to further improve the user-friendliness of the UIs of geoportals. This, for example, involves looking into what communication mechanisms and help mechanisms, icons, terminology, or controls users prefer. Furthermore, additional research into the possibilities of adaptive UIs for geoportals can be valuable to suit possible differences in the needs and preferences of the different individual users.

Preface

For one of the courses of Geomatics, the students were required to write a paper to evaluate the effects of the 2019 open data and re-use of Public Sector Information (PSI) directive on the Spatial Data Infrastructure (SDI) of the country of their choice. As I am Dutch, I gladly picked the Netherlands to work with. The preliminary literature assessment I performed set high expectations: the SDI of the Netherlands is mature and 95% of all spatial data in the Netherlands is openly available [Algemene Rekenkamer, 2016]. However, when I started to assess the SDI by performing tasks on the corresponding geoportals, I struggled. How could that be? The data is available, but it is apparently not presented in a way that is user-friendly for all kinds of users. I had found my thesis topic.

Many people supported me during my graduation process; I owe a great deal of gratitude to all the professionals who helped me by participating in my user study and the experts from PDOK for discussing my mock-up design with me. Of course, many thanks also go out to my supervisors Bastiaan van Loenen and Frederika Welle Donker for all the proofreading and also to Steffen Nijhuis for his role as co-reader. Furthermore, I would like to thank my parents and brother for the moral support and my boyfriend Bram for sharing his experience in facilitating user experiments and allowing me to pilot my sessions. Thank you very much, I could not have done it without you.

Celine Jansen
Delft, July 2020

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1 Introduction

Imagine yourself in the following situation: you are a Geographical Information System (GIS) specialist who is looking for a specific type of Geo-Information (GI). In the Netherlands, you are in luck: 95% of all the Dutch GI is openly available [Algemene Rekenkamer, 2016]. You know this GI can be accessed on a geoportal and you decide to visit Publieke Diensverlening Op de Kaart - "Public services on the map" (PDOK). This is a likely choice; with 14.4 billion hits in 2019, PDOK is a major platform for open geodata in the Netherlands. If you know what you are looking for, an example of the pages you come across to access data on PDOK is displayed in Figure 1.1. This path is the most efficient, however, with all the different pages you need to visit, it might feel quite cumbersome.

Now, imagine that you need to discover a dataset suitable for your needs, instead of accessing a dataset you are familiar with. After selecting a dataset in the catalogue, you are redirected to a dataset landing page. The limited information on this page could leave you puzzled. Did you find the right dataset? With the large amounts of available data, the corresponding discovery process becomes increasingly challenging [Veldkamp, 2017], [Janssen and Van Den Hoven, 2015], [Te'eni and Feldman, 2001]. It could be you need to go back and forth between the catalogue and different landing pages several times and if the (meta)data is not presented in a user-friendly way, you can imagine you might get lost in a maze of information [Khan, 2018], [Van Loenen and Welle Donker, 2016], [Zuiderwijk, 2015], [Van Loenen et al., 2010].

Figure 1.1: Schematic overview of the download process on PDOK.

The value of information comes from its use [Onsrud and Rushton, 1995]. Providing data as open data that is free of charge and has no (re-)use restrictions, is a first step towards accommodating user needs. However, to facilitate (re-)use and to, correspondingly, increase the value of the data, GI should not only be openly available but it should also be easy to find and obtain [Kellenberger et al., 2016], [Lee, 2012], [Giff et al., 2008]. The example displayed in Figure 1.1 already shows this is not always the case.

Furthermore, open data initiatives often focus on publishing data and not on satisfying user needs [Van Loenen, 2018], [Zuiderwijk, 2015], [Resch and Zimmer, 2013], [Koudijs, 2011]. However, for the success of open data, users are critical [Van Loenen, 2018], [Van Loenen and Welle Donker, 2016].

The lack of focus on what users need, results in unnecessarily complicated portals where irrelevant features are included merely because the technology allows it [Resch and Zimmer, 2013], [Van Welie, 2001], [Reeve and Petch, 1999].

Moreover, different users have different objectives, background knowledge, and available resources, translating in different needs [Van Loenen, 2018], [Poplin, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Lee, 2012], [Guntupalli, 2008], [Fischer, 2001]. When attempting to satisfy all these users in a single UI, such implementations often become "one-size-fits-none" [Khan, 2018], [Van Loenen, 2018], [Braggaar, 2016], [Shneiderman, 2004], [Fischer, 2001]. This also holds for geoportals. For non-geo-experts, the threshold of accessing and using open geodata is too high [Penninga, 2018], [Penninga and Van Den Brink, 2017], [Veldkamp, 2017], [Kellenberger et al., 2016]. Likewise, people who work with GIS also have varying levels of experience and even for them, the portals are not always clear [NGR, 2018], [Poplin, 2015].

Related research covers requirements for open data infrastructures (see Zuiderwijk [2015] and Zuiderwijk et al. [2013]), open data policies (see Vancauwenberghe and Van Loenen [2016]) and open data portals (see Elvira [2018], Marta [2016], Carvalho and Lafuente [2015], and Parnia [2014]). However, research related to assessing the performance of open (geo)data portals neglects the user-friendliness and the User Interface (UI) (see, for example, Cecconi and Radu [2018] and Crompvoets [2006]). This is a missed opportunity because as the communicational layer between a system and its users, user-friendly UIs increase the usability and promote the use of a platform [Veldkamp, 2017], [Mayer et al., 2016], [Resch and Zimmer, 2013], [Fu, 2012], [Reinecke and Bernstein, 2011], [Welle Donker-Kuijer et al., 2010], [Van Welie, 2001].

Furthermore, there is a lack of concrete implementation examples accompanying the available interface requirements for open data portals [Zuiderwijk, 2015], [Parnia, 2014].

Similarly to the available assessment measures for geoportals, there are several general guidelines available for user-friendly UIs. Websites from the Dutch government and the European Union are, for example, obliged to follow certain heuristics such as the Web Content Accessibility Guidelines (WCAG) to make their content more accessible and usable for a wider range of users [Welle Donker-Kuijer et al., 2010]. However, these current heuristics can be difficult to use and are often concerned with how the information is delivered rather than with the discovery and comprehension of the content. Furthermore, the validation of these heuristics often seems to be non-existent. This means their effectiveness is generally unknown [Welle Donker-Kuijer et al., 2010].

1.1. Aim and research questions

With this research, I aim to develop a guidance framework for user-friendly UIs for geoportals. A more user-friendly UI relates to more user-friendly interactions between human users and a geoportal. This should lead to more user-friendly ways of finding and accessing a dataset (*physical access*) and understanding or using the information (*intellectual access*) [Van Loenen, 2006]. This corresponds to the following research questions:

"What user interface design elements determine the user-friendliness of physical and intellectual human-computer interaction with geoportals?"

1. "What are design propositions for a user-friendly geoportal interface?"
    - 1.1 *"What characteristics of user-friendly (geoportal) interfaces are mentioned in the literature?"*
    - 1.2 *"What user-friendly interface design characteristics are implemented in existing geoportals?"*
    - 1.3 *"What are user-friendly interface design characteristics according to users?"*
2. "How can these design propositions be implemented as design elements?"

1.2. Research methodology

UI requirements for geoportals are part of a relatively unexplored body of knowledge, therefore, I applied an explorative research methodology consisting of the five steps displayed in Figure 1.2. These steps correspond to a single iteration of the UI design process (see, for example, Khan [2018], Veldkamp [2017], Mishra [2013], Rantzer [1997] and Ludolph [1997]).

I clustered my findings in a guidance framework for user-friendly UIs for geoportals, to which I will refer to as the Geoportal User Interface Design Evaluator (GUIDE) in the remainder of this thesis. Following the GUIDE can be a way to establish more consistency between different geoportals, which is currently lacking [Resch and Zimmer, 2013]. By presenting the GUIDE as a user-friendliness assessment framework, it will also help bridge the current knowledge gap in quality metrics for the UIs of geoportals.

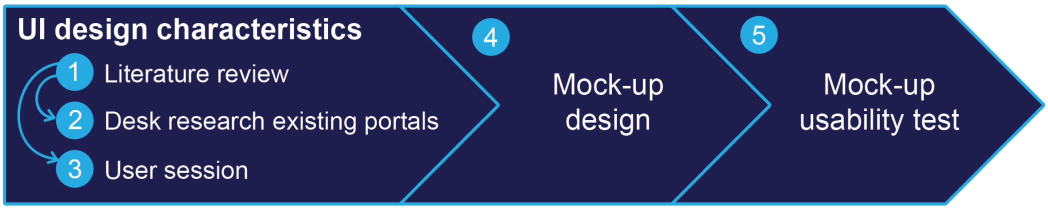


Figure 1.2: The explorative research methodology adopted to establish the GUIDE.

1. **Literature review**: I started exploring UI design characteristics that could be part of an initial version of the GUIDE by performing a literature review into the different parts of the UI of geoportals.

2. **Desk research existing portals**: In the second place, I performed desk research to examine the strengths, functionalities and unique features of existing geoportals to learn from their design choices [Fedorowic et al., 2014], [Courage and Baxter, 2005], [Simpson, 1997] and to attempt consistency between them [Scholtz, 1997]. For this desk research, I adopted a two-sided approach.

   2.1 I re-evaluated the initial GUIDE established through literature review by analysing how existing portals handle tasks related to discovering, assessing, and accessing data.

   2.2 Based on the conformity of the existing portals to the initial GUIDE, I also acquired implementation examples of best practises.

3. **User session**: Thirdly, I performed a user session following a so-called mixed-method approach, combining both qualitative and quantitative research elements. The quantitative results allow me to statistically assess and compare variables, whereas the qualitative part, for example, concerns how and why questions [Pekkanen, 2015], [Fu, 2012]. To uncover and elaborate on particular issues participants encountered when performing tasks, I used a semi-structured interview. This allows both the freedom to go into issues and comparison of the results. At the end of the session, I let users sort cards describing the design characteristics. This helped me explore two aspects.

   3.1 A usability benchmark capturing the initial status of PDOK.

   3.2 The requirements of potential users for user-friendly UI design characteristics, based on, among others, their perspective on the initial GUIDE.

4. **Mock-up design**: As a fourth step, I implemented the re-evaluated GUIDE in a mock-up. By doing this, I provided concrete implementation examples of the UI design elements.

   Adaptively presenting individual users different implementations of the UI more suited to their different characteristics or tasks, could contribute to solving the “one-size-fits-none” challenge.

5. **Mock-up usability test**: For the fifth and final step, I validated the user-friendliness of the design elements as implemented in the mock-up by comparing the results of a follow-up usability session with the mock-up to the results of the benchmark usability study.

1.3. Scope

In this section, I elaborate on several design choices I made concerning the selection of user types, functionalities, and the decision to focus on functional requirements.

1.3.1. Selection of user types

Platforms such as PDOK are used by a vast diversity of users. In short, PDOK is used by both public and private sector users; ministries and universities, individuals, large and small organisations, they all use data from PDOK [Welle Donker et al., 2019].

Since there is limited time available for this research, involving all possible types of users is not feasible. To adhere to the Specific, Measurable, Assignable, Relevant and Time-bound (SMART) principles ([Doran, 1981] as cited by [Haughey, 2014]), I only consider users whose characteristics match with the *developer / GIS specialist* and the *web developer* personas from PDOK. Previous market research confirms these are relevant user groups [PDOK, 2019], [NGR, 2018].

1.3.2. Selection of functionalities

Typically, users visit a geoportal when they want to discover datasets that are relevant for their needs [Jiang et al., 2019], [Resch and Zimmer, 2013], [He et al., 2012], [Giff et al., 2008]. In line with this, search mechanisms are important. Furthermore, users need to be able to assess if the data they found fits their needs. To support users during this assessment process, map viewers and other (meta)data visualisation mechanisms are fundamental [Kellenberger et al., 2016], [Kukimoto, 2014], [Resch and Zimmer, 2013], [He et al., 2012]. Next to enabling data discovery and assessment, geoportals should also enable data access [Resch and Zimmer, 2013], [Masó et al., 2011], [Giff et al., 2008].

1.3.3. Focus on functional requirements

For this research, I assume that non-functional requirements such as business requirements or technical requirements are met [Zuiderwijk, 2015]. This is a research limitation since the (perceived) usability will realistically be constrained by these non-functional requirements. Indirect or external factors of performance that are part of the User Experience (UX), are, for example, the download and help desk speed, and the amount and quality of the datasets [Yan and Guo, 2010], [Guntupalli, 2008].

1.4. Explanation of the adopted terminology

In this section, I clarify the adopted meaning for terms that can be defined in several ways.

Geoportals and platforms

Portals are defined to be an access or entry point. Accordingly, a geoportal can be seen as an access point or so-called one-stop-shop for GI [Jiang et al., 2019], [Braggaar, 2016], [Resch and Zimmer, 2013], [Lee, 2012], [Koudijs, 2011], [Van Loenen et al., 2010], [Giff et al., 2008], [Maguirea and Longley, 2005].

PDOK can be referred to as a geoportal. However, different platforms have varying levels of maturity and are designed for different purposes (see Crompvoets [2006]). PDOK, for example, is more than a catalogue service and also offers functionalities such as feedback options, example use cases, and so on. During the remainder of this thesis, I use the terms geoportal and geo-platform interchangeably to relate to a system similar to PDOK.

Access

The term “access” refers to data acquisition through downloads, Application Programming Interfaces (APIs), geo-web services such as Web Map Services (WMSs), or viewing data in a map viewer service.

User Interface (UI)

The UI is defined to consist of the content presentation, interaction with the available services, and enabling information [Guntupalli, 2008], [Nilsson and Ottersten, 1997], [Rantzer, 1997].

Human Computer Interaction (HCI)

In this thesis, Human Computer Interaction (HCI) describes the communication between users and a system through a UI. Note that other sources often use a broader definition. HCI is, for example, also mentioned in contexts involving UX design aspects beyond the UI [Fischer, 2001].

1.5. Reading guide

The workflow I adopted during this research is shown in Figure 1.3. After the introduction (Chapter 1), I established theoretical background research into UI design and usability as a foundation for the research (Chapter 2). After this, I performed a literature review to acquire a first version of the GUIDE (Chapter 3). This initial GUIDE and its corresponding identifiers are summarised in Annex F. I evaluated and refined this first version based on the results of desk research involving existing geoportals (Chapter 4) and the results of a user requirements and usability benchmark session (Chapter 5). The redeveloped version of the GUIDE following from these chapters is summarised in Annex G. The resulting design elements can be implemented in a mock-up (Chapter 6). A follow-up usability experiment using this mock-up allows me to evaluate the design elements and answer the main research question (Chapter 7).

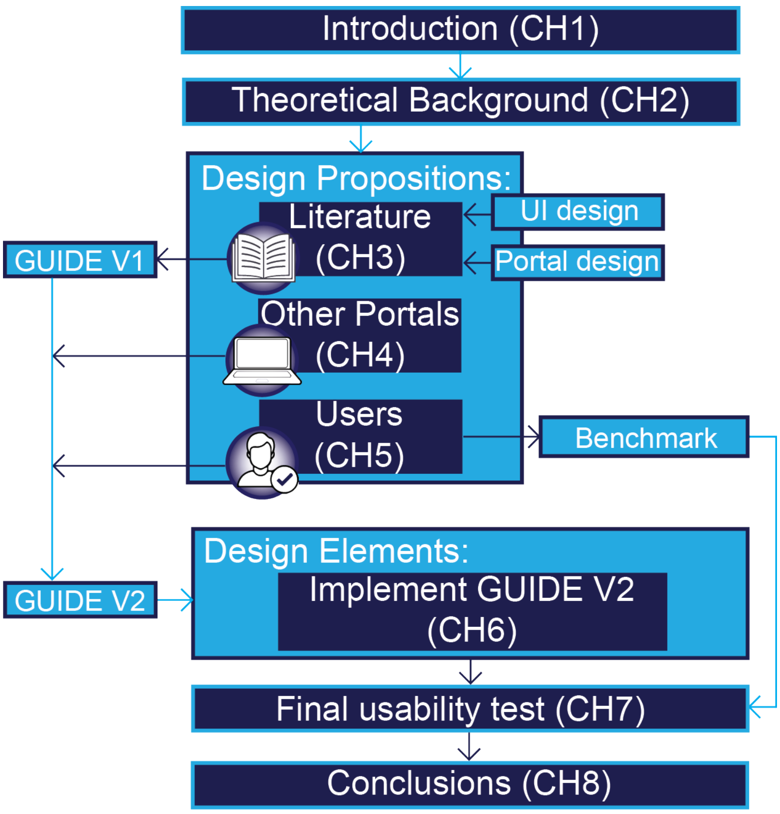


Figure 1.3: Flowchart capturing the relationship between the different chapters of this thesis.

2
User-friendly User Interface (UI) design

This thesis revolves around the concepts UI and user-friendliness. In this chapter, I elaborate on the definition of these concepts I adopted. First, I address the components of the UI itself (Section 2.1). To evaluate the user-friendliness of a UI, metrics for the (perceived) usability can be used (Section 2.2). The skills and expectations of users of the system are related to this usability [Guntupalli, 2008]. However, this could differ for different users. To deal with this, different versions of a UI can be adaptively presented to different users (Section 2.3). I summarise this chapter in Section 2.4.

2.1. The concept of UIs

The UI is the layer between the displayed content of a website and the user. It allows the user to access and interact with the content [Joo, 2017], [Roth, 2017], [Carvalho and Lafuente, 2015], [Fu, 2012]. Without a UI, the system cannot be used [Guntupalli, 2008]. Therefore, UIs are critical for the performance of websites and, more generally, of information systems. A well-designed UI helps to perform tasks efficiently and keeps users interested in using the system [Parnia, 2014], [Fu, 2012], [Smith, 1997], [Ludolph, 1997].

Literature review reveals that the UI consists of the content presentation, interaction with available services, and enabling information [Guntupalli, 2008], [Nilsson and Ottersten, 1997], [Rantzer, 1997].

2.1.1. Content presentation

The perceived user-friendliness is affected by the "beauty" of the interface [Tractinsky et al., 2000]. Moreover, aesthetically pleasing interfaces tend to increase usability in terms of engagement [Pekkanen, 2015], performance, and satisfaction [Fu, 2012], [Reinecke and Bernstein, 2011], [Bonnardel et al., 2010]. However, what is perceived to be aesthetically pleasing is both context-dependent and subjective [Reinecke and Bernstein, 2011]. Although beauty is challenging to define, some theories that are proven to be aesthetically pleasing can be related to the layout of a website. This, for example, includes balancing the content around the optical centre, the rule of thirds, and the golden section ratio. Other theories are related to the use of colour, such as the theories on colour harmony [Fu, 2012].

2.1.2. Interaction with available services

Interactions involve the "request-response" dialogue of a human user and the system via the UI.

There are several different interaction mechanisms; *direct manipulation*, for example, allows users to drag and drop something to a trash can. *Menu selection* requires the use of distinct and understandable terminology to make sure that users do not have to memorise much. When users are required to *fill a form*, the fields and the permissible values must be understandable [Shneiderman, 2004].

Human Computer Interaction (HCI)

The field of Human Computer Interaction (HCI) is focused on improving how human users can interact with systems [Huang et al., 2019]. HCI is a multidisciplinary domain consisting of, among others, computer science, cognitive psychology, and design [Fischer, 2001].

(Cognitive) ergonomics and HCI

A system designed for human users should consider the abilities and limitations of humans. One way to achieve this is by following the heuristics covered by the WCAG. Such heuristics are often based on theories involving cognitive psychology and ergonomics.

Applying these theories during the UI design can optimise the HCI [Van Welie, 2001]. Fitts' law (1954), for example, describes that the time it takes to perform a pointing interaction depends on the ratio of the size of the target and the distance to the target [Roth, 2017]. Considering this, helps to reduce the time it takes to interact with the content [Chiew and Salim, 2003], [Van Welie, 2001].

2.1.3. Enabling information

For geoportals, enabling information involves metadata and help mechanisms related to the portal and data use.

Metadata

Metadata is data about data [Zuiderwijk, 2015]. In short, metadata aids in discovery, identification, assessment, interpretation, and management of the data [Zuiderwijk, 2015], [Parnia, 2014]. Without proper metadata, users might not be able to determine if the data is suitable for their needs and how it can be used [Welle Donker et al., 2019], [Zuiderwijk, 2015].

Help mechanisms

Help mechanisms should be available to, for example, explain details about the portal access mechanisms or the data use [Jurisch et al., 2015]. Providing help can also prevent errors [Rohlfs, 1997].

There are different approaches to present help; most users only read introductory or explanatory text once they experience difficulties [Poplin, 2015]. Available help texts should not be excessively long and should be close to the content to make it easy to remember [Carvalho and Lafuente, 2015], [Guntupalli, 2008]. It is sometimes more adequate to guide users by providing hints, for example upon hovering over the content [Poplin, 2015], [Resch and Zimmer, 2013], [Nilsson and Ottersten, 1997].

2.2. The concept of user-friendliness

A UI is user-friendly if it fulfils requirements related to usability. Usability is defined by the International Organization for Standardization (ISO) 9241-11 standard as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”.

Within this definition, usability can thus be split into three sub-parts: effectiveness, efficiency, and satisfaction [Veldkamp, 2017], [Parnia, 2014], [Resch and Zimmer, 2013], [Tullis and Albert, 2013], [He et al., 2012], [Reinecke and Bernstein, 2011], [Chiew and Salim, 2003], [Haklay and Tobón, 2003], [Van Welie, 2001]. *Effectiveness* covers the ability of a user to successfully find information and accomplish tasks. *Efficiency* captures if this can be done in an adequate time frame and under a minimal cognitive load [Persad et al., 2007]. *Satisfaction* entails whether or not the user enjoys using the system [Reinecke and Bernstein, 2011], this includes everything users say and think about the interactions [Tullis and Albert, 2013].

In addition to the ISO 9241-11 definition, several scholars also describe learnability, memorability, and error occurrence as part of usability [Khan, 2018], [Veldkamp, 2017], [Parnia, 2014], [Chincholle et al., 2013], [Mishra, 2013], [Haklay and Tobón, 2003], [Van Welie, 2001]. *Learnability* covers what it would take users to become proficient with the system [Van Welie, 2001]. This requires the system to work in a non-confusing way [Tullis and Albert, 2013]. It involves familiarity, consistency, generalisability, and predictability [Mishra, 2013]. *Memorability* relates to how well users remember to use a system [Khan, 2018], [Van Welie, 2001]. *Errors* are incorrect actions that may lead to task failure [Van Welie, 2001]. They can be caused by usability issues [Tullis and Albert, 2013].

Note that the components of (perceived) usability interact. Satisfaction, for example, is not only influenced by perceived efficiency, but also by the perceived aesthetics of the UI [Reinecke and Bernstein, 2011]. Because of this interaction, there is a trade-off between the different usability criteria. Ease of use, for example, is not the only requirement. Some users need functionalities that result in more complexity [Fischer, 2001] and if all users use a product frequently, they are all bound to become experienced, and learnability is less relevant [Smith, 1997], [Rohlfs, 1997]. Another example is that users who use a system for their job could need higher task efficiency and accuracy. Factors such as fun are not a priority in this context [Chincholle et al., 2013].

Perceived usability and UX

The User Experience (UX) involves the interaction between the UI and its users [Joo, 2017], [Roth, 2017], [Resch and Zimmer, 2013]. This includes the behaviour, thoughts, feelings, and perceptions of users resulting from both direct and indirect interactions with a product [Roth, 2017], [Chincholle et al., 2013], [Resch and Zimmer, 2013], [Tullis and Albert, 2013]. Since the UI design influences the UX [Roth, 2017], UX metrics can be used to measure the perceived usability of the UI [Tullis and Albert, 2013].

2.3. Adaptive UIs

The single typical geoportal user does not exist [Van Loenen, 2018], [Braggaar, 2016], [Fischer, 2001], [Schwabe and Rossi, 1995]. Different users have different objectives, background knowledge, and available resources, translating in different needs [Van Loenen, 2018], [Poplin, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Lee, 2012], [Guntupalli, 2008], [Fischer, 2001]. This influences the (perceived) usability [Hart et al., 2013], [Roto et al., 2011]. To provide users with fitting interactions, the right thing should be said at the right time in the right way in the UI [Fischer, 2001]. Multilayered design, such as enabled by Adaptive Hypermedia (AH), is promising to promote universal usability [Shneiderman, 2004].

AH is a specific way to present hypermedia. Hypermedia refers to linked information consisting of, for example, images, audio, animation, or video. This can be envisioned as a set of human-processable information nodes that can be connected through links. These connected nodes of information allow users to search and find items that are relevant to them [Brusilovsky, 2003]. AH systems can be defined as systems that provide hypermedia in an adaptive way to better suit the individual needs of the user [Te'eni and Feldman, 2001].

In short, adaptive behaviour requires the encoding of rules prescribing adaptations which are triggered by a certain condition in a user profile. This user profile is created during a user modelling process based on the data that users leave when they use the system.

Possible adaptation effects can, for example, relate to adaptive content selection, adaptive navigation support, and adaptive presentation [Brusilovsky, 2003]. In general, AH is used to prevent obstructions from functionalities that are not of interest to users and to deliver (unknown) functionalities when needed [Fischer, 2001]. Showing users more relevant options can lead to higher user satisfaction [Khan, 2018], higher efficiency [Reinecke and Bernstein, 2011], [Te'eni and Feldman, 2001], [Brusilovsky, 2004], and fewer errors [Reinecke and Bernstein, 2011]. Furthermore, casual users stay longer if adaptive navigation support is provided [Brusilovsky, 2004]. This indicates an increase in interest [Märtin et al., 2017], [Lehmann et al., 2012], [Ahn et al., 2007], [Mark Claypool and Brown, 2001].

Despite the related advantages, adaptive websites are not often implemented because there are trade-offs between adaptive behaviour and other favourable aspects of the system design [Te'eni and Feldman, 2001]. This, for example, involves that users will be discouraged by unexpected changes and behaviour [Parnia, 2014], [Shneiderman, 2004], [Te'eni and Feldman, 2001].

To fill the gap of go-to adaptation solution for geoportals, I provide possible implementations for AH that are suitable within the context of this research in the review paper listed in Annex A.

2.4. Summary: User-friendly UI design

In this chapter, I presented definitions regarding UIs and user-friendliness as adopted in this thesis.

The UI involves the communication of system information to the users through the content presentation, interaction with available services, and enabling information.

The user-friendliness of a UI can be evaluated based on its usability. Usability consists of effectiveness, efficiency, and satisfaction. This definition can be extended with learnability, memorability, and error occurrence.

UX design involves the behaviour, thoughts, feelings, and perceptions of users during their interaction with the system. This perceived usability is influenced by the UI.

AH can be a way to present different versions of a UI to different users, suiting their different needs in a better way.

3 Theoretical UI design characteristics

In this chapter, I cover an analysis of related research into the components of User Interface (UI) (the content presentation, interaction with available services, and enabling information) in the context of geoportals. By doing this, I provide an answer to Subsubquestion 1.1.

“What characteristics of user-friendly (geoportal) interfaces are mentioned in the literature?”

By clustering and naming my findings, I established the subcategories as visualised in Figure 3.1.

Figure 3.1: The categories of the UI design characteristics.

Following these categories, the initial GUIDE as represented in Tables 3.2, 3.10, 3.11, 3.12, 3.13, 3.15, 3.16, 3.17, and 3.18 captures my findings from the literature review. In case elements of these tables are not self-explanatory, I elaborate on them in the corresponding (sub)section.

Related research into the presentation of the content is part of the *content presentation* (Section 3.1). The *interaction with available services* involves the general system interaction that applies to every interaction users have with the system, navigation between the different pages, interaction with search mechanisms, interaction with access and upload mechanisms, and mechanisms to provide feedback (Section 3.2). The *enabling information* for the UI of a geoportal involves metadata and help mechanisms (Section 3.3).

Consistency is an overarching characteristic relating to all other components of the UI design; the content presentation, interaction with available services, and enabling information should all be presented in a consistent way (Section 3.4). I summarise this chapter in Section 3.5.

3.1. Content presentation

The aesthetics of a page is the first thing users see [Reinecke and Bernstein, 2011]. This first impression will determine whether they will continue to use the system [Bonnardel et al., 2010]. Furthermore, inappropriately presented information can cause misinterpretations, which can lead to compromises in the efficiency and effectiveness of the system use [Resch and Zimmer, 2013]. For this reason, guidelines regarding the content presentation are covered in Table 3.2.

Table 3.2: Entry of the GUIDE: Content presentation (CP) covering characteristics CP1-7.

Design characteristic	Implementation suggestions	Sources
CP ***Content presentation*** Mentioned in: [WCAG 2.1], [Huang et al., 2019], [Jiang et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [Toker et al., 2018], [Van der Meer, 2018], [Proctor et al., 2017], [Roth, 2017], [Veldkamp, 2017], [Almanza et al., 2016], [Braggaar, 2016], [Kellenberger, 2016], [Vancauwenberghe et al., 2016], [Carvalho et al., 2015], [Zuiderwijk, 2015], [Kukimoto, 2014], [Parnia, 2014], [Mishra, 2013], [Resch et al., 2013], [Tullis et al., 2013], [Zuiderwijk et al., 2013], [Cousins, 2012], [Fu, 2012], [He et al., 2012], [Lee, 2012], [Bonnardel et al., 2010], [Tuck, 2010], [Yan et al., 2010], [Guntupalli, 2008], [Crompvoets, 2006], [Olsen, 2006], [Courage et al., 2005], [Krug, 2005], [Seow, 2005], [Moustakis et al., 2004], [Schneiderman, 2004], [Chiew et al., 2003], [Van Welie, 2001], [Ludolph, 1997], [Rohlfs, 1997], [Simpson, 1997], [Smith, 1997], [Tullis, 1981]	CP1 Colour harmony	[Fu, 2012]
	CP2 Distribute content in a balanced way: • Balance around the optical centre • Golden section ratio • Rule of thirds	• [Dent, 2009] • [Fu, 2012], [Olsen, 2006] • [Cousins, 2012], [Olsen, 2006]
	CP3 Ergonomics & legibility (conform WCAG 2.1): • Large button (44 by 44 CSS pixels), icon & text size (18 or 14 pt bold) • No animations or blinking without confirmative user action • Offer alternative media: text for non-text elements, communication should not solely rely on colour • Sans-serif font • Strong contrast back / foreground (7:1)	[WCAG 2.1], [Lee, 2012], [Smith, 1997] • [Van der Meer, 2018], [Carvalho et al., 2015], [Zuiderwijk, 2015], [Resch et al., 2013], [He et al., 2012], [Shneiderman, 2004], [Van Welie, 2001], [Simpson, 1997], [Smith, 1997] • [WCAG 2.1], [Shneiderman, 2004], [Chiew et al., 2003] • [WCAG 2.1], [Mishra, 2013], [Courage et al., 2005], [Schneiderman, 2004] • [Resch et al., 2013], [Van Welie, 2001] • [WCAG 2.1], [Carvalho et al., 2015]
	CP4 Full screen map availability (collapsible controls)	[Kellenberger, 2016]
	CP5 Increase "scannability" of the content: • Conveying a visual hierarchy: - (Contrasting) colours - Contours - Fonts (spacing, size, boldness) - Gestalt laws - Intensity - Location - Markers (e.g. arrows) - Shape - Size • Present content as indented lists or tables instead of linear text (use headers) • Prevent scrolling • Simple presentation & visualisation (no cluttering): - Avoid long descriptions - Incorporate graphics - Fitts' presentation in a grid: minimise the number of text rows & columns - Only show essentials - White space	[Bonnardel et al., 2010], [Chiew et al., 2003], [Van Welie, 2001]] • [Almanza et al., 2016], [Braggaar, 2016], [Carvalho et al., 2015], [Zuiderwijk, 2015], [Tuck, 2010], [Moustakis et al., 2004], [Chiew et al., 2003], [Van Welie, 2001], [Rohlfs, 1997], [Smith, 1997], [Tullis, 1981] - [Zuiderwijk, 2015], [Fu, 2012], [Shneiderman, 2004],[Simpson, 1997] - [Van der Meer, 2018], [Shneiderman, 2004] - [Van der Meer, 2018] - [Tuck, 2010] - [Van der Meer, 2018], [Shneiderman, 2004] - [Zuiderwijk, 2015], [Shneiderman, 2004] - [Van der Meer, 2018], [Simpson, 1997] - [Shneiderman, 2004] - [Van der Meer, 2018], [Simpson, 1997] - [Van der Meer, 2018], [Shneiderman, 2004], [Simpson, 1997] • [Almanza et al., 2016], [Resch et al., 2013], [Bonnardel et al., 2010], [Chiew et al., 2003] • [WCAG 2.1], [Chiew et al. 2003] • [Proctor et al., 2017], [Parnia, 2014], [Mishra, 2013], [Guntupalli, 2008], [Krug, 2005], [Van Welie, 2001] - [Parnia, 2014], [Schneiderman, 2004] - [Fu, 2012] - [Proctor et al., 2017], [Seow, 2005], [Chiew et al., 2003], [Van Welie, 2001] - [Carvalho et al., 2015], [Parnia, 2014], [Schneiderman, 2004], [Ludolph, 1997] - [Tullis et al., 2013] [Carvalho et al., 2015]
	CP6 Support flexible content display (customise map legends, screen sizes, colours)	[WCAG 2.1], [Resch et al., 2013], [Schneiderman, 2004]
	CP7 Visualise data (e.g.(map) previews)	[Huang et al., 2019], [Jiang et al., 2019], [Toker et al., 2018], [Veldkamp, 2017], [Kellenberger, 2016], [Vancauwenberghe et al., 2016], [Zuiderwijk, 2015], [Parnia, 2014], [Mishra, 2013], [Resch et al., 2013], [He et al., 2012], [Lee, 2012], [Bonnardel et al., 2010], [Crompvoets, 2006], [Smith, 1997], [Tullis, 1981]

3.1.1. Colour harmony

Colour is one of the factors determining the first impact of a website [Bonnardel et al., 2010]. Colours influence aesthetics and are not only functional in their appropriateness, but also to increase legibility, satisfaction, perceived trust, and to grasp the attention of the user [Cyr et al., 2010].

Colour harmony relates to certain colour combinations that can be perceived to be aesthetically pleasing. These combinations are listed in Figure 3.3.

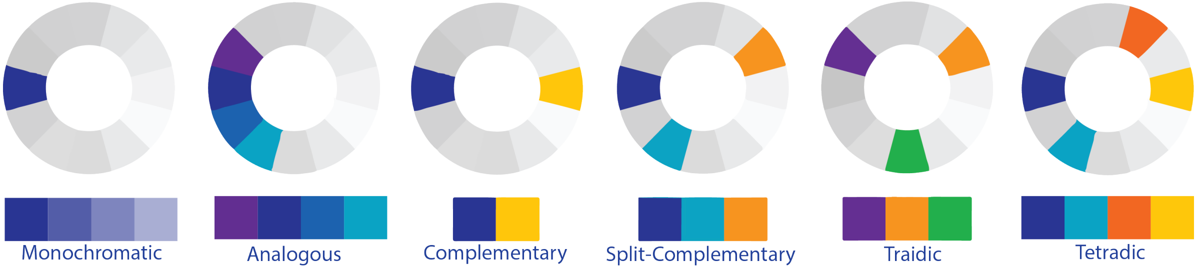


Figure 3.3: Aesthetically pleasing colour combinations based on the theory of colour harmony.

The colour combinations should follow the theory of colour harmony [Fu, 2012], but what actual colours should be picked? In their preferred colour, users browse more efficiently. Different colour preferences are noted across cultures. However, universally, blue is the most preferred colour for both users and designers [Bonnardel et al., 2010], [Cyr et al., 2010]. Blue is associated with wealth and security, and evokes emotions related to tranquillity. This in contrast to colours such as black or brown, which evoke sad emotions [Cyr et al., 2010].

3.1.2. Distribute content in a balanced way

Balancing the content around the optical centre, considering the golden section ratio and the rule of thirds, are all ways to achieve a balanced content presentation.

Balance around the optical centre

For a more pleasing content presentation, the UI elements should be balanced around the optical centre of the image space ([Dent, 2009] as cited by [Van der Meer, 2018]). The optical and the geometric centre are displayed in Figure 3.4.

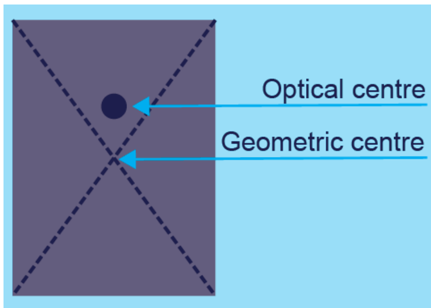


Figure 3.4: Optical versus geometric centre of the image space, based on [Dent, 2009] as cited by [Van der Meer, 2018].

Golden section ratio (based on Olsen [2006])

The golden section ratio (ψ) is a mathematical ratio that helps to achieve aesthetically pleasing, balanced compositions [Fu, 2012], [Olsen, 2006]. An example of a website design that considers the golden section ratio is displayed in Figure 3.5.

Rule of thirds (based on Olsen [2006])

The rule of thirds prescribes that content placed on either one of the intersecting points as displayed in Figure 3.6 draws the eye of the viewer to this content.

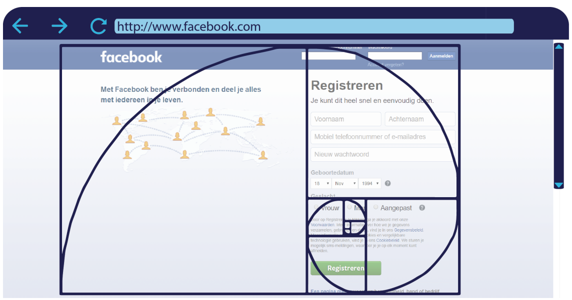


Figure 3.5: Aesthetically pleasing design of Facebook log-in page balanced around the golden section ratio.

Figure 3.6: Aesthetically pleasing design of LinkedIn log-in page according to the rule of thirds.

3.1.3. Ergonomics and legibility

For content presentation to be suitable, it should not limit the use of a system for any kind of user [WCAG, 2019], [Almanza et al., 2016], [Parnia, 2014]. For this reason, the capabilities and limitations of the sensory, cognitive, and motor skills of users should be considered when designing a UI [Arnold, 1998]. Heuristics such as the WCAG 2.1 aim to achieve this.

No animations or blinking without confirmative user action

In any case, animations or blinking can be perceived as distracting [Chiew and Salim, 2003]. Under certain conditions, blinking can even be regarded as flashing, which can cause seizures and other undesirable physical reactions [WCAG, 2019].

Offer alternative media

Instructions for comprehending the UI and its content should not be solely relying on sensory characteristics [WCAG, 2019]. It is, for example, important to think about colourblind users [Almanza et al., 2016], [Mishra, 2013]. To suit different uses, text alternatives for non-text elements, and captions or transcriptions as alternatives for time-based media are also recommended. Spoken content can be a solution for blind users [WCAG, 2019].

Strong contrast back / foreground

A strong contrast between the back- and foreground can increase the legibility. For this reason, text and background should have a contrast ratio of at least 7:1 and visualisations should have a contrast of at least 3:1 [WCAG, 2019]. Although strong contrast is recommended, the use of white and black on screens can be tiring. Dark grey text, for example, is easier to read [Carvalho and Lafuente, 2015].

3.1.4. Increase “scannability” of the content

Users prefer to scan text on a web page instead of reading [Bonnardel et al., 2010]. A clear, “scannable” layout can help to make information more easily accessible and decreases the time mental actions take [Braggaar, 2016], [Carvalho and Lafuente, 2015], [Van Welie, 2001], [Moustakis et al., 2004].

Conveying a visual hierarchy

If elements are organised meaningfully on the page, users may find information more efficiently [Tuck, 2010], [Moustakis et al., 2004], [Van Welie, 2001], [Ludolph, 1997], [Tullis, 1981]. Visual hierarchies help to show the importance of each element and can be used to introduce the content in such a meaningful way [Carvalho and Lafuente, 2015]. There are several tricks to convey visual hierarchy. Goethe’s colour theory, for example, describes that dark objects appear smaller [Fu, 2012]. Furthermore, elements with thick, closed contours appear more important. The same is true for regular, dense, or large shapes that are clustered together [Van der Meer, 2018]. Additionally, the location of an element can be used to indicate its importance. Frequently used content is shown at the top of the page and Top-Bottom / Left-Right hierarchies as with newspapers can be implemented [Smith, 1997].

Gestalt laws

The Gestalt laws describe how the human mind tries to organise content. This makes them suitable guidelines to convey a visual hierarchy. According to the Gestalt laws, elements are expected to belong together if they [Van der Meer, 2018], [Tuck, 2010]:

- are similar looking (e.g. colour, shape) (Law of Similarity),
- are located on a continuous line (Law of Good Continuity),
- can be filled to create a full design (Law of Closure),
- are close together (Law of Proximity),
- are grouped in background and foreground elements (Law of Figure/Ground),
- they appear to move in the same direction (Law of Common Fate).
- Ambiguous images are seen in the simplest way possible (Law of Prägnanz).

These laws are visualised in Figure 3.7.

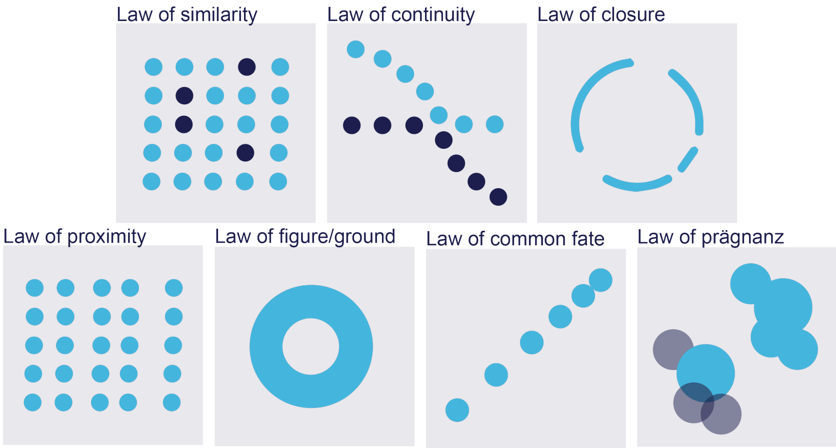


Figure 3.7: Visualisation of the Gestalt laws.

Simple presentation and visualisation

The presentation of the content should be simple [Proctor and Schneider, 2017], [Parnia, 2014], [Mishra, 2013], [Resch and Zimmer, 2013], [Krug, 2005], [Van Welie, 2001]. To achieve simplicity, the appearance of the content should not distract or confuse the user [Guntupalli, 2008]. However, simplicity remains a generic requirement. Within this research, the design choice to only display the minimal amount of content supports simplicity [Shneiderman, 2004].

Incorporate graphics
The time users need to perform a task could be related to increased simplicity and related scannability. When content is presented in a graphic, users seem to perform tasks faster [Tullis, 1981]. This could mean that graphics lead to an increased scannability. Furthermore, graphics often take up limited space [Scholtz, 1997] and lead to simpler, more understandable UIs [Fu, 2012].

Only show essentials
Hick's Law also advocated simplicity. The law states that if users are offered more options, their decision time increases. This is referred to as "analysis paralysis" and increases the chance users abandon the site [Proctor and Schneider, 2017], [Seow, 2005]. The relations from Hick's law are displayed in Figure 3.8 (based on [Seow, 2005]).

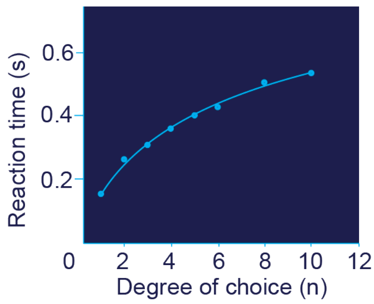


Figure 3.8: Effects of Hick's law, based on [Seow, 2005].

White space
Cluttered UIs feel cramped, unstructured, and complex. When a UI is cluttered, this could complicate the data discovery process [Zuiderwijk, 2015]. Because of this, clutter UIs are less user-friendly [Resch and Zimmer, 2013], [Shneiderman, 2004].

Avoiding clutter can be achieved by displaying a minimal amount of content and not overusing measures to show importance in the visual hierarchy [Shneiderman, 2004]. Another way to avoid clutter is the use of white space (see Figure 3.9 for an example). Related research confirms that a lack of white space between the content can lengthen the task execution [Tullis and Albert, 2013]. The importance of white space is also confirmed by the WCAG 2.1 heuristics, which prescribe that the line spacing should be at least a space-and-a-half within paragraphs, and paragraph spacing should be at least 1.5 times larger than the line spacing [WCAG, 2019].

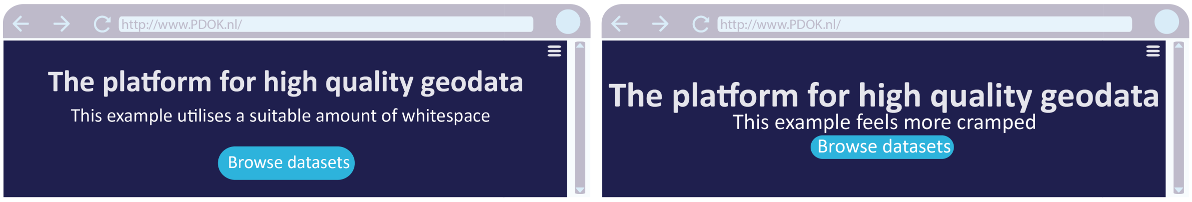


Figure 3.9: Visualisation of the effects of white space. The example on the left is more usable than the example on the right.

3.1.5. Visualise data

Most HCI happens visually [Parnia, 2014]. Because of this, visualisations are a valuable means for communication support in the UI [Veldkamp, 2017], [Mishra, 2013]. By looking at data samples before downloading, the fitness for use can be assessed [Welle Donker et al., 2019]. During this process, the visualisations make it easier to understand the data [Elvira, 2018], [Veldkamp, 2017], [Almanza et al., 2016], [Zuiderwijk, 2015], [Kukimoto, 2014] and datasets can be compared [Marta, 2016].

3.1.6. Cross device functionality

The use of different (touch screen) devices is something to keep in mind when designing a UI [Roth, 2017], [Carvalho and Lafuente, 2015], [Mishra, 2013], [He et al., 2012], [Chiew and Salim, 2003]. I decided to leave this out of the GUIDE since geoportal users are more likely to access the portal through a traditional computer screen.

3.2. Interaction with available services

The system interaction in general, navigation, and interaction with search mechanisms, access and upload mechanisms, and feedback mechanisms, are part of the interaction with available services.

3.2.1. System interaction

Knowledge exchange, trust, and confidence building are facilitated by effective communication [Elvira, 2018], [Zuiderwijk et al., 2013]. To achieve this, the interaction between users and the system should be suitable. This is covered by the guidelines displayed in Table 3.10.

Control over the system

Users are not satisfied if a system is not acting as they wish; unexpected actions and tedious mandatory entries build anxiety and dissatisfaction [Shneiderman, 2004]. Instead, users should feel in control [Guntupalli, 2008] by making them the initiator of the interaction [Parnia, 2014], [Fischer, 2001].

Error handling and preventing

To prevent errors, it is critical to predict possible mistakes and lead users in the right direction [Guntupalli, 2008]. An example of this is to show a red bounding box once a maximum area threshold for selection is passed [Kellenberger et al., 2016].

If errors do occur, informative error messages can help to acknowledge the error and to suggest corrections [WCAG, 2019], [Kellenberger et al., 2016], [Shneiderman, 2004].

Responsiveness and system status visibility

Similar to real social interactions, the system should acknowledge the actions of users [Carvalho and Lafuente, 2015], [Ludolph, 1997], [Smith, 1997]. Yielding closure of an action by providing a dialogue message, for example, gives users a feeling of accomplishment [Shneiderman, 2004].

Use of relatable semantics

By adopting familiar semantics, the interactions become more simple and natural; recognition and learnability of the system are increased, resulting in more efficiency [Tullis and Albert, 2013], [Shneiderman, 2004], [Smith, 1997], [Nielsen, 1993]. Recognition is especially important for irregular visitors [Roth, 2017], [Parnia, 2014], [Van Welie, 2001]. For PDOK, this is the case: in a year 77% of the Internet Protocol (IP) addresses only visited PDOK on a single day [Van Loenen and Welle Donker, 2016].

Table 3.10: Entry of the GUIDE: System interaction (SI) covering characteristics SI1-4.

Design characteristic	Implementation suggestions	Sources
SI ***System interaction*** Mentioned in: [WCAG 2.1], [Jiang et al., 2019], [Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [Roth, 2017], [Veldkamp, 2017], [Almanza et al., 2016], [Braggaar, 2016], [Kellenberger et al., 2016], [Marta, 2016], [Carvalho et al., 2015], [Poplin, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Mishra, 2013], [Resch et al., 2013], [He et al, 2012], [Lee, 2012], [Masó et al., 2011], [Van Loenen et al., 2010], [Yan et al., 2010], [Guntupalli, 2008], [Crompvoets, 2006], [Van Loenen, 2006], [Courage et al., 2005], [Krug, 2005], [Shneiderman, 2004], [Chiew et al., 2003], [Fischer, 2001], [Te'eni et al., 2001], [Van Welie, 2001], [Arnold, 1998], [Graefe, 1997], [Ludolph, 1997], [Rohlfs, 1997], [Scholtz, 1997], [Smith, 1997], [Nielsen, 1993]	SI1 Control over the system (postpone or suppress interruptions [WCAG 2.1])	[Parnia, 2014], [Shneiderman, 2004], [Fischer, 2001], [Te'eni et al., 2001], [Van Welie, 2001]
	SI2 Error handling & preventing: • Forgiveness & recoverability: easy reversal of actions • Informative error messages (feedback if a search keyword does not exist) • Limit (redundant) user actions or entry (check box vs string input, test user input immediately rather than at task completion) • Provide warnings	[Shneiderman, 2004], [Nielsen, 1993] • [WCAG 2.1], [Parnia, 2014], [Guntupalli, 2008], [Shneiderman, 2004], [Van Welie, 2001], [Rohlfs, 1997], [Nielsen, 1993] • [Tullis et al., 2013], [Shneiderman, 2004], [Smith, 1997] • [Roth, 2017], [Kellenberger et al., 2016], [He et al, 2012], [Guntupalli, 2008], [Krug, 2005] [Shneiderman, 2004], [Van Welie, 2001], [Rohlfs, 1997] • [WCAG 2.1]
	SI3 Responsiveness & system status visibility (system feedback on actions): • Show state of the interface (highlight active icons, differentiate between visited & unvisited links, and change the cursor in different modes) • Provide progress indicators (visible indicators, dialogue messages) • Provide summary information to compare states between interactions • Yield closure	[Parnia, 2014], [Mishra, 2013], [He et al, 2012], [Lee, 2012], [Guntupalli, 2008], [Shneiderman, 2004], [Arnold, 1998], [Ludolph, 1997], [Smith, 1997], [Nielsen, 1993] • [Roth, 2017], [Kellenberger et al., 2016], [Carvalho et al., 2015], [Resch et al., 2013], [Shneiderman, 2004], [Chiew et al., 2003] , [Nielsen, 1993] • [Carvalho et al., 2015], [Guntupalli, 2008], [Shneiderman, 2004], [Scholtz, 1997], [Nielsen, 1993] • [Roth, 2017], [Guntupalli, 2008] • [Shneiderman, 2004]
	SI4 Use of relatable semantics (correspondence to mental model): • Buttons & symbols should be clear (unambiguous, simple to interpret) & recognisable (universal or standardised, expected location) • Linguistic clarity: - allow tagging - avoid acronyms - avoid unfamiliar jargon - multi-linguality (at least English / Google translate options) • Relatable, standardised (map) controls and procedures: actions lead to expected results (e.g. Google maps, conventional web search engines)	[Roth, 2017], [Chiew et al., 2003], [Van Welie, 2001], [Graefe, 1997], [Smith, 1997] • [Roth, 2017], [Almanza et al., 2016], [Marta, 2016], [Carvalho et al., 2015], [Poplin, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Resch et al., 2013], [He et al, 2012] • [Parnia, 2014], [Mishra, 2013], [Yan et al., 2010], [Crompvoets, 2006], [Van Loenen, 2006], [Arnold, 1998], [Nielsen, 1993] - [[Marta, 2016], [Carvalho et al., 2015], [Parnia, 2014], [Masó et al., 2011] - [Yan et al., 2010] - [Veldkamp, 2017], [Carvalho et al., 2015], [Yan et al., 2010] - [Jiang et al., 2019], [Welle Donker et al., 2019], [Elvira, 2018], [Braggaar, 2016], [Marta, 2016], [Zuiderwijk, 2015], [Parnia, 2014], [Zuiderwijk et al., 2013], [Lee, 2012], [Van Loenen et al., 2010], [Crompvoets, 2006] • [Kellenberger et al., 2016], [Poplin, 2015], [Resch et al., 2013], [He et al., 2012], [Scholtz, 1997]

Buttons and symbols should be clear
An example of familiar symbology is a cross symbol to close a page [Chiew and Salim, 2003]. Visual metaphors can also be drawn from real-world interactions, such as a garbage can to delete elements [Roth, 2017]. This increases the intuitiveness of the interaction [Alvarez-Cortes et al., 2009].

Linguistic clarity
Examples of conventional terms for hyperlink destinations include “home”, “about”, or “Frequently Asked Questionss (FAQs)” [WCAG, 2019], [Parnia, 2014], [Mishra, 2013].

The use of much technical terminology can result in a too complex text [WCAG, 2019], which is frustrating to users who do not understand it [Carvalho and Lafuente, 2015]. For geoportals, non-geoprofessional users are expected to adopt a different jargon [Veldkamp, 2017]. One possible way to deal with such differences in terminology is to allow users to tag data [Welle Donker et al., 2019].

Relatable, standardised (map) controls and procedures
The relationship between a control and its function should be understandable [Smith, 1997]. Since maps are a big part of the geoportal, interactive maps should also follow this rule [Poplin, 2015], [Resch and Zimmer, 2013]. “Natural” map controls that behave as expected are highly valued by users. This, for example, includes scrolling to zoom and panning the map through dragging [Kellenberger et al., 2016], [Poplin, 2015].

3.2.2. Navigation

The navigation structure of a portal should enable users to find what they are looking for [Tullis and Albert, 2013]. Guidelines regarding the navigation through the portal are displayed in Table 3.11.

Table 3.11: Entry of the GUIDE: Navigation (N) covering characteristics N1, N2.

Design characteristic	Implementation suggestions	Sources
N ***Navigation*** Mentioned in: [WCAG 2.1], [Elvira, 2018], [Roth, 2017], [Almanza et al., 2016], [Braggaar, 2016], [Kellenberger et al., 2016], [Carvalho et al., 2015], [Parnia, 2014], [Mishra, 2013], [Resch et al., 2013], [Tullis et al., 2013], [Zuiderwijk et al., 2013], [He et al., 2012], [Lee, 2012], [Reinecke et al., 2011], [Guntupalli, 2008], [Courage et al., 2005], [Moustakis et al., 2004], [Shneiderman, 2004], [Chiew et al., 2003], [De Bra et al., 2001], [Arnold, 1998], [Simpson, 1997], [Smith, 1997], [Nielsen, 1993]	N1 Provide direct ways to do a task, show highly used content on all screens (allow shortcuts): • Include a quick-links drop-down menu to the most used pages (up to 15) • Search bar prominently visible	[WCAG 2.1], [Almanza et al., 2016], [Carvalho et al., 2015], [Parnia, 2014], [Guntupalli, 2008], [Shneiderman, 2004], [Nielsen, 1993], [Simpson, 1997], [Smith, 1997], [Arnold, 1998] • [Courage et al., 2005] • [Kellenberger et al., 2016], [Carvalho et al., 2015], [Resch et al., 2013], [Lee, 2012]
	N2 Provide sufficient navigational aids: • Breadcrumbs: current page position related to full sitemap to show previous steps in the interaction and to provide options to go back ("home" button) • Link page bottom to go back to the top • Utility links at the bottom of each page (including sitemap, help, feedback & contact info)	[Courage et al., 2005], [Moustakis et al., 2004], [Chiew et al., 2003] • [WCAG 2.1], [Roth, 2017], [Almanza et al., 2016], [Parnia, 2014], [Mishra, 2013], [Tullis et al., 2013], [Courage et al., 2005], [Chiew et al., 2003], [De Bra et al., 2001], [Nielsen, 1993] • [Chiew et al., 2003] • [Courage et al., 2005]

To achieve efficient navigation and a pleasant UX, the most frequent tasks should be easy to perform [Almanza et al., 2016], [Carvalho and Lafuente, 2015], [Krug, 2005], [Fischer, 2001]. The three clicks rule is an indicator to determine if the navigation is sufficiently efficient [Carvalho and Lafuente, 2015].

3.2.3. Search mechanisms

To support data discovery, the search mechanisms of the geoportal should work well [Yan and Guo, 2010]. Guidelines that cover this are displayed in Table 3.12.

Table 3.12: Entry of the GUIDE: Search mechanisms (S) covering characteristics S1-7.

Design characteristic	Implementation suggestions	Sources
S ***Search mechanisms*** Mentioned in: [Hao et al., 2019], [Welle Donker et al., 2019], [Marta, 2016], [Cecconi et al., 2018], [Elvira, 2018], [NGR, 2018], [Kellenberger et al., 2016], [Almanza et al., 2016], [Van Loenen et al., 2016], [Zuiderwijk, 2015], [Resch et al., 2013], [Zuiderwijk et al., 2013] [Braggaar, 2016], [Parnia, 2014], [Carvalho et al., 2015], [Huang et al., 2019], [He et al., 2012], [Chiew et al., 2003], [Yan et al., 2010], [Tullis et al., 2013], [Guntupalli, 2008], [Crompvoets, 2006], [Van Loenen, 2006], [Courage et al., 2005], [Moustakis et al., 2004], [Scholtz, 1997]	S1 Data recommender system	[Elvira, 2018], [Braggaar, 2016], [Marta, 2016], [Parnia, 2014]
	S2 Different (meta)data search possibilities: • Keywords (free text) • Map search (visually supported search) • Themes	• [NGR, 2018], [Braggaar, 2016], [Zuiderwijk, 2015], [Hao et al., 2019], [Courage et al., 2005] • [Braggaar, 2016], [Hao et al., 2019], [Resch et al., 2013], [Crompvoets, 2006] • [Braggaar, 2016], [Zuiderwijk, 2015], [Parnia, 2014]
	S3 Display the active search criteria	[He et al., 2012]
	S4 Filter results based on: • Access option (download, API, geo-web service) • Data provider • Dataset category • Geolocation • Time range	[Cecconi et al., 2018], [Elvira, 2018], [Marta, 2016], [Braggaar, 2016], [Zuiderwijk, 2015], [Parnia, 2014], [Van Loenen, 2006] • [Elvira, 2018] • [Hao et al., 2019] • [Hao et al., 2019], [Elvira, 2018], [Marta, 2016], [Braggaar, 2016], [Zuiderwijk, 2015], [Moustakis et al., 2004], [Guntupalli, 2008], [Courage et al., 2005], [Scholtz, 1997] • [Hao et al., 2019] • [Hao et al., 2019]
	S5 Let users tag data for search	[Welle Donker et al., 2019], [Parnia, 2014], [Marta, 2016] [Carvalho et al., 2015], [Huang et al., 2019], [Chiew et al., 2003]
	S6 Sort results based on: • Alphabetical order • Rating or comments from users • File format • Number of downloads • Number of views • Upload date	[Zuiderwijk, 2015], [Parnia, 2014] • [Almanza et al., 2016], [Courage et al., 2005] • [[Zuiderwijk et al., 2013] • [Almanza et al., 2016], [Courage et al., 2005] • [NGR, 2018], [Braggaar, 2016], [Zuiderwijk, 2015], [Zuiderwijk et al., 2013] • [Braggaar, 2016], [Zuiderwijk et al., 2013], [Crompvoets, 2006] • [Almanza et al., 2016], [Crompvoets, 2006]
	S7 Suggestion functionality (more flexible & intuitive search): • Auto-completion of the search keyword • Handling synonyms and typos ("did-you-mean" suggestions and best matching results for the query)	[Welle Donker et al., 2019], [Elvira, 2018], [NGR, 2018], [Marta, 2016], [Resch et al., 2013] • [Resch et al., 2013] • [Welle Donker et al., 2019], [Tullis et al., 2013]

Keyword search is the most preferred option of all search mechanisms that are frequently available on geoportals, followed by visually supported search on a map. The least favoured option is a category search [Resch and Zimmer, 2013].

There are many advanced search possibilities. However, on Nationaal Geo- Register - "National Geo Registry" (NGR), most users use the basic search functionality in which they search on title or location (55%) without any filters [NGR, 2018]. A possible downside of allowing advanced search with many filters could be that it can increase complexity and can prevent users from discovering more [Elvira, 2018], [Carvalho and Lafuente, 2015]. For this reason, a simple search option should always remain available [Carvalho and Lafuente, 2015].

3.2.4. Access and upload mechanisms

Many users visit geoportals to access GI [Resch and Zimmer, 2013], [Masó et al., 2011], [Giff et al., 2008]. Guidelines covering this are represented by the design characteristic displayed in Table 3.13.

Table 3.13: Entry of the GUIDE: Access and upload mechanisms (A) covering characteristics A1-8.

Design characteristic	Implementation suggestions	Sources
A ***Access & upload mechanisms*** Mentioned in: [Huang et al., 2019], [Jiang et al., 2019], [Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [Roth, 2017], [Braggaar, 2016], [Kellenberger et al., 2016], [Marta, 2016], [Vancauwenberghe et al., 2016], [Van Loenen et al., 2016], [Carvalho et al., 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Mischra, 2013], [Resch et al., 2013], [Zuiderwijk et al., 2013], [He et al., 2012], [Lee, 2012], [Koudijs, 2011], [Masó et al., 2011], Van Loenen et al., 2010], [Budhathoki et al., 2008], [Guntupalli, 2008], [Crompvoets, 2006], [Shneiderman, 2004], [Chiew et al., 2003]	A1 Allow users to register for an advanced user account: • Do not make registration mandatory • Provide possibility for data storage	[Cecconi et al., 2018], [Parnia, 2014], [Lee, 2012] • [Braggaar, 2016], [Marta, 2016], [Zuiderwijk et al., 2013], [Van Loenen et al., 2010], [Crompvoets, 2006] • [Roth, 2017], [Parnia, 2014], [Resch et al., 2013]
	A2 Develop pages that will print properly	[Resch et al., 2013], [Shneiderman, 2004]
	A3 Minimise memory loading: • Minimise the size of graphics (tumbnail images for preview) • Prevent redundancy	[Guntupalli, 2008] • [Mischra, 2013], [Shneiderman, 2004] • [Guntupalli, 2008]
	A4 Provide (meta)data in various formats: machine-readable & non-proprietary	[Jiang et al., 2019], [Welle Donker et al., 2019], [Elvira, 2018], [Braggaar, 2016], [Kellenberger et al., 2016], [Marta, 2016], [Van Loenen et al., 2016], [Zuiderwijk, 2015], [Parnia, 2014], [Zuiderwijk et al., 2013], [Lee, 2012]: [Welle Donker et al., 2019], [Elvira, 2018], [NGR, 2018], [Braggaar, 2016], [Marta, 2016], [Parnia, 2014], [Masó et al., 2011]
	A5 Provide data access: view service, downloads, (internationally standardised) APIs, geo-web services	[Huang et al., 2019], [Jiang et al., 2019], [Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [NGR, 2-18], [Braggaar, 2016], [Marta, 2016], [Vancauwenberghe et al., 2016], [Van Loenen et al., 2016], [Parnia, 2014], [Zuiderwijk et al., 2013], [Lee, 2012], [Koudijs, 2011], [Van Loenen et al., 2010], [Crompvoets, 2006]
	A6 Provide tools for processing (GIS functionality): • For analysis & cleaning • For coordinate transformations & classification • To change the format of a dataset • To combine data • Querying	[Huang et al., 2019], [Jiang et al., 2019], [Braggaar, 2016] • [Jiang et al., 2019], [Zuiderwijk et al., 2013] • [Jiang et al., 2019] • [Jiang et al., 2019], [Welle Donker et al., 2019], [Parnia, 2014], [Zuiderwijk et al., 2013] • [Parnia, 2014] • [Welle Donker et al., 2019], [Braggaar, 2016], [Zuiderwijk, 2015], [Parnia, 2014], [Lee, 2012]
	A7 Provide upload facilities: • Allow users to edit or create metadata • Allow users to upload data related to published datasets (such as re-use cases [Cecconi et al., 2018]) • Official (automated) validation criteria & quality assurance	[Elvira, 2018], [Marta, 2016], [Lee, 2012] • [Jiang et al., 2019], [Parnia, 2014], [Masó et al., 2011] • [Braggaar, 2016], [Marta, 2016], [Zuiderwijk et al., 2013] • [Welle Donker et al., 2019], [Vancauwenberghe et al., 2016], [Parnia, 2014], [Lee, 2012], [Budhathoki et al., 2008]
	A8 Subscribe for updates of datasets or news via email, ATOM or RSS feed	[Huang et al., 2019], [Cecconi et al., 2018], [Carvalho et al., 2015], [Parnia, 2014], [Zuiderwijk et al., 2013]

Allow users to register for an advanced user account

Although mandatory registration for an account with mandatory questions can annoy users [Tmimi et al., 2018], [Krug, 2005], the advantage of additional functionalities can be an incentive to create such an account [Marta, 2016]. However, one of the requirements for open data is that the data is freely available without registration [Tauberer, 2014], [Open Government, 2007]. Even when user accounts are introduced, this should remain true.

Provide data access

Different types of users prefer different types of data access mechanisms. Relatively speaking, developers, for example, use more APIs [Huang et al., 2019], [PDOK, 2019], [NGR, 2018]. Developers use less geo-web services [NGR, 2018], which might be due to a lack of experience in GIS. Downloads are appreciated by non-professionals or users who are not used to APIs [Koudijs, 2011].

Application Programming Interfaces (APIs)

An API is a software intermediary that allows communication between two applications. The API can be seen as a messenger that delivers requests and responses from a client to a provider application (see Figure 3.14).

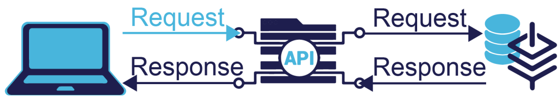


Figure 3.14: API workflow.

APIs can be used to prevent downloads from being necessary and allows automating the processing of datasets. Especially when it is necessary to process a large number of datasets, this results in an increase in efficiency [De Jong, 2019].

Geo-web services

So-called geo-web services enable access to data according to Open Geospatial Consortium (OGC) standards such as Web Map Service (WMS), Web Map Tile Service (WMTS), Tile Map Service (TMS), or Web Feature Service (WFS). Accessing datasets through geo-web services often involves making a request through GIS software.

Provide upload facilities

Volunteerd Geographic Information (VGI) is a viable option to keep GI such as the Basisregistratie Grootschalige Topografie - “Base registry large scale Topography” (BGT) up to date [Sjoukema, 2015]. Mechanisms enabling VGI should deal with the challenge of guaranteeing a desired quality level [Vancauwenberghe and Van Loenen, 2016], [Sjoukema, 2015], [Budhathoki et al., 2008]. To ensure this, the VGI should be validated [Welle Donker et al., 2019], [Mishra, 2013], [Budhathoki et al., 2008]. By providing clear instructions, consistency can be achieved [Parnia, 2014]. To help users correct mistakes, their submissions should be reversible [Welle Donker et al., 2019].

3.2.5. Feedback mechanisms

Feedback mechanisms allow communication among users and providers. This can increase the quality of both the system and the data [Welle Donker et al., 2019], [Van Loenen and Welle Donker, 2016], [Guntupalli, 2008]. To be able to publish the data content that users require, data providers should listen to their users [Van Loenen, 2018], [Van Loenen, 2006]. Feedback mechanisms can also help users share insights about the data. By allowing conversations between users, they can help each other during the (re-)use process [Welle Donker et al., 2019].

Guidelines that cover this are displayed in Table 3.15.

Table 3.15: Entry of the GUIDE: Feedback mechanisms (F) covering characteristics F1-3.

Design characteristic	Implementation suggestions	Sources
F ***Feedback mechanisms*** Mentioned in: [Huang et al., 2019], [Jiang et al., 2019], [Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [Roth, 2017], [Kellenberger et al., 2016], [Marta, 2016], [Van Loenen et al., 2016], [Carvalho et al., 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Resch et al., 2013], [Zuiderwijk et al., 2013], [Lee, 2012], [Masó et al., 2011], [Van Loenen et al., 2010], [Van Loenen, 2006], [Courage et al., 2005]	F1 Allow discussions & sharing among users and providers: • Collaboration system • Social media integration (share button)	• [Huang et al., 2019], [Cecconi et al., 2018], [Roth, 2017], [Marta, 2016], [Carvalho et al., 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Lee, 2012] • [Marta, 2016], [Carvalho et al., 2015], [Zuiderwijk et al., 2013]
	F2 Data request mechanism (allow users to request missing datasets)	[Cecconi et al., 2018], [Marta, 2016], [Parnia, 2014], [Zuiderwijk et al., 2013]
	F3 Mechanisms to provide feedback: • Commenting • Rating	[Huang et al., 2019], [Jiang et al., 2019], [Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [Marta, 2016], [Van Loenen et al., 2016], [Zuiderwijk, 2015] • [Elvira, 2018], [Marta, 2016], [Parnia, 2014], [Masó et al., 2011], [Zuiderwijk et al., 2013] • [Welle Donker et al., 2019], [Marta, 2016], [Parnia, 2014], [Zuiderwijk et al., 2013]

3.3. Enabling information

Metadata and help mechanisms are enabling information for geoportals.

3.3.1. Metadata

Open government initiatives do not always provide adequate metadata [Jurisch et al., 2015]. However, good quality metadata is important for users [De Jong, 2019], [Koudijs, 2011], [Van Loenen and Onsrud, 2004] and leads to easier use [Van Loenen, 2006]. For this reason, metadata is covered by the guidelines displayed in Table 3.16.

Table 3.16: Entry of the GUIDE: Metadata (M) covering characteristics M1-8.

Design characteristic		Implementation suggestions	Sources
M ***Metadata*** Mentioned in: [Huang et al., 2019], [Jiang et al., 2019], [Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [NGR, 2018], [Braggaar, 2016], [Marta, 2016], [Vancauwenberghe et al., 2016], [Van Loenen et al., 2016], [Welle Donker, 2016], [Lourenço, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Zuiderwijk et al., 2013], [Lee, 2012], [Koudijs, 2011], [Masó et al., 2011], [Crompvoets, 2006], [Van Loenen, 2006], [Courage et al., 2005], [Van Loenen et al., 2004], [Backx, 2003], [Chiew et al., 2003]	M1	Accessibility (license conditions & their meaning)	[Braggaar, 2016], [Marta, 2016], [Van Loenen et al., 2016], [Welle Donker, 2016], [Zuiderwijk, 2015], [Parnia, 2014], [Lee, 2012]
	M2	Available according to international standards	[Braggaar, 2016], [Marta, 2016], [Zuiderwijk, 2015], [Lee, 2012], [Koudijs, 2011], [Crompvoets, 2006]
	M3	Data governance: • Aggregation level & processing • Data interpretation support: context (original use / purpose) • Overview of editors, including the original creator • Version management: overview of data update history, methods to track changes, & update frequency (sustainability)	• [Welle Donker et al., 2019], [Parnia, 2014], [Backx, 2003] • [Elvira, 2018], [Zuiderwijk, 2015] • [Jiang et al., 2019], [Welle Donker et al., 2019], [Elvira, 2018], [NGR, 2018], [Marta, 2016], [Zuiderwijk, 2015], [Parnia, 2014], [Zuiderwijk et al., 2013], [Lee, 2012], [Crompvoets, 2006], [Courage et al., 2005], [Backx, 2003], [Chiew et al., 2003]
	M4	Linking sources: • Link to other access & information channels • Link to the original data source	[Van Loenen et al., 2016] • [Welle Donker et al., 2019], [Marta, 2016], [Kellenberger et al., 2016], [Zuiderwijk, 2015], [Lee, 2012] • [Marta, 2016], [Parnia, 2014], [Zuiderwijk et al., 2013], [Courage et al., 2005]
	M5	Quality indicators: • Accuracy (correctness) / precision • Completeness: - no missing values - coverage - granularity - timeliness	• [Lourenço, 2015], [Zuiderwijk, 2015], [Van Loenen, 2006] • [Lourenço, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Van Loenen, 2006], [Backx, 2003] - [Welle Donker et al., 2019], [Parnia, 2014], [Courage et al., 2005], [Backx, 2003] - [Marta, 2016] - [Lourenço, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Courage et al., 2005]
	M6	Semantics: what are the data attributes & what do they mean	[Welle Donker et al., 2019], [Parnia, 2014], [Backx, 2003]
	M7	Structure of the data:data model, format, size, service level (view service, downloads, APIs, geo-web services)	[Welle Donker et al., 2019], [Marta, 2016], [Van Loenen, 2006], [Courage et al., 2005], [Backx, 2003]
	M8	Topic & description of the data	[Jiang et al., 2019], [Marta, 2016], [Lee, 2012]

Available according to international standards

Standardised metadata is required because a lack of consistent metadata can lead to reduced data usability [Zuiderwijk, 2015] and less harmonised data discovery [Jiang et al., 2019]. The ISO 19115 standard is the common metadata standard for GI in the European Union. This standard prescribes metadata entities such as the extent and quality of the data. The ISO 19139 standard defines the encoding of ISO 19115 to describe, validate and exchange metadata in an interoperable way [Jiang et al., 2019]. This involves the XML Schema Definition (XSD) of the Extensible Markup Language (XML).

Despite standardisation, metadata provision is cumbersome [Zuiderwijk, 2015]. It is challenging that the fields are standardised, but the actual values are not [Van Loenen and Welle Donker, 2016].

Data governance

To be able to assess the suitability of the data, its lineage should be known. Furthermore, it is important to users whether or not a dataset will remain open [Zuiderwijk, 2015]. A possible indication of this sustainability can be provided by clear version management or a list of planned updates [Lee, 2012]. Most users are interested in the most recent data [NGR, 2018].

Linking sources

To deal with fragmentation, it could be beneficial to link different access and information channels [Welle Donker et al., 2019]. An example when this is useful could be when information about the data is published at different channels.

Number of suppliers

Statistics on data producers, such as the number of suppliers whose data is published on the portal, are mentioned as requirements in related research (see Marta [2016] and Crompvoets [2006]). However, other research suggests this type of information is less important to users (see Braggaar [2016] and Koudijs [2011]). Possible producer biases aside, the number of suppliers does not say much about the quality of the portal [Braggaar, 2016]. For this reason, I decided to leave the number of suppliers out of the GUIDE.

3.3.2. Help mechanisms

The UI should provide the help mechanisms necessary in a certain context [WCAG, 2019], [Jurisch et al., 2015]. Such mechanisms can be used to explain details about the data or the portal use. Guidelines that cover this are displayed in Table 3.17.

Table 3.17: Entry of the GUIDE: Help mechanisms (H) covering characteristics H1-9.

Design characteristic		Implementation suggestions	Sources
H ***Help mechanisms*** Mentioned in: [WCAG 2.1], [Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [Roth, 2017], [Marta, 2016], [Braggaar, 2016], [Vancauwenberghe et al., 2016], [Carvalho et al., 2015], [Jurisch et al., 2015], [Lourenço, 2015], [Poplin, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Zuiderwijk et al., 2013], [He et al., 2012], [Lee, 2012], [Reinecke et al., 2011], [Guntupalli, 2008], [Crompvoets, 2006], [Van Loenen, 2006], [Courage et al., 2005], [Van Welie, 2001], [Dayton et al., 1997], [Rohlfs, 1997], [Smith, 1997]	H1	Audience-oriented sections covering functions for different types of users	[Courage et al., 2005]
	H2	Contact form or contact information (phone numbers, email addresses)	[Zuiderwijk et al., 2013], [Lee, 2012], [Van Loenen et al. 2010], [Crompvoets, 2006], [Courage et al., 2005]
	H3	Data manual or Wiki (guidance for data usage)	[Elvira, 2018], [Zuiderwijk et al., 2013], [Marta, 2016], [Parnia, 2014]
	H4	Discussion forum (for example through social media) & help desk	[Elvira, 2018], [Braggaar, 2016], [Marta, 2016], [Zuiderwijk, 2015], [Zuiderwijk et al., 2013]
	H5	Examples of data applications & use (including relevant analysis & tools)	[Welle Donker et al., 2019], [Cecconi et al., 2018], [Elvira, 2018], [Marta, 2016], [Vancauwenberghe et al., 2016], [Zuiderwijk, 2015], [Parnia, 2014]
	H6	FAQs	[Elvira, 2018], [Marta, 2016], [Braggaar, 2016], [Carvalho et al., 2015], [Parnia, 2014], [Zuiderwijk et al., 2013]
	H7	Portal manual or glossary (terms, definitions, procedures & operations)	[Elvira, 2018], [Marta, 2016], [Braggaar, 2016], [Zuiderwijk et al., 2013], [He et al., 2012], [Lee, 2012], [Guntupalli, 2008]
	H8	Tips & hints: • Mechanism to identify definitions • Visual clues about functionality	[Poplin, 2015], [Zuiderwijk et al., 2013], [Nilsson et al., 1997] • [WCAG 2.1] • [Poplin, 2015], [Smith, 1997]
	H9	Tutorials	[Elvira, 2018], [Marta, 2016], [Parnia, 2014], [Zuiderwijk et al., 2013]

3.4. Consistency

Unless a user initiates changes, the system should be consistent [WCAG, 2019]. A consistent design is simpler to use [Parnia, 2014] and easier to remember, which results in an increased learnability [Mishra, 2013]. For this reason, consistent implementation of all the previously mentioned design characteristics is required. The overarching requirement of consistency is displayed in Table 3.18.

Table 3.18: Entry of the GUIDE: Consistency (C) covering characteristics C1-3.

Design characteristic	Implementation suggestions	Sources
C *Consistency* Mentioned in: [WCAG 2.1], [Viloria et al., 2019], [Almanza et al., 2016], [Braggaar, 2016], [Marta, 2016], [Lourenço, 2015], [Zuiderwijk, 2015], [Parnia, 2014], [Mishra, 2013], [Guntupalli, 2008], [Van Loenen, 2006], [Shneiderman, 2004], [Backx, 2003], [Chiew et al., 2003], [Smith, 1997], [Dayton et al., 1997], [Nielsen, 1993]	C1 Consistent appearance: • Colours • Font type & size • Placement of page elements (lay-out header, footer, menus)	[Parnia, 2014], [Guntupalli, 2008] • [Mishra, 2013], [Shneiderman, 2004], [Chiew et al., 2003] • [Mishra, 2013] • [Parnia, 2014], [Shneiderman, 2004], [Chiew et al., 2003]
	C2 Consistent behaviour: • Homogeneous formats • Identification of functionality • Interaction: consistent style system feedback, perform similar tasks in a similar way (order yes / no buttons), standardised task sequence	[Parnia, 2014] • [Braggaar, 2016], [Zuiderwijk, 2015] • [WCAG 2.1] • [WCAG 2.1], [Mishra, 2013], [Guntupalli, 2008], [Shneiderman, 2004], [Smith, 1997]
	C3 Consistent semantics: • Graphics & icons • Terminology homogeneity (controlled vocabularies)	[Lourenço, 2015], [Zuiderwijk, 2015], [Shneiderman, 2004]

Considering consistency is beneficial at both an internal and external level. If a consistent design is adopted among different portals, this could result in better interoperability.

3.5. Summary: Theoretical UI design characteristics

In this chapter, I listed the results of a literature review into what design characteristics could contribute to a user-friendly UI. I came to these characteristics by categorising statements I retrieved from research into the different components of the UI in the context of geoportals.

Important factors for the content presentation involve the use of colour and the placement of the content on the page. Scanning pages for important elements becomes easier by adopting a visual hierarchy and by only displaying essential information.

On a general level, the interaction involves communication between the user and the system. This communication should feel natural in the sense that the system should respond to the actions of the users and should use familiar symbols, language, and controls. The navigation of a user through the system is also part of the interaction. The UI should enable direct ways to do a task and the users should be guided through the system with navigational aids. Furthermore, several system functionalities that are characteristic for geoportals should be communicated through the UI. This commonly involves interaction with a search mechanism, access and upload mechanisms, and feedback mechanisms. Search mechanisms should allow different search possibilities such as searching with keywords, on a map, or based on themes. Allowing users to filter or sort their search results can lead to an increase in efficiency. Users should be able to access datasets in a format and with the service they require. Upload functionalities can be beneficial to achieve VGI. The UI should enable users to collaborate; allowing communication among users and providers can lead to more relevant data offerings and an increase in data quality.

To use the portal or the data, users require enabling information. Specifically for geoportals, this means metadata should be provided. Furthermore, help mechanisms should be available to support users in using the portal and the data. The required help can be offered through manuals, a discussion forum, FAQs, tutorials, and by providing hints.

Consistency is an overarching characteristic relating to all other components of the UI design. This means the portal should adopt consistent appearance, behaviour, and semantics.

4
UI design characteristics from existing geoportals

In this chapter, I present the results of a desk research into best practises of the geoportals of France[1], Ireland[2], Luxembourg[3], and Norway[4]. In Annex B I discuss the corresponding selection process.

In Section 4.1, I present screenshots of the home page and the other pages of the analysed portals related to the processes of searching, assessing, and accessing data. To indicate the availability of design characteristics and to point out related implementation examples, I annotated these screenshots. For elements available through a menu bar, solely the screenshot in which these elements first occur is annotated. Some of the annotations are self-explanatory, such as the use of harmonious colours (CP1) or the display of active search criteria (S3). However, elaboration on annotations related to, for example, navigational aids (N2) or the intuitiveness of the search functionality (S7) could be required. I discuss these cases in Section 4.2. Each coloured text box in this section matches a category of the initial GUIDE. Annex F contains a cheat sheet regarding the colour codes and abbreviations of design characteristics related to the initial version of the GUIDE.

The desk research involves an analysis of each of the selected portals by using them in the process of searching, assessing, and accessing a topographic (base) map, a map of administrative areas, and a road map. Based on the compliance of the different portals to the initial GUIDE, I assess in which cases re-evaluation is required. If, for example, none of the portals implements a certain design characteristic, this characteristic might be infeasible, and it should be reconsidered. The other way around, the initial GUIDE can be extended by design characteristics existing portals implement that I did not retrieve from literature. Moreover, I acquired implementation examples of the design characteristics of the initial GUIDE by looking into well-performing portals for that characteristic. I analysed this in Section 4.2 and summarised it in Section 4.3. By taking this approach, I answered Subsubquestion 1.2.

"What user-friendly interface design characteristics are implemented in existing geoportals?"

Although I performed the rating process as objectively as possible, it could be that different users with different characteristics would have acquired different results. This is especially true for requirements for characteristics that are more challenging to concretise, such as the "scannability" of the content (CP5) and the control over the system (SI1). Such characteristics could be specified with implementation examples; in the case of CP5, certain users might think there are enough headings and a proper amount of text, whereas others are not satisfied. With more specific, visual guidelines, more objective use of a characteristic might be enabled. However, other characteristics could still not be following the SMART principles and should be re-evaluated.

[1] https://www.geoportail.gouv.fr accessed on 09-12-2019
[2] https://www.geohive.ie/ accessed on 09-01-2020
[3] https://www.geoportail.lu/en/ accessed on 27-11-2019
[4] https://www.geonorge.no/en/ accessed on 28-11-2019

4.1. Annotated implementations of design characteristics

In this section, I annotate the availability of design characteristics of the initial GUIDE on the pages users need to search, assess and access data.

4.1.1. The start of using a portal: Home pages

The process of using a geoportal starts on a home page. The upper part of the home page of the portal of France is shown in Figure 4.1. For Ireland this is done in Figure 4.2, for Luxembourg in Figure 4.3, and for Norway in Figure 4.4.

Figure 4.1: Upper part of the home page of the geoportal of France and the corresponding design characteristics.

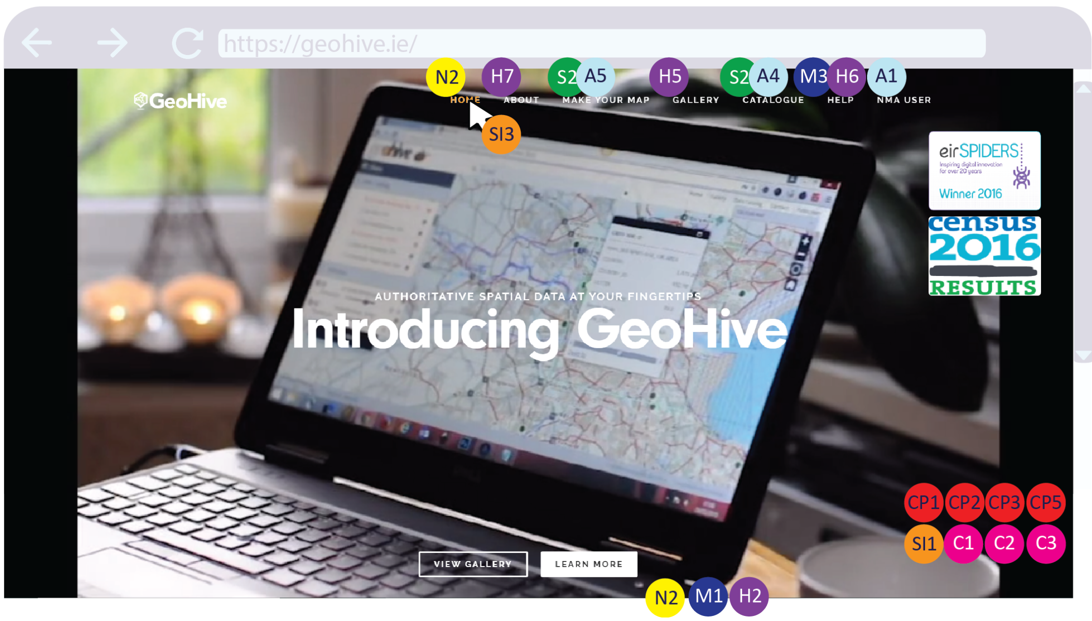


Figure 4.2: Upper part of the home page of the geoportal of Ireland and the corresponding design characteristics.

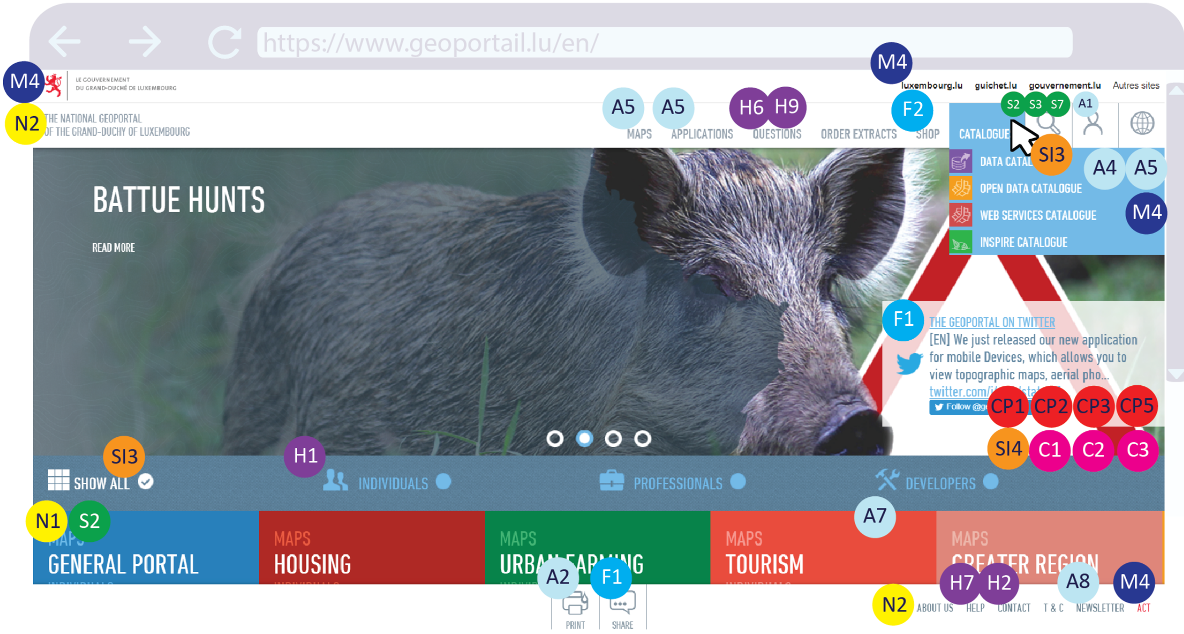


Figure 4.3: Upper part of the home page of the geoportal of Luxembourg and the corresponding design characteristics.

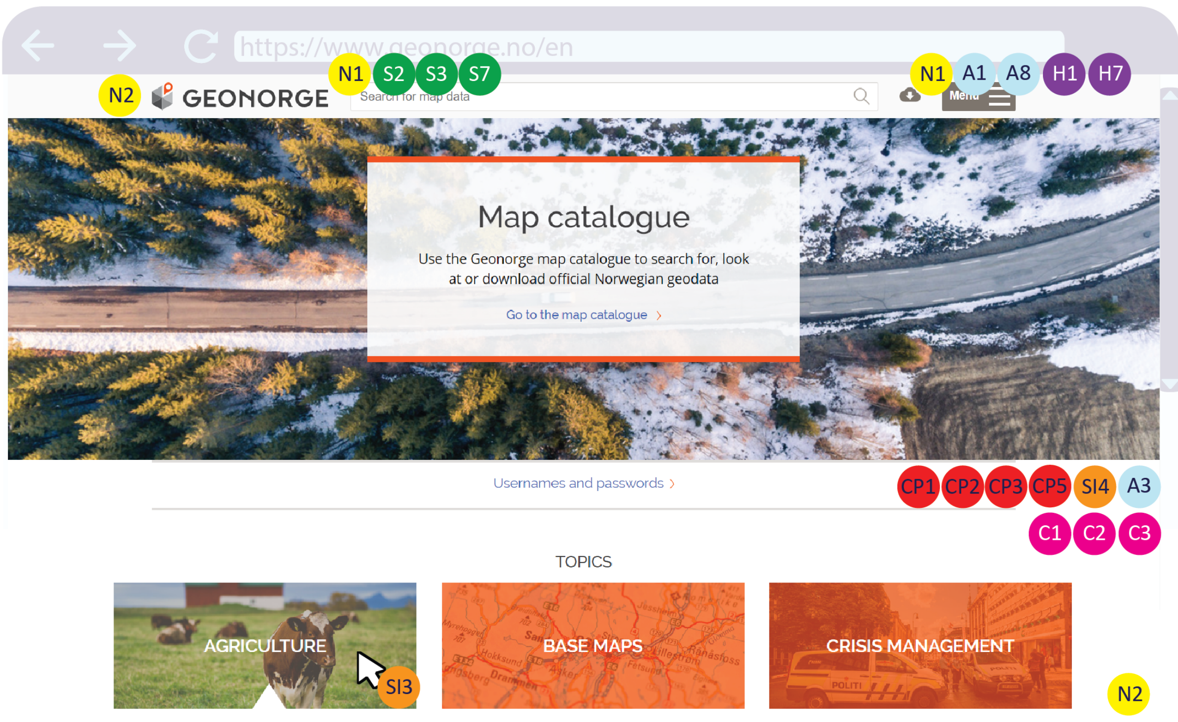


Figure 4.4: Upper part of the home page of the geoportal of Norway and the corresponding design characteristics.

4.1.2. The search process: Pages for discovery

Most portals have a separate so-called catalogue page, on which users can search (meta)data. For the portal of Ireland, this page is displayed in Figure 4.5. Upon selecting the red "end point" button on this page, the user is shown a dialogue containing a Unique Resource Locator (URL). This URL links to an external metadata page hosted in an ArcGIS REST services directory, on which it is, among others, possible to query data, and view data through the ArcGIS web map viewer.

For data discovery on the portal of Luxembourg, users can directly browse themes on the home page or under the "map" tab of the menu bar. Via this tab, the page as shown in Figure 4.6 can be accessed. Here, users can go to the map viewer via a general page, or through a specific theme.

On the Norwegian portal, it is possible to search data directly from the home page or on a catalogue page. The hits of the search query are displayed on the catalogue page as shown in Figure 4.7. On this page, datasets can be selected for access.

The portal of France has no dedicated page for data discovery. Instead, it is possible to search directly on the home page or the map viewer page (Figure 4.8).

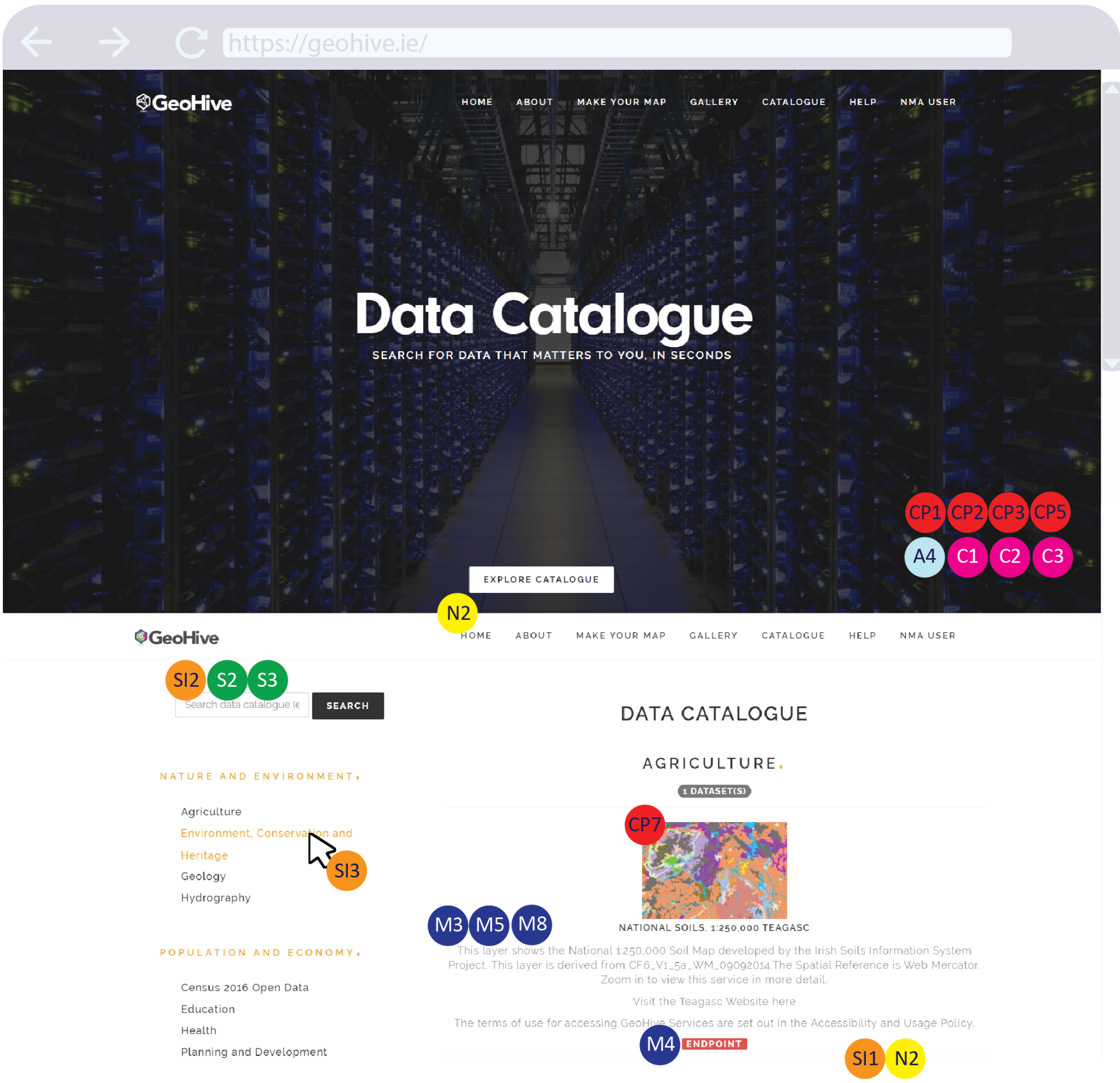


Figure 4.5: Catalogue page of the geoportal of Ireland and the corresponding design characteristics.

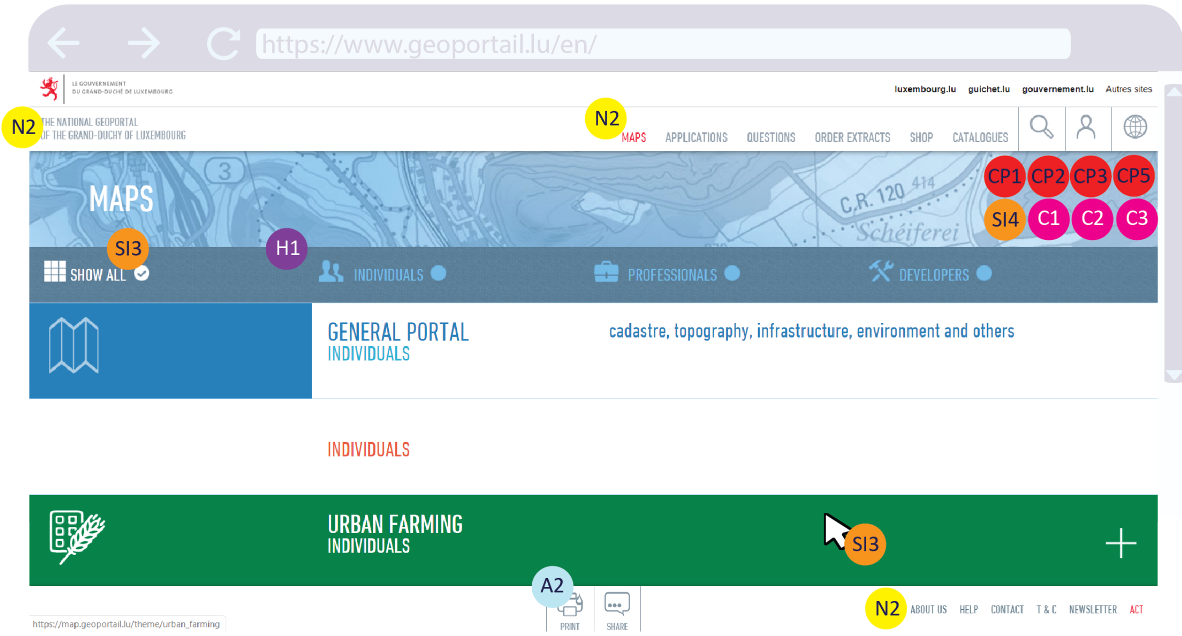


Figure 4.6: Overview page for map selection on the geoportal of Luxembourg and the corresponding design characteristics.

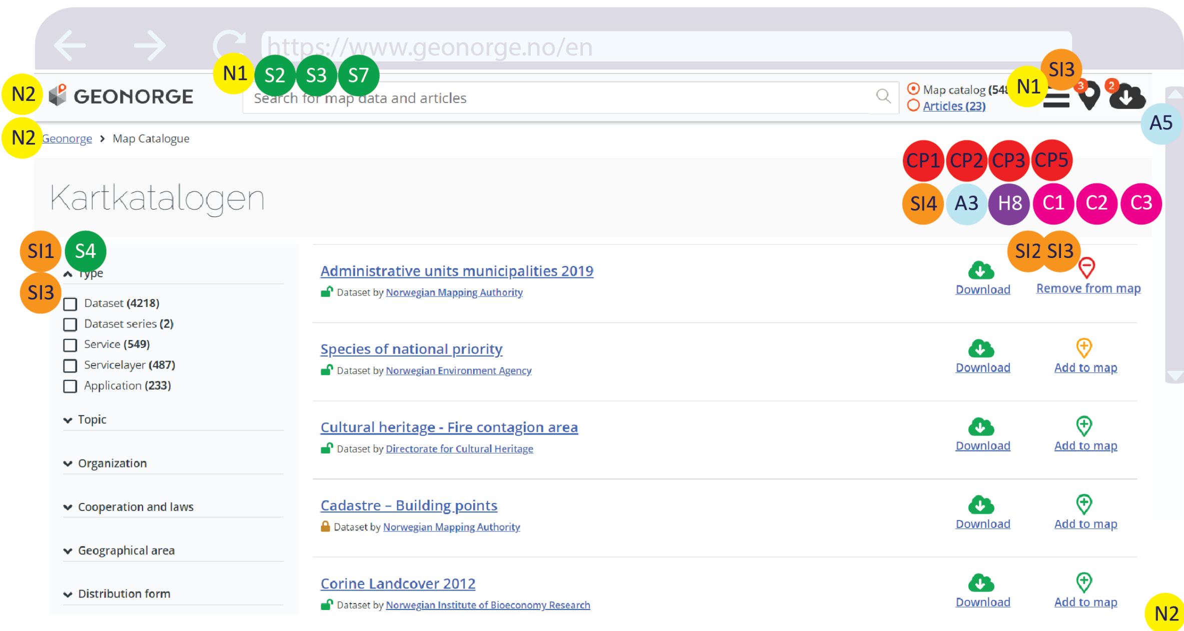


Figure 4.7: Catalogue page of the geoportal of Norway and the corresponding design characteristics.

4.1.3. The assessment process: Acquiring and consulting metadata

The map viewer page of the portal of France is displayed in Figure 4.8. This page integrates all tasks related to searching, assessing, and accessing the data in a view service. The map viewer of the portal of Ireland as displayed in Figure 4.9 and Luxembourg as displayed Figure 4.10, also support data discovery and assessment.

The portal of Norway is the only analysed portal that adopts dataset landing pages; upon selection of the name of a dataset in the catalogue, users are directed to the corresponding landing page containing more information and options regarding this dataset. The top part of such a page is displayed in Figure 4.11.

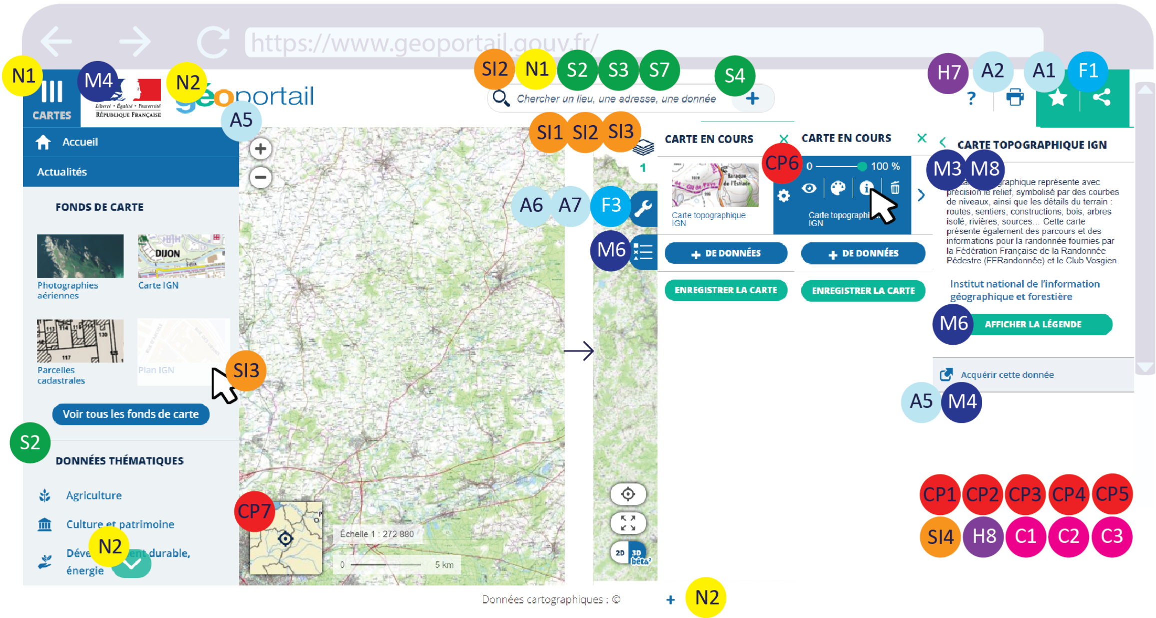


Figure 4.8: Assessing layers in the map viewer of the geoportal of France and the corresponding design characteristics.

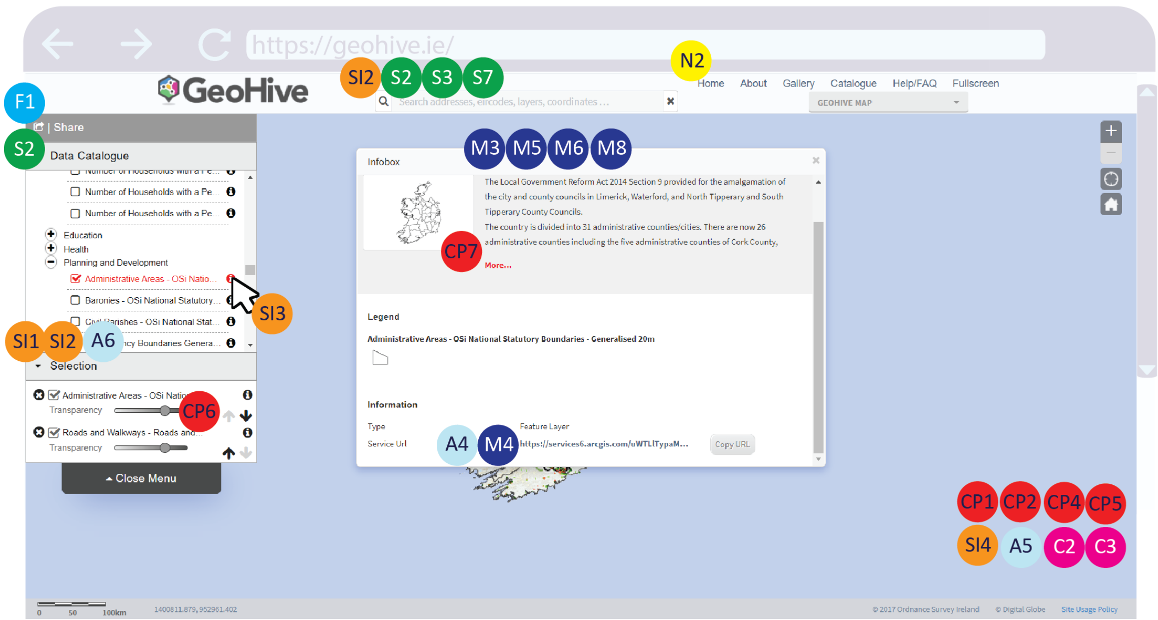


Figure 4.9: Assessing layers in the map viewer of the geoportal of Ireland and the corresponding design characteristics.

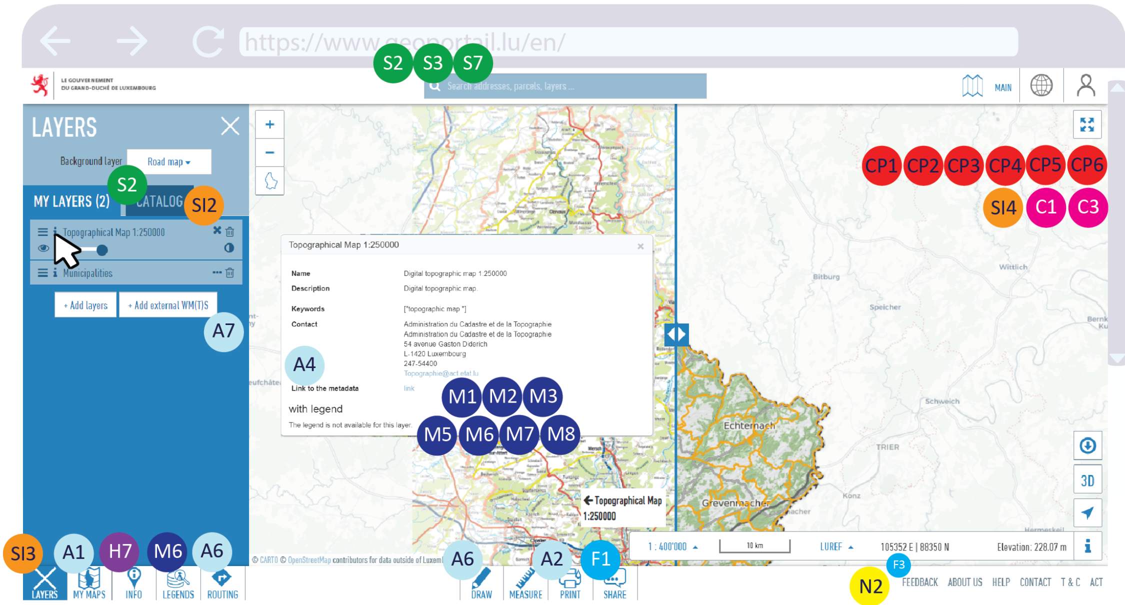


Figure 4.10: Assessing layers in the map viewer of the geoportal of Luxembourg and the corresponding design characteristics.

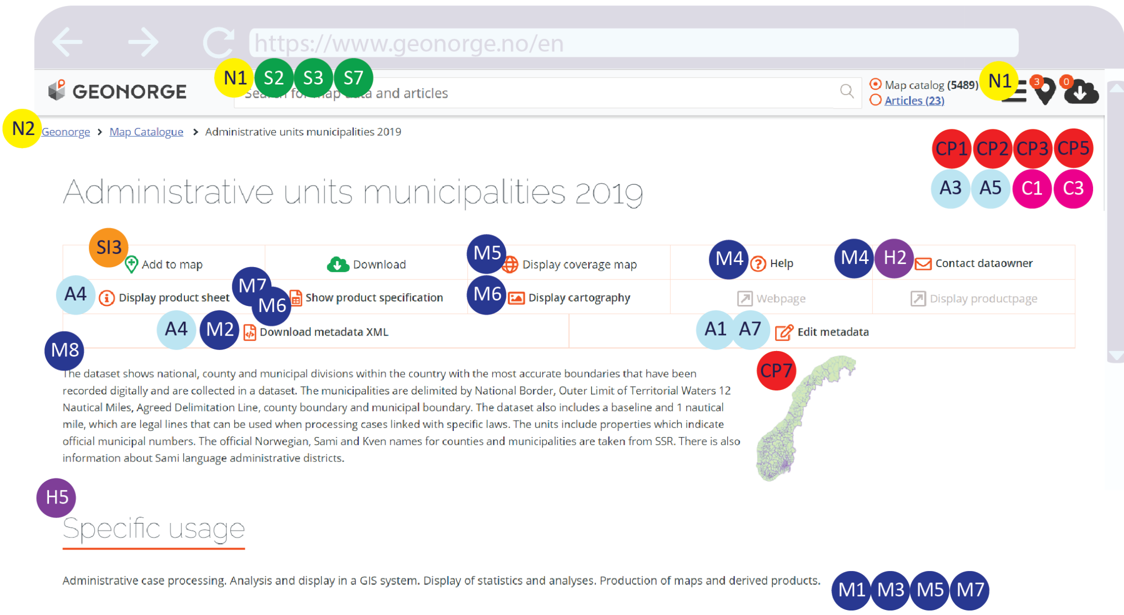


Figure 4.11: Example of a dataset landing page of the geoportal of Norway and the corresponding design characteristics.

4.1.4. The access process: Acquiring data

Norway is the only analysed portal with dedicated pages for data access.

Upon selection of the map viewer icon (see Figure 4.7), the user is directed to the map viewer page as is shown in Figure 4.12. Browsing, assessing, and accessing data on the map, can also be done on the so-called “thematic-map” page (see Figure 4.13).

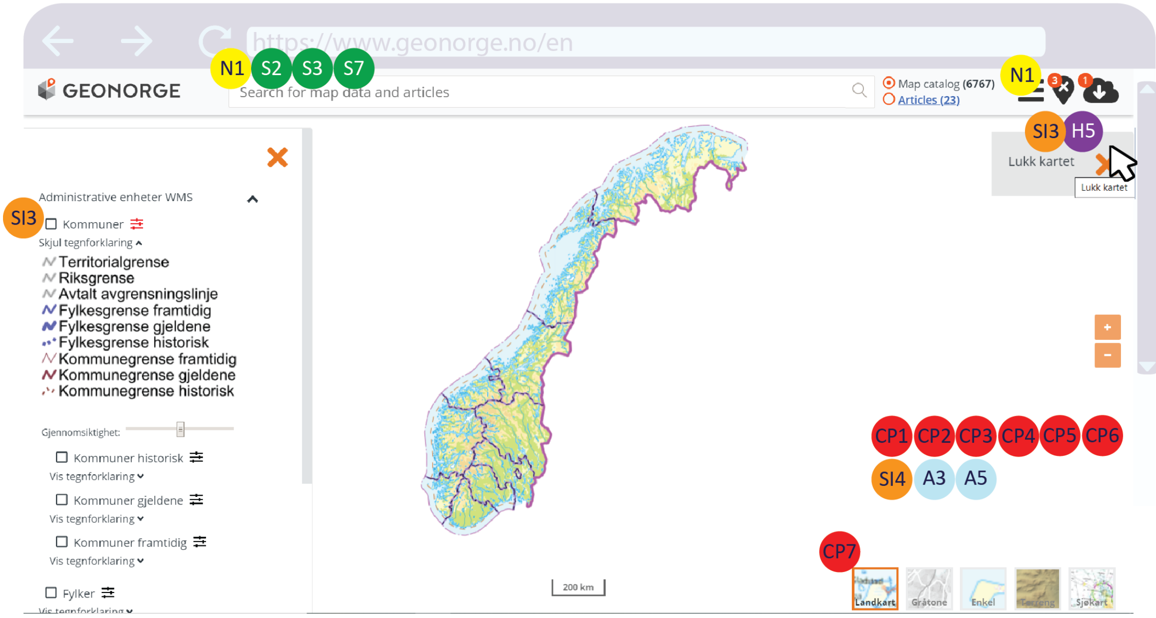


Figure 4.12: Map viewer page of the geoportal of Norway and the corresponding design characteristics.

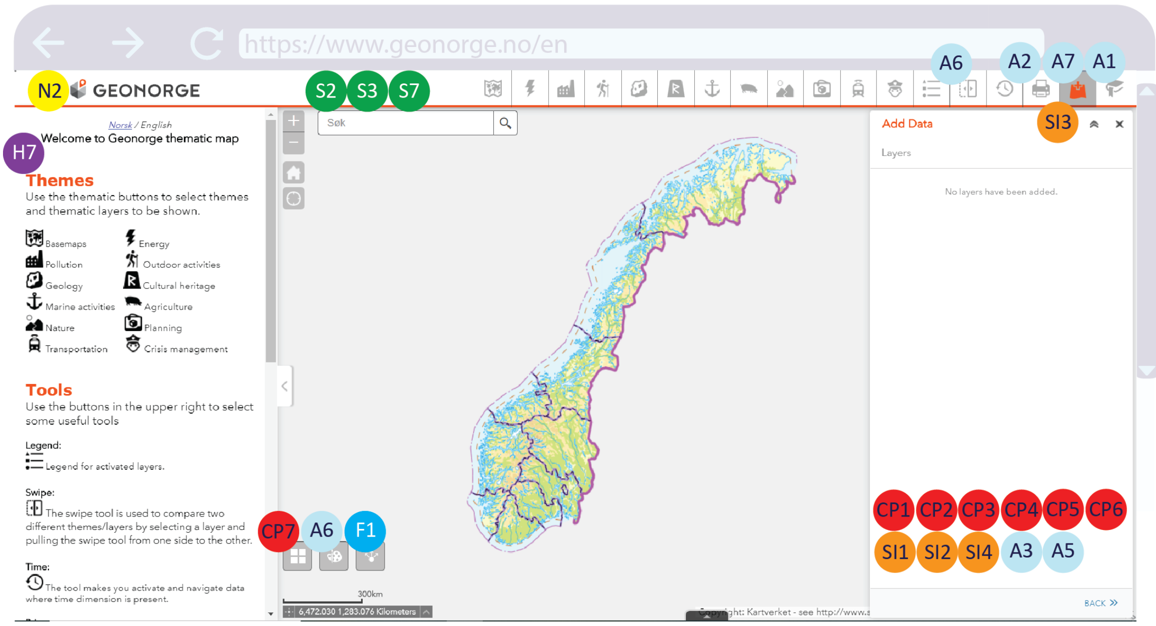


Figure 4.13: Thematic map page of the geoportal of Norway and the corresponding design characteristics.

When selecting the download icon (see Figure 4.7), the user is directed to a download page listing all datasets that have previously been selected for download purposes. The top part of this download page is shown in Figure 4.14. On this page, common download presets involving the area, map projection, and format of the dataset can be specified. Since the topographic map and the road map were not available as a download, I also selected the "Height DTM 10" dataset to evaluate the consistency of the download process. Before users can use the download button, they also have to provide their user group and purpose of use. For the actual download, they are redirected to another page (see Figure 4.15).

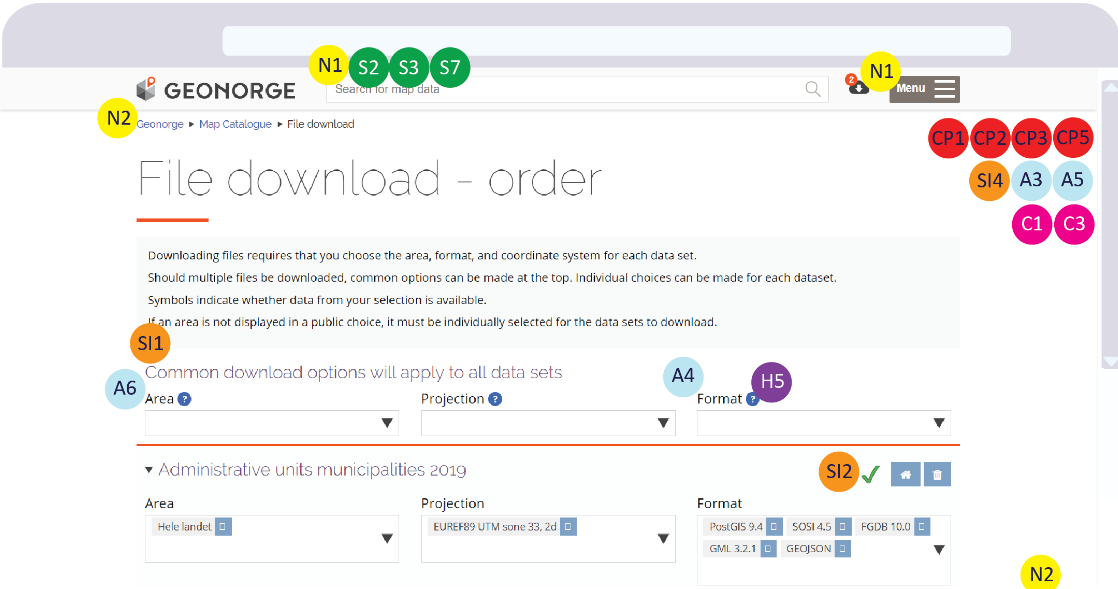


Figure 4.14: Download page of the geoportal of Norway and the corresponding design characteristics.

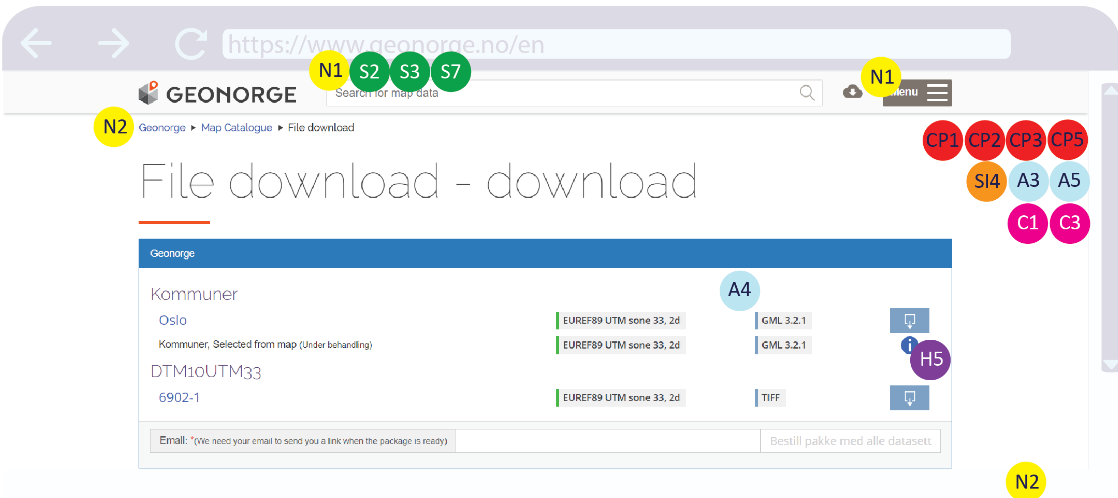


Figure 4.15: Download page redirection of the geoportal of Norway and the corresponding design characteristics.

4.2. Insights desk research

In Table 4.16, the strengths and weaknesses of the geoportals of France, Ireland, Luxembourg, and Norway according to the initial version of the GUIDE are displayed. This overview indicates which portals can serve as implementation examples for a certain design characteristic. Characteristics that are not often implemented indicate a need for re-evaluation.

Table 4.16: Performance of the geoportals of France, Ireland, Luxembourg, and Norway according to the initial GUIDE. The portal is rated: ■ Compliant: if a design characteristic is implemented as listed in the GUIDE. ■ Partly compliant: if the portal complies with more than half of the listed implementation suggestions. ■ Not compliant: in all other cases.

	France	Ireland	Luxembourgh	Norway
CP1	Yes	Yes	Yes	Yes
CP2	Yes	Yes	Yes	Yes
CP3	Yes	Yes	Yes	Yes
CP4	Yes	Yes	Yes	Yes
CP5	Yes	Yes	Yes	Yes
CP6	Yes, black and white option of layers	Partly, only opacity of layers	Yes, customisable colours in viewer	Partly, only opacity of layers
CP7	Yes	Yes	No	Yes
SI1	Yes	Partly, less control over redirections	Partly, less control over redirections	Partly, less control over redirections
SI2	Yes	Yes	Partly, no feedback unsuccessful search	Yes
SI3	Partly, only indicating the system state	Yes	Partly, only indicating the system state	Yes
SI4	Yes	Yes	Yes	Partly, extra download page
N1	Yes	Partly, no direct search from home page	Partly, only data keyword search in viewer	Yes
N2	Yes	Partly, no sitemap, no link cat. to viewer	Partly, no link to homepage from viewer	Yes
S1	No	No	No	No
S2	Yes	Yes	Yes	Yes
S3	Yes	Yes	Yes	Yes
S4	No	No	No	Yes
S5	No	No	No	No
S6	No	No	No	No
S7	Party, not handling typos	Party, not handling typos	Party, not handling typos	Party, not handling typos
A1	Yes	Yes	Yes	Yes
A2	Yes, dedicated print button in viewer	No	Yes, dedicated print button	Yes, print button in thematic viewer
A3	Yes	Partly, takes some time to load	Yes	Yes
A4	No	No	Partly, metadata in XML and text	Yes
A5	Yes, but only viewing	Yes, but only viewing	Yes, but only viewing	Yes
A6	Yes	Partly, not clickable or drawable	Yes	Yes
A7	No, but uploading layers in the viewer	No, but storage in the gallery	No, but uploading layers in the viewer	Partly, metadata and view own layers
A8	Yes, newsletter	No	Yes, newsletter	Yes, service notifications
F1	Partly, share on social media, email	Partly, share on social media, QR, email	Partly, share on social media, email	Partly, share on social media, email
F2	No	No	Partly, shop and ordering extracts	No
F3	Partly, report abnormalities	No	Partly, report abnormalities	No
M1	No	No	Yes	Yes
M2	No	No	Yes, ISO 19115	Yes, ISO 19115
M3	Sometimes	Sometimes	Yes	Yes
M4	Yes, to data source	Sometimes	Yes	Yes
M5	Sometimes	Partly, extent	Yes	Yes
M6	Partly, legend information	Sometimes, can be empty	Partly, legend information	Yes, product specifications
M7	No	Partly, (geometry) type	Partly, representation type (vector, raster)	Yes
M8	Yes	Yes	Yes	Yes
H1	No	No	Yes	Yes
H2	Yes	Yes	Partly, only an address	Yes
H3	No	No	No	No
H4	No	No	No	No
H5	No	Yes, the gallery	No	Yes
H6	Yes	Yes	Yes	No
H7	Yes	Yes	Yes	Yes
H8	Yes	Partly, sometimes info upon hover	Partly, no information upon hover	Yes, hover and I buttons
H9	Yes	No	Yes	No
C1	Yes	Partly, different viewer page	Partly, different viewer page	Partly, different viewer page
C2	Yes	Yes	Yes	Partly, different controls area selection
C3	Yes	Yes	Yes	Yes

Content presentation (CP)

Ireland and Norway use grey as their main colour with orange accents. Grey has proven to be a preferable colour for Canadians [Cyr et al., 2010] but can also be perceived as less appealing [Bonnardel et al., 2010]. Luxembourg uses many different colours linked to different themes adopted on the portal. However, the use of more than four colours is not recommended to prevent the interface from being too busy [Carvalho and Lafuente, 2015]. The blue colour scheme of France is universally the most preferred [Bonnardel et al., 2010], [Cyr et al., 2010] (CP1).

Scannability is mainly achieved by establishing a visual hierarchy by introducing differently sized headers. For France, scannability is also achieved by using little text combined with much white space, contouring, and graphics. Ireland uses similar techniques. Additionally, the pages of Ireland are introduced with an image. Although this looks appealing, clean, and modern, it decreases the scannability since users have to scroll to get to the content. Luxembourg offers big buttons (CP3), correspondingly too little elements are displayed on a single page to be able to scan the full picture at once. For Norway, the many different elements and larger textual blocks on the landing pages decrease the scannability (CP5).

France enables showing maps in black and white for colourblind users (CP3), and the map viewer page of Luxembourg can be recoloured based on the available themes (CP6).

France, Ireland, and Norway provide visualisations of the data. France and Ireland provide these in their menu or catalogue and Norway on the landing page of a dataset (CP7).

Proposal for related changes to the GUIDE

Not all portals enable customisation of the colours and none of the portals allows adjusting the text size or font. This could indicate that as long as the content presentation in terms of colours and font follows the WCAG 2.1 heuristics and zooming with the universal `ctrl +` key-combination is still allowed, sticking to one, readable colour scheme and font could be sufficient. On the other hand, all analysed geoportals do allow the user to select different background maps in the map viewer. France allows users to enable a coordinate grid, and Ireland allows viewing layers on a white background. This can both introduce changes to the implementation suggestions related to a customisable content display (CP6).

System interaction (SI)

The need for reversible actions is mainly manifested in allowing the (de)activation of map layers. The main cause for warning messages involves acknowledging if a search keyword could not be matched to a dataset. Apart from Luxembourg, all portals provide these. France also warns users before redirecting to an external source via the “remonter le temps” tab. Furthermore, a warning is provided if the settings on the download page of the portal of Norway (Figure 4.14) do not match the possibilities for the data (SI2).

All portals show the state of the interface by highlighting, changing, or annotating the active or hovered elements and by changing the cursor based on the available interactions. Ireland and Norway also acknowledge if pages are loading, and Norway yields closure after a download by removing the dataset from the download list. All portals list active layers, France, Ireland, and Luxembourg do this in a dedicated “active layers” menu (SI3).

Much of the semantics adopted on the different portals in terms of symbology, language, and controls are recognisable. The `?` or `i` icons are used to indicate help or information options, a magnifying glass to confirm a search keyword, arrows indicate possibilities to expand menus, and a cross indicates the possibility to close an active element. Examples of the differences and similarities between some of the other icons of the different portals are provided in Figure 4.17.

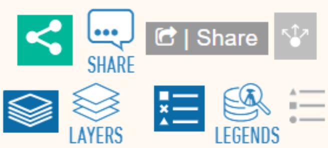


Figure 4.17: Icons for sharing, layers, and legends. The latter two are not available on all portals.

Even though existing portals sometimes use different icons to indicate the same thing, all icons remain recognisable. The French portal is especially relatable. As a result of the strong visual support of the system interactions, even non-French speakers can use it (SI4).
Familiar terms such as "about", "home", and "help" are frequently adopted. However, more geomatics specific terminology is often not standardised. Similar datasets are named differently on different portals, and the themes to support the search process are not uniform either. What information is contained by all the different headings of the portal of Norway is sometimes unclear; tabs such as "product sheet" and "product specification", for example, need to be clicked to assess what they contain.
The controls in the map viewers are recognisable. Similarly to Google maps, all of the analysed portals allow panning by clicking and dragging the right mouse button, zooming by using the scroll wheel of the mouse or by clicking a zoom button, and left-clicking to extract feature information. The more general portal controls are not always self-explanatory. The location of the error report mechanism under the tool symbol (the wrench) on the map viewer page of the portal of France, for example, could be unexpected. Furthermore, the portal of Ireland redirects users to a manual part upon selection of a corresponding element on the about page. Instead, users could expect to be redirected to that specific element on the portal. On the portal of Norway, the follow-up download page, and the fact that some map layers are not visible in the map viewer unless the user zooms in can be unforeseen. Moreover, Luxembourg and Norway have some links to external sources that could be unexpected (SI4).

Proposal for related changes to the GUIDE
When using the GUIDE, the measure for control seemed to be influenced by all other design characteristics related to system interaction. Furthermore, this metric might be ambiguous and impossible to measure. Because of this, the characteristic could be left out of the GUIDE (SI1).
None of the analysed portals provides summary information between interactions (SI3). Since the interactions in a geoportal are relatively simple, this might be superfluous.
In the map viewer, active datasets should be distinguished from inactive ones. For example, by checkboxes or in a (separate) dialogue (SI3).

Navigation (N)
Direct ways to perform tasks are established by menu options for the frequent steps a user could take, such as a link to the catalogue or viewer page. The different geoportals support this in different ways. France and Norway enable keyword search of data directly from the home page. Additionally, France, for example, allows searching, assessing, and accessing in the map viewer page, whereas Ireland adopts a separate catalogue to search for metadata. To show the navigational possibilities and the corresponding available elements, the parts of the sitemap of the analysed geoportals that are relevant for this research are shown in Figure 4.18. To some degree, all portals integrate the different pages. This is especially true for the portal of Norway. Ireland and Luxembourg have a more linear navigation structure. For Ireland, for example, users cannot directly select datasets from the catalogue page in the viewer (N1).
Dead ends in the navigation are mostly prevented by allowing users to click the logo of the portal to go back to the home page. Although Luxembourg generally also adopts this mechanism, it is not possible to go back to the portal home on the map viewer page. Other navigational support includes showing a sitemap and utility links capturing elements such as contact, help, about, or links to popular pages. Only Ireland has no sitemap available, but they do offer a dedicated home tab and a button to go to the top of the page when scrolled down. Norway provides additional navigational aid in the form of clickable breadcrumbs on the upper left of the screen. Luxembourg recolours the menu bar elements for this purpose (N2).

Proposal for related changes to the GUIDE
Ireland, Luxembourg, and Norway all have either a menu bar, utility links, or both, that remain visible regardless of scrolling. This results in additional navigational aid (N2).

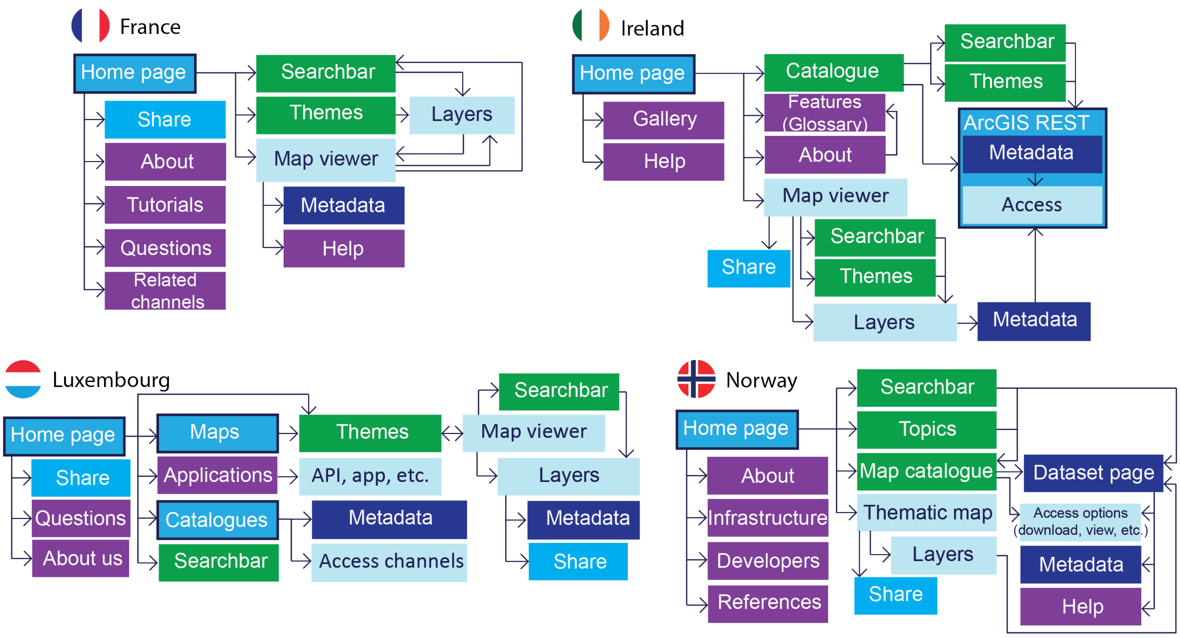


Figure 4.18: Sitemaps of the geoportals of France, Ireland, Luxembourg and Norway.

Search mechanisms (S)
All analysed portals allow data discovery based on keywords, map search, or themes (S2). The keyword search option is not fully intuitive; all portals use autosuggestions for the inputted keys, but none provided mechanisms to handle spelling mistakes or unsuccessful keywords. Moreover, synonyms do not always result in hits. In the case of Ireland, for example, the keywords `topographic map`, `topographic`, `topo`, `topography` or `topographical` did not lead to any results, although the base map displayed when opening the map viewer is a topographic map. This is also the case for Luxembourg (S7).
Users can use the plus sign next to the search bar of the map viewer of the portal of France to specify whether they want to search for addresses, coordinates, datasets, or metadata. On the portal of Norway, filtering data is enabled (S4).

Proposal for related changes to the GUIDE
Added to the filter options covered in the initial GUIDE, Norway provides filters based on accessibility conditions and geographical area (S4). None of the portals has a data recommender system (S1), tagging data is not enabled (S5), and users cannot change the criteria for sorting the results of a keyword search. France and Norway sort the results on relevance, Ireland does this alphabetically. For Luxembourg, the mechanism is unclear (S6). The lack of implementation of these design characteristics is not in line with the important role of data discovery in a portal and I do not yet re-evaluate these characteristics.
When working with the GUIDE, the display of active search criteria (S3), turned out to be a part of the responsiveness of the system (SI3).
Next to allowing keyword search for datasets, a keyword search for locations based on addresses or coordinates, or portal functionalities could be considered.

Access and upload mechanisms (A)
All analysed portals offer users the possibility to register for an account for additional functionalities. This mainly involves the possibility to store datasets (A1). Additionally, registered users can edit metadata on the portal of Norway (A7).

Since only Norway focuses on additional service levels beyond viewing the data (A5), the accessibility of data in various formats is limited for the other portals. For Norway, the data is also available in various formats. These depend on the type of data. The administrative units are, among others, available in Geographic Mark-up Language (GML) and GeoJavaScript Object Notation (JSON) format, whilst the height Digital Terrain Model (DTM) is, for example, available as a Tagged Image File Format (TIFF) file (A4). Before downloading, the preferred region of the dataset can be queried, and it is possible to set the Coordinate Reference System (CRS) of the data (A6).
Next to providing metadata in XML format, metadata is also available in human-readable text on the portals of Luxembourg and Norway (A4). Additionally, France, Ireland, and Luxembourg display some limited metadata elements in a description as information in the map viewer.
France and Luxembourg allow users to subscribe to a newsletter and Norway provides service notifications (A8).

Proposal for related changes to the GUIDE
Measuring whether or not the memory loading of pages is minimised, is challenging since loading times depend on factors outside the scope of the UI. However, graphics that are too big might introduce serious problems [Mishra, 2013], so this should be kept in mind (A3).
All studied portals enable the display of a scale bar and the cursor coordinates in the map viewer. The application tab of the portal of Luxembourg also captures a coordinate converter from World Geodetic System 1984 (WGS84) to the national reference system. France and Luxembourg allow users to measure areas, an azimuth, distances, height profiles, isochrones, and plan routes.
On the portals of France, Ireland, and Luxembourg, map features are clickable for more information. All portals except Ireland enable the user to annotate the map and all portals allow for the overlaying of different map layers. Additionally, Luxembourg and Norway, allow the comparison of two different layers by offering a layer slider functionality. None of the portals allows converting the format of a dataset (A6).
France, Luxembourg, and Norway shed new light on possible upload functionalities by allowing users to upload external map layers in the map viewer of the portal. On the portal of Ireland, users can upload maps they created to a gallery (A7).
Furthermore, users are enabled to embed an image of a map they created in the map viewer of the portals of France and Norway in their HyperText Markup Language (HTML) code.

Feedback mechanisms (F)
All of the portals offer functionalities to share a link to a created map view on social media or via email. Additionally, Ireland allows sharing via QR code and a map gallery (F1).
Other mechanisms to provide feedback seem to be unavailable. However, the portal of Luxembourg enables users to order extracts and links a data shop (F2).

Proposal for related changes to the GUIDE
None of the suggested implementation examples of feedback mechanisms is available on the analysed portals. This could have to do with a lack of responsibility of the portal owners for the data. However, depending on whether or not users would appreciate such features, the portals should try to support them. This could involve redirecting the user to the contact details of the provider (M4) if they do not have the capacity to deal with feedback themselves. Since none of the studied portals adopts a dedicated data request mechanism, this might be superfluous (F2). Instead, general contact information or a collaboration system can be used for data request purposes. Ireland, for example, lists an information email address to request (inaccessible) datasets in their FAQ. In the initial GUIDE, contact information is listed under "help mechanisms" (H2), this characteristic could be combined with characteristic F1. As could be the case for the characteristic covering a discussion forum or help desk (H4). In this case, the characteristic "communication mechanisms" (CM) would be more suitable.
As an additional mechanism to provide feedback, France, Ireland, and Luxembourg allow users to report mistakes or abnormalities in the data or the viewer (F3).

Metadata (M)
All analysed portals link to related governmental websites and portals. Luxembourg, for example, lists links to open data, geo-web services, and an Infrastructure for Spatial Information in Europe (INSPIRE) catalogue under their “catalogue” tab. On the portal of Norway, links to the help, for example, redirect to the external “Kartverket” website (M4).
To some degree, all portals provide information about the data in the form of readable text (M8). Additionally, Norway captures metadata on the dataset landing pages, and Luxembourg consistently links to metadata channels. France and Ireland did not standardise the information covered in the dataset descriptions in the map viewer (M8). In some cases, the data governance (M3) and quality information (M5) are covered, sometimes not. Ireland covers general information regarding the update frequency of the data in the FAQ (M3). A topic (M8) and a link to the data source are provided in all analysed cases (M4). Luxembourg standardised the elements of the general description on their viewer with a name, description (M8), revision data (M3), contact (M4), and a link to more elaborate metadata. On this more elaborate metadata channel, metadata according to ISO 19115 can be accessed (M2).
On the ArcGIS REST service directory of Ireland, fields regarding, among others, a name and description (M8), versioning (M3), extent (M5), attributes (M6), and (geometry) type (M7), are covered. However, in some cases, these fields are empty. Norway standardised the headers on the landing pages of their datasets containing a general description (M8), a description regarding the usage (M3), distributions (format and service levels) (M7), use constraints (M1), contact information for (meta)data owner and publisher (M4), and detailed information covering data quality, time, coverage (M5) and purpose (M3). It is also possible to access metadata in accordance with ISO 19115 (M2) and product specifications (M6), (M7) on this page.

Proposal for related changes to the GUIDE
All analysed portals display legend information about the layers in the map viewer (M6).
Luxembourg and Norway also use keywords to describe the dataset (M8).
All analysed portals in some way or another included (utility) links to information about terms and (use) conditions involving privacy and cookies, and accessibility in terms of compliance to WCAG. Furthermore, they all have some form of an about page. Such a page can contain a textual explanation about the portal, statistics about the dataset offering (Ireland and Luxembourg), or information regarding the up-time (Luxembourg).

Help mechanisms (H)
Help is mostly separated from the context. This requires users to actively search for support. The map viewers are an exception. Luxembourg and the thematic viewer of Norway have an information tab, and France an information overlay, capturing manual-like instructions for using the viewer (H7). Furthermore, hints about the functionality are provided when hovering over the content in the portal of France. Norway sometimes does this as well. Additionally, Norway offers contextual information icons to provide explanations about different settings on the download page (see Figure 4.14) (H8).
Although the different portals all offer help, they do this within different areas. Norway, for example, covers general information about CRSs and formats, whilst Ireland is more focused on the available portal elements (H7). Ideally, both should be addressed. This is reflected by topics frequently covered in the FAQ of the different portals. These relate to the portal and its use, generic information regarding geomatics related knowledge, and the data (H6).
Luxembourg allows users to select their user type (individual, professional, or developer) and provides content suggestions based on this. Norway has a section for developers (H1).
All portals cover contact information, usually in the form of phone numbers and email addresses. Additionally, Ireland has social media accounts and France a contact form (H2).
The portal of Ireland has a page called “gallery” on which users are allowed to share maps they created in the map viewer. This feature is a different way of showing examples of data applications (H5). Norway provides such examples on the dataset landing pages (H5).

Proposal for related changes to the GUIDE
All analysed portals cover a portal manual (H7), but they use different means for this; France provides tutorial videos (H9), Ireland explains possible functionalities on a "features" page, Luxembourg displays step-by-step tutorials regarding performing certain tasks on the portal (H9), and Norway covers more general information regarding geomatics related knowledge on a "reference" page. This shows there is a distinction between tools to provide help (manuals, glossary pages, forums, FAQ, tips and hints, and tutorials) and areas in which help can be provided. Such a distinction should possibly be adopted in the GUIDE.
None of the portals offers data manuals to guide the users in using the data (H3) or discussion forums (H4). It could be that portals do not feel responsible for this. Additionally, manuals could be regarded as superfluous since users might not read them [Poplin, 2015]. The relevance and possibilities of these characteristics should be re-evaluated with users.

Consistency (C)
Ireland, Luxembourg, and Norway show slightly different menu options and looks on their map viewer page compared to other parts of their portal, mostly being different navigational options (C1). Furthermore, France, Ireland, and Norway are not fully consistent in terms of the available information for each dataset. Although the availability of such information is out of scope for this research, the elements captured in the descriptions should still be consistent.
The same is true for the differences in available service levels for different datasets hosted on the portal of Norway. Furthermore, not all pages of this portal have utility links (C2) and the fact that there are two map viewers with different appearances and functionalities might be perceived as inconsistent (C1), (C2). Depending on the type of dataset, differences in download settings can be inevitable. However, more avoidable inconsistencies also occur during the download process on the portal of Norway: for the topographic map, an area selection can be confirmed by double-clicking after drawing a free form polygon or through selection from a list of locations, whereas the requested area for the "Height DTM 10" is not confirmed by double-clicking but by exiting the area selection menu (C2).

Generally speaking, the individual portals are consistent, however, there is little consistency between the different portals. The portal of France, for example, has a clean interface with a relatively simple, flat navigational structure. This could simplify learning to use this portal compared to the portal of Norway, which requires more scrolling and clicking. However, the portal of Norway offers additional functionalities compared to the view service of France, which means it is more attractive for expert users. This indicates that a difference in intended use can be a reason for inconsistencies between portals in terms of functionalities. Nonetheless, there are also inconsistencies between similar functionalities. All analysed portals, for example, use different themes or categories for their data. Another example includes how the different portals present the keyword functionality to their users in terms of look and location of the search bar, and the means for which this search bar can be used. From analysing existing portals, it is challenging to be sure whether or not a search bar should only allow users to search for a dataset, or if searching for a location, theme or portal functionality should also work. The same is true for preferable locations of buttons with similar functionalities; for the portal of France, the share button is located on the top right, for Ireland on the top left, for Luxembourg in the middle of the footer, and for Norway on the bottom left. Furthermore, the used icons are different. Such inconsistencies might be prevented by following the UI design guidelines and corresponding implementation examples as I will provide through this research.

Proposal for related changes to the GUIDE
In some cases, different data characteristics require different procedures, as becomes clear when using the portal of Norway (C2).

4.3. Summary: UI design characteristics from existing geoportals

Content presentation (CP)
All portals perform well on content presentation. Preferences regarding this can be subjective. However, the less scannable presentation of Norway is unlikely to be preferable.

System interaction (SI)
The warnings regarding redirections to other webpages as provided in the portal of France can prevent unexpected system behaviour. All portals use relatable semantics. However, the portal of France could be used without knowing the language. This indicates the adopted symbology and controls are especially clear.

Navigation (N)
Direct ways to do tasks are mainly supported by integrating different pages. This includes enabling data discovery on the home page, as is done by France and Norway. Additionally, the dataset landing pages of Norway are, for example, accessible from the viewer, and vice versa. Dead ends in the navigation are prevented in each portal by presenting a home button linked to the portal logo. Norway offers elaborate functionalities. Despite this elaborateness, users are supported in understanding at which page of the portal they are and where they need to be through breadcrumbs.

Search mechanisms (S)
The search functionality on the portals is often basic, without the possibility to handle cases in which a keyword search is unsuccessful. Only the portal of Norway provides advanced filters.

Access and upload mechanisms (A)
Since the portal of Norway offers the widest spectrum of service levels of all analysed portals, their approach to this can be used as an example. The functionalities available on the (thematic) map viewers of Norway, France, and Luxembourg provide examples of analysis functionalities.

Feedback mechanisms (F)
All portals offer the option to share the created map view on social media or by email. The integration of feedback mechanisms in the map viewer, as is available on the portal of France and Luxembourg, can be a user-friendly way to report mistakes.

Metadata (M)
Norway sets an example for the presentation of metadata by using dataset landing pages.

Help mechanisms (H)
Based on what information is provided on the analysed portals, it seems to make sense to have help mechanisms covering information regarding the portal and its use and generic information regarding geomatics related knowledge. FAQ are a popular mechanism for this. Luxembourg provides different information if users indicate their user type. The gallery of Ireland is an innovative way to showcase example use cases uploaded by users.

Consistency (C)
Especially Luxembourg and Norway provide information in a consistent way. Although most portals are consistent on their own, consistency between the different portals is lacking.

5

Analysing PDOK: Benchmark and design characteristics from a users' perspective

The goal of this chapter is two-fold; it involves setting a benchmark based on the initial performance of the UI of PDOK and the evaluation of the initial GUIDE from the perspective of (potential) users. By considering the needs, requirements, and constraints related to users and their characteristics, a more usable design can be achieved [Kellenberger et al., 2016], [Chincholle et al., 2013], [Te'eni and Feldman, 2001], [Nilsson and Ottersten, 1997]. This results in an answer to Subsubquestion 1.3.

"What are (PDOK's) user-friendly interface design characteristics according to users?"

For the benchmarking process, I first provide some background information about PDOK (Section 5.1). After this, I assess PDOK based on the initial GUIDE. Annex F contains a cheat sheet regarding the colour codes and abbreviations related to the design characteristics of this initial version of the GUIDE. The aim of this preliminary assessment is to learn from how PDOK implements certain UI design elements and see where there is room for improvement (Section 5.2). To support this preliminary assessment, I included a brief analysis of comments on the GeoForum[1].

Furthermore, I perform a user session for usability benchmarking and to evaluate the initial GUIDE in a user requirements session. I describe the methodology of this user session in Section 5.3, the results of the benchmark in Section 5.4, and a re-evaluation of the GUIDE in Section 5.5. In Section 5.6, I discuss the validity of the user study. Lastly, I summarise this chapter in Section 5.7.

Since PDOK is only available in Dutch, some of the discussed terminologies are in Dutch. When relevant, I provide translations.

5.1. Background information about PDOK

PDOK is a platform that hosts open geodatasets of Dutch governmental organisations for re-use purposes.[2] Following the definition established in this thesis, PDOK can be considered a geoportal.

PDOK is founded in collaboration between the Dutch Cadastre ("het Kadaster"), the Dutch standardisation organisation Geonovum, the ministry of infrastructure and water management and its executive agency ("Rijkswaterstaat"), the ministry of interior and kingdom relations, and the ministry of economic affairs and climate policy.

Governmental organisations can host their geodata on PDOK for re-use purposes. The data owners are responsible for the content and decide if, when, and how data is provided [Salzmann, 2018]. Data owners who publish their data on PDOK pay a charge. For this reason, the business directive of PDOK involves hosting as many datasets as possible. To accomplish this, PDOK aims to get more people to access these datasets, because popularity could be an incentive for local governments to publish their GI on PDOK [PDOK, 2019].

PDOK offers several functionalities related to the data search, assessment, and access. The discovery process is supported by a keyword search functionality, thematic search, and visually supported search in a map viewer. Additionally, users can visit a dataset landing page containing a description and links to relevant metadata pages hosted on NGR to assess the data, and access options such as downloads, geo-web services, APIs, or a view service. Downloads are the most popular option [Welle Donker et al., 2019].

[1] `https://geoforum.nl/`, a discussion forum for the Dutch geo-sector.
[2] `https://www.pdok.nl` accessed on February 2020

5.2. Initial status of PDOK: A preliminary assessment

Past designs can be a valuable information source for redesign [Simpson, 1997]. For this reason, I evaluate PDOK based on its correspondence to the initial GUIDE, and comments on the GeoForum.

5.2.1. Status of PDOK based on the initial GUIDE

The main parts of the sitemap of PDOK that are relevant for this research are shown in Figure 5.1.

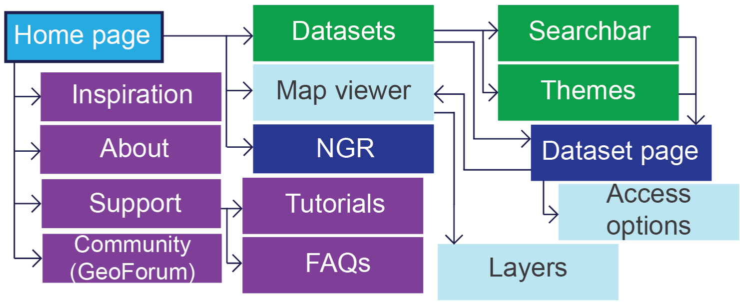


Figure 5.1: Sitemap of PDOK.

The upper part of the homepage of PDOK is displayed in Figure 5.2.

Figure 5.2: View of the upper part of the homepage of PDOK and the corresponding design characteristics.

On PDOK, data discovery is supported on the catalogue page as displayed in Figure 5.3.

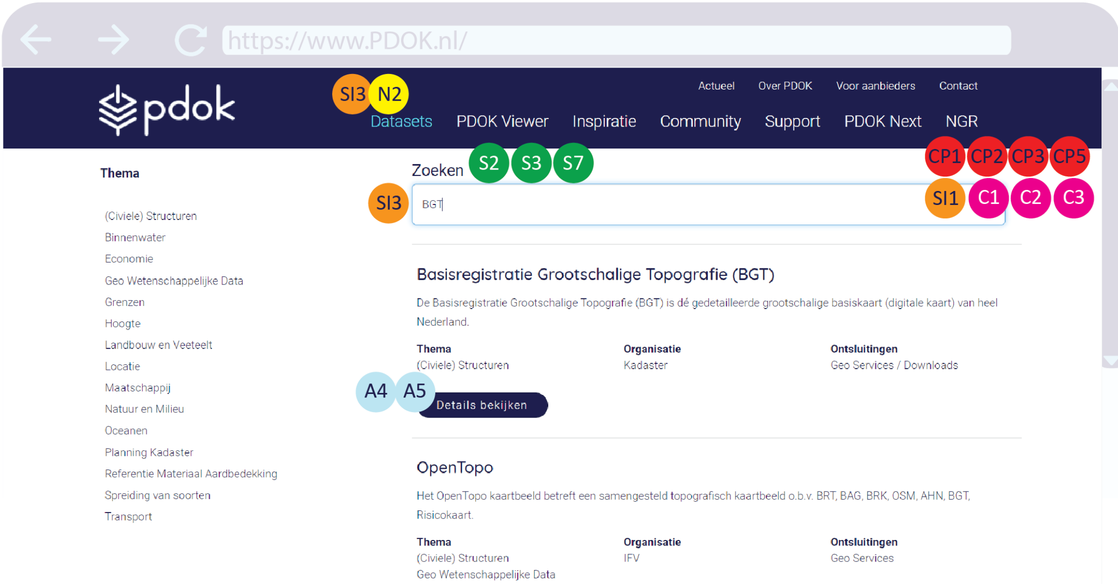


Figure 5.3: Catalogue page of PDOK and the corresponding design characteristics.

Via dataset landing pages (see, for example, Figure 5.4), the corresponding (meta)data can be accessed. The service levels for data access vary for each dataset. Generally, access through geo-web and download services is supported. An example of the "Geo Services" page for access through geo-web services is shown in Figure 5.5 and an example of the "Download" page related to download services is shown in Figure 5.6.

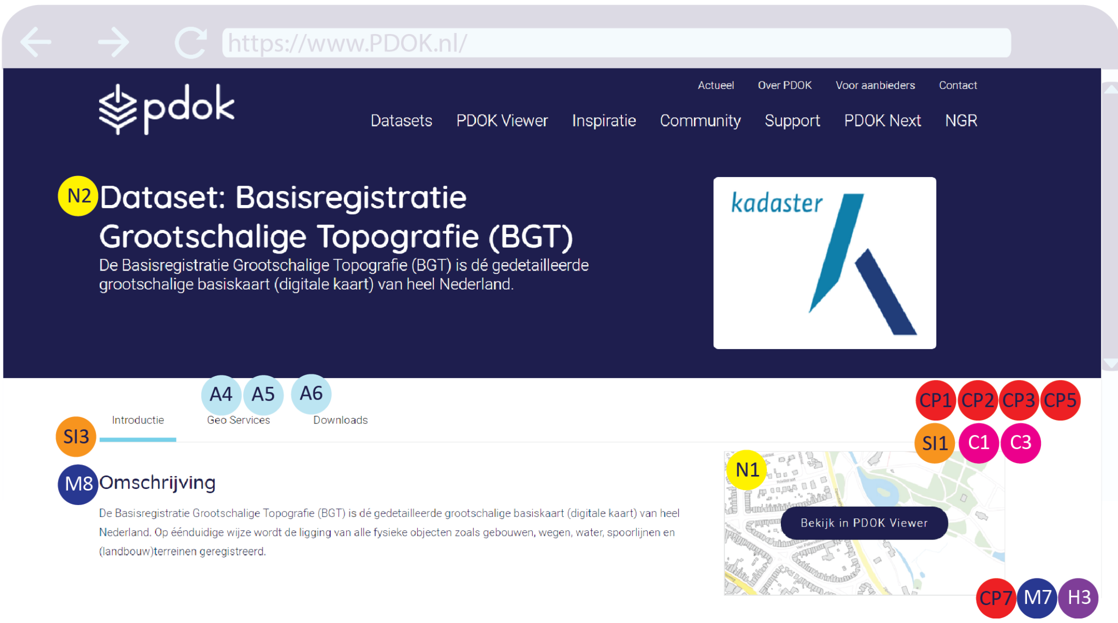


Figure 5.4: Dataset landing page of the BGT on PDOK and the corresponding design characteristics.

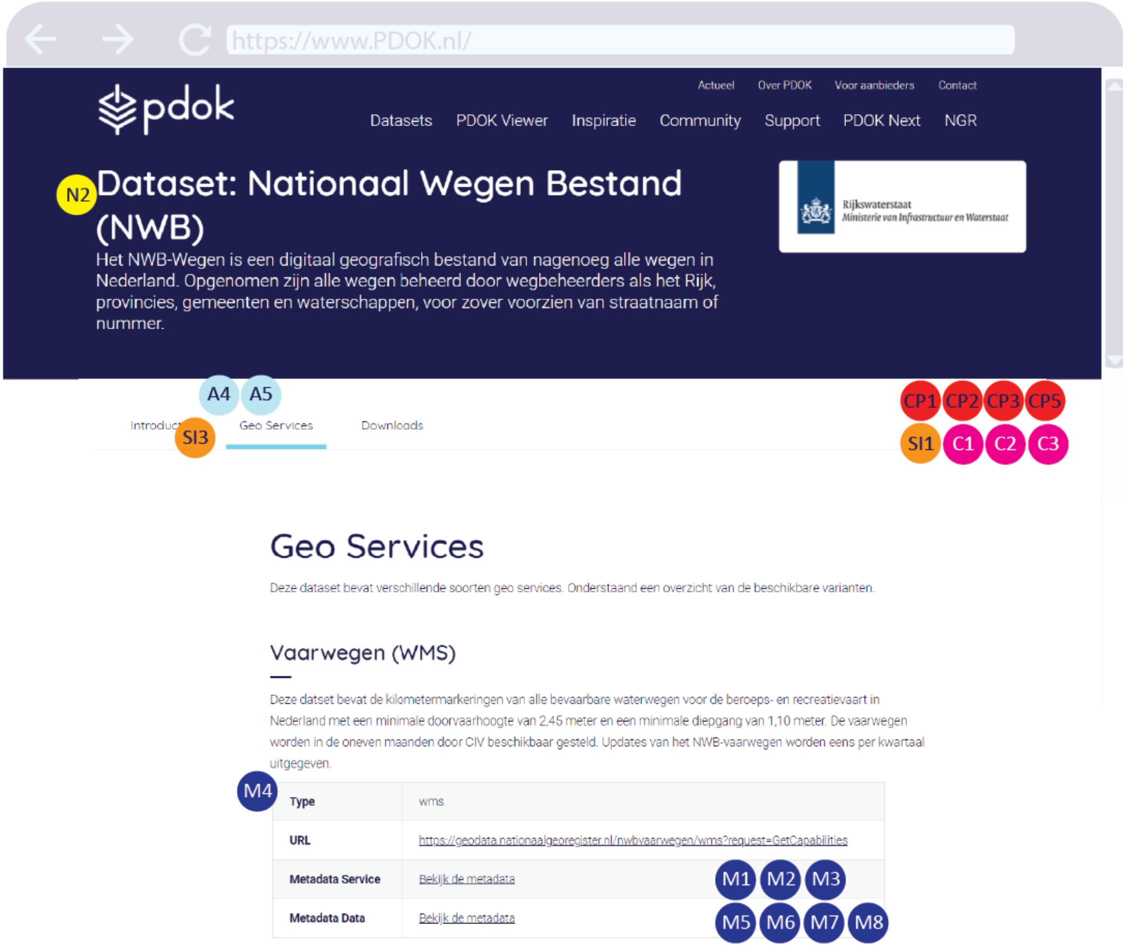


Figure 5.5: Geo services page of the NWB on PDOK and the corresponding design characteristics.

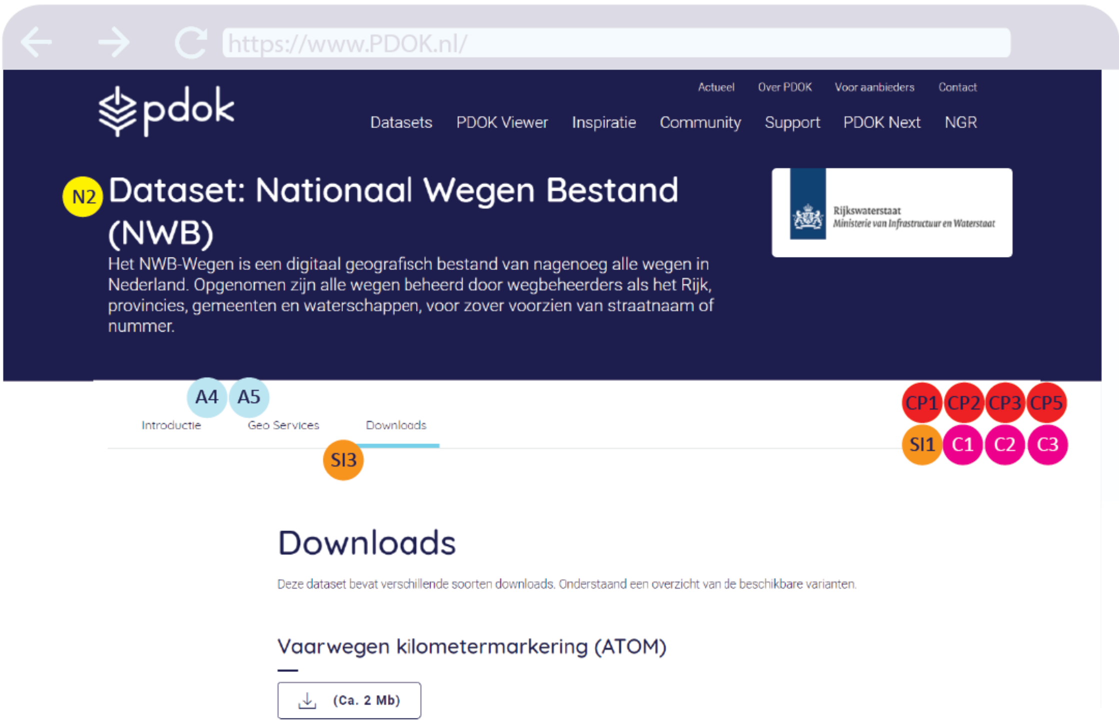


Figure 5.6: Download page of the NWB on PDOK and the corresponding design characteristics.

The data is also accessible through a view service in a map viewer as is displayed in Figure 5.7.

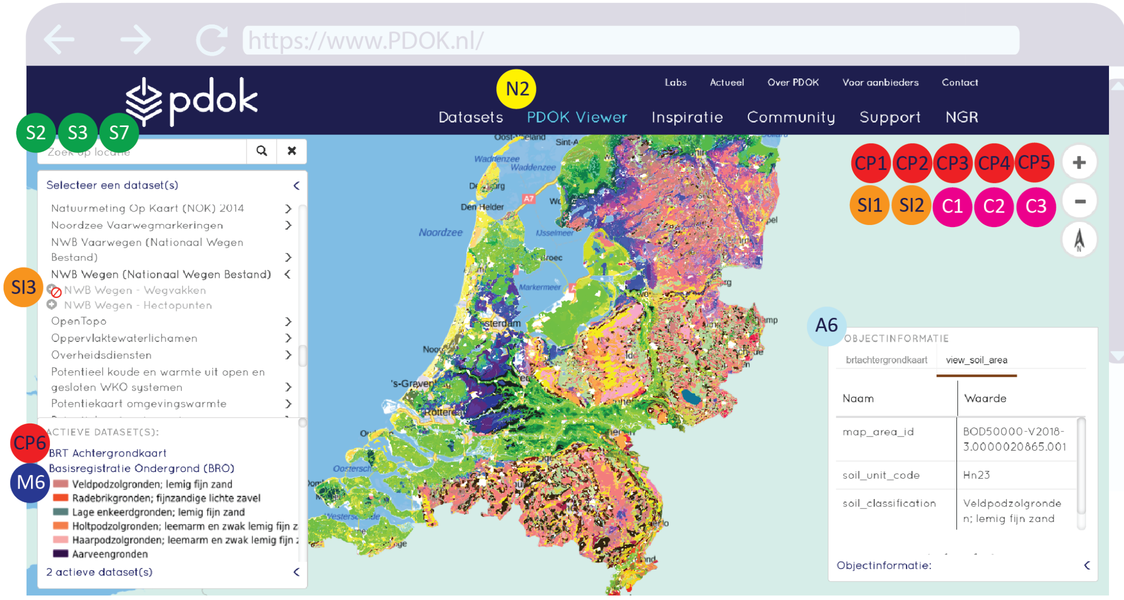


Figure 5.7: Map viewer of PDOK with the "bodemkaart" of the BRO as active dataset and the corresponding design characteristics.

The performance of PDOK in accordance to the initial GUIDE

In Table 5.8, the performance of PDOK according to the initial version of the GUIDE is displayed. Based on this overview, the strengths, and weaknesses of the UI of PDOK can be evaluated.

Content presentation (CP)

PDOK adopts a navy blue colour scheme with cyan accents (CP1). Generally speaking, the rule of thirds is applied (CP2) and PDOK is WCAG 2.0 compliant (CP3).

Headers and colours are used to increase the scannability of the content. However, the dataset landing pages contain relatively large blocks of text. In such cases, users might have to scroll a lot to know if the page contains what they are looking for. Furthermore, the tabs linked to the access options on the dataset landing pages might not be prominent enough (CP5).

The colours and sizes of the portal elements are fixed. However, users can select different background maps, including a white background (CP6).

In some cases, datasets are visualised on their landing page (CP7).

System interaction (SI)

When a keyword does not correspond to a dataset, this is not acknowledged, neither are there any indications for redirections to external information channels (SI1), (SI2). Actions such as activating a dataset, are reversible (SI2).

The system mainly responds to the actions of users by colour changes. In the map viewer, active layers are displayed in a separate dialogue (SI3).

PDOK does not use many icons and the adopted terminology is often restricted to jargon. There are some occasions in which the behaviour of the system can be unexpected, such as (SI4):

- When hovering over datasets in the viewer, some cannot be selected (see, for example, the "wegvakken" in Figure 5.7), it is not listed why.
- Although it is impossible to rotate the map view, there is a button to undo rotations.
- The FAQ lists no questions for the categories "map" and "programme".

- The tutorial page starts with promotional videos and the tutorials mainly relate to NGR.
- A link to the metadata hosted on NGR is only available under the "Geo Services" tab.
- Users are often presented download buttons linked to ATOM services. After selecting such a button, they manually have to deduce a download link from an XML.

Navigation (N)
The map viewer page and data catalogue can be accessed from both the utility and menu links. On some of the dataset landing pages, the viewer is linked (N1). However, when accessing the viewer from the dataset page, the corresponding dataset is not activated. This is unexpected (N1), (SI4). It is impossible to search for data on the home page. Furthermore, the menu does not remain visible if the user scrolls.
Users can go back to the homepage by clicking the PDOK logo on the upper left of the screen. The position of the user is indicated by recolouring the corresponding item in the menu bar. Furthermore, the utility links include a sitemap. However, dead ends in the navigation are not always prevented; to view metadata, users are redirected to NGR, where they are not provided with options to go back to PDOK. The same is true for the XML pages linked to the ATOM services (N2).

Search mechanisms (S)
On the catalogue page, it is possible to search for data with keywords. Furthermore, it is also possible to browse datasets based on their theme. The keyword search option in the map viewer is dedicated to locations (S2).
The results are sorted alphabetically instead of on relevance (S6). This, for example, results in the keyword `wegen` ("roads"), having the Nationaal Wegen Bestand - "National roadmap data" (NWB) as the fourth hit instead of the first.
If users know the name of a dataset, the findability is good. However, the search is not yet fully intuitive. Alternative terminology often leads to a lack of results, and spelling mistakes are not accommodated for (S7). `Topografische kaart` solely results in the Basisregistratie Topografie - "Base registry Topography" (BRT) and not the BGT. `Grootschalige topografische kaart` ("large scale topographic map") does not lead to the any results. When searching for the NWB, `nationale` instead of `nationaal`, does not provide any results, neither does `wegennetwerk` ("road network"), `wegenkaart` ("road map"), or `vaarwegen` ("waterways"). The keyword `grondwatermonitoringsput` leads to the Basisregistratie Ondergrond - "Base registry sub-surface" (BRO), however, `bodemkaart` results in no hits.

Access and upload mechanisms (A)
There is no print option and the browser print is deformed (A2).

Table 5.8: The performance of PDOK according to the initial GUIDE. ■ Compliant: if a design characteristic is implemented as listed in the GUIDE. ■ Partly compliant: if PDOK complies with more than half of the listed implementation suggestions. ■ Not compliant: all other cases.

	PDOK
CP1	Yes
CP2	Yes
CP3	Yes, WCAG 2.0 compliant
CP4	Yes
CP5	Partly, large blocks of text sometimes
CP6	No, only changing background maps
CP7	Partly, sometimes on dataset page
SI1	Partly, not for the redirection to NGR
SI2	Yes
SI3	Yes
SI4	Partly, not for ATOM and tiles BGT
N1	Partly, not many (working) shortcuts
N2	Yes
S1	No
S2	Yes
S3	Yes
S4	No
S5	No
S6	No
S7	Partly, not handling typos
A1	No, but this is possible for the GeoForum
A2	No, and no dedicated button
A3	Yes, but the viewer takes some time
A4	Partly, mostly one format
A5	Yes
A6	Partly, clickable map features for info
A7	No
A8	Yes
F1	Yes, via the GeoForum
F2	No
F3	No, initiatives for this are not linked
M1	Yes, but only via a link to NGR
M2	Yes, but only via a link to NGR
M3	Yes, but only via a link to NGR
M4	Yes, often the data owner
M5	Yes, but only via a link to NGR
M6	Partly, limited and only on NGR
M7	Partly
M8	Yes
H1	Partly, for producers
H2	Yes
H3	Partly, some videos regarding the data
H4	Yes, the GeoForum
H5	Yes, in a separate "inspiratie" section
H6	Yes
H7	Partly, somethings covered by FAQ, tutorial videos are mostly for NGR
H8	Partly, sometimes info upon hover
H9	Yes
C1	Partly, the dataset landing pages differ
C2	Yes
C3	Yes

Although the service level varies for different datasets, PDOK generally provides data through downloads, geo-web services, APIs, and view services (A5).
For the BGT, users can select specific tiles to download. This mechanism is not ideal since users are required to download a full tile even if they only need a small area. In the map viewer, different layers can be overlayed and features are clickable for additional information (A6).
PDOK offers email notifications ("attenderingsservice") regarding news and service updates (A8).

Feedback mechanisms (F)
Discussion and sharing among users and providers is enabled through the GeoForum (F1). Furthermore, PDOK lists that their contact form can be used for questions, requests, reporting outages, and complaints (F2), (F3).

Metadata (M)
PDOK links to NGR, where metadata is published in accordance to ISO 19115 (M2).
On the dataset landing pages of PDOK, a description of the datasets is provided (M8). In some cases, additional metadata is also captured. For the NWB, this involves the update frequency, different kinds of applications, how the data is acquired (M3), and a link to the GeoForum and an information email address (M4). For the BRO, this involves a description of the types of users and their use goals, the method of collection, an overview listing when different registration objects of the BRO will be available (M3), and objects that are not covered by the BRO (M6). Furthermore, there are links to the BRO website, the BRO service desk, a channel to report possible errors, the GeoForum, and an information email address (M4).
The utility links of PDOK capture pages regarding copyright, privacy, cookies, and accessibility. Furthermore, there is information regarding the up-time of services and an about page.

Help mechanisms (H)
PDOK has a page capturing additional information for data providers (H1).
For the BGT and BRO, there are contextual information videos (H3). Furthermore, there are FAQ covering, among others, use conditions and instructions on how to use PDOK (H6), (H7).
There is also a tutorial page with videos (H9), some of these cover the portal use (H7). Tips and hints about the terminology, such as the full names behind acronyms, are sometimes provided upon mouse hover (H9). However, in some cases, contextual information, or manuals on how to use the portal are missing. During the download process of the BGT, for example, it is not explained how (multiple) tiles can be selected (H7).

Consistency (C)
In general, the content presentation is consistent. However, under the "recent" tab, the different headings are not placed and formatted consistently (CP1). Furthermore, the content of the dataset landing pages differs for the different datasets; for the BGT, it contains a brief explanation and an introduction video. For the Basisregistratie Adressen en Gebouwen - "Base registry Address and building information" (BAG), there is a similar explanation but no introduction video. The descriptions on the page of the NWB are more elaborate and the data is visualised here. However, there are no introduction videos, and the redirection to the viewer at the top of the page is missing. The page of the BRO also contains a more elaborate description covering different types of metadata. On the bottom of the pages of the base registries, the most recent posts on the GeoForum regarding these datasets are displayed. For the NWB, this is unavailable (C1).
The download process is inconsistent between the BGT and the ATOM services of the other datasets. However, the BGT is a large dataset, so it can be desirable to only download a subset. It makes sense that this requires separate steps (C2).

5.2.2. Status of PDOK according to comments on the GeoForum

An analysis of topics published on the GeoForum[3] can provide insights into some of the requirements users could have. For this analysis, I considered comments if they meet the following three criteria:

1. they have not been resolved yet,
2. they are posted in the period from June 2018 to January 2020,
3. they have a relation to the UI regarding searching, assessing and accessing data.

Users encounter difficulties in finding the data they need if they do not know the exact name of the dataset (SI4).[4] This semantic unclarity also plays a role when assessing the usefulness of a dataset; some of the descriptions of similar datasets are the same. This makes it challenging for users to assess which dataset they should download without much clicking and scrolling for further inspection.[4] This is, for example, the case for the datasets of Algemeen Hoogtebestand Nederland - "Height data of the Netherlands" (AHN).[5] For the BGT and the BAG, the different WMS and WFS layers on the "Geo Services" page also all have the same description. For the NWB and BRO there is a difference in explanations for the different datasets, however, the explanation for the WMS and WFS is again repeated. This introduces room for an addition to the GUIDE: if possible, dataset descriptions should be *distinctive* (M8).

Furthermore, users comment they feel like there is much scrolling and clicking required to find relevant information or to perform relevant actions (N1).[4] This can indicate a lack of perceived usability. Among the most mentioned issues, is users experiencing problems with downloading data. Some users, for example, think the download option is hard to find (N2).[6] In this light, it is also mentioned that getting to the download option of the BGT requires lots of clicks and that selecting map tiles to initiate a download is not intuitive (SI4).[7] One user suggests wanting to see a list with all available downloads and geo-web services to get a more general overview of all options without having to click so much.[4] An example of such an overview is available on the geoportal of Luxembourg.

In the PDOK viewer, users would value functionalities allowing them to search based on coordinates (S2), retrieve their cursor coordinates, measure lengths or areas, and adjust the transparency of the different layers (A6). Furthermore, they would like to see other access options in the viewer (N1).[4]

5.2.3. PDOK: Good practises and room for improvement

Based on the evaluation of the performance of PDOK, it is possible to learn from their good practices and see where there is room for improvement.

Content presentation (CP)
The colours, placement, and spacing of elements on PDOK are suitable. However, the pages are not always scannable due to large blocks of text and long pages. Furthermore, more consistent availability of visualisations could be beneficial to support the process of assessing data.

System interaction (SI)
PDOK is responsive. However, the sudden redirections to NGR when looking for metadata is unannounced and irreversible, as is the behaviour of the ATOM download service.

Navigation (N)
Users cannot search for data from the home page, data cannot be accessed from the viewer, and data cannot be activated in the viewer from its landing page. However, there is a sitemap available, and colours are used to indicate the position of the user in the portal.

[3] Discussion forum for the Dutch geo-sector on which users, producers, and publishers can discuss data and its applications, standardisation, organisation, and so on.
[4] https://geoforum.nl/t/wensen-bugs-en-issues-pdok-website-en-viewer/1499/8
[5] https://geoforum.nl/t/ahn-kiezen-en-downloaden-voor-beginner/2737/3
[6] https://geoforum.nl/t/waar-bevindt-de-bgt-download-mogelijkheid-zich/2276/9
[7] https://geoforum.nl/t/enorme-bestanden/2746

Search mechanisms (S)
The keyword search mechanism on PDOK refreshes after users enter a character. This is a way of auto-completing the search. Spelling mistakes and synonyms are not covered. Furthermore, there is no keywords search for datasets in the viewer.

Access and upload mechanisms (A)
PDOK offers several service levels for data access. Even though this is outside the scope of the UI, such availability is user-friendly. Users are not allowed to upload (meta)data.

Feedback mechanisms (F)
The GeoForum allows discussion between users, PDOK, and producers.

Metadata (M)
A link to standardised metadata is available on NGR, but not aggregated on PDOK. The dataset descriptions on PDOK could be made more distinguishable.

Help mechanisms (H)
PDOK offers several help mechanisms covering, for example, download processes, data formats, and service levels. Because help is often provided out of context, it is less usable.

Consistency (C)
Apart from differences in information captured on the dataset landing pages, PDOK is consistent.

Current improvements

PDOK is constantly being improved and revised. Consequently, some of the issues I discovered have already been addressed. This, for example, included some dead links (error 404) I reported to test the help-desk facilities. In an automated response, the PDOK help-desk stated a reaction could take up to five working days. Regardless, the issue was fixed and reported back the next day. Although this single sample is no valid representation of the overall performance of the PDOK help-desk, it does indicate that the general help-desk functionalities are available.

Another issue involves that on an older version of PDOK, it was impossible to go back to another part of the portal from the "LABS" linked open data page. In a newer version, the LABS page is inaccessible.

Furthermore, a beta functionality of PDOK allows users to draw a free form polygonal selection of the required area to download a specific part of the BGT.[8] This reduces some of the limitations that come with the current tile selection process.

5.3. Methodology of the benchmark user session

The different elements of the user session discussed in this chapter are visualised in Figure 5.9.

Both usability and user requirements can be measured with user studies. For the user session discussed in this chapter, I follow a distinction between usability testing and requirement gathering. *Usability testing* is relevant to determine whether or not a solution is (perceived to be) usable [Parnia, 2014], [Courage and Baxter, 2005]. I use usability testing to assess the user-friendliness of the UI. Furthermore, I perform user *requirement gathering* to evaluate the initial GUIDE and to acquire additional design characteristics.

[8] https://download.pdok.io/lv/bgt/viewer/

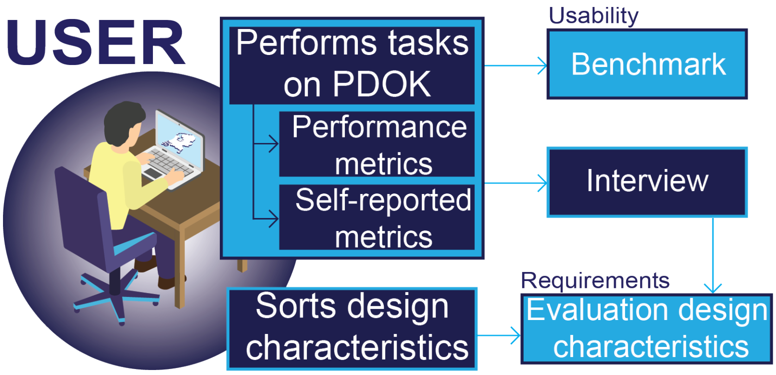


Figure 5.9: Visualisation of the different elements of the user study as described in Chapter 5 (see Annex C for a proposal).

During the user experiment, I observed participants while they perform tasks. To quantitatively rate the usability, both performance metrics and self-reported metrics are SMART for this research. In a semi-structured interview, I also ask participants about their ratings and their experiences related to the task to qualitatively evaluate the usability and related requirements for the UI (see, for example, Huang et al. [2019], He et al. [2012], Simpson [1997]). Additionally, I asked the participants to sort cards with the initial design characteristics of the GUIDE to quantitatively evaluate their importance.

The specific tasks, the related usability metrics, and the questions of the user study discussed in this section are listed in Annex D.

5.3.1. Participant selection

To acquire realistic results and for the design to fit the target group, user sessions must be performed with users who match the intended personas [Mishra, 2013], [Roto et al., 2011], [Dayton et al., 1997]. For this reason, I approached people within the *developer / GIS specialist* and the *web developer* personas to participate.

Keeping suggestions from related research regarding a suitable amount of participants in mind (see Poplin [2015], Tullis and Albert [2013], Courage and Baxter [2005] and Rohlfs [1997]), I decided to recruit three participants with knowledge about (web)development and three with a focus on geo-related knowledge. Although larger sample sizes would increase the confidence level, a smaller amount is more SMART within this research. I assumed three participants from each persona would be sufficient to acquire a representation of reality for the benchmark and to involve the most common opinions about the user-friendliness of the design characteristics.

Users of the same user type can still have diverse characteristics and varying needs. To capture a broad spectrum of possible different needs, I recruited participants within a large spectrum of characteristics. For the GIS specialists, I selected a geodetic professional who uses (open) data for tenders and two geomatics students, one of which works with open data often, the other not so much. For the developer persona, two participants have geo-related knowledge, one is more focused on geo-developing, whilst the other is closer to a GIS specialist. A third participant within the developer persona is a front-end developer without any geo-related knowledge, who is most in line with a web developer. Recruiting a web developer as a participant has additional value because evaluating a design with feedback from an expert is regarded as beneficial [Purao et al., 2008].

5.3.2. Task selection and instructions

Performing tasks can be a way to evaluate the current performance of a system [Rohlfs, 1997]. To ensure the results are valid, the selected tasks and their contexts should be realistic [Roto et al., 2011]. This means the tasks should relate to discovery, assessment, and access of the selected datasets: the BGT, BAG, NWB, and BRO. The data access process solely involves the download and view services since the full access process via geo-web services or APIs is challenging to execute solely within the portal environment. If the download option is successfully located, I assume the other service levels are also executable.

I decided to not specifically incorporate any tasks requiring participants to consult help mechanisms, since not every user uses such functionalities [Poplin, 2015]. Regardless, all participants are free to use help mechanisms if they wish to do so.

The task instructions of the first two tasks are specific; I mention the exact name of the dataset to support the discovery process. For the two other tasks, I use more generic criteria in the instruction. This way, two possible scenarios can be evaluated:

1. the scenario of a user with knowledge regarding a dataset and having to access it as part of a more general routine,
2. and the scenario of a user having to discover a suitable dataset matching generic criteria in a more exploratory process.

To check for memorability, some tasks are repeated. Furthermore, a so-called “think-aloud-protocol” is adopted to capture why participants take certain steps [Courage and Baxter, 2005].

5.3.3. Usability metrics to measure (perceived) usability

The usability of a system can be measured during a usability test by using usability metrics.

Performance metrics are objective usability indicators [Chiew and Salim, 2003] related to task success, the time spent on a task, error rates, efficiency, and learnability [Tullis and Albert, 2013], [Van Welie, 2001]. *Self-reported metrics* rated on Likert scales (see Likert [1932]) can be used to acquire the subjective perceived usability [Resch and Zimmer, 2013], [Tullis and Albert, 2013], [Chiew and Salim, 2003]. *Behavioural and psychological metrics* also exist [Tullis and Albert, 2013]. Examples of such metrics involve keeping track of the heart rates of participants to see if they are stressed [Tullis and Albert, 2013] or tracking the eye movement of participants to indicate the visual clarity of an interface [Masciocchi and Still, 2013].

A metric more specific to the geomatics field is the Demand Geo-information Transaction Cost (DGTC). The DGTC can be used to measure the transaction cost related to the exchange of GI. This involves quantifying the level of effort of discovering, accessing, and using GI. It primarily consists of the time spent searching for GI, contacting the organisation, inquiring its characteristics, testing its fitness for use, and acquiring it [Van Loenen et al., 2010]. In a geoportal of good quality, these transaction costs are minimised [Lee, 2012].

In this user session, I employed both performance metrics and self-reported metrics.

Performance metrics to measure usability

Effectiveness: task success (Mentioned by: [Tullis and Albert, 2013], [Te’eni and Feldman, 2001], [Van Welie, 2001]). Task success can be measured in binary, this means participants either are successful (1) or fail (0) at completing a task.

Efficiency: task completion time (Mentioned by: [Khan, 2018], [Zuiderwijk, 2015], [Tullis and Albert, 2013], [Reinecke and Bernstein, 2011], [Te’eni and Feldman, 2001], [Van Welie, 2001], [Nilsson and Ottersten, 1997], [Smith, 1997]). To reveal the required effort to complete a task it is possible to time the participants. The time element is also central to the DGTC usability metric [Van Loenen et al., 2010].

Efficiency: number of clicks (Mentioned by: [Khan, 2018], [Tullis and Albert, 2013], [Reinecke and Bernstein, 2011], [Van Welie, 2001], [Smith, 1997], [Nilsson and Ottersten, 1997]). Each irrelevant action in a task sequence represents an increase in effort. The number of clicks required by a participant as opposed to an optimal number of clicks can be used as a measure for efficiency.

Efficiency: lostness (Mentioned by: [Khan, 2018], [Tullis and Albert, 2013], [Reinecke and Bernstein, 2011], [Van Welie, 2001], [Smith, 1997], [Nilsson and Ottersten, 1997]). The formula to calculate lostness is listed in Equation 2.2. In this equation, R represents the optimal number of page visits, S the actual number of page visits, and N the number of unique page views [Tullis and Albert, 2013].

$$L = \sqrt{(\frac{N}{S} - 1)^2 + (\frac{R}{S} - 1)^2} \tag{2.2}$$

Higher lostness values are undesirable. This can, for example, indicate when a task would require a workaround [Van Welie, 2001].

Learnability (Mentioned by: [Tullis and Albert, 2013], [Reinecke and Bernstein, 2011], [Van Welie, 2001], [Nilsson and Ottersten, 1997], [Rohlfs, 1997]). Learnability covers what it would take for the user to become proficient with the system [Van Welie, 2001]. As a performance metric, this involves the frequency and duration users consult help mechanisms, which should be minimised.

Memorability (Mentioned by: [Khan, 2018], [Tullis and Albert, 2013], [Van Welie, 2001]). Memorability relates to what degree users remembered how to use the system [Van Welie, 2001]. To capture this, it should be analysed whether or not similar tasks introduce an improved efficiency [Khan, 2018].

Error occurrence: amount of errors (Mentioned by: [Khan, 2018], [Tullis and Albert, 2013], [Reinecke and Bernstein, 2011], [Te'eni and Feldman, 2001], [Van Welie, 2001], [Rohlfs, 1997]). It is possible to perform a binary error measurement in which a participant either has no errors (1) or has errors (0). It is also possible to count each separate error. Optionally, the severity of errors can be determined by their frequency, impact, and persistence [Tullis and Albert, 2013], [Rohlfs, 1997].

Self-reported metrics to measure perceived usability

The Software Usability Measurement Inventory (SUMI)[9], Website Analysis and Measurement Inventory (WAMMI)[10], and Software Usability Survey (SUS)[11] are some renowned tools to quantitatively measure how users perceive the usability [Tullis and Albert, 2013]. Such measures are, for example, involved with the satisfaction or learnability of the system.

Satisfaction (Mentioned by: [Khan, 2018], [Reinecke and Bernstein, 2011], [Van Welie, 2001], [Rohlfs, 1997]). Entails whether or not the user enjoys using the system. Examples include whether or not users are satisfied with the ease of use or the efficiency of the system.

Learnability (Mentioned by: [Tullis and Albert, 2013], [Van Welie, 2001]). Requires the system to work in a non-confusing way, related to familiarity, consistency, generalisability, and predictability.

5.3.4. Guidelines for the performance metrics

Keeping track of the performance metrics is done in a consistent way by extracting information captured in screen recordings of the participants performing tasks following the specific approach discussed in this subsection.

To capture the right information in the right context, I aimed at minimising the effects of the research setup on the participants by allowing interruptions of the tasks. Such an approach allows users to work with the portal more naturally. This can help to discover new points of interest [Roto et al., 2011]. However, an exploratory approach also results in less representative performance metrics. In this sense, the time users spend on a task can solely be used as an indication, not as a strong definitive metric. A more natural process also means the different participants are likely to start each task from a different point. I dealt with this by correcting the number of clicks and pages from a certain starting point with a general starting point. In case a metric is not deemed representative, I noted this.

[9] https://www.sumi.uxp.ie/about/whatis.html
[10] https://www.wammi.com
[11] https://www.measuringux.com/SUS.pdf

Timing

To measure how long it takes the participants to perform a task, I noted a starting time in seconds once the participant started moving the cursor in the screen capture after I stated the task. Once the participant finished the task, I noted the end time. This way of timing does not result in high accuracy measurements, however, other factors such as the "think-aloud-protocol" (see Tullis and Albert [2013]), varying speeds of the internet connection, and the research environment are likely to influence the timing as well. This makes a higher accuracy less meaningful anyway. In some cases, the participants will stop their task to comment on the process. It is possible to deduce this discussion time from the full execution time. However, I decided not to do this and solely noted the cases where the results might be less representative. The reason for this is that participants might stop and think for a while in a real situation as well, making it challenging to decide how much time to deduce.

In similar research, similar approaches in measuring the time are adopted (see Tullis and Albert [2013]). As an alternative, Tullis and Albert [2013] suggests automated timekeeping by having the participant press a button to start and end the timing. I did not follow this approach because the corresponding additional actions could also influence the timing and it is likely to interrupt natural interaction patterns.

Clicks

Only the clicks resulting in changes in the interface count since clicks on non-clickable elements are challenging to assess in the screen captures. For the same reason, clicks to pan the map do not count either. The selection of a link in an XML file of the ATOM service is counted as a click, as are external interactions, such as the use of `ctrl f` or the back button of the browser.

Task success

Since the participants are asked to invest about 1.5 hours of their time in the user session, it is desirable to keep the research process within this time frame. Therefore, I decided to provide hints for the task execution as soon as the participant seemed to be out of ideas. Statements such as "At this point I would have started using Google" triggered this.

In case participants required hint(s) to complete a task, I asked them to assess whether they think they could have completed the task on their own. If not, I rated the task unsuccessful.

Errors

Each time a hint is provided, I counted an error. This approach matches the nature of the context in which the hints are provided; if a participant deviates from the right path of accomplishing a task and is getting unsure or frustrated, I provide a hint to save time. In a real-world situation, such diversions could result in an error.

"Incorrect" interactions the participants handled on their own are not counted as errors because these are already captured by the other performance metrics. Clicking on the wrong element, for example, results in an increased number of clicks and might also lead to an increase in lostness.

5.3.5. Questions of the interview

PDOK is a Dutch platform, correspondingly, I selected participants who speak the Dutch language. To avoid possible confusions and to allow the participants to stick to a single language, the interview is also in Dutch. The interview questions are available in both English and Dutch in Annex D. Since the interview covered in this research is semi-structured, different questions may be stated depending on my observations during the experiment. If a participant, for example, uses an element that is not part of the most optimal task flow, it is beneficial to explore this action, although it is not captured by the suggested questions.

Interviews generally have three stages [Kellenberger et al., 2016], [Courage and Baxter, 2005]:

1. In the pre-test, demographic questions cover, among others, type of use and experience.
2. The middle part is the actual interview, which can help to identify areas that need improvement [Tullis and Albert, 2013].
3. This is followed by post-test questions covering if the portal met the expectations of the participant concerning the design characteristics.

Pre-test

The acquired demographic information is used to confirm the user type of the participant [Veldkamp, 2017], [Scholtz, 1997].

It would also be possible to inquire about the effort expectancy and attitude of the participants towards the system [Reinecke and Bernstein, 2011]. However, this first benchmark experiment is likely to influence the attitude of the participants and their corresponding answer to such questions in a follow-up experiment. Because the effects of this are uncertain, I did not include questions covering the expectations of the participants.

Middle part of the interview

The middle part of the interview consists of two statements for each task regarding the perceived complexity (relating to *satisfaction*) and the sensibility of the interaction (relating to *learnability*) [Te'eni and Feldman, 2001]. I asked the participants to rate these statements on a 5-point Likert scale (see Likert [1932]), as is the case for the WAMMI and SUS. Furthermore, I can ask participants what triggered them to perform certain actions [Courage and Baxter, 2005] and to explain their ratings.

Since the tasks are focused on discovering, assessing, and accessing data, the different ratings reflect how well the design characteristics supporting these processes are executed. A task related to downloading data, for example, tests the access mechanisms, whereas a task related to discovering a certain dataset reflects on the search mechanisms. Since the participants are not asked to use help or feedback mechanisms, the need for these mechanisms can solely be evaluated during the interview and the card sorting activity if participants do not use them on a natural point during the task execution.

Post-test

The first part of the post-test requires participants to rate and elaborate on eleven statements on a 5-point Likert scale (see Likert [1932]). Among others, these statements are based on statements from the SUMI, WAMMI, and SUS.

I did not cover all design characteristics individually by each statement; to reduce the number of questions, a single statement regarding the functionality (P-SQ1) of the portal, for example, covers multiple design characteristics. This statement is followed by an open question allowing participants to elaborate on specific functionalities they (dis)liked.

Some of the statements regarding the satisfaction or the perceived learnability of the user are not aimed at the interface specifically: instead of "thanks to the interface, PDOK is easy to use", I decided to use statements such as "PDOK is easy to use". The reason for this is that the effects of the interface on aspects such as the ease of use might be subconscious, meaning participants might not be able to assess this. Furthermore, different people may adopt different definitions of what elements are part of the interface. This could lead to less representative results.

The severity of usability issues and corresponding satisfaction can be measured through the likelihood of return [Tullis and Albert, 2013], [Te'eni and Feldman, 2001]. This is covered by statement P-SQ11. Similarly, the Net Promoter Score (NPS) is a way to track loyalty of the user based on how likely users are to recommend the product [Chincholle et al., 2013], [Tullis and Albert, 2013].

During the post-test, participants are also asked about the importance of different functionalities for their job. This is not only relevant to assess the different requirements of different users but also to evaluate the relevance of the selected tasks [Scholtz, 1997].

5.3.6. Card sorting experiment

For a traditional card sort, the participants are asked to sort cards containing interface elements into categories that make sense to them. This would result in qualitative insights into how participants would like to see information organised [Tullis and Albert, 2013]. Such insights can, for example, help to plan the information architecture of a website. However, in this user session, I already assess this with an interview.

For this reason, I decided to let users sort cards in a range from very important to very unimportant to evaluate the desirability of the design characteristics for the intended geoportal users. To discover missing or unnecessary characteristics, the participants may remove, rename, or add characteristics.

5.4. Usability benchmark of PDOK

In this section, a benchmark for the usability of a UI is set based on how well participants are enabled to execute tasks on PDOK. This is measured by the amount of time, clicks, lostness, errors, and self-reported ease of use and sensibility of the process.
Furthermore, the navigational path of the participants is provided as an insight into their mental model. The nodes in this navigational path are abbreviated as shown in Figure 5.10.

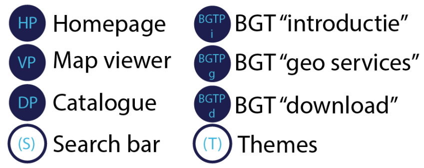


Figure 5.10: Abbreviations adopted to visualise the nodes in the navigational paths of users on PDOK.

5.4.1. Task 1.1: Consult metadata

For this task, the participants were required to consult the metadata of the BGT. The resulting usability metrics are shown in Table 5.11 and the corresponding navigational paths in Figure 5.12.

Table 5.11: Usability metrics related to Task 1.1: Consult metadata. Row C represents an ideal control performance.

T1.1	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:22	6	0	0	1	1
1	01:21	9	0,32	0	4	4
2	02:07	6	0	1	2	2
3	01:29	14	0,17	1	1	2
4	01:50	7	0,17	1	2	3
5	02:10	9	0,45	1	4	5
6	01:46	11	0,56	0	2	4

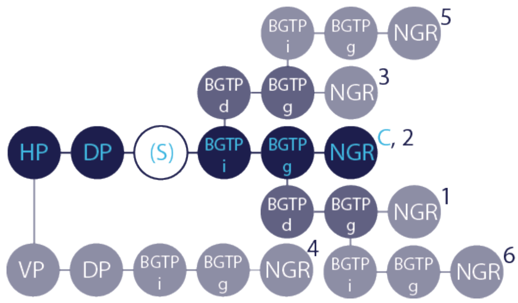


Figure 5.12: Navigational paths of Task 1.1: Consult metadata. If a participant deviated from the control path C this is annotated with her/his identifier from Table 5.11. More frequently visited paths are less opaque.

Observed behaviour

All participants agree they are unsure why general metadata is captured under the "Geo Services" tab. Displaying general metadata on the main "Informatie" tab or at least also under the "Download" tab would make more sense. This is reflected by the navigational decisions of participants 1, 3, 5, and 6, who only checked the "Geo services" page thoroughly after not finding the suitable information on the other pages. Participant 4 mentioned (s)he just clicked the first link (s)he saw without any specific reason. Two participants mentioned the term "metadata" triggered them to click the link on the "Geo Services" page.

Each service captures two links to NGR: one to the metadata of that specific service and another one to general metadata of the dataset. Only half of the participants understood this, the others were confused or paid no attention and just clicked the top link to the service. One of the participants who picked correctly, also mentions the two links are unclear. Because both pages capture metadata, I rated the task successful with one error in case a participant selected the wrong link.

Evaluation of the usability metrics

Most errors are due to the erroneous selection of the metadata link. Because the participants did not notice this, it did not negatively influence their self-reported metrics. Other than this, the self-reported metrics and performance metrics seem to match; participant 5 contemplated leaving the landing page of the BGT, upon which I hinted (s)he was on the right track. Correspondingly, (s)he scores lower in the self-reported measures. Furthermore, participants who took long and required more clicks rated less positive. Although the task did not feel difficult, it did not make complete sense. The latter is reflected by higher lostness values and the comment of one participant that (s)he would be unsure about how to redo the process. Additionally, the lack of acknowledgement when redirecting to NGR can confuse users. Participant 2, for example, did not notice being redirected and mentions to miss a way to get back to PDOK. Participant 5 mentions (s)he feels tricked if (s)he is unexpectedly redirected to a different source on which (s)he has to get used to an unfamiliar layout. Not leaving PDOK makes more sense.

5.4.2. Task 1.2: Download data

For this task, the participants were required to download the BGT. The resulting usability metrics are shown in Table 5.13 and the corresponding navigational path in Figure 5.14.

Table 5.13: Usability metrics related to Task 1.2: Download data. Row C represents an ideal control performance.

T1.2	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:25	9	0	0	1	1
1	00:26	11	0	0	4	1
2	01:52	6*	0	0	2	3
3	01:05	10	0	0	1	1
4	02:02	27	0	1	2	2
5	00:37	12	0	0	1	1
6	00:51	12	0	0	3	3

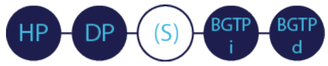


Figure 5.14: Navigational path of Task 1.2: Download data.

Observed behaviour

As soon as the participant managed to select four tiles, I rated this task successful. This approach resulted in some irregularities when judging participant 2; instead of zooming beforehand, (s)he double-clicked on Delft at a smaller scale. This resulted in zooming in and selecting four tiles in fewer clicks. Additional clicks of the other participants in this task are mainly the result of difficulties experienced when trying to select multiple tiles. Four participants first tried using `shift`, before figuring out to use `ctrl`. Participant 4 required a hint for this. Five participants mention they would have liked some instructions on how the process works. The front-end developer was also unsure about what format to select, so in the case of non-expert users, information regarding the different formats could be beneficial.

Evaluation of the usability metrics

Four of the participants commented on their previous experiences with this task. This shows in their performance metrics. The self-reported metrics do not always correspond to this; participant 1 mentioned to be familiar with the task and performs well, however, (s)he still rated the task to be difficult because (s)he thinks it is only easy due to her/his previous experiences. Participant 2 was familiar with the task as well, however, (s)he mentions the download mechanism of the BGT is so insensible for her/his job, (s)he uses a workaround. Participant 5 comments (s)he would usually use NL Extract, since downloading the BGT on PDOK is very slow. Regardless (s)he still rated the current process to be easy and sensible. The main reason why participants think this task makes sense involves the recognisable map controls and their previous experiences.

5.4.3. Task 2.1: View data

For this task, the participants were required to view the "woonplaatsen" layer, which is part of the BAG, in the PDOK map viewer. The resulting usability metrics are shown in Table 5.15 and the corresponding navigational paths in Figure 5.16.

Table 5.15: Usability metrics related to Task 2.1: View data. Row C represents an ideal control performance.

T2.1	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:09	5	0	0	1	1
1	00:22	6	0	0	1	1
2	01:30	9	0,33	0	3	3
3	00:22	5	0	0	1	1
4	00:21	5	0	0	1	1
5	00:26	9	0	0	2	3
6	00:32	7	0	0	1	1

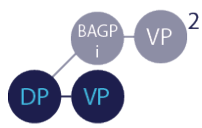


Figure 5.16: Navigational paths of Task 2.1: View data. If a participant deviated from the control path C this is annotated with her/his identifier from Table 5.15. More frequently visited paths are less opaque.

Observed behaviour

Two of the participants first try to select the location search bar on the viewer page. The participants think searching data on keywords would make sense, especially with a large number of available datasets and not always knowing the label under which the data is captured; browsing for "woonplaatsen" would, for example, be challenging had the participants been unaware to look for the BAG.

Furthermore, three of the participants click the "achtergrondkaarten" tab before clicking the "overige kaarten". This could indicate that the semantics of these tabs are unclear. One participant suggests "overige" ("other") map layers should be called "thematische kaarten" ("thematic maps").

Evaluation of the usability metrics

Most participants experienced no problems with this task. This is reflected by the positive self-reported ratings. However, participant 2 started looking for the BAG within the catalogue service. During this process, (s)he missed the dedicated button to display the BAG in the viewer on the BAG landing page and used the menu bar option to go to the viewer instead. Upon showing the participant the option on the landing page, (s)he thinks it is a mistake in the web-development it solely opens the default map view instead of the BAG. Furthermore, the plus sign to add data is unexpected, a checkbox would make more sense.

5.4.4. Task 2.2: Analyse data in the viewer

For this task, the participants were asked to figure out of which "woonplaats" the location "Kleine huisjes" is part of using the analysis functionality of the map viewer. The resulting usability metrics are shown in Table 5.17 and the corresponding navigational path in Figure 5.18.

Table 5.17: Usability metrics related to Task 2.2: Analyse data in the viewer. Row C represents an ideal control performance.

T2.2	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:13	3	0	0	1	1
1	00:53	8	0	0	2	4
2	04:16*	13	0	1	3	3
3	00:32	4	0	0	1	1
4	01:23	6	0	0	2	4
5	00:48	10	0	0	1	1
6	00:48	7	0	0	2	2

Figure 5.18: Navigational path of Task 2.2: Analyse data in the viewer.

Observed behaviour

It made sense to almost all participants that map features can be clicked with the left mouse button for more information. Only participant 2 first attempted to right-click instead. I corrected this with a hint.

One participant opened the "actieve dataset(s)" dialogue and the "objectinformatie" dialogue before starting the keyword query because (s)he expected information here. However, it is user-friendly the "objectinformatie" dialogue opens automatically upon confirmation of a location keyword: four participants mention that if the dialogue had not been open, they might not have found the information.

All participants think it is insensible the "objectinformatie" dialogue is initialised with a base map layer without any feature information. Three participants comment that it is easy to overlook the tab of the active "woonplaatsen" layer.

Two participants zoomed out to acquire more context. One of them thinks the view to which is focused after confirming the query feels random. It could be preferable to zoom to the contours of a "woonplaats" query object directly.

The corresponding "woonplaats" is recoloured after confirming a query. This is appreciated, since it shows something is selected. However, it is disturbing and unexpected this annotation only appears when selecting the "woonplaatsen" tab and disappears when zooming out, because the participants would like to see the borders of the area. One of them would also appreciate seeing the borders of "Kleine huisjes".

Evaluation of the usability metrics

Due to problems with the internet connection, participant 2 can be considered an outlier for this task.

The implementation of the "objectinformatie" dialogue caused participants 1 and 4 to rate the task to be less sensible. Additional clicks are mostly related to participants dealing with the re-selection of the "Kleine huisjes" and interactions with the "objectinformatie" dialogue. Participant 5 switched between the background layer and the "woonplaats" layer in the "objectinformatie" dialogue thrice to try it out. This explains her/his positive ratings as opposed to a relatively large number of clicks.

5.4.5. Task 3.1: Search and download unfamiliar data

For this task, the participants were asked to download a map of the Dutch road network via the dataset menu. The resulting usability metrics are shown in Table 5.19 and the corresponding navigational paths in Figure 5.20.

Table 5.19: Usability metrics related to Task 3.1: Search and download unfamiliar data. Row C represents an ideal control performance.

T3.1	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:20	6	0	0	1	1
1	01:05	8	0,40	1	2	4
2	~~02:38~~	~~11~~	~~0~~	~~3~~	~~4~~	~~5~~
3	00:55	6	0	0	2	3
4	~~03:38~~	~~12~~	~~0,17~~	~~2~~	~~5~~	~~5~~
5	02:03	10	0	1	2	4
6	01:06	8	0	0	2	3

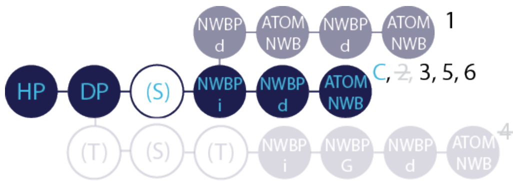


Figure 5.20: Navigational paths of Task 3.1: Search and download unfamiliar data. If a participant deviated from the control path C this is annotated with her/his identifier from Table 5.19. More frequently visited paths are less opaque.

Observed behaviour

Participants 1, and 3 recalled the name of the NWB. Participant 5 searched on `nationale` before recalling to search on NWB and others tried searching on `wegenkaart`, `nederlandse wegen`, `nationale wegen`, and `nwk`. This provides no results. Searching for `wegen` caused some confusion: the results are sorted alphabetically, causing less relevant datasets including "geluidskaarten" ("noise maps") to be listed above the NWB. Participant 4 also browsed the theme "transport". Here, the NWB is again not within the first hits. Since the participant could not find the right data by scrolling through the full list of datasets, the search bar, or `ctrl f`, I provided a hint to look for the NWB.

Evaluation of the usability metrics

The self-reported ratings are less positive for this task because the dataset was difficult to find based on synonyms and because the ATOM service linked to the download button felt counter-intuitive. Five participants mention they would expect a direct download based on the presentation of the download button. One participant mentions that the task is not necessarily difficult, but that it does not make much sense in case no hints are available. This is reflected by that participants 1, 2, 4, and 5 required a hint, and that participants 2 and 4 indicated they would not have been able to find the link in the XML file on their own. Participants 3 and 6 expected the XML to pop-up based on the ATOM annotation. However, even they mention a traditional download button next to the ATOM service would make sense.

5.4.6. Task 3.2: View data

For this task, the participants were required to view the "vaarwegvakken" data layer in the PDOK map viewer. This task can be used to check for the effects of memorability in viewing a dataset by comparing the resulting performance metrics to the performance metrics of the similar Task 2.1 (Table 5.15). The resulting usability metrics are shown in Table 5.21 and the corresponding navigational path in Figure 5.22.

Observed behaviour

One participant likes it the list is alphabetically ordered; however, this is only true if users know the name under which the dataset they are looking for is stored. Participant 4, for example, needed a hint because (s)he started by looking for the "v" for "vaarwegen", instead of the "n" for NWB.

Table 5.21: Usability metrics related to Task 3.2: View data. Row C represents an ideal control performance.

T3.2	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:17	5	0	0	1	1
1	00:31	5	0	0	1	1
2	00:29	5	0	0	2	2
3	00:24	5	0	0	1	1
4	01:16	7	0	1	2	1
5	00:54	6	0	0	1	1
6	00:28	5	0	0	1	1

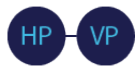


Figure 5.22: Navigational path of Task 3.2: View data.

Evaluation of the usability metrics

Searching for the "vaarwegvakken" of the NWB takes more time than searching for the BAG, as it requires scrolling further down the alphabetically ordered list in the viewer. Because of this, two participants again comment it would be easier for them to be able to search for data in the viewer based on keywords.

Compared to Task 2.1, Task 3.2 is rated more positively, and users need fewer clicks. This indicates the effects of memorability. One participant even specifically mentions that this task is now easy due to their previous experience.

5.4.7. Task 4.1: Discover a dataset suiting specific criteria

For this task, the participants were required to find a dataset covering information of the bottom on 500 metres depth. The resulting usability metrics are shown in Table 5.23 and the corresponding navigational paths in Figure 5.24.

Table 5.23: Usability metrics related to Task 4.1: Discover a dataset suiting specific criteria. Row C represents an ideal control performance.

T4.1	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:13	4	0	0	1	1
1	01:28	7	0,20	0	3	2
2	03:24	4	0	1	2	2
3	02:20	7	0,47	0	2	1
4	04:54*	14	0,37	0	2	2
5	01:38	4	0	0	1	2
6	03:59	12	0,71	1	4	4

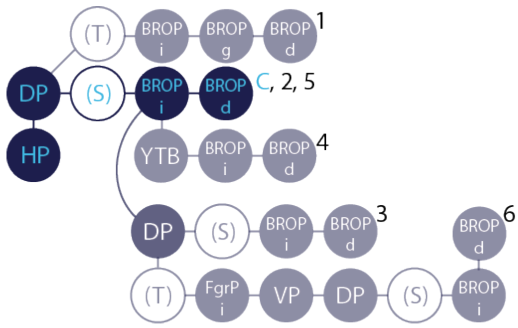


Figure 5.24: Navigational paths of Task 4.1: Discover a dataset suiting specific criteria. If a participant deviated from the control path C this is annotated with her/his identifier from Table 5.23. More frequently visited paths are less opaque.

Observed behaviour

Two participants started by browsing the themes. They mention they do this due to previous experiences with the keyword search function of PDOK not working on more general keywords. One participant tried the category "natuur en milieu" and recognised the BRO as the first hit. The other could not find a suitable theme and uses the keyword `bodem`. The four remaining participants started with this as well.

Although the BRO is the first hit, some participants did not match it to the task description immediately. One of them mentions (s)he associates the BRO with the shallower ground, based on the examples of "boormonsters" and "grondwater". Even after visiting the landing page of the BRO, another participant also thinks (s)he is on the wrong track. Back on the catalogue page, (s)he selects the theme "geo wetenschappelijke data", leading her/him to the dataset "fysisch geografische regio's" (FgrP). I hinted both of them to look into the BRO.

Since all the participants first scrolled on the "Introductie" tab on the BRO landing page, it can be assumed they expected to find the required information here. One participant specifically mentioned that (s)he thinks it is insensible this information is captured under the "Download" tab instead.

Two participants comment on the large amount of text on the "Introductie" tab of the BRO and mention this does not help in quickly assessing whether or not the proper data is captured by the BRO. This is supported by another participant who used the `ctrl f` search function of the browser on both the "Introductie" and "Download" page. However, yet another participant commented (s)he does not mind having to scan some text when looking for something relatively specific. (S)he appreciates the descriptions for this and thinks they are of a nice length. It should be noted that this participant seemed to have more experience with these kinds of datasets, since (s)he managed to pick the proper dataset based on its title alone.

Evaluation of the usability metrics

For this task, participants 2 and 4 started to explore the portal without keeping the task in mind. In some cases, this resulted in less representative performance metrics. I corrected these by excluding "subconscious" actions performed whilst not working on the task. Participant 4 visited YouTube (YTB) via one of the introduction videos on the landing page. Since this was part of an attempt to gather the required information, I did include the corresponding eight clicks and the additional page visit. Even though this task required some more effort from the participants in terms of time, and sub-optimal clicks and page visits, most of them did not evaluate the task negatively. They felt like they were looking for a specific type of data in a field they did not necessarily have much knowledge about. For this reason, they expect and accept the discovery process to require some more effort. Participant 2 specifically comments (s)he is already pleasantly surprised the keyword "bottom" provided results. Participant 6 agrees, however, (s)he thinks the process could be supported even more by providing information regarding the subdatasets under the base registry in the catalogue.

5.4.8. Task 4.2: Download data

For this task, the participants were required to download a dataset regarding "grondwatermonitoring". This task can be used to check for the effects of memorability in downloading a dataset by comparing the resulting performance metrics to the performance metrics of the similar Task 3.1 (Table 5.19). The resulting usability metrics are shown in Table 5.25 and the corresponding navigational paths in Figure 5.26.

Table 5.25: Usability metrics related to Task 4.2: Download data. Row C represents an ideal control performance.

T4.2	Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
C	00:11	5	0	0	0	0
1	01:39	14	0,84	0	3	4
2	02:00	5	0	0	3	4
3	02:22	10	0	1	3	2
4	00:50	6	0,28	0	1	1
5	00:29	5	0	0	1	1
6	00:39	5	0	0	1	1

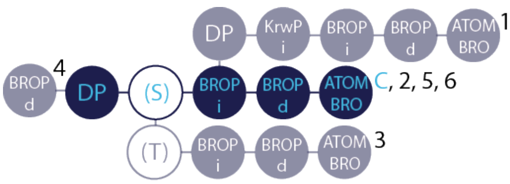


Figure 5.26: Navigational paths of Task 4.2: Download data. If a participant deviated from the control path C this is annotated with her/his identifier from Table 5.25. More frequently visited paths are less opaque.

Observed behaviour

Five participants searched on the keyword `grondwater`. Although the BRO is the first hit, not all participants recognise it as suitable. One participant did not notice a typo (`grondwoter`), so (s)he tried searching for `bodem` and `monitoring`. This participant does not recognise the BRO to be suitable either, so (s)he turns to search based on the themes "geo wetenschappelijke data" and "natuur en milieu". Even though the BRO is the first hit here as well, the participant still does not link the dataset to the task description. At this point, I provided a hint to look into the BRO. After this hint, the participant notices "grondwatermonitoring" is mentioned in the description of the BRO, however, (s)he mentions that carefully reading descriptions is not something (s)he usually does. Other participants also state they are unsure if the right data is part of the BRO, which is supported by their navigational decisions. Participant 1, for example, went to the dataset page of "kaderrichtlijnen water" (KrwP). One participant specifically mentions to appreciate it the BRO can be found by searching for `grondwater` because this way, users do not have to think about searching for the bottom on their own.

Evaluation of the usability metrics

This task was meant to be comparable to Task 3.1, however, some participants did not notice the data to be part of the BRO at the end of the previous task. Although this made Task 4.2 more challenging and less comparable, all participants remembered how to acquire the link from the XML. This does indicate the task is memorable. Furthermore, the performance metrics match the self-reported metrics. Participants who required more effort rated the task less positively and participants who remembered or noticed the “grondwatermonitoring” to be part of the BRO from the previous task, requires less effort and were generally more positive in their self-reported metrics.

5.4.9. Post questions

After the participants finished performing all the tasks, I asked them to rate several statements related to their experiences when using PDOK. For specifically positive or negative opinions, I asked for elaboration.

P-SQ1. I am satisfied with the functionalities of PDOK.

All participants feel like they needed to be too specific in their keyword search. Three participants suggest they would appreciate being able to search for data in a more “Google-like” way (S7). Three participants mention they would like additional filter functionalities (S4). Furthermore, two participants would appreciate the option to sort the search results based on their relevance to the input keyword, as opposed to sorting the results alphabetically (S6).
Additionally, all participants agree they would like to see a keyword search mechanism for data on the map viewer page. To separate the results, the front-end developer suggests implementing two search bars in this case: one dedicated to a location search and one for the datasets.

One participant comments the download mechanism of the BGT is insensible for their job (A6). In the first place, (s)he would appreciate a tool for free-form polygonal area selection. Two other participants would also like this. Furthermore, (s)he would like to not have to access all ImGeo features. Two others would like such a tool to be able to see what features are captured in a dataset. Additionally, (s)he would like to search on location. This is supported by participant 6, who thinks it makes sense to be able to pre-select a municipality. All this is possible in the beta BGT download functionality of PDOK[a]. Another participant mentions (s)he usually works with data on country-level, and that (s)he misses a functionality to work with lightweight, fast to use data dumps for this. Although this is out of scope, this preference could be noted (A4).

[a] https://download.pdok.io/lv/bgt/viewer/

One participant especially appreciates the community (GeoForum) (F1). The participant would also appreciate the data request mechanism from Data.overheid[a] on PDOK (F2).

[a] https://data.overheid.nl/community/dataverzoeken/dataverzoek-indienen

As support for assessing the suitability of a dataset for a specific use case, four participants would like a more prominent display of the hierarchy of available elements inside a dataset and the subdatasets within an overarching base registry (M6). This need is reflected by the hints some participants required to confirm they were on the right track during the discovery process. One participant states that if users have little knowledge about how the datasets are structured and named, using the portal is likely to become cumbersome.

Only the front-end developer elaborately commented on the support functionalities of PDOK. (S)he values e-learning facilities and tutorials, however, (s)he is not positive about the current “how-to” page of PDOK (H9). The long list of videos is not inviting, the promotional videos are out of place, and it is not immediately clear what information is covered.

Two participants attempted to click a textual element in case they required additional information. This indicates a mechanism that provides a hint or tip when users hover over unfamiliar terminology or the use of clickable information icons can be beneficial to provide contextual background information (H8). An example where this could be implemented involves the ATOM annotation. Participant 3, for example, mentions (s)he prefers using ATOM services over direct downloads because it results in up-to-date data. Participant 5 would be interested in this, however, since (s)he was unfamiliar with the concept, (s)he could not benefit from its advantages. Two participants feel like the current annotation might solely cause confusion.

P-LQ3. The use of PDOK is self-explanatory. (SI4)

Whilst the general map controls and the selection of a single tile are intuitive, the selection of multiple tiles of the BGT with `ctrl` instead of `shift` is not self-explanatory. Two participants additionally comment that the `E` symbol on the map of the BGT to zoom out is insensible.
Certain datasets are unavailable in the default map view. Three participants guess this could be temporarily, only under certain licence conditions, or due to a large file size. The front-end developer recommends using a tooltip to show this is because of the zoom level.
Furthermore, the selection of the download link in the ATOM XML does not speak for itself.
Although (s)he agrees additional explanations could be desirable in some cases, one participant would like the design to speak for itself.

P-LQ4. During use, PDOK behaved as expected.

Being re-directed to NGR without any further notice is unexpected and obtrusive (SI2), (SI4).
One participant mentions the message in the "objectinformatie" dialogue of the viewer stating "Feature informatie niet beschikbaar" ("Feature information unavailable") is annoying. Providing more relevant feedback as to why there are no features available and how this can be fixed is preferable (SI2). Two participants mention downloading the BGT including "plaatsbepalingspunten" results in long waiting times and big files. A warning might be beneficial here (SI2).
Users can click a plus sign in the layer dialogue to activate a dataset. Once active, a minus sign appears to deactivate the dataset again (SI3). Four participants think this can be confusing. This is reflected by them having to try out the functionality. Instead of adding a dataset, they expect a drop-down with additional information by clicking the plus sign. A checkbox to (de)activate datasets would be more intuitive. One participant mentioned it was not very clear if a map layer is active altogether (SI3). However, three other participants used the "actieve datasets" dialogue to check this, two of them even indicate this is a nice feature.
One participant thinks it is strange the roads and waterways of the NWB are split in the layer selection dialogue of the viewer as opposed to them being captured under a single, general NWB tab as is the case for other datasets. Furthermore, one participant noticed the presentation of dates on NGR is ambiguous (2014-04-08) (SI4). Two participants think the map controls work as expected. Three participants who noticed that the viewer button on the dataset page does not automatically activate the desired dataset in the viewer comment this is unexpected and disappointing. Furthermore, five participants mention they expected a direct download instead of an XML based on the look of the download button of the ATOM service (SI4).

P-SQ5. It is easy to navigate on PDOK.

Two participants comment the navigational structure is clear; the "dataset" and the "PDOK viewer" tab are the only features they often use, and these are prominently available. However, more integration of the viewer service and the dataset catalogue is appreciated. For this, two participants comment it would make sense to be able to activate a dataset in the viewer from the catalogue or dataset landing page, and to download data in the map viewer (N1).

With a minimum of five clicks, the metadata information as provided on NGR is hidden away deep in the portal. Every participant with geo-related knowledge mentions they would like to see certain metadata elements more prominently on the landing pages, or even on the catalogue page (N1). The front-end developer also mentions preferable metadata characteristics could be a means of promotion: frequent updates, open licences, and high-quality are selling points.
One participant was unfamiliar with the mechanism to hide a home button in a portal logo. However, another participant uses the mechanism, whilst others used the back buttons of the browser. One participant comments (s)he would like to see an option to go back from the landing page to the catalogue page (N2).

P-LQ6. I am familiar with the terminology used on PDOK. (SI4)

The participants with geo-related knowledge are familiar with the terminology. The front-end developer commented (s)he did experience difficulties, however, (s)he acknowledges that it makes sense (s)he does not understand all headings and descriptions, since (s)he is no expert. In some cases, terminology could be adopted to suit non-geo-experts. An example is the term metadata, specifications would make more sense to a developer.
It makes sense data can be found with a catalogue service under “datasets” and viewed with the “PDOK viewer”. However, the headings of the less frequently visited menu items can be less clear. One participant, for example, knew about several of the supporting pages through Google, but would not have guessed that example use cases are covered under the “inspiratie” tab, and that “community” links to the GeoForum. (S)he agrees that naming the community GeoForum would make more sense. This would also support two other participants who did not know about the existence of the forum. For another participant, it is not a problem to click the headers of supportive elements that sound interesting to figure out what they contain.
In the map viewer, one participant thinks the category of “overige” (“other”) map layers is unclear since “overige” is expected to be more of a remainder category. This is reflected by the behaviour of three participants, who first selected the base map category. “Basis kaarten” (“base maps”) and “thematische kaarten” (“thematic maps”) could make more sense. Based on the title “objectinformatie”, two participants acknowledge they do not know what to expect. One of them suggests the dialogue could be called “attribute information” instead. Furthermore, the adopted terminology in this “objectinformatie” dialogue of the viewer is very domain-specific.
Although the themes on the catalogue page capture the attention of the participants, two participants could not find a suitable theme to match the task description. Three participants think the current themes could require some additional explanation; it is unclear what kind of data is captured under each theme, there seems to be some overlap between the themes, and some datasets have many themes assigned to them. One participant would have preferred it if there had been more themes to choose from.
One participant comments that it is unclear what kind of information (s)he can expect by clicking “details bekijken” (“see details”) on the catalogue page and (s)he does not feel invited to click.

P-LQ8. The presentation of the content on PDOK is clear and understandable.

According to four participants, it would support them if the elements covered by a dataset are presented more prominently, for example in a schematic overview, table, or list, instead of being unavailable or hidden in a textual block. One participant mentions the video or a preview image on the landing page could work for this (CP5), (CP7).
There is a lot of information covered on the BRO landing page, this information seems to be relatively structured in terms of the use of headings. However, one participant mentions it is impossible to know what kind of information is captured on the page without scrolling through. A possible way to deal with this would be to prevent scrolling and use drop-downs (CP5), or by providing an index of the information that is captured on the top of the page (N2). In the latter case, cluttering the UI is at risk.

P-SQ9. The presentation of the content of PDOK is attractive.

All participants comment the content presentation is attractive since it looks clean and modern. One participant comments it feels trustworthy. This is nice when you have to download data. The front-end developer adds the modern appearance shows the website is still in active use. Such sustainability is nice to promote the use of the portal. For the front-end developer, the modern appearance has to do with the font (CP3) and lay-out choices (CP2). Another participant suggests the use of more colour could make the presentation of PDOK more attractive (CP1), however, (s)he also thinks the page should not become too busy and (s)he appreciates the less-is-more kind of approach of the current presentation.

In Figure 5.27, all ratings are displayed.

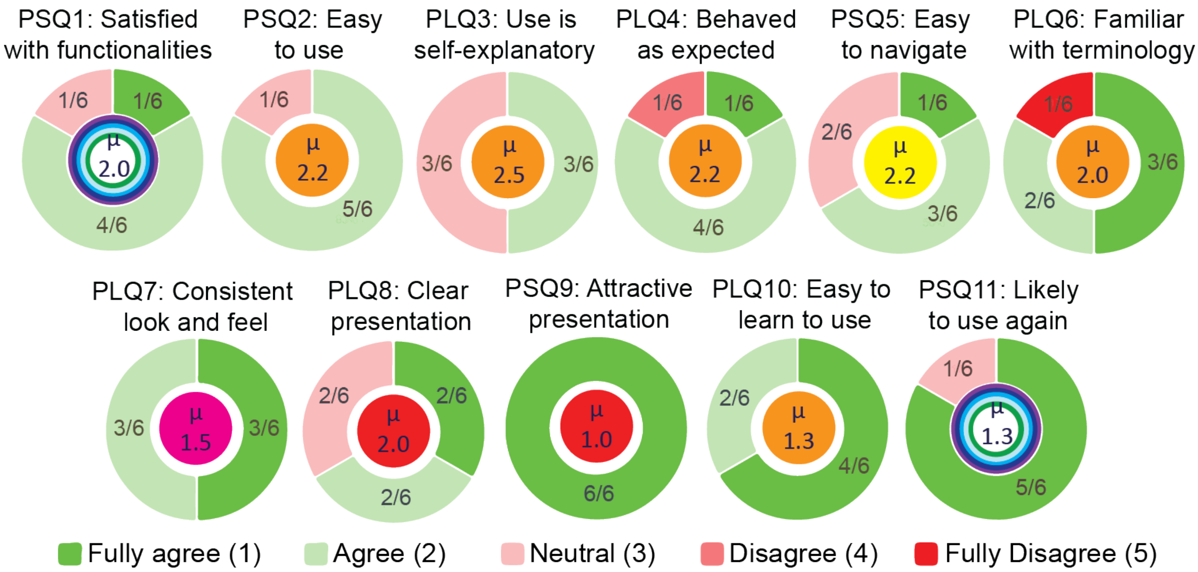


Figure 5.27: Ratings participants accounted to statements regarding PDOK (see Annex D for the full statements).

Net Promoter Score (NPS)

Participants are also asked how likely they are to recommend PDOK to their colleagues on a scale from zero to ten. These ratings can be used to calculate the NPS, as is displayed in Equation 5.1.

$$NPS = \%Promoters - \%Detractors \tag{5.1}$$

Promoters give a score of 9 or 10, detractors score below 6, all other scores are passive. Without any detractors, and three promotors scoring a 10, PDOK scores 50% for this benchmark. Any positive NPS is good already, so this is a high score. According to four of the geo-professionals, they inevitably recommend PDOK to a colleague because the portal contains so much valuable data.

The same is true for statement P-SQ11 regarding the likeliness the participant would use PDOK again. Only the participant without geo-knowledge scored neutral. One of the participants mentioned (s)he incorporated a comparison between the different portals of the Netherlands in her/his answer. (S)he would most likely recommend NGR since their offering for geo-data is the broadest. Solely based on interface aspects, the participant still seems to have a slight preference for the NGR because (s)he thinks the homepage of NGR is clearer than the one from PDOK and (s)he likes the data previewing options. Another participant comments that while (s)he appreciates the homepage of NGR, (s)he feels like the terminology is more technical.

5.4.10. General findings

Related research presents a usability merit for quantitatively ranked statements. Here, values are assigned to ratings of strongly agree (1), agree (0.75), neutral (0.5), disagree (0.25) and strongly disagree (0). The usability point is the sum of the merit divided by the number of questions, where a level between 0 and 0.2 is bad, between 0.2 and 0.4 poor, between 0.4 and 0.6 moderate, between 0.6 and 0.8 good and between 0.8 and 1 excellent [Chiew and Salim, 2003].
A boxplot containing the results of this merit for the benchmark activity is shown in Figure 5.28. With a median value of 0.73, the performance of PDOK is good.

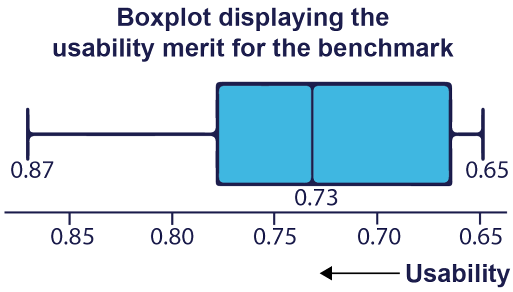


Figure 5.28: Boxplot showing the self-reported performance of PDOK in terms of the usability merit of Chiew and Salim [2003].

This is in line with the comments of the participants, who all indicated they are generally satisfied with PDOK, and that on some aspects it would be possible to learn from their implementations. Two participants mentioned that portals of other countries are sometimes cluttered and offer many similar options. In this sense, using PDOK, with one clear catalogue page and viewer, is user-friendly. Another participant did not use PDOK for a while and was pleasantly surprised by the large amount of data and the possibilities of PDOK for her/his job.

A general comment of three participants involves that they mainly want to access the data they need as fast as possible. For this reason, they do not want to spend much time on the portal.

5.5. A user's perspective on geoportal UI design characteristics

How participants sorted the design characteristics of the initial GUIDE on a range from very important (1) to very unimportant (5), is displayed in Figure 5.29.

The behaviour and comments of participants that can be related to these design characteristics are summarised in this section. I re-evaluated characteristics that averagely scored three or higher. Specific comments of participants could also trigger the re-evaluation of a design characteristic.

Content presentation (CP)
Four participants do not see the added value of colour choices. However, colour choices do influence the usability (see Cyr et al. [2010] and Bonnardel et al. [2010]) and one participant agrees (CP1). For this reason, CP1 remains part of the GUIDE.
Despite the existence of heuristics, one participant mentions (s)he experienced problems with the legibility of geoportals in the past, which was frustrating for her/him (CP3).
Scannability is important; three participants do not read descriptions, two participants negatively comment on the large text blocks they needed to scroll past, and one participant mentions the visual hierarchy introduced by headings helps her/him in the process of searching data. This is supported by that all participants seem to start by scanning the headings. Another participant also mentions (s)he appreciates the icons next to the themes on NGR for this (CP5).
One participant comments on the preview images on NGR that are lacking on PDOK. (S)he mentions these are nice to get an idea of what the data looks like before downloading (CP7).
Two other participants agree that it is nice to have visual examples (M5).

Proposal for related changes to the GUIDE
Fullscreen map viewer availability is not necessary for two of the participants, as long as the content is legible (CP4). Fullscreen can be suggested in the GUIDE to achieve this (CP3).
Two participants suggest collapsible text blocks as a way to prevent overflows of information and achieve a more structured, scannable, content presentation (CP5).
One participant recalls websites that allow users to adjust the size of elements with an icon of three As. The front-end developer states this could be appreciated by users with bad eyesight.

Regardless, it might still be undesirable to continuously display a mechanism to change the text size, whilst most of the users do not need this. Influencing colour choices is regarded as unimportant; two participants specifically mention they would not use this. A third participant states (s)he wants the portal developer to design a UI with a usable content presentation, instead of requiring effort from the user (CP6). For this reason, I limit the characteristic related to flexible content display to changeable background maps in the map viewer.
The front-end developer mentions cross-device functionality as a possible additional design characteristic. However, (s)he acknowledges this might be less relevant for a geoportal.

System interaction (SI)
Errors could be a point at which users decide to stop using the portal. Informative error messages can reduce this. This involves, for example, providing suggestions to fix the problem, instead of showing "feature unavailable". Furthermore, one participant mentions (s)he likes to try things out to get familiar with the functionalities. For this, actions should be reversible. Another participant would like warnings for long download times (SI2).
One participant appreciates system feedback to be sure a process is working. Especially for data with extensive download times, a progress bar could be beneficial (SI3).
All users value relatable semantics. What exactly is relatable could be different for different kinds of users. However, generally speaking, the map controls of PDOK are appreciated. Three participants mention this is because they are used to the similar controls of Google maps (SI4).

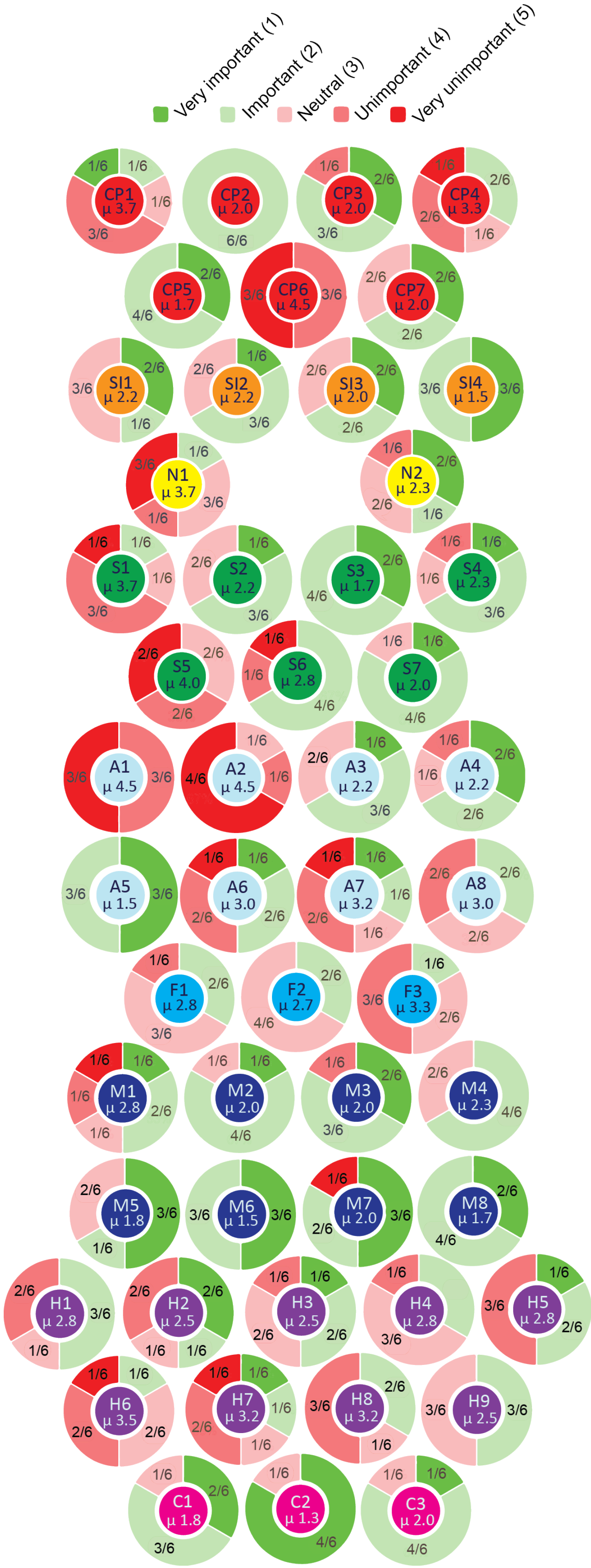


Figure 5.29: Ratings of participants regarding the initial GUIDE (see Annex F for a cheat sheet).

Proposal for related changes to the GUIDE
One participant mentions (s)he does not like to be forced to follow suggestions of the interface. Another participant values being able to understand what (s)he is doing whilst using the system. Both of these aspects are part of being in control (SI1). However, they are achieved by other design characteristics (SI2), (SI3) and (SI4). Furthermore, two participants mention they do not have to be in control of everything; it can be desirable if some actions are taken care of behind the scenes to relieve effort from the user. Because of this, characteristic SI1 seems to be both ambiguous and superfluous.

Navigation (N)
Most participants mention they see no real need for shortcuts (N1). Two participants specify that background information they scarcely need, does not have to be prominently available, the front-end developer comments that too many shortcuts can make the pages look less clean, and two other participants mention they do not mind having to push some additional buttons. Three participants even comment it helps them align their thoughts if they can visit a few additional pages during the access process. However, visiting more pages seems to be contradictory with the statement of two of the same participants that they mainly want efficient ways of acquiring data. Furthermore, the participants do comment on shortcuts they would like. This includes being able to see more basic metadata, directly view a dataset from the results on the catalogue page or dataset landing page, search for data on the map viewer page based on keywords, and access data from the map viewer page. One participant who was neutral to shortcuts commented that it is nice to have elements (s)he often needs visible on all screens (N1).
On the home page of PDOK, a tab to the dataset catalogue page is displayed in a striking colour, one participant mentions (s)he appreciates this as a support for navigating to a relevant part of the portal (N2). Three participants are also positive about breadcrumbs to show and act on their position on a page. However, the front-end developer mentions this could clutter the pages. The participants are not interested in a wizard providing more active navigational suggestions as could be achieved within an adaptive interface.

Proposal for related changes to the GUIDE
Even though it does not correspond with the general ratings, participants do list several examples they would appreciate to do directly. For this reason, design characteristics N1 is maintained, and annotated with these examples.
Two participants used the `ctrl click` functionality in their browser to open pages in a new window, this behaviour could be standardised for redirections.
The front-end developer mentions it is possible to provide an index of what is captured on a page. However, such a feature could again result in a cluttered interface, so if possible, its need should be omitted (N2).

Search mechanisms (S)
The keyword search mechanism is regarded as the most important aspect of a portal and should be assigned a high relevance in the GUIDE. Having multiple search mechanisms is deemed less relevant. One participant even mentions (s)he would never use the themes to search for data. The others suggested or used the themes if they could not come up with a successful keyword. One participant mentions (s)he appreciates being able to perform a visually supported, more geocentrically oriented search in which (s)he can immediately view datasets on the map (S2).
Three participants comment they would appreciate being able to filter data based on scale, recency, available formats and access options, organisation (or municipality), location, licence conditions, or other metadata characteristics (S4). Two others think such mechanisms should be used with care since they might over-complicate the process and clutter the interface.

One of the participants who mentioned a filter option could be nice, also states (s)he usually does not use these mechanisms since they are inconsistent between different portals. This makes it cumbersome to figure out how they work (S4).
Relevance and the most recent update date are mentioned to be desirable characteristics to sort data on (S6). One participant who regarded sorting as unimportant assumed the most relevant results are displayed first. Furthermore, one participant comments (s)he would like to be able to sort data on popularity.
The participants would appreciate it if they were able to acquire results by searching on synonyms and metadata, and they would like to see typos acknowledged (S7).

Proposal for related changes to the GUIDE
A system that recommends data is not necessarily nice, two participants specify this could limit or distract users from finding new datasets.
Users appreciate being able to see active search criteria (S3), which I made part of SI3.
The participants who had previous experience with PDOK knew their search keywords needed to be specific when searching data, and they think this is not user-friendly. However, none of the participants is interested in being able to tag datasets (S5). They think the portal owners should do this for them. One participant suggested that instead of tagging, more relevant search suggestions can be achieved by asking users to rate the usefulness of the provided suggestion.
Participants would appreciate being able to search datasets in the viewer, one participant suggests (s)he would appreciate being able to search on a location or within a spatial boundary on the catalogue page and another participant specifically mentions (s)he appreciates the location search in the viewer. These additional purposes of a search bar should be covered in the GUIDE.

Access and upload mechanisms (A)
Availability of data in different file formats is important for all of the participants with geo-related knowledge. One participant prefers shape files due to geo-referencing problems with GML. Two others would appreciate more lightweight, fast to use data dumps (A4).
Accessing data is important for users (A5). To achieve this, one participant comments the UI should prominently support the steps that are required to be able to access the data.
The opinions of participants regarding tools for processing vary; more advanced GIS analysis functionalities are not regarded to be useful by two participants, since actual GIS software can be used for this. However, another participant mentions (s)he appreciates web GIS, and (s)he comments more GIS like functionalities could especially be important for users using the PDOK viewer as standalone. Basic GIS functionalities participants appreciate include clicking features for information, and a scale bar and cursor coordinates in the viewer. Furthermore, only accessing specific features or areas is appreciated for the BGT. One participant thinks different overlays look unstructured. Changing the transparency of different layers could help (A6).
There are varying opinions about being able to subscribe for updates: some participants never do this or see no need for it. Others like subscribing for updates of a specific dataset (A8). There are no major arguments against including this for those interested.

Proposal for related changes to the GUIDE
All participants think the portal should be usable without an account and they prefer to use the portal anonymously, even if an account comes with additional functionalities or performance. However, this might depend on the kind of functionalities offered: one participant mentions bookmarking datasets sounds nice (A1).
Pages that print properly are less important to the participants, two of them are against it to save paper (A2). One participant comments (s)he does use map views as backgrounds. However, instead of a dedicated mechanism, `print screen` or other snipping tools can be used.
As long as it is not extremely slow, two participants do not mind having to wait for a few seconds for a page to load (A3). Even though others value fast loading times, it is challenging to measure what is the part of the UI in this. Because minimising memory loading should be kept in mind during the UI design, I annotated this in the GUIDE.

Two participants appreciate the possibility to access the uploads of other users. For example, to prevent having to re-do operations others already performed. However, two others mention they suspect this can result in a serious loss of quality. Because of this, their trust in the portal would reduce significantly when upload mechanisms are available, especially without any additional regulation. One participant comments that acknowledging source holders of issues to prevent possible tunnel vision via a feedback mechanism could work, instead of allowing the actual uploads. However, another participant comments that uploading data can be important for such feedback platforms. On Verbeterdekaart.nl, for example, it is only possible to mention what is wrong, whilst many organisations can rectify these mistakes. Another participant agrees Verbeterdekaart.nl could be improved by looking at editing functionalities such as offered by OpenStreetMap, possibly with a strategy more fit for base registries (A7). All in all, I did not include the upload functionality as a separate measure in the GUIDE. Instead, I introduced upload mechanisms as a part of feedback mechanisms (F3).
All participants with GIS-related knowledge are familiar with the QGIS plugin of PDOK. This may be a more sensible way to access data for users who work with GIS than downloading data, since it prevents them from having to take additional steps in opening the browser and the portal. To support and acknowledge the possibilities of such tools, one participant suggests adding a design characteristic covering system integration. The front-end developer prefers simpler, more visual-based solutions to access data than APIs. An example of this could be the possibility to acquire HTML code to be able to easily embed a map. PDOK already offers such a solution[a], which could be provided in the context of the viewer or the dataset to acknowledge its availability. Another participant mentions (s)he appreciates the linked data option on PDOK. Both could be tools for system integration that should be listed on the portal.
To be able to see how the data is structured, and what kind of attributes are captured (M6) one participant suggests the possibility to download a small sample of the dataset. However, this could also be provided in a list or table on the portal and is thus not part of the GUIDE.

[a] https://kaart.pdok.nl/

Feedback mechanisms (F)
Upon being asked whether they would be interested in a mechanism to communicate with other users and source holders (F1, H4), one participant mentions GitHub as a preferable example. The GeoForum option on PDOK could be used for this.
Another participant appreciates the "terug-meld" functionalities to provide feedback on the base registries. (S)he thinks such mechanisms help to keep the data quality as high as possible. For this, (s)he and another participant also think communication mechanisms with the source holder could be beneficial. Such a mechanism should be enabled by simply clicking a button. Another participant would appreciate this from a commercial point of view; if (s)he sees problems with a dataset, a dedicated button on a dataset landing page or map would enable her/him to contact the source holder and promote her/his company to fix the problem.

Proposal for related changes to the GUIDE
A data request mechanism such as a contact form is perceived to be user-friendly since it has a lower threshold than sending an email (F2). However, two participants comment, that they expect that data they request will either not come or arrive too late, will not be interoperable, or will contain mistakes. This supports annotating data request mechanisms in other contact possibilities, instead of providing a dedicated button.
Three participants mention that rating or commenting on a dataset is not something they would do. However, a public way to provide feedback can be nice to warn other users about issues. For this reason, comments can be publicly shown, as is, for example, done on Verbeterdekaart.nl (F3).

Metadata (M)

According to the participants with geo-related knowledge, basic metadata information should be displayed prominently on the dataset landing page, or even in the descriptions of the catalogue page. However, participants also mention they prefer the descriptions to be short. What can be considered basic information, and what background information is not required as often? Displaying the name of the dataset makes sense in all cases (M8). Furthermore, four participants want to see what is captured in a dataset (M6); currently, it is unclear what is covered under an overarching label such as the BRO, which makes the discovery process less sensible. Other preferences regarding metadata are different for different users and the participants even commented that the kind of metadata they need varies for the different projects they do. This means deciding what metadata should be provided where remains a trade-off. One participant mentions the available file format (M7) and update date (M5) of a dataset are already displayed on the catalogue page of Data.overheid. (S)he mentions it saves time to immediately see this information to assess the fitness for use. Furthermore, participants mention the contact information of source holders to be relevant for the acquisition of additional information (M4).
Although one participant mentions (s)he generally trusts the quality is okay for a platform such as PDOK, aspects related the quality of the dataset could be relevant to display on the dataset landing page according to four others. Two of them mention the accuracy, in which regard they both mention aggregation levels (M3) and update frequencies to be important; they often need data that is as recent as possible (M5). In this sense, information to distinguish between different versions, and changes in data attributes between these different versions can also be important (M3). One participant specifically mentions this to be relevant to her/his job. (S)he also appreciates the preview image on NGR, which provides coverage information.
Furthermore, one participant would like to see links or even aggregations of available information catalogues that elaborate on the data objects and lineage (M4).
To clarify what kind of data a user is accessing and what the possibilities are, one participant suggests listing the file format, size, and maybe even attributes of the data contained under each button (M7). The importance of this is supported by the behaviour of the participants, one of them, for example, comments on the file size of the NWB file before downloading.
Regular users of PDOK know that the provided open data is free to use. However, two participants mentioned that displaying licence conditions might be valuable for data that is not open (M1).
According to two participants, standardised metadata is only useful if the executioners stick to these standards, which is not always the case (M2). This is not within scope of the UI.

Proposal for related changes to the GUIDE

Some datasets have tools developed for them which are available on different channels. As well as to other access channels or information sources, geoportals should link to these related tools (M4). For PDOK, for example, one participant mentions the BAG viewer.[a]
In the PDOK viewer, one participant mentions it is nice layer legends are provided (M6).
Another participant mentions the scale levels at which data is available might also be relevant (M5). Someone else would like to see the CRS of a dataset (M7).
Furthermore, one participant thinks it does not make sense the texts describing the different services of the BGT under the "Geo Services tab" are all the same (M8).
Two participants mentioned the state of a system (SI3) could involve the up-time of services.

[a] https://www.bagviewer.kadaster.nl/lvbag/bag-viewer/

Help mechanisms (H)

One participant thinks separate sections for separate users could make helping each other more challenging and that the sections for expert users will be more well-developed than others. Another participant warns that separate sections for separate users could even reduce the usability if the captured information is not fully suited to the corresponding user type. However, the front-end developer would appreciate assistance regarding data access and use. (S)he suggests this can be linked to a dialogue on the homepage ("Are you a developer? Click here.") (H1).

Three participants state they are likely to join a discussion on the Geoforum (H4). However, two of them think facilitating help regarding data use in the form of forums or by providing data manuals (H3) is not the responsibility of the portal keepers. Instead, a link to such services could be provided in case this is offered by the data owners. Furthermore, the participants have varying opinions about whether or not they would appreciate manuals. Three participants comment they are unlikely to use a manual, except maybe if they encounter problems, others are keener on having a manual available. According to them, a data manual (H3) could capture what the data is about, what its attributes are, what one can do with it and how this can be done. It would be user-friendly if this is provided in a consistent way for all the different datasets on a portal. The participants would, for example, also like a tutorial on how to use an ATOM service (H9). In this sense, a portal manual (H7) can be captured by tutorials. One participant specifically comments (s)he appreciates the introduction videos on the page of the BRO. This participant also mentions that it could make her/him more confident in working with the portal when some kind of e-learning centre would be available that guides users through the functionalities of the portal (H7), (H9). Another participant mentions (s)he would only use tutorials if they are easy to find and if the tutorial itself is specific enough for her/his problem.
For other help mechanisms, the opinions also vary; example use cases are regarded as a valuable mechanism that could help to assess if a dataset is fit for a certain use case according to one of the participants (H5). Two others comment they never look into such examples.
FAQ seem to be the least preferred help mechanism. However, the differences in score between the different tools are small, and different geoportals do all implement FAQ. For this reason, FAQ remain part of the GUIDE (H6).

Proposal for related changes to the GUIDE
The participants appreciate contact information of both the portal and the data owners (H2). However, this information is not solely used to get help, but also as a general feedback mechanism. Two participants also mention such similarities between a forum (H4) and collaboration system (F1). For this reason, I decide to make H2 and H4 part of the design characteristic feedback mechanisms, which I renamed communication mechanisms (CM). The front-end developer also suggests a chat functionality could be included.
Providing additional explanations regarding terminology upon mouse hover or providing contextual information buttons, can support users by informing them on what to expect and how to proceed if they would perform a corresponding action. However, since pop-ups can be disturbing, two participants are not solely positive about such tips and hints (H8).
One participant mentions it can be cumbersome to find what (s)he needs in a help mechanism such as a tutorial video. Instead, (s)he would want the portal use to speak for itself. This is a sensible goal, however, help should still be presented for those who are interested. Because the preferences of the participants differ, it is challenging to assess what possible help categories or mechanisms are appreciated. To suit the different preferences of different users, it would be preferable if a portal offers multiple tools within a single category.

Consistency (C)
Consistency is valued by the participants; one participant mentions consistency is important to be able to know what to expect. Because currently different types of information are captured for different datasets, this is not yet achieved (C2).
Consistent semantics in terms of language and symbology are especially appreciated if participants have to discover a dataset they are unfamiliar with (C3).
One participant mentions that the different access options and formats differ for the different datasets offered on PDOK. Although this availability is outside the scope of this research, the participant would appreciate it if every dataset is consistently available in the same format. This participant would also appreciate it if the different open (geo)data portals in the Netherlands (red. NGR, PDOK, and Data.overheid) would be more consistent. It would be even better to capture their strengths in a single portal. Another participant also appreciates consistent behaviour between different systems to prevent getting used to different layouts, structures, and tags.

5.6. Reflection benchmark user session

Generally speaking, it is no longer required to interview participants once the amount of new information starts to become limited [Courage and Baxter, 2005], [Rohlfs, 1997]. During this session, the qualitative comments regarding usability issues and design characteristics became similar around the fifth participant. A multi-channel and customer process manager from PDOK agrees that six participants is not a lot, but it can give a good indication. Experts from PDOK also confirm the findings from this research represent reality; they agree users mainly want to efficiently find data.

Quantitatively, statistical analyses about the different ratings of the participants are not sound due to the limited sample size. Especially in cases where there is a big variance, it is not possible to know if some of the results are outliers. This means this user study does fulfil the goal of acquiring design characteristics from the perspective of users but is less statistically sound as a benchmark. When planning the experiment, I already acknowledged the shortcomings of the small sample size. However, this kind of user study seemed the most suitable for the limited available time for this research. Moreover, the comparison of results of the benchmark and the follow-up experiment is solely an indication because of the exploratory nature of the research.

For certain decisions regarding preferable semantics, I did not involve enough participants and user types. Since only the front-end developer was unfamiliar with geo-jargon and terminology, additional user sessions with participants without geo-knowledge are also required in case it would be desirable to be able to cater to their requirements. For this research, I did not attempt this because it is not yet clear how likely it is that developers without any geo-knowledge would need geo-information and are even able to find the geoportal as their source of information. The front-end developer, for example, mentions that even if (s)he would need to use geodata for a project, (s)he would ask her/his customers or other experts to back them up.

5.6.1. Evaluation of the realism of the tasks

All participants with geo-related knowledge comment they use the datasets offered on PDOK. Especially the BGT is popular. Other base registries such as the BAG and the BRT are mentioned as well. The participants use this data to perform analyses and for further processing. In this sense, the tasks are realistic. This is supported by that all participants with geo-related knowledge have previously used PDOK. However, all but one of these participants commented they would more often use geo-web services, the QGIS plugin, or data dumps, as opposed to the download mechanism. One participant commented (s)he usually downloads data when (s)he needs it as a background. This need for background and base maps was also acknowledged by others, but they preferred the QGIS plugin for this.

The front-end developer had no previous experiences with PDOK and commented that for the display of simple maps on a website, (s)he uses Google maps iframes to embed the map. (S)he mentions such an approach is easier from a developer's point of view, but also for the users, who are familiar with the look and controls of Google maps. (S)he states it might be undesirable to try to compete with Google maps on this. However, (s)he does acknowledge the data of PDOK is probably preferable when more advanced maps and functionalities are required.

Furthermore, one of the other participants mentions (s)he usually searches for data on Google, and that (s)he is redirected to portals such as PDOK based on these search results. (S)he prefers Google, because (s)he is more familiar with this platform. Three others also mention they would normally use Google if they cannot find something on the portal. The lack of using Google during the user session might be unrealistic, however, providing hints possibly partly made up for this.

5.6.2. Biases

When observing users, there are all kinds of biases that should be kept in mind. The "Hawthorne effect", for example, can lead to participants displaying different behaviour because they know they are being observed [Courage and Baxter, 2005]. On a general level, I assumed that the participants who were part of this research are professional enough to try to prevent biases as much as possible. Furthermore, recruiting participants with varying backgrounds also helps to prevent biases.

To see if this assumption is justified, I checked for outliers using the Z-score and the Interquartile Range (IQR). Both methods work for a small sample size to see if there are participants who rate significantly more extreme than others. This did not turn out to be the case.

Additionally, I used Cronbach's Alpha Coefficient to determine the reliability of the results in terms of the internal consistency of the questions [Tullis and Albert, 2013], [Reinecke and Bernstein, 2011]. The formula to calculate this coefficient is listed in Equation 5.2. In this equation, n is the number of questions, σ_i^2 is the variance of a single rating topic and σ^2 is the variance of the total rating.

Values closer to 1 indicate a higher internal consistency and higher reliability. For the self-reported metrics in this research, the Cronbach's Alpha Coefficient is 0.75. Because this is higher than 0.7, the internal consistency of this research is sufficient (see Te'eni and Feldman [2001]).

$$\alpha = \frac{n}{n-1} * (1 - \frac{\sum \sigma_i^2}{\sigma^2}) \tag{5.2}$$

5.6.3. Trade-offs

When ranking the design characteristics, the front-end developer mentions that certain characteristics, such as "visual hierarchy", and "consistent system behaviour" should always be part of the web design. Between other characteristics, there can be a trade-off. This is, for example, reflected by that participants mention they would appreciate all kinds of functionalities, but they also appreciate it if the interface is not cluttered. To decide on these trade-offs, I will use the examples set by other portals.

Furthermore, I discussed decisions regarding the implementation of some of the trade-offs with experts from PDOK. This involves taking into consideration if certain implementations would be feasible for them. For example, whether or not they see it as their responsibility to deal with support regarding the use of data, and with balancing the service strategy in general. The advantage of the low threshold of help mechanisms, for example, could be a disadvantage at the same time if users ask questions they could have easily figured out on their own. Whether help mechanisms with a low or slightly higher threshold are more suitable, is influenced by the capacity of the portal owners.

Adaptivity

As was expected, different users appreciate different implementations of design characteristics. I intended dealing with this by adapting the interface accordingly. However, even for users with the same user type who use the current portal in the same way, different preferences can be noted. For example, between the two developers with geo-related knowledge, one was very interested in sorting and filtering the data, whilst the other one was not. They also appreciated different types of help mechanisms. One was interested in a portal manual, whilst the other was keener on using the forum. This suggests such preferences are challenging to link to a user type.

Provided that it is possible to store which functionalities an individual user uses, these can be presented more prominently to them. However, before such preferences are known, all possible functionalities need to be available. This results in a cluttered UI, in which features that are rarely used by most users, could still negatively influence their UX. One way to deal with this would be to offer functionalities that are appreciated most on an average level more prominently than others. A downside of this approach is that the functionalities that are not offered at the top level of the interface are less likely to be used, resulting in a so-called "filter bubble".

Furthermore, sudden changes in the interface due to such adaptivity can result in a less user-friendly UI. The front-end developer agrees with this, according to her/him crisp transitions can be strange and unpleasant, since users may no longer recognise the UI they became accustomed to.

The results of this small-scale experiment seem to indicate that some trade-offs in the design in terms of dealing with the varying preferences of different users are likely to remain. Due to the small scale of this research, it is challenging to provide a more definitive answer regarding the feasibility of adaptive behaviour based on user type and corresponding behaviour. Additionally, challenges related to recognising re-occurring users due to changing, dynamic IP addresses, removal of cookies, and the unwillingness of users to subscribe to an account remain as well.

However, for other cases, such as providing contextual help, adaptive behaviour could still be a solution. Based on the user study, it seems that users who do not know what to look for, either slow their process because they start reading the content, or they start to click and try things. Both can often be recognised as sub-optimal behaviour. Furthermore, providing separate sections for specific users could also help deal with the differences between different users, be it in a less automated way.

5.7. Summary: Analysing PDOK

In this chapter, I described the benchmarking process and the resulting indication for the user-friendliness of the UI of PDOK (Subsection 5.7.1). Furthermore, users evaluated the initial GUIDE (Subsection 5.7.2).

5.7.1. Usability benchmark of PDOK

PDOK is a Dutch platform on which governmental organisations can host their open geodata. With a median value of 0.73 in the usability merit of Chiew and Salim [2003], the participants already rate the performance of PDOK to be good. Especially the clean, modern content presentation and the prominently located catalogue and viewer service are appreciated. However, participants would like the search functionality to be more intuitive in handling synonyms and typos, to be able to search for keywords and download data in the viewer, and to see certain metadata displayed more prominently.

5.7.2. A user's perspective on geoportal UI design characteristics

Content presentation (CP)
The participants value a scannable content presentation. Furthermore, they think designing a suitable UI is a job for the developer: they do not care much for adaptable colours and sizes.

System interaction (SI)
Participants have varying ideas of what it means to be in control. Such an ambiguous design characteristic is less suitable. The participants appreciate relatable semantics.

Navigation (N)
Participants prefer integration of the viewer page and landing pages and to see more "basic" metadata here. They would also like a keyword search for data in the map viewer.

Search mechanisms (S)
Participants prefer a search mechanism to be flexible with synonyms and typos. However, they think tagging is the job of the developer.

Access and upload mechanisms (A)
Participants are generally unwilling to subscribe to an account. Although upload mechanisms might degenerate the data quality, uploading data as feedback could be desirable.

Feedback mechanisms (F)
Participants might be interested in mechanisms to contact source holders and other users to ask questions or to point out mistakes in the data.

Metadata (M)
Next to the title and description of a dataset, participants would like to see the format, most recent update date, and the attributes of data aggregated on the portal.

Help mechanisms (H)
Different participants value help in different areas and with different tools. To suit different users, the portal should provide multiple of these tools in multiple areas.

Consistency (C)
Participants value consistency on the portal itself and between different portals.

6 Implement design propositions

In this chapter, I combine the resulting design characteristics of Chapters 3, 4 and 5 into a re-evaluated version of the GUIDE. To enable the assessment of geoportals based on the GUIDE, certain criteria and related scores are assigned to the design propositions (Section 6.1). Some of these propositions are not specific or measurable on their own. Implementation examples can be used as guidelines to solve this challenge (Section 6.2). To indicate the availability of the design proposition, I annotated these examples. For elements available through a menu bar, solely the screenshot in which these elements first occur is annotated. In case the annotated implementation example requires additional explanation, I discuss this in the subsequent subsection. A cheat sheet capturing the abbreviations and colour codes of the re-evaluated GUIDE is provided in Annex G. I summarised this chapter in Section 6.3.

Together, this results in an answer to Subquestion 2.

"How can the design propositions of the GUIDE be implemented as design elements?"

As an inspiration for implementation guidelines, I use the portals analysed in Chapter 3, and PDOK. Additionally, one participant of the user session suggested looking into Data.overheid and NGR, and a geomatics specialist recommended me to investigate Google Dataset Search. For this reason, I consider examples of these three portals as well. Since users are likely to be familiar with Google, I also consider other Google products such as Google maps. Analysing existing geoportals does not guarantee that the implementations I encounter are the most on-trend UI solutions. However, geoportals are the most representative examples because well-performing general websites have different use goals.

6.1. The re-evaluated GUIDE

By analysing existing geoportals and the user requirements study, I re-evaluated the initial GUIDE that was based on literature review. In this section, I provide this re-evaluated GUIDE.

To quantitatively rate the performance of a geoportal with the GUIDE, I related the design propositions to a score. This score is based on if many existing portals implement the proposition and if users think this is important. The number of geoportals implementing a characteristic should be larger than three because this would be more than average when considering France, Ireland, Luxembourg, Ireland, and PDOK. The rating of participants should be lower than 2.7 because they averagely assigned a score of 2.5. I used the standard deviation of 0.2 as a buffer. The frequency in which characteristics are mentioned in the literature I studied during the literature review phase is not included because I studied different amounts of papers for different topics.

Must have (3 points) The proposition should inevitably be available. If a characteristic is relevant and feasible based on their implementation in other geoportals (> 3 portals) AND relevant according to the rating of users (< 2.7).

Should have (2 points) The proposition is desirable. If a characteristic is relevant and feasible based on their implementation in other geoportals (> 3 portals) OR relevant according to the rating of users (< 2.7).

Could have (1 point) For bonus propositions that are nice to have. Neither of the above cases is true.

The different ways in which these points should be divided over the implementation examples are listed in the GUIDE. The score of a portal indicates how user-friendly the UI of that portal is, where higher scores are more preferable than lower scores. Since the number of design propositions within a category does not necessarily reflect its importance, the scores can be normalised by dividing each score within a category by the total amount of propositions.

Corrected for fractions, a perfect score is 2039 ($\frac{16}{6} + \frac{9}{3} + \frac{5}{2} + \frac{11}{5} + \frac{12}{5} + \frac{9}{4} + \frac{26}{9} + \frac{7}{4} + \frac{9}{3} = \frac{2039}{90}$). A portal with a satisfactory user-friendly UI could score 2 instead of 3 in the *must have* rating, 1 instead of 2 in the *should have* rating, and 0 instead of 1 in the *could have* rating. This corresponds to a score of 1229 ($\frac{10}{6} + \frac{6}{3} + \frac{3}{2} + \frac{6}{5} + \frac{7}{5} + \frac{5}{4} + \frac{17}{9} + \frac{3}{4} + \frac{6}{3} = \frac{1229}{90}$). A portal with an unsatisfactory user-friendly UI could score 1 instead of 3 in the *must have* rating and 0 instead of 2 in the *should have*, their score would be 482 ($\frac{4}{6} + \frac{3}{3} + \frac{1}{2} + \frac{2}{5} + \frac{2}{5} + \frac{2}{4} + \frac{8}{9} + \frac{0}{4} + \frac{3}{3} = \frac{241}{45}$).

Because I did not calibrate this merit it is not necessarily fair and can solely be used as an indication.

6.1.1. Content presentation

Design propositions regarding the content presentation are displayed in Table 6.1.

Table 6.1: Entry of the GUIDE: Content presentation (CP).

Content presentation (CP)	Score
CP1 Colour harmony: aesthetically pleasing colour combinations	Yes (2) / No (0)
CP2 Distribute content in a balanced way: balance around the optical centre, golden section ratio, or rule of thirds	Yes (3) if at least one is used, else (0)
CP3 Ergonomics & legibility (WCAG 2.1 compliant): • Large button (44 by 44 CSS pixels), icon & text size (18 or 14 pt bold) • No animations without confirmative user action • Readable maps (for example through full-screen availability) • Offer alternative media: text for non-text elements, colour replacement • Sans-serif font • Strong contrast back / foreground (7:1)	 • Yes (0.5) / No (0) • Yes (0.5) / No (0) • Yes (0.5) / No (0) • Yes (0.5) / No (0) • Yes (0.5) / No (0) • Yes (0.5) / No (0)
CP4 Increase "scannability" of the content: • Conveying a visual hierarchy using: (contrasting) colours, contours, fonts (spacing, size, boldness), Gestalt laws, intensity, location, markers (e.g. arrows), shape, size • Present content as indented lists or tables instead of linear text • Prevent scrolling (use collapsibles, in case scrolling is required it is possible to show what is captured on a page with an index) • Simple presentation & visualisation (no cluttering): - Avoid long texts: use collapsible if necessary - Incorporate graphics - Fitts' presentation in a grid: minimise text rows & columns - Only show essentials - White space	 • Yes (1), if at least two are used, if one is used (0.5), else (0) • Yes (1) / No (0) • Advisable (0) • Yes (1) / No (0)
CP5 Support flexible background maps (including a white background)	Yes (2) / No (0)
CP6 Visualise data (e.g. previews)	Yes (3) / No (0)

Visual hierarchies are most often implemented by using colours, size, and location. However, if at least two of the suggested mechanisms are used, this is deemed sufficient (CP4). Preventing scrolling as much as possible is difficult to measure. For this reason, I solely included it as an advice.

6.1.2. System interaction

Design propositions regarding the system interaction with the portal are displayed in Table 6.2.

According to the comments of participants, easy reversal of actions and informative error messages are regarded to be the most important aspects of error handling (SI1).

The active maps in the viewer should be clearly annotated. This is supported by the comments of two participants and by that the analysed portals all have ways to differentiate between either active or inactive datasets varying from the sole use of a checkbox, to a dedicated active dataset dialogue. The possibility to differentiate between visited and unvisited links (see Shneiderman [2004]) is no longer included in the GUIDE since such a mechanism is not adopted in any of the analysed portals (SI2).

To assess whether or not the semantics adopted in the portal are familiar (SI3), the implementation examples as described in Section 6.2 can be used as guidelines. However, it should be noted that these examples could be one of many solutions and they are limited to the portals and opinions of the (types of) users analysed in this research.

Table 6.2: Entry of the GUIDE: System interaction (SI).

	System interaction (SI)	Score
SI1	Error handling & preventing:	
	• Easy reversal of actions ((de)activating layers)	• Yes (1) / No (0)
	• Informative error messages: show how to fix the problem (feedback if a search keyword does not lead to any hits)	• Yes (1) / No (0)
	• Limit (redundant) user actions or entry (check box vs string input, test user input immediately rather than at task completion)	• Yes (0.5) / No (0)
	• Provide warnings (prompt to postpone interruptions, be clear about redirections from the portal, and warn for long download times)	• Yes (0.5) / No (0)
SI2	Responsiveness & system status visibility (system feedback on actions):	
	• Show state of the interface (differentiate active icons, change the cursor in different modes, show active datasets in the viewer)	• Yes (1) if at least two are used, (-0.25) for each not used until (0)
	• Provide progress indicators and yield closure (dialogue messages, progress bar, or other visible indicators)	• Yes (1) if at least one is used, else (0)
	• Display the active search criteria	• Yes (1) / No (0)
SI3	Use of relatable semantics (correspondence to mental model):	
	• Buttons & symbols should be clear (unambiguous, simple to interpret) & recognisable (universal or standardised, expected location)	• Yes (1) / No (0)
	• Linguistic clarity: avoid acronyms and unfamiliar jargon, multi-linguality (at least English / Google translate options)	• Yes (1) / No (0)
	• Relatable, standardised (map) controls and procedures: actions lead to expected results (e.g. Google maps, conventional web search engines)	• Yes (1) / No (0)

6.1.3. Navigation

Design propositions regarding the navigation through the portal are displayed in Table 6.3.

Table 6.3: Entry of the GUIDE: Navigation (N).

	Navigation (N)	Score
N1	Provide direct ways to do a task (allow shortcuts):	
	• Include most important (most used) pages to the menu bar: (for geoportals this are the map viewer and the catalogue page)	• Yes (0.5) / No (0)
	• Link to a dataset landing page from the viewer and catalogue page	• Yes (0.5) / No (0)
	• Link to view datasets from the catalogue and dataset landing page	• Yes (0.5) / No (0)
	• Search bar prominently visible on all pages (incl. map viewer)	• Yes (0.5) / No (0)
N2	Provide sufficient navigational aids:	
	• Breadcrumbs: show current page position related to full sitemap to show previous steps in the interaction	• Yes (1) / No (0)
	• If scrolling is required: show the content of the page with an index, show menu bar and / or utility links regardless of scrolling, and provide an option to go back from the bottom to the top of the page	• Optional (0)
	• Prevent dead ends (prevent 404 errors, provide options to go back)	• Yes (1) / No (0)
	• Show utility links at the bottom of each page, if these are not already visible elsewhere on the page: about page, accessibility (WCAG compliance), catalogue page, contact information, privacy and cookies, related (governmental) portals, sitemap, support / help pages, update service, usage policy, viewer page	• Yes (1), if all these are available, else (-0.25) for each missing link until (0)
	(Optional: audience-oriented sections, community, different language options, home page, information regarding \ac{inspire} or open data, inspiration gallery, news, popular portal elements such as services, tools, or specific types of data, producers, themes)	Optional (0), (-0.25) for each additional link over 13 until (0)

Being clear about redirection is part of the system interaction. Additionally, dead ends in the navigation could be prevented by opening redirections to external channels in a new browser window. Although this goes against WCAG 2.1 heuristics PDOK has to comply to as a semi-governmental organisation, an expert from PDOK agrees this would make more sense for the average user. Utility links also support the navigation [Courage and Baxter, 2005]. But what elements should be captured in these utility links? The utility links available on the eight analysed portals differ strongly in both semantics and availability. In case utility links are captured by three or more portals, I added them to the GUIDE. The other elements are listed as optional. Menu bar elements only have to be part of the utility links if the menu bar does not remain visible when scrolling.

All portals cover information regarding cookies. However, Ireland, Norway and Data.overheid cover these within a privacy tab and Luxembourg within a “terms and conditions” tab, whereas the other portals cover them separately. Furthermore, PDOK offers a copyright tab, France a legal mentions tab, Ireland a usage policy tab, and Luxembourg a terms and condition tab, to cover the same types of content. This can cause confusion, and it is unsure which term would be most suitable. Within the GUIDE, I use “usage policy” since this relates to a native English portal.

Quantitatively speaking, there are also differences: NGR only has three utility links, whereas France captures twenty-four elements. The number of optional utility links should be limited to prevent overwhelming the users. I associated this limit to the median value of thirteen of utility links of the analysed portals. To prevent minus points, this amount should not be exceeded.

Providing an index to show the content of the page is also possible, however, if scrolling is prevented and the pages are structured sensibly, this is not necessary, and it could even clutter the interface. The same is true for the option to go back to the top of the page. These suggestions are mentioned but not awarded any points (N2).

6.1.4. Search mechanisms

Design propositions regarding the search mechanisms are displayed in Table 6.4.

Table 6.4: Entry of the GUIDE: Search mechanisms (S).

	Search mechanisms (S)	Scores
S1	Allow keyword searches for: • (Meta)data in both viewer and catalogue • Location (address, coordinates) in both viewer and catalogue • Portal functionalities	 • Yes (2) / No (0) • Yes (1) / No (0) • Optional (0)
S2	Different (meta)data search possibilities: • Keywords (free text) • Map search (visually supported search) • Themes	 • Yes (2) / No (0) • Yes (0.5) / No (0) • Yes (0.5) / No (0)
S3	Enable more intuitive, flexible search: • Auto-completion of the search keyword • Handling synonyms • Handling typos (“did-you-mean” suggestions)	 • Yes (0.5) / No (0) • Yes (0.75) / No (0) • Yes (0.75) / No (0)
S4	Filter results based on: • Access service type (download, API, geo-web service) • Format (GML, SHP, CSV) • License (accessibility) • Location (regions of a country) • Organisation (data owners) • Spatial scope (country-wide, provinces, municipalities) • Time range (update date, optional: publish or creation date) • Optional: depth, scale, metadata language, cooperation and laws	Yes (2) if all non-optional filters are available, else (-0.25) for each missing filter until (0) Optional (0)
S5	Sort results based on: • Alphabetical order • Popularity: number of downloads or views, or ratings • Relevance • Scale • Upload date (most recent)	 • Yes (0.25) / No (0) • Optional (0) • Yes (0.5) / No (0) • Optional (0) • Yes (0.25) / No (0)

Enabling data discovery is crucial for geoportals. Additionally, two participants appreciate the option to search for a location, which is also regarded some importance. The possibility to search for portal functionalities (as, for example, provided by Luxembourg) is optional since none of the participants attempted or mentioned this (S1). Participants mainly appreciated searching for keywords (S2).

Related portals mainly focus on auto-completion of the search keyword. However, users mention to especially appreciate a more flexible search in terms of handling synonyms and typos (S3).

The filters listed in the GUIDE are based on suggestions of participants, the filter options from the portal of Norway, and the filter options of NGR and Data.overheid (S4). These filters should be generally applicable and self-explanatory. Data.overheid, for example, offers the possibly ambiguous filters “thema” (“theme”), “groep” (“group”), and “tags”. Participants would like to filter on depth or scale. However, such characteristics are unavailable on the analysed portals and might not always be applicable.

Themes are a specific type of filter. During the benchmark session, the participants commented it can be unclear what kind of data is captured under which themes. Ideally, the selected themes match the mental model of the user to prevent possible confusion and the need for further explanations. This could be easier to achieve if users recognise themes from other portals. For this reason, I started analysing if certain themes are frequently used in existing portals.

The first challenge I encountered during this process, involves the differences in how the different portals approach the themes. The themes of Ireland, for example, are subdivided into two overarching categories: "nature and environment" and "population and economy". This is conflicting with that nature and environment is a theme often adopted on its own in other portals. For the portal of Luxembourg, the themes also contain subthemes. The theme "main", for example, contains culture and environment, biology, and geology, and infrastructure and communications. This last subtheme contains a subsubtheme transportation networks. This is a theme on its own in other portals.

Similar themes can also have slight differences in names. Because of this, the themes need to be harmonised to analyse their occurrence frequency. An example would be to count "agriculture and livestock" as "agriculture". The challenge with this is determining how far to take this harmonisation. Can "traffic", for example, be combined with "transportation"? This goes beyond the scope of this research.

NGR and Data.overheid allow sorting data on the most recent update date, relevance, and title (alphabetical). Especially relevance is important to the participants. Additionally, NGR allows sorting on rating, popularity, and scale. These are listed as optional (S5).

6.1.5. Access mechanisms

Design propositions regarding the access mechanisms are displayed in Table 6.5.

Table 6.5: Entry of the GUIDE: Access mechanisms (A).

	Access mechanisms (A)	Scores
A1	Provide data access: view service, downloads, (internationally standardised) APIs, geo-web services	Yes (3) if all available, else (-1) for each missing service until (0)
A2	Provide (meta)data in various formats: • Metadata: machine-readable, proprietary, and human-readable formats • Data: machine-readable, both non-proprietary and proprietary formats, and lightweight alternatives	• Yes (1) if both, if only one (0.5), else (0) • Yes (2) if all available, else (0.5) for each
A3	Provide tools for data analysis and processing that allow: • Direct measurements in the map viewer (areas, azimuth, distances, height profiles, isochrones, routes) • Clicking map features for more information • Show coordinates of the mouse cursor (in applicable CRSs) and scale • Conversion of the format of a dataset • Combining data (overlaying layers (changing the transparency, send layer to the back or fore-ground), layer slider, uploading local layers) • Drawing on the map (add placemarkers) • Querying (selective area coverage or features)	• Yes (0.25) / No (0) • Yes (0.5) / No (0) • Yes (0.5) / No (0) • Optional (0) • Yes (0.25) / No (0) • Yes (0.25) / No (0) • Yes (0.25) / No (0)
A4	Provide tools for system integration: • HTML code to embed the created map layers on a website • Linked open data • Plug-ins for GIS	If three are available (2), if two are available (1), if one is available (0.5), else (0)
A5	Subscribe for updates of datasets or news via email, ATOM or RSS feed	Yes (2) if both, if one is available (1), else (0)
	Allow users to register for an advanced user account: • Provide possibility for data and preference storage (bookmarking) • User authentication	Optional (0), do not make registration mandatory
	Minimise memory loading of the UI: • Minimise the size of graphics (tumbnail images for preview) • Prevent redundancy	Advisable (0)

Providing data in various formats is especially important to the participants (A2). Conversion options are superfluous if data is provided in all relevant formats (A3).

6.1.6. Communication mechanisms

Design propositions regarding communication mechanisms are displayed in Table 6.6.

Table 6.6: Entry of the GUIDE: Communication mechanisms (CM).

	Communication mechanisms (CM)	Scores
CM1	Allow link sharing of the (map view) pages (via social media or email)	Yes (2) / No (0)
CM2	Collaboration system / forum to allow communication between users, portal owners, and providers about the data and portal functionalities	Yes (1) / No (0)
CM3	Contact information (to report problems, ask questions & make requests): • Phone number, address, email, social media of the data owner • Phone number, address, email, social media of the portal owner	• Yes (1.5) if all, else (-0.5) until (0) • Yes (1.5) if all, else (-0.5) until (0)
CM4	Contextual contact button linked to form or chat (in map viewer or on dataset landing page to report problems, ask questions & make requests): • To portal owners regarding the portal • To data owners regarding the data, including an upload button for rectification purposes	• Yes (1) / No (0) • Yes (2) including upload button, (1) without upload button, else (0)

The front-end developer states that a general contact email address (CM3) is less user-friendly than a forum (CM2) or contact form (CM4). Two other participants agree the threshold for sending an email is high because they usually associate sending an email with slow, automated responses. If sending an email is required, they might rely on others to report problems. As an alternative and depending on the capacity of the portal owners, a contextual button leading to a contact form or chat should also be available.

France and Luxembourg have a contact button in their map viewer in which users can mark an area of the viewer that contains problems. Here an upload button can be incorporated to enable users to provide rectifications for mistakes without degrading the quality of the data (CM4).

6.1.7. Metadata

Design propositions regarding metadata are displayed in Table 6.7.

Participant in the user session used the term “basic metadata” to refer to certain metadata elements they think should be prominently available on the dataset landing page and should be captured in the GUIDE. But what is “basic metadata”? On existing portals, the available information can vary for different datasets. Ireland sometimes lists metadata elements in the textual description of a dataset such as contact information of the data owners, information regarding revisions, scale, or how the dataset is created. On PDOK, the BAG, for example, comes with a data model, and only on the page of the BRO links to the website of the base registry are provided.

Even though four portals display keywords or tags, and three portals display themes as information for a dataset, this is not part of the basic metadata listed in the GUIDE. The reason for this is that these aspects are not relevant to determine the fitness for a certain use case. Instead, I consider them as filter mechanisms that are used behind the scenes to present the most suitable data to users.

Links to recommended similar datasets or data from the same producer as provided by Data.overheid are not included in the GUIDE since participants mention they do not care for this. Two of them even mention this could hinder them in their discovery process.

Three of the eight existing portals display license conditions. In case all data is open, the participants think this may be less relevant. For this reason, this characteristic has slightly lower importance than the other metadata elements (M1). Five portals provide (links to) standardised metadata (M2).

Two participants mention they like to know how data is aggregated. However, this is not listed on the portals and is only relevant if applicable. Four portals do list some information about how data is collected, which can be part of this. Three portals mention the original purpose of a dataset and four portals list maintenance frequencies. All portals list the source or organisation that produced the data. The origin of the data and seeing the differences between different versions are regarded as important by the participants. Version information is available on two portals. The tranches listed for the BRO show that it is also possible to list information about intended updates (M3).

All studied portals have an about page. Up-times of services and statistics of dataset offerings are covered on different pages if available, however, they could be part of such an about page (M4).

Participants mention the contact information of source holders to be relevant for the acquisition of additional information, six portals capture this. Links to other related information or tools include links to external feedback functionalities (two portals) or to corresponding websites (three portals) (M5).

The coverage and scale range of the data is listed on two portals. Norway also lists specific quality specifications the data complies to. It could be sufficient to provide these in either a drop-down or a download. The most recent update date is most relevant for users, this is displayed on five portals. The publish and creation date as displayed on two and three portals, are less relevant (M6).

Attributes of the data are relevant according to four participants, none of the portals aggregates this. One participant mentions there are often so-called catalogues or data sheets available that elaborate on the data objects. Norway links these. All portals with a viewer display legend information here (M7).

The CRS, file format, and file size are mentioned by one participant and on one, four, and none of the portals. Three portals provide information about service levels and two portals provide a data model for one of the datasets (M8). All eight portals show the title of the dataset and a description (M9).

Table 6.7: Entry of the GUIDE: Metadata (M).

	Metadata (M)	Scores
M1	Accessibility (license conditions & their meaning)	Yes (2) / No (0)
M2	Available according to international standards	Yes (3) / No (0)
M3	Data governance: • Collection method, aggregation level & processing • Data context (original purpose) • Data editors, including the original creator • Version management: overview of data update history, methods to track changes & update frequency (sustainability)	• Yes (0.5) / No (0) • Yes (0.5) / No (0) • Yes (1) / No (0) • Yes (1) if all available, (0.5) if one missing element, else (0)
M4	Information about the portal (on an about page or utility links): • Statistics about the dataset offering (indices of offered datasets) • Textual explanation about what the portal is, and (promotion of) the service levels and functionalities that are offered • Up-time of services	• Yes (0.75) / No (0) • Yes (1.25) if all available, (-0.5) for missing elements • Yes (1) / No (0)
M5	Linking sources: • Link to other access & information channels (data sheets) • Link to all data editors or producers, including contact info • Link to related applications (conversions, data dumps, software, tools)	• Yes (1) / No (0) • Yes (1) / No (0) • Yes (1) / No (0)
M6	Quality indicators: • Accuracy (correctness) / precision • Completeness: - no missing values - coverage - granularity / scale • Timeliness (update date or creation date)	• Yes (1) / No (0) • Yes (1) / No (0) • Yes (1) / No (0)
M7	Semantics: • Layer legends • What are the data attributes & what do they mean	• Yes (1.5) / No (0) • Yes (1.5) / No (0)
M8	Structure of the data: CRS, data model, format, size, service level (view service, downloads, APIs, geo-web services)	Yes (3) if all, else (0.5) for each element
M9	Topic & distinctive description of the data (about 30 words)	Yes (3) / No (0)

Dataset titles

Existing geoportals do not always use similar approaches for capturing the name of a dataset. Ireland, for example, often lists the scale of the dataset in its title. Other portals also occasionally do this. However, this is done inconsistently. Another example involves that some portals put the creation year of a dataset in its title. This can make sense if new datasets are produced from time to time and each of these versions has its own access services and metadata, however, this is not always the case. So, what should a dataset title consist of?

Since a title should describe the content of a dataset in a distinctive way, it may differ from case to case what should be captured. However, consistency is desirable. This may be achieved by keeping metadata elements from the title unless there is a need to distinguish between several similar datasets.

Dataset descriptions

For the description of the data, the GUIDE solely lists that such a description should be available. However, some descriptions are more user-friendly than others.

To see what length is suitable, I analysed the description text lengths of existing portals for three datasets: a topographic map, a dataset of administrative units, and a roadmap dataset. This resulted in a median value of 30 words for a textual description. That this median value is a representative fit can be supported with the boxplot shown in Figure 6.8.

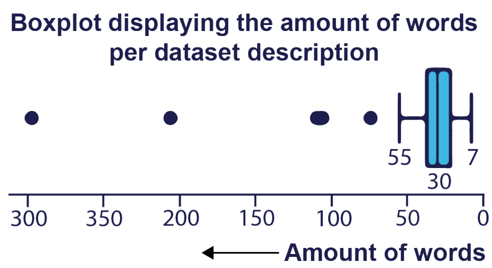


Figure 6.8: Boxplot of the amount of words in a textual description of a dataset based on 27 samples.

The average of 51 words is less representative since this average includes the outliers of Google Dataset Search with two descriptions over 200 words and Norway with one description over 100 words. These lengthy descriptions can be explained since these channels only display these descriptions on a dataset landing page, instead of for each search result.

To keep the descriptions of the search results of consistent length, it is possible to cut off sentences or even words. Data.overheid and NGR both do this; however, this might be undesirable for readability.

WCAG 2.1 prescribes that the width of text blocks should be no more than 80 characters and the text should not be justified. With around 12 words as a median value for the existing portals, and words having an average of five characters, the average width of a text block is 60 characters. However, this width strongly depends on other design decisions such as the font size or dialogue width. The amount of characters per line for the information dialogue of France and Luxembourg is, for example around 25 characters. Because of this, all character widths below 80 characters could be suitable, as long as it goes with the rest of the design.

What should these texts contain? The descriptive texts of the existing portals differ to some degree; however, they all have in common they attempt to capture what is represented in a dataset. France mentions specific objects such as contour lines, regions, roads, buildings, and trees. Norway stays on more general terms by mentioning topographic data. During the user session, participants also mentioned they would like to see what attributes and objects are captured in a dataset. What type of approach is most suitable depends on the intended users and could be offered in an adaptive way. For the mock-up, the initial texts of PDOK are used as much as possible since these can be assumed to be written for their intended audience.

Some portals also list additional metadata elements in the short textual description. An issue with this is that it is often not done consistently. Ireland, for example, mentions the scale and CRS for the topographic map dataset, the publisher and contact information for the road map, and none of these elements for the administrative areas. Furthermore, covering metadata information in a text is not good for the scannability.

6.1.8. Help mechanisms

Design propositions regarding help mechanisms are displayed in Table 6.9.

Table 6.9: Entry of the GUIDE: Help mechanisms (H).

	Help mechanisms (H)	Scores
H1	Audience-oriented sections (covering functions for different types of users)	Yes (1) / No (0)
H2	Support for data use (including relevant analysis & tools): • Examples of data applications & use • FAQ • Manuals • Tutorials (step by step pictures or videos, e.g. loading data in GIS)	If any is available (1), if more (2), else (0)
H3	Support for geomatics related knowledge: • FAQ • Glossary with terms and definitions • Tips & hints (in context, no pop-ups): mechanism to identify definition (hovering, i button)	If any is available (1), if more (2), else (0)
H4	Support for portal use: • FAQ • Manuals • Tutorials (step by step pictures or videos) • Tips & hints (in context, no pop-ups): - Mechanism to identify functionality (hovering, i button) - Visual clues about functionality (put function in the search bar, textual description of the control)	If any is available (1), if more (2), else (0)

Providing several help mechanisms can help fit the needs of different users, however, it is not necessarily true that a portal should offer all these tools to be user-friendly. The participants did not significantly prefer a certain type of mechanism. For this reason, I solely specified that allowing users to choose is beneficial, but that at least one mechanism should be available.

The GUIDE solely captures the areas in which help should be provided, and which tools can be used to do this. Note that this does not necessarily result in high-quality, user-friendly help mechanisms.

6.1.9. Consistency

Design propositions regarding consistency are displayed in Table 6.10.

Table 6.10: Entry of the GUIDE: Consistency (C).

	Consistency (C)	Scores
C1	Consistent appearance: • Colours • Font type & size • Placement of page elements (lay-out header, footer, menus)	Yes (3), for each inconsistency in the appearance of similar elements (- 0.5) until (0)
C2	Consistent behaviour (for similar procedures and situations): • Homogeneous formats • Identification of functionality • Interaction: consistent style system feedback, perform similar tasks in a similar way (order yes / no buttons), standardised task sequence	Yes (3), for each inconsistency in the behaviour (- 0.5) until (0)
C3	Consistent semantics: • Graphics & icons • Terminology homogeneity (controlled vocabularies)	Yes (3), for each inconsistency in the semantics (- 0.5) until (0)

6.2. Implementation examples in the form of a mock-up design

The implementation examples provided in this section revolve around the discovery, assess, and access processes that should be supported on a geoportal. To enable these processes, there are three pages that must be available: the home page (Subsection 6.2.2), catalogue page (Subsection 6.2.3), and map viewer page (Subsection 6.2.4). Before I cover the implementation examples for these pages, I discuss some general decisions that relate to the full portal in Subsection 6.2.1.

6.2.1. General decisions

General design decisions related to the full geoportal are listed in this subsection.

Content presentation

Two experts on design indicate that the aesthetics of the UI can help users to feel at ease with the portal. For governmentally hosted platforms, the portal should help portray governmental values. This means it should look sound and modern. A more technical-minded expert from PDOK assumes different design options can be equally suitable as long as they support the functionalities of the portal.

Colour choices

For websites, a maximum of four standard colours is advisable [Carvalho and Lafuente, 2015]. In line with this, I maintained the original colour scheme of PDOK, as shown in Figure 6.11. Apart from the colour blue being the universally most preferred colour for both users and designers [Bonnardel et al., 2010], [Cyr et al., 2010], the colour blue is often adopted in existing brand logos that relate to technology. Furthermore, this colour scheme suits the theory of colour harmony.

Figure 6.11: Colours I adopt in the mock-up.

To some degree, colour choices remain subjective. However, ergonomics should always be considered. According to the WCAG 2.1 AAA heuristics, the text and background should have a contrast ratio of at least 7:1 [WCAG, 2019], the main text and background are white and navy. This makes reading on the screen less tiresome than would be the case for black and white combinations [Carvalho and Lafuente, 2015]. Since navy and white have a contrast ratio of 15.64, this is WCAG 2.1 AAA compliant. For navy and cyan, the ratio is 11.02. White and cyan should not be paired together due to their contrast ratio of 1.42.

Font choices

Using many different fonts results in a cluttered design [Shneiderman, 2004]. Two distinct fonts, one for headers and one for the body, are usually sufficient [Carvalho and Lafuente, 2015]. PDOK uses the Quicksand font for headers and Roboto for their text. Both are sans-serif fonts that are easier to read on a screen. Since the front-end developer appreciated these fonts and they are listed as a good font pair[1], I decided to use them for the mock-up as well.

Furthermore, no more than four different font sizes should be used [Shneiderman, 2004]. To distinguish different sizes, they should differ by at least 2pts [Carvalho and Lafuente, 2015]. Most of the analysed portals adopt a font size of 12pt for their default text, Ireland goes even lower with 10.5pt. To support legibility for a wide range of users, I decided to follow the WCAG 2.1 heuristics. These prescribe a large font size is at least 18pt or 14pt bold WCAG [2019].
In line with this, I decided on the font choices as displayed in Figure 6.12.

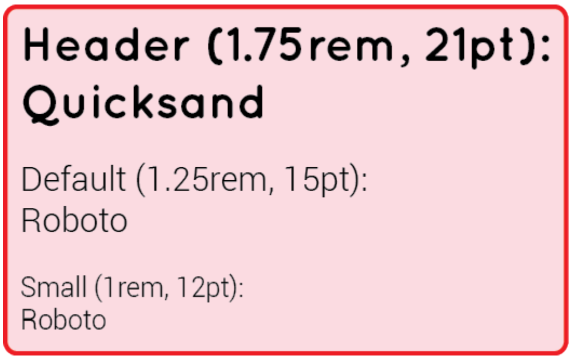


Figure 6.12: Font types and sizes that I use in the mock-up.

[1] https://fonts.google.com/specimen/Quicksand

Shapes of portal elements

Generally speaking, buttons and website elements such as search bars are either rectangular, rectangular with rounded corners, or round. Is one of these more user-friendly than others? The choice for rounded or sharp corners might not necessarily be a matter of good or bad but is more related to the desired atmosphere and associations users should have with a portal. Shapes can subconsciously influence these associations.

In related research, for example, participants associate different concepts to two different nonsense forms. A round shape seemed more calm, mature, and friendly, but also less exciting than a sharp one [Lyman, 1979].
A famous example showing the association people have with shapes is the case in which the round sounding non-words Bouba or Maluma are associated with round shapes and the sharp sounding non-words Kiki or Takete with sharp shapes. This is also the case when asking participants to name character silhouettes as displayed in Figure 6.13 with a round sounding name such as Molly, or a sharp name such as Kate [Sidhu and Pexman, 2015]. This could, for example, result in Molly seeming more easy-going, and Kate more determined. Such associations could be a reason to go with a certain shape matching the personality of a brand [Koe, 2018].

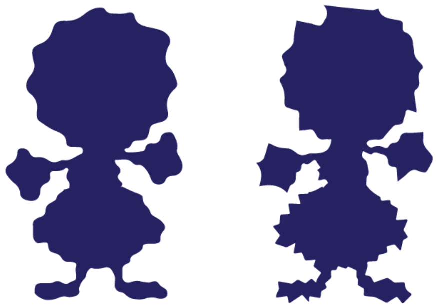


Figure 6.13: Who is Molly, who is Kate? Generally speaking, the round shapes of the left character are more likely to be associated with Molly [Sidhu and Pexman, 2015].

When analysing the implementation of shapes in geoportals, the search bar is a prominent feature. The shapes of these search bars of different portals are displayed in Figure 6.14.

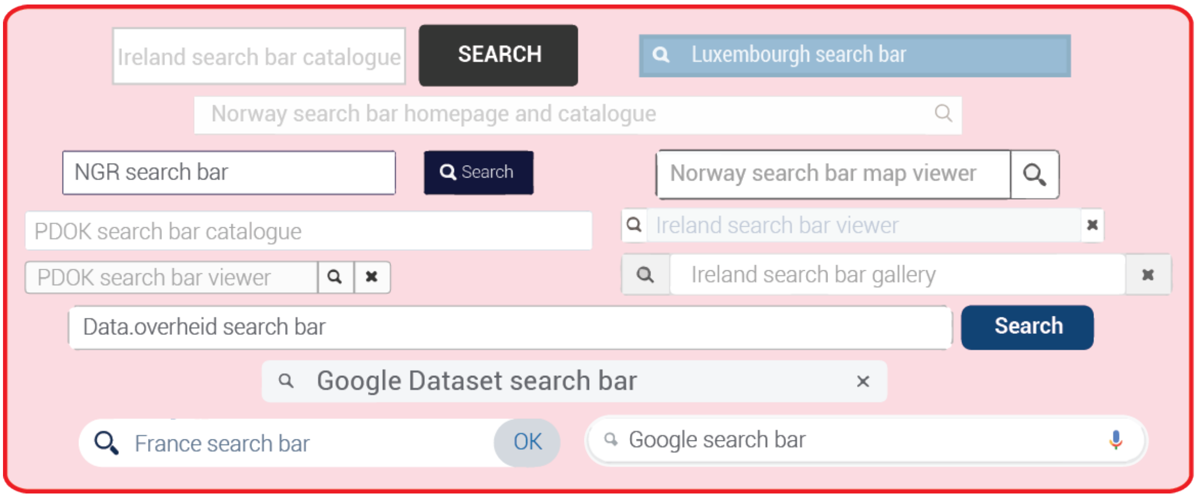


Figure 6.14: Differently shaped search bars on different (geo)portals. Note that these are re-scaled for presentation purposes, the actual sizes differ between portals and even on the same portal.

Search bars with clearly rounded corners (around 4px) seem the most popular option. There are a few exceptions. These all make sense in the surrounding design context of the portal. Luxembourg, for example, decided for search bars with sharp corners that fit the tile-like design of the other elements. Ireland has three different search bars with different shapes for different purposes. This is not nice for consistency; however, it could be that a search bar with a certain appearance is more suitable on certain locations than others. A round search bar as is adopted by France or Google, for example, could look more appealing on a prominent spot on a home page, whereas rectangular search bars with rounded corners look nicer at the top of a page. Since consistency is valued as well, each search bar in the mock-up has rounded corners.

The different button shapes of the analysed portals are displayed in Figure 6.15. Most buttons are shaped like rounded rectangles. For this reason, the buttons of the mock-up are rounded rectangles as well, again with a corner radius of 4px.
Note that differently shaped buttons could be just as user-friendly. What shape is most preferable could depend on trends and is influenced by what works with the general design aesthetics of a portal. Norway does not even adopt traditional buttons but instead uses links, icons, and tiles in a grid that can be selected. The same is true for Luxembourg, where large clickable tiles replace the buttons.

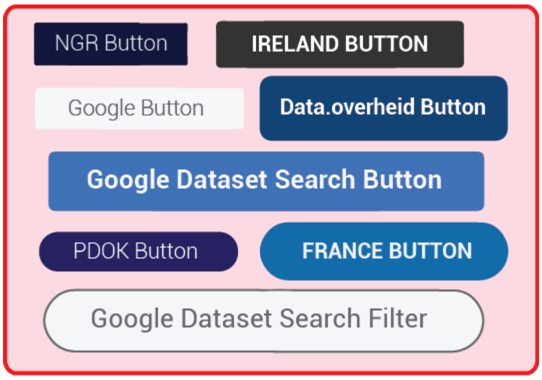


Figure 6.15: Differently shaped buttons on different (geo)portals. Note that these are re-scaled for presentation purposes, the actual sizes differ.

Margin and padding
In a UI there should be enough white space to prevent a cluttered design. How different elements are spaced from each other is determined by their *margin*. Additionally, there should be space between the text inside elements and its border, the *padding*. This is explained in Figure 6.16.

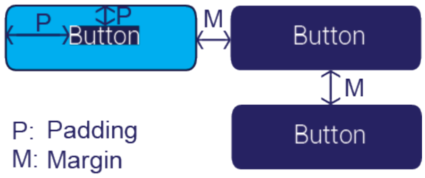


Figure 6.16: Margin and padding explained.

There are no specific guidelines for margin and padding since this depends on the desired aesthetics of a design. In some cases, for example, a negative margin might even look good. Generally speaking, I expected the margin and padding to depend on the size of the element they correspond to.

Analysing patterns in the margin and padding turned out to introduce some challenges. In some portals, for example, elements have a margin on the left due to the right-sided margin of their neighbouring element. There are also cases in which icons on one side of the element result in different padding. Furthermore, the sizes of elements that contain text and their related margin and padding, likely depend on the size of the text. To correct for the different font sizes and units adopted by different portals, I first divided the occurring height values by the corresponding font size, converted px values to rem, and took the median of these converted values. This median times the font size of 1.25rem of the mock-up, provides a desirable height, top and bottom padding. The width, left, and right padding likely also depends on the number of characters captured on a line.

- For images, there is most likely no padding, and the margin is assumed to be larger for larger images, however, I did not manage to select a desirable margin to size ratio based on this assumption. One of the analysed images with a size of 776x586px, for example, had a margin of 24px, where another image on the same portal of 100x100px has a margin of 40px. For the mock-up design, I assess for each separate case what seems most suitable.

- For text blocks, the pattern behind margin and padding also turned out to be complex. In the first place since portals have different preferences in using either margins or padding. All portals except Norway use padding, but only Norway and Data.overheid use horizontal margins. Vertical margins are more popular, they are used by four portals. Furthermore, some portals pick equal values for padding or margins in the horizontal and vertical position, even though the text blocks are not square. Although, the assumption that larger elements require larger white space generally holds, PDOK uses horizontal padding of 6 and 20px for elements of the same text size and width. If a pattern for the ideal padding and margin exists, it likely depends on more parameters than I considered during this limited analysis. As a simple substitute guideline based on the median values of padding and margin related to text size, a minimum horizontal space of at least 1.25rem, and vertical space of 0.833rem could be adopted for a text size of 1.25rem.

- For the search bar, I could not discover a pattern for the margin. Although horizontal padding does seem to be related to the text size, this is less clear for vertical padding. For a text size of 13px, Ireland adopts a vertical padding of 10px, whereas NGR adopts the same padding for a text size of 16px. For its two other search bars related to a text size of 14px, Ireland adopts vertical padding of 2px in one case and 6px in another. When looking at median values, 1rem horizontal, and 0.5rem vertical padding seem suitable.

- For buttons 1.3rem horizontal, and 0.65rem vertical padding could be suitable with a median horizontal margin of 0.37rem and a median vertical margin of 0.22rem.

- For the header, the median horizontal margin for a text size of 1.25rem is 1.1rem.

- For the footer, the median vertical margin is 0.9rem and the median horizontal margin is 0.7rem.

Sizes of elements

The height of search bars and buttons relate to the size of the text, and their width depends on the number of characters. However, for their search bars, Ireland, Luxembourg, and PDOK are inconsistent with this. PDOK, for example, has two search bars of different heights (34 and 52px) for a font size of 14px. Although this font size is below average, their search bar height of 52px is the second highest of all portals. When looking at median values corrected for a text size of 1.25rem, a search bar height of 3rem could be suitable for the mock-up.

Furthermore, the search bar should be sufficiently wide to display the search queries of the user [He et al., 2012]. The median width of the search bars on the home page of the analysed portals is 45% compared to the full width of the viewport. I use this for the mock-up.

For buttons, there are again exceptions to the general rule that their size depends on the text size. The portal of France, for example, has two buttons containing 14.4px text, one is 30px high, while the other is 60px high. When looking at median values corrected for a text size of 1.25rem, a button height of 3rem (48px) could be suitable. This corresponds to the WCAG 2.1 guideline that pointers should be a minimum size of 44 by 44 Cascading Style Sheet (CSS) pixels. The button width depends on the width of the text. Google specifies a minimum button width of 54px (3.375rem).

To determine the height of the header and footer, I could not look into median values due to the differences in layout decisions of different portals. Vertically stacked links, for example, require a larger vertical area, than horizontally stacked links. Except for Norway and France, who adopt a collapsible menu, all portals align menu elements in the header horizontally. PDOK combines this with vertical stacking. For the footer, all portals except Google, NGR, and Luxembourg, also stack links vertically. For the mock-up design, I decided to prevent scrolling, meaning the menu and utility links are always visible. In such an approach, the space occupied by the header and footer should be kept at a minimum, leaving only a limited space for the links. This is a good thing, since it helps keep the pages simple. If required, drop-downs can be used to capture more links. However, this is only feasible for less important elements because such mechanisms make it more challenging for users to assess what navigational decisions they can make.

Because I want to capture a search bar in the header, the header should at least be as high as this search bar (3rem). Norway and Luxembourg also capture search bars in their headers and keep 10px additional margin, France even keeps a vertical margin of 20px. With a search bar of 3rem, this would result in a header of minimal 4.25rem.

For the footer, a text size of 1rem indicates a 2.3rem median height for a single line of text.

The inconsistencies between different cases on the same portal could indicate that it might not be possible or even sensible to establish rules for suitable margin, padding, and the size of elements. Based on the brief analysis I performed, it seems likely that patterns behind sizes and spacing depend on more variables than just the text size. Additionally, the current sample size might be too small to deal with outliers. The values that are discussed in this subsection can be used as possible indications, however, they should not be considered as strict rules.

System interaction

To provide users with feedback regarding the interactive elements of the interface, the clickable elements change colour, and the cursor changes to a pointer upon mouse hover. Upon activation, the elements appear in this changed colour and for the search bar I made the border light up in cyan.

As listed in the GUIDE, multilingualism is important. Two participants of the user session also confirm this. However, for this research, I decided to keep the mock-up in Dutch. This is the most SMART and consistent for my research since the first user session, the datasets, and descriptions are all in Dutch.

The portals of Norway and Luxembourg provide a function to switch between languages on the top right of the screen, so in case this would be implemented, this would be a suitable location.

Relatable subdivisions of dataset

Currently, PDOK provides dataset landing pages for full base registries or overarching categories. This introduces a challenge in the discovery process: when users do not know what kind of data is captured under such an overarching category, it can be challenging for them to find the data they need.

There are two possible solutions for this challenge:

1. listing more clearly what is captured on each landing page,
2. or providing separate landing pages for separate datasets.

Option 1 could clutter the UI, whereas option 2 results in a long list of entries. Provided there are properly functioning search mechanisms, the latter case seems more favourable. This is supported by an expert from PDOK, Moreover, both Data.overheid and NGR take this approach.

Deciding how the individual datasets should be presented is another challenge. As illustrated by Figure 6.17, the different portals of the Netherlands have no consistent approach for this.

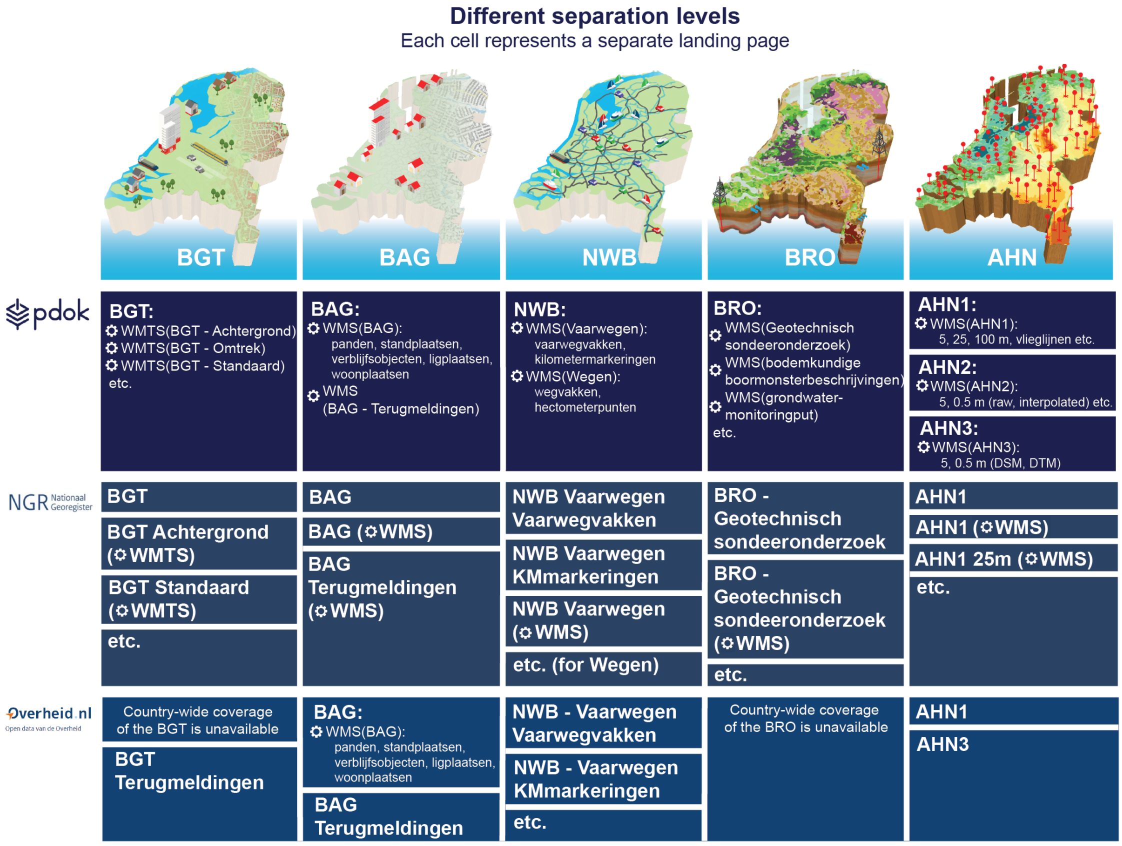


Figure 6.17: Inconsistencies in the presentation of datasets on the Dutch open (geo)portals. For simplicity's sake, not all subdataset options and only the WM(T)S service options are displayed.

The separation criterion I adopted is to provide separate landing pages for each separation of the same service. This means that if there are two WMS service options provided under the same overarching category on the current version of PDOK, these are each assigned a separate dataset landing page. Data.overheid seems to take this approach. However, this is not equally sensible for every dataset; separating each WMTS service of the BGT, for example, makes less sense than separating the different WMS services of the BRO, since the different services of the BGT solely show different representations of the same dataset, whereas the services of the BRO relate to completely different datasets.

Following the logic that separating "different" datasets is desirable, separating the different layers from the BAG would also make sense. However, these are all captured under the same WMS service. Under the condition the BAG can still be found by searching for its different layers, a single landing page could still work. This is reflected by that Data.overheid adopts a single landing page for the BAG. The "BAG terugmeldingen" do have a separate landing page, as these are captured by a separate service.

Separating datasets based on which subdatasets have a separate service can result in inconsistencies if this subdivision is different for different service levels. The NWB, for example, has a download service for "wegvakken", "hectometerpunten", "vaarwegvakken", and "kilometermarkeringen", but a WMS which solely separates "wegen" and "vaarwegen". If this is the case, the finest division of services could be leading. For the example of the NWB, this results in four separate landing pages.

NGR sometimes takes the separation even further and provides separate landing pages for each service. This means that, for example, the "BGT Standard" has a separate WMTS service page, just like the WFS, and so on. This results in a long list of landing pages.

Data.overheid also separates data on coverage. Furthermore, both Data.overheid and NGR also separate older versions of the NWB (e.g. 2011, 2015, 2016, etc.) on different landing pages. This separation criterion is not used in the mock-up since PDOK solely offers full country data and the most recent version of the NWB. However, two participants appreciate having access to different versions and smaller areas. Other than having separate landing pages, a different solution to provide this is to include pointers to different versions of the same dataset from a single landing page.

Navigation

The navigational structure of the mock-up is shown in Figure 6.18.

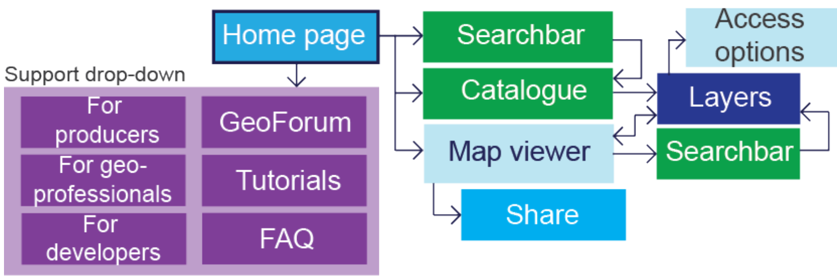


Figure 6.18: The main elements of the navigational structure of the mock-up.

PDOK, NGR, Data.overheid, and the portal of Norway offer so-called dataset landing pages containing more information and access options regarding a specific dataset. These pages are also part of the mock-up. However, instead of presenting them separately, I took the approach of Google Dataset Search and integrated the landing pages with the catalogue page to achieve more efficient interactions.

The full navigational structure is focused on having the most important pages of a portal (the catalogue and the map viewer) prominently accessible from every page. Added to the menu bar links to the default versions of these pages, the catalogue and the map viewer are also linked to work together. Within this flat navigation structure, users can view more information and options by redirecting to the corresponding landing page from the viewer, or directly view a dataset from the catalogue. This is more clear and more efficient than a linear navigation structure that requires many clicks and page visits to arrive at the intended destination. Possible other pages could still be accessible in a more linear way, guiding the user instead of having them select supportive pages from a long list of menu options.

The menu bar of a website can be made collapsible, as is done for the portal of France and Norway. This can make the interface look cleaner, and an expert from PDOK has been advised that a collapsible menu bar is more modern. However, for the mock-up, I decided to keep the menu options of the important pages visible at all times to provide sufficient navigational aid. Because scrolling is prevented, elements covered in the menu bar do not have to be covered in the utility links and vice versa.

The menu bar element of the current page of the user is highlighted in cyan to show them which page is active. Textual breadcrumbs have less value in the flat navigation of the mock-up and are in this case not worth the risk of cluttering the UI. The general help mechanisms of the portal are captured under a drop-down called "Support" to prevent cluttering the UI.

For the placement of the navigational elements, I took into account that users expect a home button to be located on the top left of the screen [Raju and Harinarayanan, 2015], [Bernard, 2001]. In the mock-up, this button is not only hidden in the logo of the portal but also provided in textual form to acknowledge users of the option. The other menu elements are located next to the home button. The order "support - viewer - catalogue" does not match with their importance, however, the drop-down looks best in a corner of the screen.

Communication mechanisms

In the support drop-down, a link to the GeoForum covers the availability of a collaboration system. Furthermore, the contact tab in the utility links provides users with the general contact details of the portal and a contact form which they can use to directly ask a question, file a complaint, provide feedback, or request data. An indication of what this could look like is provided in Figure 6.19.

Additionally, contextual contact buttons should be included to allow users to communicate about the data.

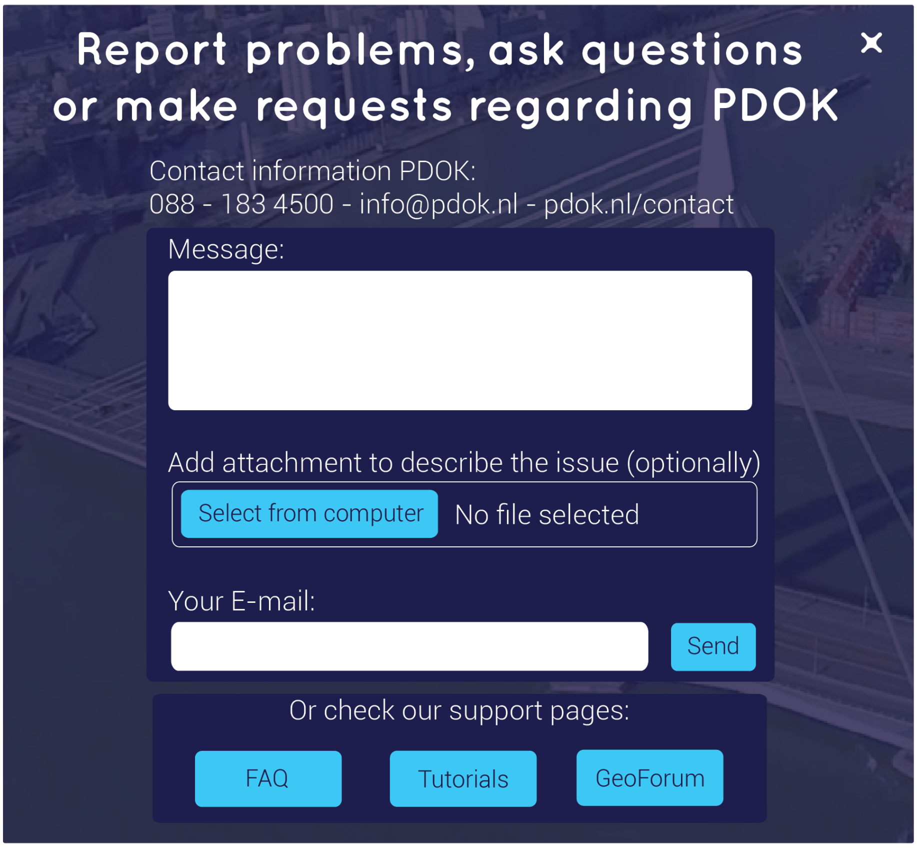


Figure 6.19: General contact dialogue.

Help mechanisms

Where on the page users would appreciate help functionalities to be available is unclear [Raju and Harinarayanan, 2015]. For the mock-up, I decided to capture general help pages in the support drop-down that is part of the menu bar. Furthermore, I include contextual help elements. By providing help close to the corresponding element, users do not have to search for the help they need.

Audience-oriented sections

The option of audience-oriented sections, or even providing more adaptive content, could be achieved by letting users pick their user type on the home page and changing the available options on the portal based on this. Luxembourg, for example, adopts such a mechanism. An example of an interactive feature in which users can select their user type is displayed in Figure 6.20.
Another option is to have separate menu links in the menu bar, as is done for the portal of Norway. Placeholders for this approach are incorporated in the support drop-down of the mock-up.

Figure 6.20: An example of an interactive feature that can be used to let users select their user type. On mouse hover the selection dialogue appears.

Audience-oriented sections must cover content that is of actual relevance for the targeted persona. During my research I did not investigate this, since PDOK (and likely the other portals as well) already has data from elaborate market research covering what their different personas want and need. Based on this data, it is possible to determine what audience-oriented sections have to cover. As an example: for the geo-professional, it could be interesting to provide more information regarding tools such as GIS plug-ins and ATOM services. For developers, it would be possible to provide links to GitHub[2] for documentation and code regarding applications such as the location server and NL Maps[3], documentation about APIs, and examples of how data from the portal can be used in an application. It would also be possible to explain geomatics related terminology or even provide more suitable semantics for this user type.

More specific guidelines than these examples strongly depend on what kind of functionalities are available on the portal. For this reason, I am not covering such guidelines in this thesis.

Tooltips

All clickable elements in the mock-up have a related tooltip in which the effects of a click are briefly explained. For redirections, this involves describing to the users where they will end up. For a download, the tooltip can list the format and the size of the file.
Furthermore, a tooltip as shown in Figure 6.21 can be provided to users in case they hover their mouse over a definition on the page that can be unfamiliar to them. For abbreviations, PDOK sometimes already adopted this mechanism. In the FAQ, for example, one could hover over PDOK to get a tooltip displaying "Publieke Dienstverlening Op de Kaart".

Figure 6.21: Example of a tooltip appearing if users hover their mouse over an unfamiliar definition.

[2] https://github.com/PDOK
[3] https://nlmaps.nl/

6.2.2. Home page

The home page is the first thing users see of the portal and should show what the portal is about [Guntupalli, 2008]. For a geoportal, this means the home page should provide a starting point to the most popular functionalities. The home page of the mock-up is displayed in Figure 6.22.

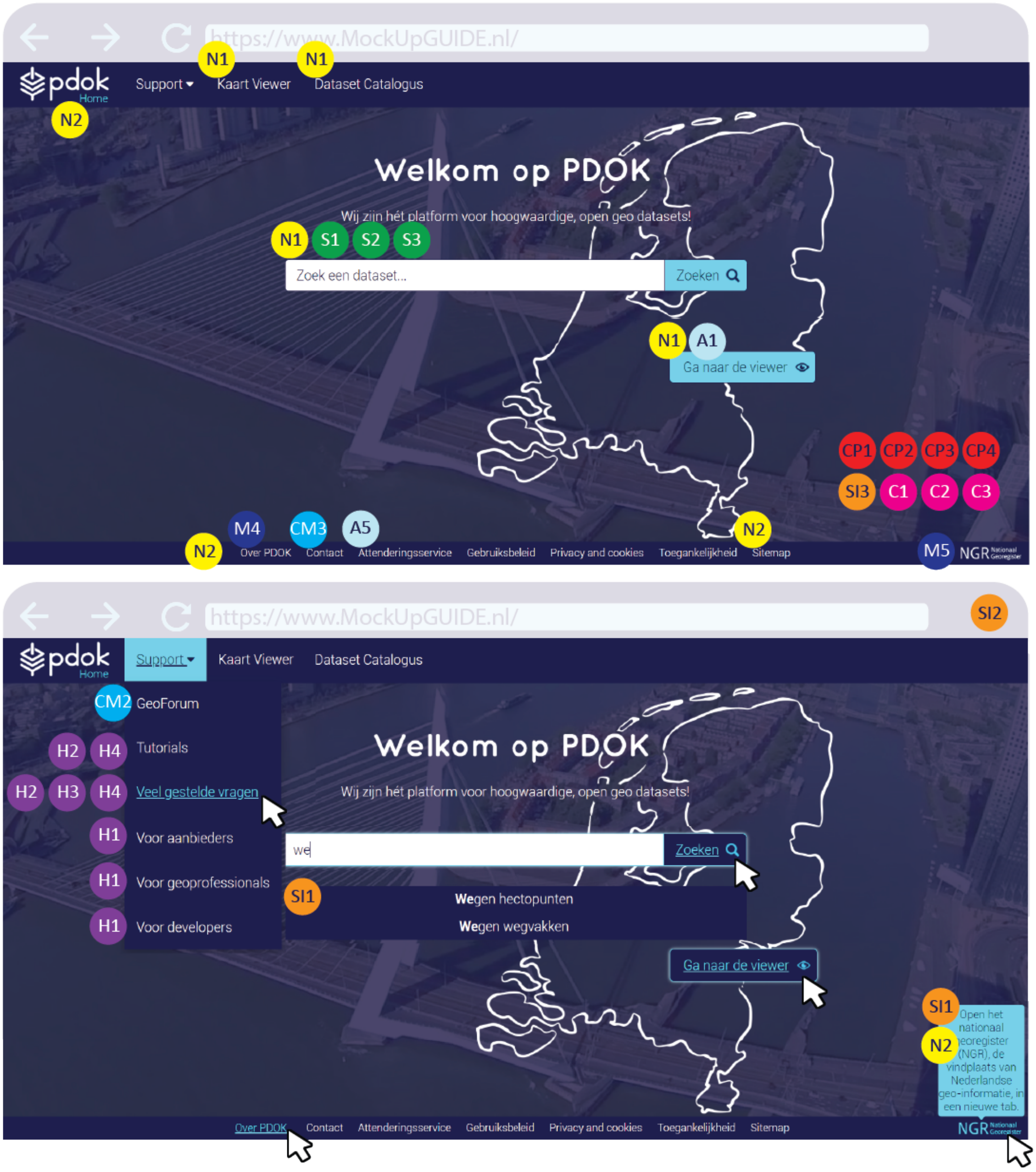


Figure 6.22: Home page of the mock-up design according to the UI design elements as listed in the GUIDE. The lower part of the image is meant to indicate how the possible interactions look on the page.

Content presentation

The analysed portals display all kinds of different elements on their home pages. Since it is desirable to keep things simple (CP4), I decided to display as little elements as possible. By doing this, the home page of the mock-up becomes similar in appearance to the homepages of NGR, Google, and Google Dataset Search. This approach is supported by the comment of one user in the benchmark session who mentioned (s)he appreciated the homepage of NGR more because it clearly showed them what they needed from the portal: discovering data.

Users are supported in discovering data by providing a keyword search bar. On a home page, users prefer such a search bar to be located on the optical centre of the page [Bernard, 2001]. Except for Norway, the portals I analysed place the search bar on roughly the same height. When disregarding this outlier, three portals place the search bar on their home page at around 40% height from the total viewport height seen from the top of the page. Google and Google Data Search place it at around 30%. For a geoportal, 40% might be the most suitable, so I used this for the mock-up.

With this search bar location and the location of the viewer button, the content on the home page is distributed over the page following the rule of thirds (CP2).

The contour of the Netherlands I added in the background, is not only used to show the scope of the portal but also to visually group all elements captured on the home page (CP4).

System interaction

In the case of redirections, users are warned they leave the mock-up by the link text and with tooltips. This is, for example, the case for the NGR logo in the bottom right of the footer (SI1).

Upon selection of the search bar, it lights up (SI2). Once the user inputs a key, corresponding autosuggestions are displayed. There are several possibilities of dealing with these suggestions. I decided to load the search suggestion in the search bar once users click it, upon which they can confirm the search by clicking the search button or the `enter` key. An advantage of this additional confirmation step is that users can correct for an erroneous selection (SI1). Another possible approach could be to directly redirect a selected autosuggestion to the catalogue once it is selected.

The functionalities of the buttons are clarified by the use of both icons and text. The placeholder "Zoek een dataset..." ("Search a dataset") in the search bar also suggests its functionality (SI3).

Navigation

The search bar that is linked to the dataset catalogue has a prominent location on the page to support data discovery. Since geoportals are based around maps, a button to the map viewer also deserves a prominent spot (N1).

Search

Once a user starts typing an input keyword, autosuggestions are presented (S3).

On the home page of the mock-up, users cannot select any advanced search options to prevent cluttering the interface (S4), (S5).

6.2.3. Catalogue page

The catalogue page should support data discovery. For the mock-up, the catalogue page integrates the dataset landing pages as is done by Google Dataset Search. Such landing pages should support data assessment and access. This is displayed in Figure 6.23.

Content presentation

On NGR, Data.overheid, PDOK, and the portal of Norway, the search results are presented in the middle of a dedicated page, surrounded by lots of white space. This results in clean pages on which it is easy to spot individual headers. However, users need to click a search result and redirect to a dedicated landing page to acquire more in-depth information and get to the corresponding access options. In case they select the wrong dataset, they need to go back and repeat the process. On the landing page, the users again have to scroll to get to the information or access option they require. If users are unsure if what they are looking for is present on the page, this can be a cumbersome process.

Integration of a dataset landing page as a featured search result on the catalogue page allows for more direct interaction between the landing pages and the catalogue and prevents the need for redirections. An expert of PDOK thinks this integration of searching and providing more information and access options embodies what most users want. (S)he expects that most things a user could need on the portal is presented on the catalogue page of the mock-up. To be able to provide a direct overview of all available information, I also omitted the need to scroll on the default page of the featured result. This prevents users from overlooking information (SI1), (N1).

The current catalogue page of the mock-up increases the efficiency and intuitiveness of discovering data. However, there is a lot of information captured in a single view. The symmetrical look of the page helps to present all this in a more balanced, calmer way (CP2).

Figure 6.23: Catalogue page of the mock-up design according to the UI design elements as listed in the GUIDE. The lower part of the image is meant to indicate how the possible interactions look on the page.

Presentation of access options (left)

Accessing the data is important to users, so I presented the access options on a prominent location in striking colours (CP4). With the larger text size, the corresponding buttons are also relatively large. This is striking and it makes pointer interactions easier for a wider range of users [WCAG, 2019] (CP3).

The order in which the different access options are presented can be adapted based on the previous behaviour of the user or the most frequent behaviour of users with similar browsing patterns.

Presentation of the featured result (middle)

In the middle part of the view, the metadata information is covered. By limiting this information to the "basic metadata" preferred by users and used on existing portals, I tried to keep the amount of information to its minimum. This basic information can be extended with drop-downs or redirections to related information channels in case the user is looking for more in-depth information or tools (CP4).

Regardless, the amount of information covered on the page is still relatively large. To compensate for this, I tried to keep this part of the page as calm as possible by using little colours and text-decoration. Scannability is still supported by the bold headers and the tabular-like blocks.

Presentation of search mechanism (right)
The upper right corner of a page is the location users are most likely to expect a search bar [Raju and Harinarayanan, 2015], [Shaikh and Lenz, 2006], [Ström and Whitehand, 2006]. However, the catalogue page of a geoportal might be a special case; on the catalogue pages of other portals, the search bar often has a prominent spot in the centre of the page. Because the mock-up uses a different strategy, this space is reserved for the landing page of the featured result. Google and Data.overheid do move the search bar, but they place the bar on the top left. This matches the approach of Google Data Search, in which the search results are presented on the left of the page. Since it would make more sense to put the search bar closer to these results according to the Gestalt law of proximity, this would mean the search bar could also be placed on the top left of the page. For the mock-up, I decided to keep both the search bar and the results on the right of the page because this is more balanced with the navigational menu bar elements on the left. The importance of the search mechanism is established by the cyan I used to mark the active featured result (CP4).

To achieve familiarity, I kept the look of the search bar in the catalogue similar to the one from the home page. I did decrease the width to fit its current location. Based on the median width of search bars in navigational headers of the portals I analysed, a preferable width is 25% of the viewer width.

System interaction

As a way to respond to the actions of users, I implemented a so-called "toast". This notification appears once the users select one of the access buttons. For a download, it is first acknowledged the download has started, upon which the toast remains visible during the download process displaying a progress bar. Once the download is complete, this is listed as well. The buttons related to geo-web services are linked to copy the corresponding service URL. The toast linked to these buttons shows the result of their action ("WMS URL copied") and the URL itself, so that users who prefer this can manually copy it again, or visit the corresponding destination (SI2). The toast disappears after three seconds. This is enough to spot and read the message. I also added a cross users can use to discard the message (SI1).

The API and linked data options are linked to a separate page to which the users are redirected. This is expected behaviour thanks to the button and tooltip texts (SI3).

Navigation

More direct interaction between the catalogue and the landing pages is desirable for more efficient data discovery. On the catalogue page, this is achieved by integrating landing pages (N1). Users can pick a search result from the list on the right of the screen. Upon activation, the corresponding landing page is displayed as a featured result. The landing page displayed upon initialisation of the catalogue page corresponds to the top result of the search list. This top result is either based on a previous query, or, if this is unavailable, the dataset that is the default top result in the adopted sorting mechanism. The featured result automatically adapts on each key input of the user. In case users revisit the catalogue page in a single session, the landing page of the result that was most recently active is displayed as a featured result.

In case the portal uses an adaptive mechanism to store the preferences of the user, the default featured result can be the dataset the user most frequently visits.

Search mechanisms

In the mock-up, the keyword search mechanism is dedicated to datasets. For this, I included the metadata and title of the dataset as search tags (S3). The GUIDE prescribes that searching on location is also desirable. I did not implement this specifically since this is irrelevant for any of the tasks in the user session. However, because the location is part of the metadata, this is automatically handled (S1).

Upon each key change in the search query, the list of search results and the corresponding featured result is adapted, auto-completing the search. If there is no match, the mock-up displays the following message: "We could not find a result for the keyword "INPUT KEYWORD". Please try a synonym or a different spelling." (SI1). PDOK and the portal of Luxembourg do not even provide such a message.

However, it would be best to prevent such a message from occurring. To do this, I included numerous tags with various spelling and synonyms for the available datasets. This solution works for the relatively small number of datasets used in the mock-up, however, an elaborate tagging process can become cumbersome for large amounts of data. A so-called fuzzy search would also provide results in case a keyword is no perfect match to a tag. Based on the fuzzy search results, it would be possible to present "did-you-mean" suggestions (S3). Because fine-tuning the threshold and implementing such a mechanism is a complex process, I did not attempt this for the mock-up.

Some participants of the user requirement session would appreciate advanced search options to sort or filter search results. However, always displaying advanced search options on the screen can take up a relatively large amount of space and might confuse users. For this reason, I included a button next to the search bar to turn advanced search options on and off. In case they are on, they replace the featured dataset on the left of the screen. This helps to maintain a clean page.

Searching on themes (S2), filters (S4), and sorting (S5), are all part of the advanced search dialogue of the mock-up (see Figure 6.24). An expert of PDOK supports that these filters would be a nice addition. The lack of filters on PDOK has to do with the technical limitations that occurred at the time the catalogue was developed. With filters and options to sort, users are more likely to get the results they are looking for. Note that although I included the filter categories in correspondence to the GUIDE, I did not consider all possible dataset formats or organisations. Instead, I included some popular dataset formats and organisations to visualise the general idea. In an actual implementation, all available formats and organisations should be covered.

How the advanced search options are sorted in the dialogue can be made adaptive depending on previous use or the preferences of users with similar browsing behaviour. Filters that are used more often by a specific (type of) user can be displayed more prominently and can even be activated on default.

Figure 6.24: Advanced search options as described in the GUIDE.

Searching on data based on themes (S2)

The themes I decided to adopt are the same PDOK uses because this selection of themes is already linked to the available datasets. However, I did make some changes: PDOK solely adopts the theme "transportation" for the NWB, I also matched the "inland water" theme to suit the waterway datasets of the NWB. Additionally, I matched the dataset containing "zeegebieden" to the "oceans" theme. Note that I solely displayed the themes of the limited datasets available in the mock-up. Displaying themes without any corresponding datasets could confuse the participants of the user session.

The icons are mainly inspired by the icons of NGR. I took the liberty to replace icons I did not think made sense; the water droplet for inland waters, for example, could be better represented by a river shape, the anchor related to oceans seems to be better represented by a wave, and I replaced the flag of NGR with a vertical arrow to suggest height. This redevelopment process is not scientifically sound, as it is mostly based on my own mental model and some limited examples from existing portals (SI3).

Filtering data (S4)
The available input options for filtering must be suitable for the desired input value [Shneiderman, 2004] (SI1). When there is a relatively small amount of fixed values, checkboxes are an easy way to ask users for input. For a larger amount of fixed, numerical values, a range slider can be more suitable. This is, for example, the case for the time input. A more modern approach would be to allow users to select a range of dates by clicking on a date in a calendar interaction mechanism. Allowing users to input a string allows more freedom but is more error-prone and is thus only suitable when there are too many options to allow a checkbox selection and users know what kind of input is expected from them. This is the case for a location input. Setting a bounding box by directly drawing a polygon on a map could also be suitable for this. PDOK solely offers country-wide data, however, specifying a bounding box could also be used to cut country-wide data to a specified region.

Sorting data (S5)
In the mock-up, users can sort data alphabetically and on relevance. As suggested by one participant, sorting on relevance is the default. Several aspects could indicate relevance. For a fuzzy search, the best matching keyword should be sorted the highest. However, some datasets could have the same tags that match equally well to the submitted keyword. For such cases, it is possible to add importance values to a certain tag of a specific dataset. This way, the keyword `roads` sorts the NWB before a dataset covering a noise map of major roads. When the importance values of tags are similar or cannot be specified, the relevance of a dataset can also be determined by collaborative filtering techniques or the previous behaviour of a user. In case a dataset is more popular in terms of downloads or views, this dataset can be considered to be more relevant.

Existing portals also allow users to sort data based on update date. Since the follow-up experiment does not require users to access the most recent data, I inserted a non-functional placeholder for this.

Communication mechanisms

Share mechanism (CM1)
On the upper right of the landing page, a share button is located. Upon selection of this button, the dialogue as shown in Figure 6.25 is displayed. Each of the icons can be clicked to go to a dialogue of their related (social media) channels. These dialogues then display a default post with a link to the shared page. Users are enabled to edit and share this post. Additionally, they can copy a link to the landing page to their clipboard.

Figure 6.25: The look of the UI when the share button is selected. The interactions and look of the share mechanisms are based on those from the thematic map viewer page of Norway and the portal of France.

Contextual contact button (CM3), (CM4)
A contextual communication dialogue concerning a dataset could look as displayed in Figure 6.26. I based this dialogue on a combination of the contact form of the portal of Luxembourg, and Verbeterdekaart.nl. The option for attaching a file is currently already available on Verbeterdekaart.nl, however, the file size is limited, and the accepted formats are restricted to formats such as PDF or image files. Supporting actual data uploads would enable users to rectify mistakes. By displaying rectifications and reported issues on the map, users are enabled to work with each other's warnings and solutions.

For portal owners, such services result in challenges since they should be provided for all available datasets. If not all source holders offer such services, it is not the responsibility of the portal owners to provide them. An expert from PDOK comments a contact form dedicated to datasets would mean they have to forward comments to the corresponding contact address of the data owner and having to deal with their response times. PDOK cannot influence this. According to this expert, most users use the GeoForum anyway because this is quick.

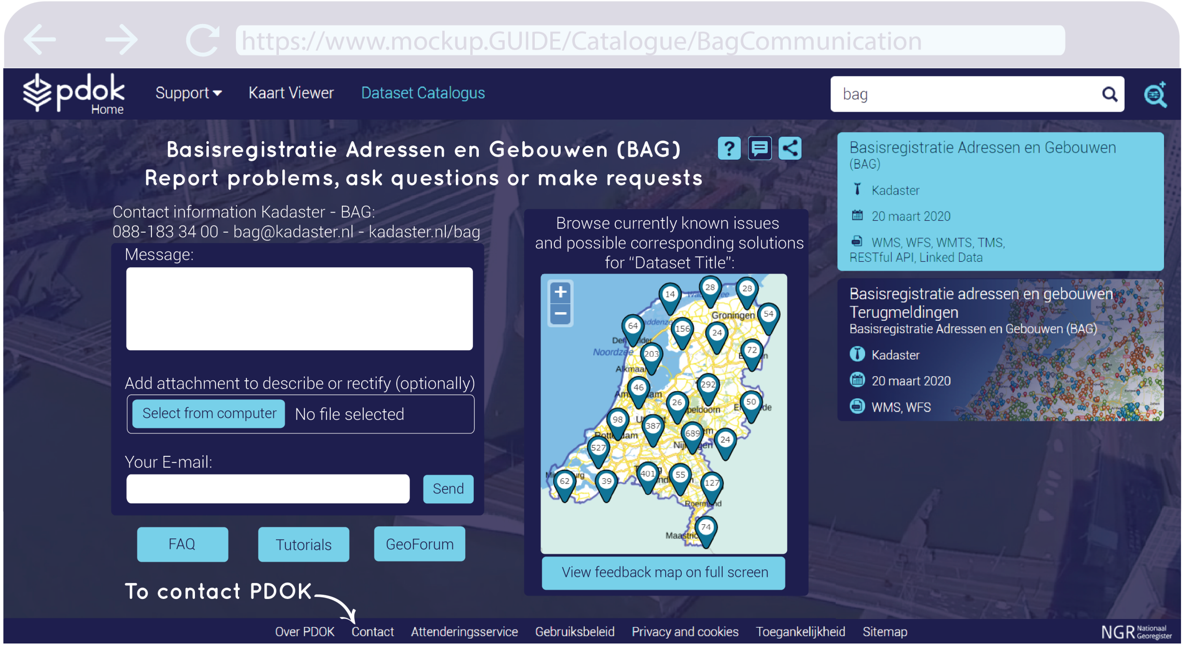


Figure 6.26: Contextual contact options for an active dataset.

Metadata

All "basic" metadata elements listed in the GUIDE are aggregated on the dataset landing pages of the mock-up as human-readable text (A2). Unlike NGR, PDOK is no catalogue service. This means their focus is broader than just providing metadata. In this sense, linking to NGR for more in-depth metadata could make sense. However, it would be possible to replace the link to NGR on the mock-up with a direct access option to the standardised metadata in XML format (M2).

During the benchmark, two participants additionally commented that the redirection from PDOK does not take them to the relevant part of NGR. Instead of the "downloads, views, and links", they want to see the "description" tab when they are looking for metadata. Making sure users end up on the intended part of the page is something to keep in mind with all redirections (M5).

The information texts of the mock-up I mostly copied from PDOK. In case these texts were unavailable or inconsistent, I adapted them based on information from other official sources such as Geonovum or the websites of the base registries (M9).

Metadata elements in search results

There is a risk of cluttering the page if too many metadata elements are displayed for each search result. Participants comment they most likely need the title, most recent update date, available file formats, and the source holder. These are also the most popular options to display among the analysed portals. Furthermore, the participants would like to see visualisations to help them assess the fitness for use of a dataset (CP6).

Moreover, existing portals frequently list elements related to tags, themes, subjects, or keywords. In the mock-up, I did not include this, since these kind of things are more likely to be used as a filtering mechanism than to define fitness for a use case. Data.overheid, NGR, PDOK, and Ireland additionally show a short description of the dataset in the list of search results. For the mock-up, this would make the list of search results too extensive.

Specifically, for the situation of PDOK, users also mention they missed a way to see what datasets are captured under an overarching base registry. In the mock-up, this issue has been taken care of by showing all captured datasets separately. Additionally, the overarching base registries are shown to allow users to search on this as well. Data.overheid and NGR also do this.

Metadata elements covered under a contextual information button
During the benchmark session, two participants requested contextual information buttons. The information captured under such a button can support users by informing them on what to expect, and how to proceed if they would perform a corresponding action. This could, for example, include the corresponding file format and file size, and some brief information about what the format is and how to use it. Data.overheid implements such buttons to provide metadata information about a corresponding service. In the mock-up, a link to this information on NGR is provided. Repeating and aggregating this data would also be an option if desired.

Help page catalogue
Examples of how contextual help can be provided in the catalogue page are displayed in Figure 6.27.

Currently, PDOK offers a general "inspiratie" ("inspiration") page with example use cases. These can also be mentioned in the context of the dataset (H2). The examples displayed in Figure 6.27 come from the BAG website[4]. How the most recent posts on the GeoForum are displayed (CM2), is similar as is done on PDOK.

Upon hovering a filter option or jargon in the catalogue, a tooltip with additional explanation is provided (H3).

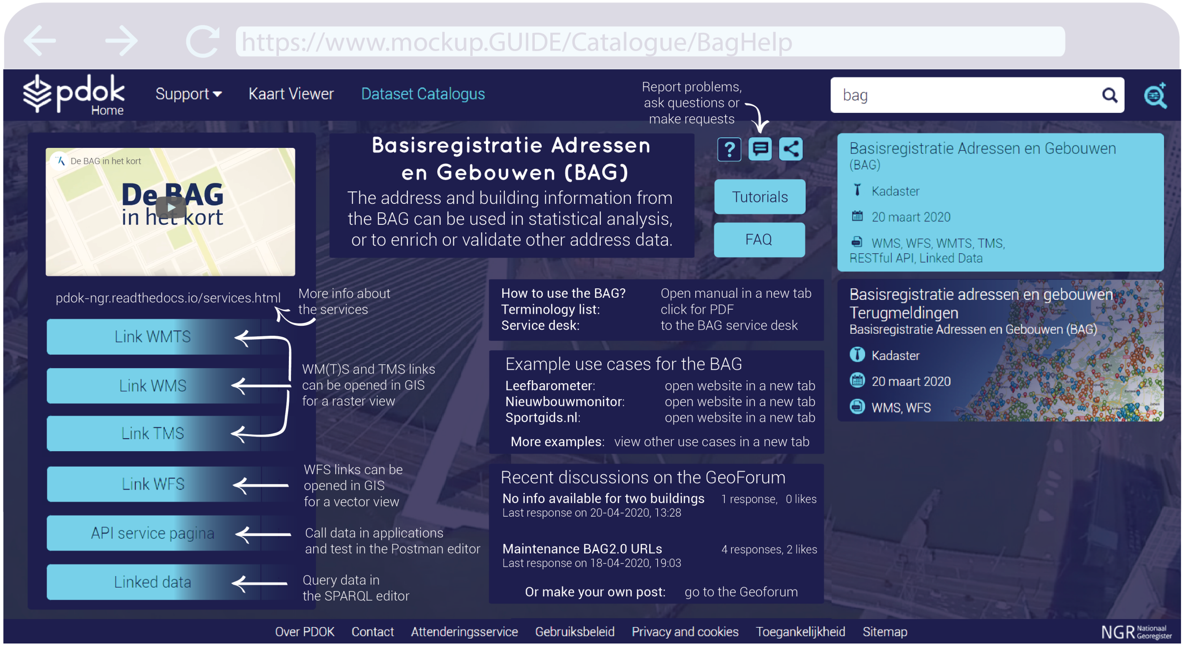


Figure 6.27: Contextual help page for an active dataset in the catalogue.

6.2.4. Map viewer page
Within the map, discovery functionalities, data display, and data retrieval can potentially be accomplished [Kellenberger et al., 2016], [Resch and Zimmer, 2013]. In line with this, the map viewer page of the mock-up looks as displayed in Figure 6.28.

Content presentation
The map viewer page is an exception where the rule-of-thirds and golden-section ratio is not applied to reserve as much room as possible for the map (CP2).

The different elements that should be available in the map viewer and an analysis of their most preferable location are listed in each corresponding subsubsection.

[4] https://zakelijk.kadaster.nl/klantenservice-bag

Figure 6.28: Map viewer page of the mock-up design according to the UI design elements as listed in the GUIDE. The lower part of the image is meant to indicate how the possible interactions look on the page.

System interaction

Some datasets offered on PDOK are unavailable at a certain zoom level. The redirections from the catalogue page to a view of the corresponding dataset and the search bar handle this by directly zooming to the required minimum level. In the layer dialogue, the checkboxes of layers that are unavailable at a specific zoom level are still shown to acknowledge the availability of the layers. To clarify users have to zoom to view these layers, I included a tooltip (SI1).

In case a map feature can be clicked for additional information, it highlights upon mouse hover (SI2). To prevent possible confusion about the purpose of both search bars, the place holders “View data in the viewer...” and “Search a location...” are included (SI3).

The portals that support mechanisms for drawing and/or making measurements in the map mostly adopt similar controls: the cursor is changed to a point, once the user clicks the screen the process starts, and double-clicking confirms the action (SI3).

Zooming and changing the map extent (SI3)

All of the analysed map viewers could be panned by clicking and dragging the right mouse button and all map viewers allow zooming with the scroll wheel of the mouse, or by clicking a dedicated zoom button. The buttons that influence the zoom level or extent of the map are displayed in Figure 6.29. The top left is a popular location for this. Some portals also provide buttons to go back to the default extent of the map view. These vary from a house to the outline of the country. On NGR, this symbol is the same as the symbol of France and Luxembourg to show a full-screen map. This can be confusing. A target circle is used by France, Ireland, Norway, and Google to allow the user to go to their own location on the map, Luxembourg uses an arrow symbol for this. These are all optional functions I did not include in the mock-up.

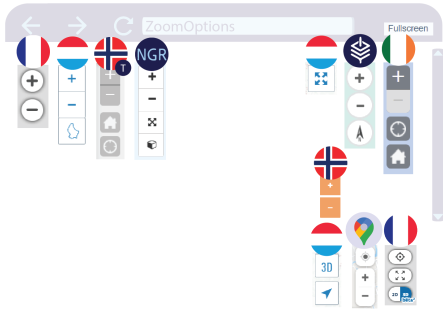


Figure 6.29: Mechanisms of different portals to change the extent of the viewer. The elements displayed in this figure are not on scale, and the position is no exact representation.

Layer selection menu

The analysed portals either have a layer selection dialogue that is always open or implement a collapsible menu. The positions of these layer selection elements are shown in Figure 6.30.

Norway and Ireland have two selection menus, the regular layer selection dialogue, and an additional mechanism dedicated to the selection of background layers. For the mock-up, I decided to include this separation as well to deal with the confusion the participants experienced with the separation of "base layers" and "remaining layers" currently adopted by PDOK. In the layer dialogue of the mock-up, both overlay, and base maps are displayed without any separation. To change the background layers, the collapsible tiles in the lower right of the screen can also be used (CP5).

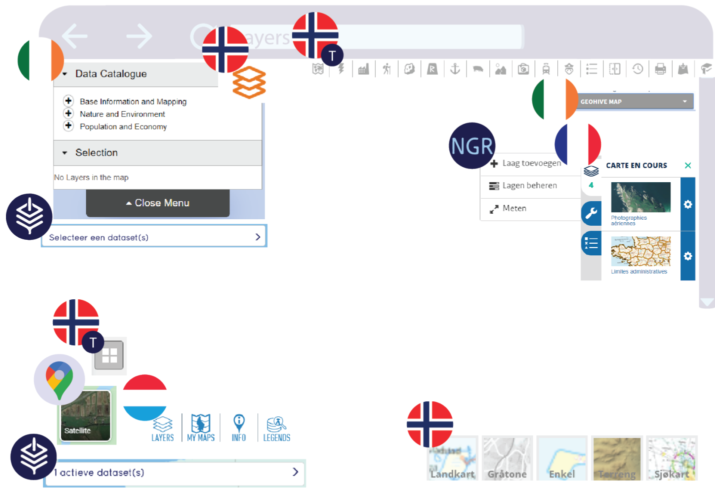


Figure 6.30: The position of the layer selection dialogue in the analysed portals. The elements displayed in this figure are not on scale, and the position is no exact representation.

Comparable to PDOK, I created a separate entry for each separate layer of a dataset in the layer dialogue of the map viewer of the mock-up. Without this separation, displaying the AHN or the BAG, for example, would result in an illegible overlay of different layers. It would be possible to cluster these entries under an overarching header, as is done on PDOK. An advantage of this approach is that this results in a shorter list of datasets. However, users who are unfamiliar with what subdatasets are captured under such an overarching header, experience more difficulties in discovering the data they are looking for. For some datasets, such as the AHN, this is less of an issue since each layer specifically refers to the AHN. However, for the BAG and BRO problems could occur. For the mock-up, I decided to consistently display all datasets without any overarching headers.

Similar to the portal of Norway, whether or not a layer is active in the mock-up is indicated by checkboxes in the ordinary layer dialogue. All other portals display the active layers separately. I did not manage to implement such an "active layer" dialogue during this research, however, the situation as displayed in Figure 6.32 would be more preferable.

Navigation

Presenting multiple options makes the UI more usable [Arnold, 1998] (N1). There are three different ways to activate a dataset in the viewer of the mock-up:

1. redirecting from a corresponding landing page,
2. searching a dataset based on keywords,
3. and checking a box in a layer dialogue.

In the thematic viewer of Norway, a link to additional information is available to redirect users to the dataset landing page. I implemented this approach for the mock-up as well (N1).

Search mechanisms

On the catalogue page, a search bar for data is displayed on the upper right of the screen. However, only NGR displays a search bar on the top right of the map viewer page. France, Ireland, Norway, and Luxembourg have a search bar in the centre in the header of their viewer, and the thematic map viewer of Norway, Google maps, and PDOK display a search bar on the top left. To maintain a consistent layout and recognisable features, I still located the search bar for data on the top right of the map viewer.

Upon activating this search bar, the UI looks as displayed in Figure 6.31. In this dialogue, I limited the options of the users to activating a dataset in the viewer to avoid confusion.

A more preferable solution I did not manage to implement would be to directly enable searching the layer dialogue as shown in Figure 6.32. This option links the search bar to the objects it applies to more clearly by following the Gestalt laws in placing related objects closer together.

Figure 6.31: Mock-up UI upon activation of the search bar for data in the map viewer.

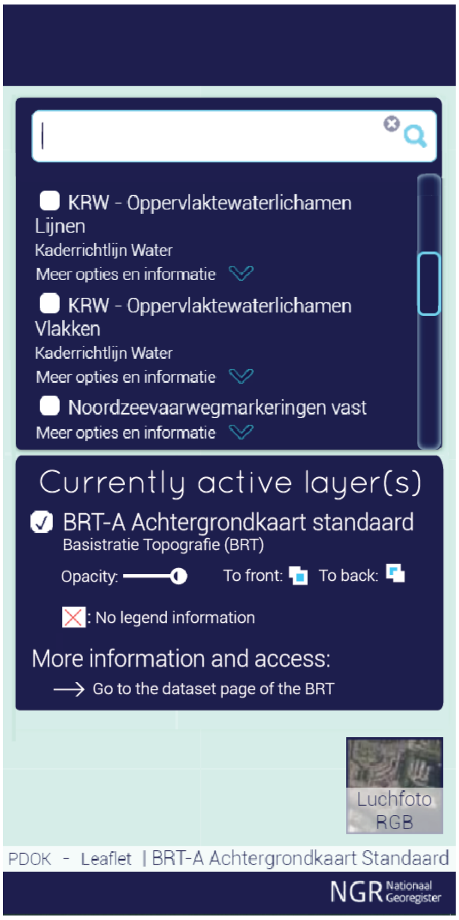


Figure 6.32: More preferable layer dialogue with integrated search bar and active layers.

In the map viewer of the mock-up, a search bar for locations is located on the top left of the map canvas. This search bar looks different than the search bar for data to distinguish both and to make the search for the location fit in with the other map tools. France, Ireland, and Luxembourg allow users to search for both data and locations using the same search bar, the other portals only allow sole data or sole location search. Although none of the portals adopts two separate search bars for location and data, the front-end developer recommended it could be nice to keep these separated. The reason for this is that it is very important to keep the results separated. The user should be able to tell if a result is either a portal element, a map, or a location. By offering two separate search bars, this separation is the clearest. In case the same search bar is used for multiple purposes, the results need to be separated on their type and it could also be possible to allow users to specify what they want to search for. This is implemented in the map viewer of France, and one participant mentions such a functionality as a possibility.

Access mechanisms (tools for data analysis (A3))

Scale and cursor coordinates
The different ways in which different portals display the map scale and cursor coordinates are displayed in Figure 6.33. Stacking scale information and cursor coordinates on the bottom left seems the most preferred approach. In case multiple CRSs can be used, the one that is employed should also be displayed (see Luxembourg).

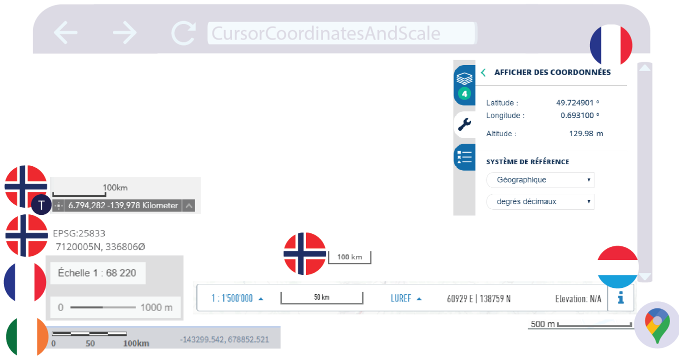


Figure 6.33: The way in which cursor coordinates and map scale are displayed on the different portals. The elements displayed in this figure are not on scale, and the position is no exact representation.

Measurement and drawing tools
The positions of tools that enable users to measure or draw on the map in existing portals are shown in Figure 6.34. Instead of implementing these mechanisms in the mock-up, I positioned placeholders on the upper right of the screen. Combining the most common implementations by other portals, a possible look of a measurement functionality in a UI is provided in Figure 6.35, for drawing mechanisms, this is displayed in Figure 6.36.

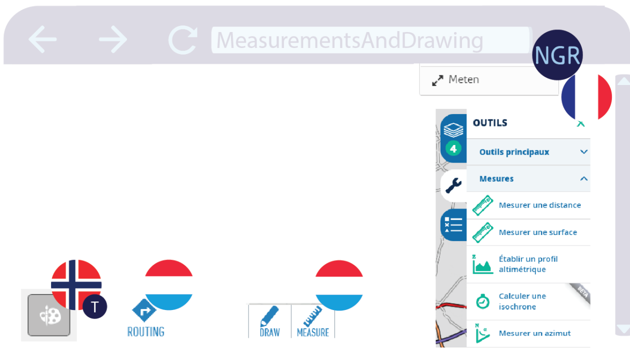


Figure 6.34: The way in which measurement and drawing tools are located in the different portals. The elements displayed in this figure are not on scale, and the position is no exact representation.

As shown in Figure 6.35, different possible measurements on the map include length and area measures. Additionally, France and Luxembourg support measuring an azimuth, height profiles, and isochrones. This could be achieved with a similar menu. The height profile can be displayed in a dialogue based on a line users draw on the map. To display isochrones, users can, for example, select a centre point and a preferable distance.

After selecting the desired tool, the measurement can be started by clicking in the viewer and can be confirmed by double-clicking. These instructions show on the screen when activating the measurement tool, as Luxembourg does. Upon hovering over the different elements, additional instruction about their purpose should also be provided in the form of a tooltip.

The measured values can be displayed together with their corresponding geometries on the map view (France, Luxembourg), or in a separate dialogue (NGR).

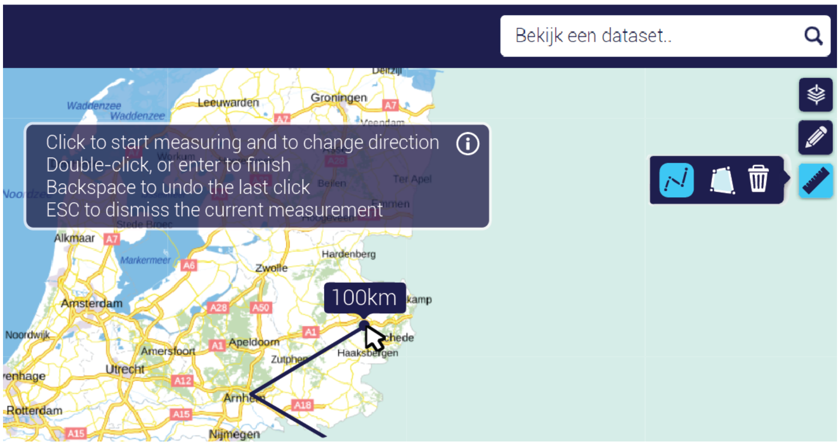


Figure 6.35: Possible implementation of measurement functionality in a map viewer of a geoportal. The portals of France and Luxembourg are the main inspiration for how this feature is represented. To ensure the legibility of this visualisation, only half of the viewer screen is shown.

France, Luxembourg, and Norway all support annotating the map with points (or markers), lines, polygons, and labels. A possible implementation of such drawing mechanisms is shown in Figure 6.36. In the existing portals, clicking on a drawn object could result in information regarding its measurements.

Furthermore, editing the colours, annotations, or even shapes of a drawn object can be achieved by selecting it. This selection can, for example, be acknowledged by surrounding the selected shape with a highlight. The customisation options displayed in Figure 6.36 are suggestions and can be extended if this is desirable. Furthermore, different options are possible to suit the different types of annotations, lines, and markers, for example, have no fill colour.

Selecting the thrash can icon before selecting an object results in the removal of that object. A "remove all" button could also be a possibility.

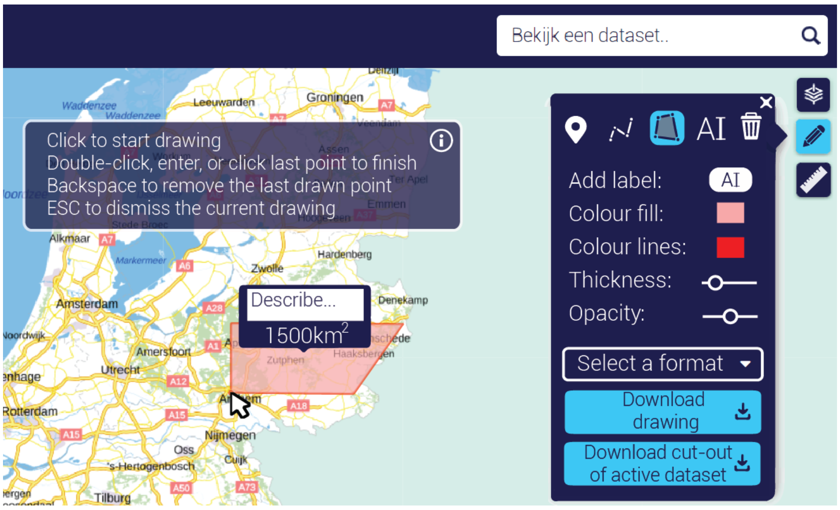


Figure 6.36: Possible implementation of drawing functionality in a map viewer of a geoportal. The portals of France and Luxembourg are the main inspiration for how this functionality is represented. To ensure the legibility of this visualisation, only half of the viewer screen is shown.

Luxembourg offers users the possibility to export their drawings. Furthermore, the drawing tools can be used to integrate data access in the viewer. An option for such a mechanism includes allowing users to download all data inside a specified polygon. For datasets that can be downloaded in such a way, a button on the corresponding landing page can redirect users to a separate page on which they can select an area on the map for download purposes using similar controls as the polygonal drawing mechanism.

Overlaying layers
Next to (de)activating layers, some portals allow changing the opacity or the order of layers in the active layers dialogue (France, Ireland, Luxembourg, Norway, NGR).

Furthermore, Luxembourg, the thematic viewer of Norway, and NGR enable users to upload map layers in various formats or through the URLs of geo-web services. Both Luxembourg and NGR offer this option in the layer selection dialogue.

Communication mechanisms

Communication mechanisms on the map involve options to share the current map view and feedback buttons to report mistakes or ask questions regarding a certain map view. The positions of these elements are shown in Figure 6.37.

Share mechanism (CM1)
For sharing the map view, the same options as in the catalogue (previously displayed in Figure 6.25) are present. Moreover, it is also possible to allow users to embed the HTML code of their map (A4). This could look as displayed in Figure 6.38.

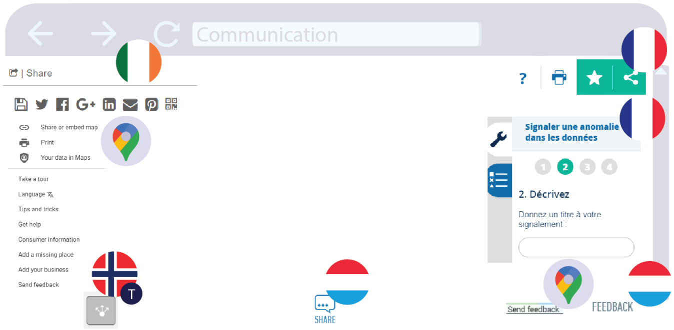


Figure 6.37: The position of the communication mechanisms on the different portals. The elements displayed in this figure are not on scale, and the position is no exact representation.

Figure 6.38: The look of the UI when the share button is selected, based on the thematic map viewer page of Norway and the portal of France.

Contextual contact button map viewer (CM3), (CM4)
A contact form linked to a contextual contact button in the map viewer is displayed in Figure 6.39. By ticking a box, users can specify whether their question relates to a specific dataset or the portal itself. Depending on what box they tick, they get different information and options in the rest of the form.

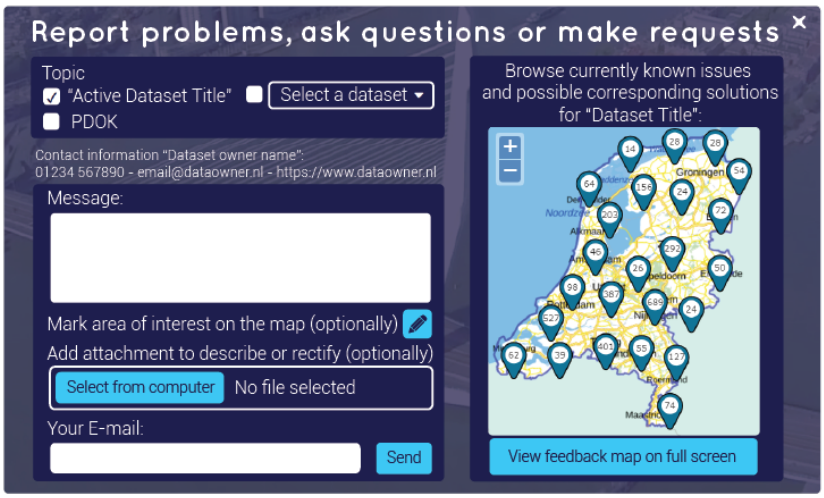


Figure 6.39: Communication mechanism on the map viewer page.

Metadata

Metadata displayed in the map viewer is most often accessible through an information button related to the layer header in the layer selection dialogue (France, Ireland, Luxembourg, Thematic viewer of Norway) (M9).

Attributions (M5)

Attributions are traditionally a way to acknowledge or link to providers of the layer (A5). In the mock-up, I used them to indicate what layers are active in the viewer. I picked the bottom right of the view for this, as is done on Ireland, the thematic viewer of Norway, NGR, and Google maps.

Legends (M7)

Legend information can be part of the information captured in the layer selection menu (France, Ireland, Luxembourg, Norway, Thematic viewer of Norway, NGR).

Object information (M7)

All map viewers of the analysed geoportals allow users to left-click a map feature for more information (A3). This so-called object information mostly consists of a list of attributes. What should be contained in such a list, depends on the available information per dataset, and can thus not be prescribed. However, there are different ways in which the available object information is presented to the user: PDOK uses a dedicated dialogue, Luxembourg a layer sidebar, and France, Ireland and Norway show a pop-up upon selection of a feature. The latter approach is recreated for the mock-up.

An example of a possible object information dialogue for the BGT is displayed in Figure 6.40.
Two participants of the benchmark mentioned the attributes captured in the object information dialogue of **pdo!** (**pdo!**) do not make much sense for users who are no experts in the field. To deal with this the attributes should be named as clearly as possible. However, it also seems sensible to keep the attributes and their names consistent with the ones available in the actual data. This way, the information acquired upon clicking an object in the viewer can be related to a corresponding GML object. For this reason, I did not address possible unclear attribute names in the mock-up. I did include a contextual link to a page containing additional explanations to help clarify the attributes (H2). Added to unrecognisable attribute names, fields can be empty as well. However, displaying these empty fields makes sense to show users the available attributes.

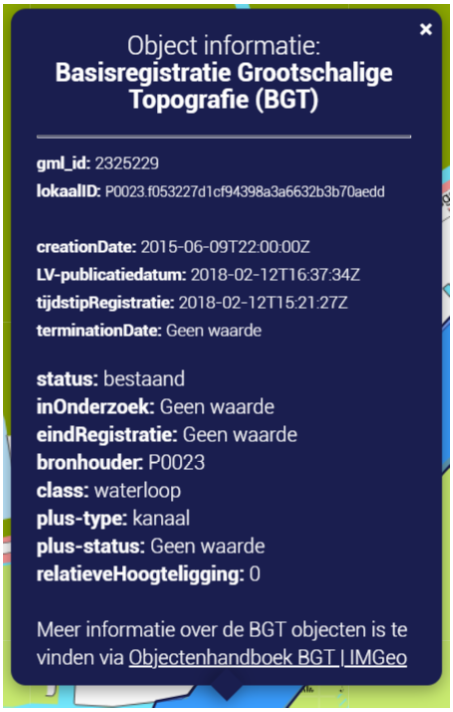


Figure 6.40: Example of an object information dialogue that pops up once a user clicks a corresponding feature in the BGT.

In case no feature information is available, this should be clarified in the interface. This can be done by showing a warning such as "There is no feature information available for this object." upon clicking, and by making the map elements look non-clickable. One way to achieve the latter, is by not making the cursor change to a pointer and omitting appearance changes of the feature upon mouse hover.

Help mechanisms

Contextual instructions on how to use the map viewer are provided if users click the `?` icon in the portal of France (upper right) or the `i` icon in the portal of Luxembourg (lower left). In the thematic viewer of Norway, help is provided in a sidebar on the left of the screen. France provides this help by overlaying the viewer with a screen with contextual explanations. This approach is implemented in the mock-up as well, as is shown in Figure 6.41 (H4). The trigger for the overlay is located on the top left of the viewer since the upper right is preoccupied with the search bar and the lower left is pre-occupied with information regarding cursor coordinates and scale.

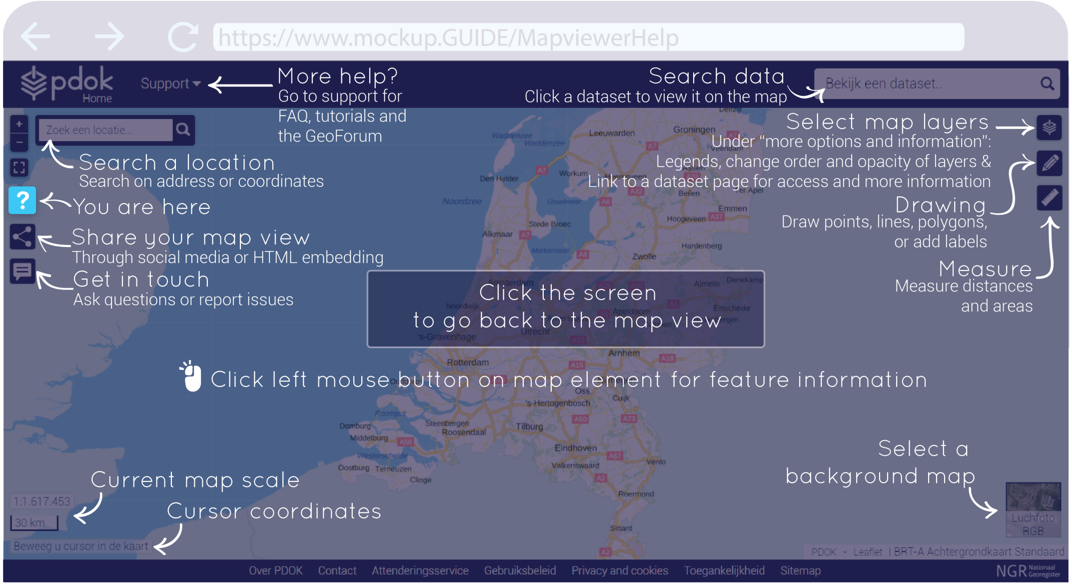


Figure 6.41: Contextual help screen in the viewer of the mock-up, based on the help screen of the geoportal of France.

Another option would be to walk the user through different functions using a wizard. However, for the fast-paced use of experts, the mechanism displayed in Figure 6.41 is deemed more suitable.

6.3. Summary: Implement design propositions

In this chapter, I presented the re-evaluate GUIDE (Subsection 6.3.1) and I provided concrete implementation examples following this GUIDE (Subsection 6.3.2).

6.3.1. The re-evaluated GUIDE

The design propositions in the GUIDE are assigned points depending on whether they are *must haves (3 points)*, *should haves (2 points)*, or *could haves (1 point)* based on if they are frequently implemented by existing geoportals and preferred by users.

6.3.2. Implementation examples

To provide implementation examples of the GUIDE, I developed a mock-up following the listed design elements. This mock-up consists of a home page, catalogue page, dataset landing pages, and a map viewer, since these are the necessary pages to perform the required searching, assessment, and access processes on a geoportal.

Users commented they want to find and access the data they need as efficiently as possible. The mock-up supports this by the integration of its most important pages: the dataset catalogue and the landing pages are combined, users are enabled to view datasets from the catalogue page, and users are enabled to acquire more information and options concerning the data by redirecting to a corresponding landing page from the viewer.

7
Evaluation of the design elements

In this chapter, I compare the usability of the benchmark and the mock-up that is implemented following the GUIDE to assess whether or not the implementation of the elements of the GUIDE results in increased usability. To enable this comparison, I perform a follow-up user session. I list the methodology of this session in Section 7.1 and the results in Section 7.2. After this, I compare the results of the benchmark and the follow-up experiment and reflect on this comparison in Section 7.3. In Section 7.4, I cover possible new iterations of the mock-up I could not implement. I summarise this chapter in Section 7.5.

7.1. Methodology of the usability session with the mock-up

The specific tasks for this user session are listed in Annex E.

7.1.1. Participant selection

Due to prior experiences and different backgrounds, different users have different perceptions that are never truly objective [Pekkanen, 2015]. When performing research with a large number of participants, this becomes less of an issue, and it would be possible to filter outliers. However, I only considered a limited sample size. This means that the results of the benchmark and the follow-up are less comparable if I would recruit different participants for both sessions. For this reason, I asked the same participants to perform both the benchmark and the follow-up experiment.

A possible downside to this is that the participants could have practised the tasks of the benchmark, giving them an unfair advantage in the follow-up session. Since the sessions are more than two months apart and because the mock-up interface is completely new for the participants, these effects are assumed to be minimal. Regardless, I asked them to try to keep any changes in skill with using geoportals outside of their judgement.

Due to external circumstances, the original participant 6 who performed the benchmark was no longer able to take part in the follow-up experiment. To deal with this, I recruited a new participant within the same persona. This means that in this chapter, the results of participant 6 are different than in Chapter 5. Different people have different backgrounds and experiences, even if they are part of the same persona. For this reason, the main points of interest for the benchmark experiment of the substitute participant 6 are listed below. Substitute participant 6:

- thinks the "Geo Services" tab is unsuitable for metadata and the redirection to NGR is unclear.
- mentions the available information videos are basic and seem to be more focused on users who have little technical knowledge. The actual metadata is too complicated to acquire.
- is disappointed map layers are not activated by redirecting from the corresponding landing page. Furthermore, (s)he first looked for the data in "basis kaarten" instead of "overige kaarten".
- would like a mechanism to search for data based on keywords in the viewer to be able to search data without knowing its title: (s)he looked for the "v" of "vaarwegen" instead of the "n" for NWB.
- was unfamiliar with the ATOM service. (S)he expected a direct download.

These issues are similar to what other participants experienced.

The qualitative opinion of substitute participant 6 is also in line with the others: (s)he appreciates it the data is available; however, the execution of the portal could be more user-friendly in the details. This indicates the opinion of the substitute participant is representative. However, there are some differences in quantitative ratings. The original participant 6 scored 0.78 in the usability metric of Chiew and Salim [2003], whereas the substitute scored 0.56. This is the lowest score of all participants, not yet an outlier, but it does influence the median due to the small sample size. This median would have been 0.73 with the original participant and is 0.69 with the substitute, both are within the category “good” [Chiew and Salim, 2003].

The best explanation for this is probably that there are some differences in background. This causes some participants to be more extreme or critical in their qualitative ratings than others. A larger sample size would cancel out these effects, however, for this research comparing the benchmark and the follow-up result of the same participant is assumed to be sufficient.

An advantage of having the new participant 6 perform tasks on the benchmark and the mock-up consecutively is that (s)he can directly compare the benchmark to the mock-up. Although it should be noted that a single opinion is not necessarily representative of all possible users, this can still result in some valuable indications.

7.1.2. Task selection

The tasks of the follow-up experiment should be comparable to the benchmark. To prevent users from remembering, I used different datasets for comparable tasks. When I, for example, asked participants to consult metadata for the BGT during the benchmark, I asked them to look up a different type of metadata for the BAG in the follow-up.

Since there are fewer datasets available on the mock-up than on PDOK, the discovery process could become easier. To make this process more realistic, I included placeholders for all datasets hosted on PDOK that are similar to the ones the participants are looking for. For the “vaarwegen” (“waterways”), this means I included not only the required datasets from the NWB but also the “Vaarweg Informatie Nederland (VIN)” and “Noordzee Vaarwegmarkeringen”. Furthermore, I asked participants to look for a dataset containing “boormonsterprofielen” instead of requesting the dataset “Boormonsterbeschrijvingen” (“drilling hole descriptions”) by its name. Based on searching for `boor`, this means participants have to decide between the required dataset and “Booronderzoek”.

The only task of the benchmark that is not comparable to the one from the mock-up, is Task 1.2. In this task, I originally asked participants to download a specific area of the BGT. I decided not to implement or test this since I was unsure if implementing such a complicated solution was manageable within my research. Furthermore, PDOK already came up with a solution in line with the requests of the participants. This could make a solution I come up with redundant. I did consider testing the mechanism of the solution of PDOK, however, this solution does not fit in the interface I developed and would require the participants to leave my mock-up.

As a replacement for the original Task 1.2, it would make sense to ask users to copy the WMS URL of the BAG. The reason for this is that during the benchmark, the participants mentioned they did not necessarily use downloads. The new Task 1.2 can be used to analyse if there is a difference in performance between accessing data via geo-web services and downloading. To still be able to include Task 1.2 in the average calculations, I assigned the score of substitute participant 6, who did perform the right benchmark, to all other participants.

7.1.3. Guidelines for performance metrics

To get an objective, quantitative indication of the performance of the mock-up compared to the benchmark, I captured the time, number of clicks, and visited pages during both user sessions. For a fair comparison, I used the same methodology as described in Section 5.3 for both the benchmark and the follow-up. It should again be noted that the exploratory approach I took results in less representative performance metrics. In this sense, the time users spend on a task can solely be used as an indication, not as a strong definitive metric.

In the mock-up, not all dataset landing pages contain information. This means that once a participant encounters a default page, (s)he is immediately aware that (s)he is not on the right path.

There are several ways to deal with this in the performance metrics. Regardless if that page is implemented, each time participants visit a page that is not part of the task, their clicks and lostness scores are influenced. However, the additional time they could lose by reading a page to assess if it is suitable or not is decreased in the situation of the mock-up. A possible way to correct for this could be to assign an error each time a participant encounters a page that is not implemented since this encounter is a "hint" for the participant to look elsewhere. However, the hints I provided during the benchmark contained more information than such a "hint" does.

Although I tried to keep the conditions between the benchmark and the follow-up experiment similar, I did not fully succeed in this. Due to external circumstances, the follow-up experiment could not take place in person. Theoretically, this does not matter much. However, in practice, there are some consequences for the performance metrics. A rather noticeable one was some lagging the participants experienced. I did not correct for this since the timing solely provides an indication anyway. Another consequence I experienced as a facilitator involved that it was more challenging for me to assess if the participant understood my explanation of the task.

7.1.4. Questions of the interview

The qualitative statements regarding the tasks are the same for both the benchmark and the mock-up, as are the suggested questions for elaboration purposes. Additionally, I attempted to cover changes between the benchmark and the mock-up with individual participants who specifically commented on these areas of the benchmark interface.

In the post part of the interview, it would be possible to ask users to directly compare the interface of the benchmark to the interface of the mock-up. I decided not to include such a question since the benchmark and the follow-up experiment might be too far apart for the participants to make a fair comparison. Substitute participant 6 is the exception to this rule. Since (s)he performed the follow-up experiment straight after the benchmark, (s)he is asked to compare both interfaces.

7.2. Usability of the mock-up

In this subsection, an analysis of quantitative and qualitative ratings of the usability of the UI of the mock-up compared to the benchmark is provided. This is measured by the amount of time, clicks, lostness, errors, and self-reported ease of use and sensibility of the process.
Furthermore, I presented the navigational paths of the participants. The nodes in these navigational paths are abbreviated as shown in Figure 7.1.

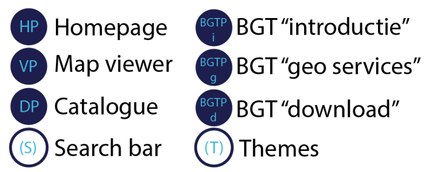


Figure 7.1: Abbreviations adopted to visualise the nodes in the navigational paths of users on PDOK.

7.2.1. Task 1.1: Consult metadata

For this task, the participants were required to consult the metadata of the BAG. The resulting usability metrics are shown in Table 7.2 and the corresponding navigational paths in Figure 7.3.

Observed behaviour

All but one of the participants wait a while to confirm the search keyword after selecting an auto-suggestion. This indicates it could be desirable to automate this confirmation.

Evaluation of the usability metrics

Acquiring metadata seems more efficient for the mock-up than for the benchmark. This is reflected by the self-reported metrics. Because the catalogue page is busy, some participants do not immediately spot the information. For participant 5, this makes the task a little less easy. However, (s)he thinks this is especially true for the first time of use when it is not yet clear where the information is located.

The participants all appreciate it that "basic metadata" is displayed directly on the landing page.

Table 7.2: Usability metrics related to Task 1.1: Consult metadata. The "Control" rows represent an ideal control performance.

T1.1		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:22	6	0	0	1	1
Mock-up (M) Control		**00:08**	**1 or 3**	**0**	**0**	**1**	**1**
1	B	01:21	9/6	0,32	0	4	4
	M	00:29	3/3	0	0	1	1
2	B	02:07	6/6	0	1	2	2
	M	00:24	3/3	0	0	1	1
3	B	01:29	14/6	0,17	1	1	2
	M	00:28	3/3	0	0	1	1
4	B	01:50	7/6	0,17	1	2	3
	M	00:12	1/1	0	0	1	1
5	B	02:10	9/6	0,45	1	4	5
	M	00:36	3/3	0	0	2	1
6	B	01:59	6/6	0	1	3	4
	M	00:16	3/3	0	0	1	1

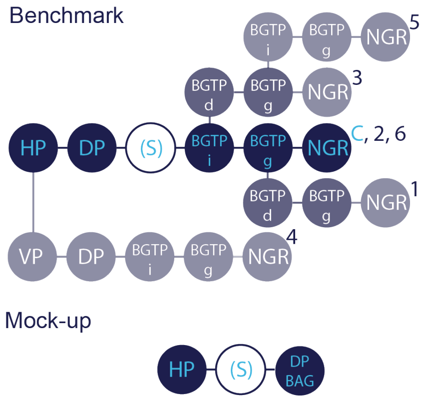


Figure 7.3: Navigational paths of Task 1.1: Consult metadata. If a participant deviated from the control path C this is annotated with her/his identifier from Table 7.2. More frequently visited paths are less opaque.

7.2.2. Task 1.2: Copy WMS URL

For this task, the participants were required to copy the WMS URL of the BAG. The resulting usability metrics are shown in Table 7.4 and the corresponding navigational paths in Figure 7.5.

Table 7.4: Usability metrics related to Task 1.2: Copy WMS URL. The "Control" rows represent an ideal control performance.

T1.2		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:06	1	0	0	1	1
Mock-up (M) Control		**00:03**	**1**	**0**	**0**	**1**	**1**
1	M	00:05	1/1	0	0	1	1
2	M	00:04	1/1	0	0	1	1
3	M	00:09	1/1	0	0	1	1
4	M	00:15	2/1	0	0	1	1
5	M	00:05	1/1	0	0	1	1
6	B	00:08	1/1	0	0	1	1
	M	00:05	1/1	0	0	1	1

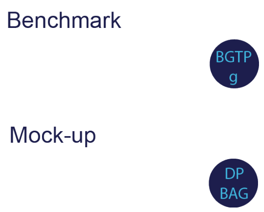


Figure 7.5: Navigational paths of Task 1.2: Copy WMS URL.

Observed behaviour

One participant first tried to select the WMS text on the search results list on the right of the screen. Once (s)he notices the access options on the left, (s)he figures this is where (s)he needs to be.

Evaluation of the usability metrics

Two participants mention it is nice the button immediately copies the WMS link. None of the participants experienced major troubles during this task, which is reflected in their self-reported metrics.

7.2.3. Task 2.1: View data

For this task, the participants were required to view the standard BGT in the PDOK map viewer. The resulting usability metrics are shown in Table 7.6 and the corresponding navigational paths in Figure 7.7.

Observed behaviour

In the mock-up, participants can activate data in the viewer by searching on a keyword (participant 1 and 2) or selecting a checkbox in a layer dialogue (participant 4). Furthermore, it is possible to redirect from a corresponding dataset landing page (participant 3, 5, and 6).

Table 7.6: Usability metrics related to Task 2.1: View data. The "Control" rows represent an ideal control performance.

T2.1		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:09	5	0	0	1	1
Mock-up (M) Control		00:05	2 or 3	0	0	1	1
1	B	00:22	6/5	0	0	1	1
	M	00:30	6/3	0	0	1	2
2	B	01:30	9/5	0,33	0	3	3
	M	00:10	4/3	0	0	1	1
3	B	00:22	5/5	0	0	1	1
	M	00:18	2/2	0	0	1	1
4	B	00:21	5/5	0	0	1	1
	M	02:15	6/3	0	0	3	2
5	B	00:26	9/5	0	0	2	3
	M	00:09	2/2	0	0	1	1
6	B	01:30	12/5	0,33	0	3	4
	M	00:16	2/2	0	0	1	1

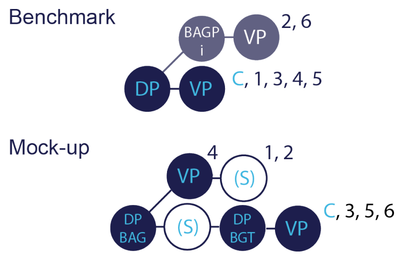


Figure 7.7: Navigational paths of Task 2.1: View data. If a participant deviated from the control path C this is annotated with her/his identifier from Table 7.6. More frequently visited paths are less opaque.

All three participants who search for the dataset in the viewer first clicked the search bar for locations on the top left of the page. This shows that this search bar is more prominent than the search bar for data. After this, participant 1 and 4 scroll the layer dialogue. Upon being asked, participant 1 comments (s)he first overlooked the other search bar. (S)he thinks this has to do with that it is not overlayed on the map viewer, making it seem as if it does not belong to the map. Participant 4 did notice the search bar, however, (s)he did not use it at all because (s)he expected it belonged to the full portal due to its location in the navigational header.

Evaluation of the usability metrics

Users redirecting to the map from a corresponding landing page achieve an efficient task execution and high ratings in the self-reported metrics.

All participants who started in the viewer, look for or use the search bar for data. This supports that a search bar for data is appreciated. However, only participant 2 managed to find and efficiently use the search bar. Participant 1 thinks that once you find the search bar, it is very easy to use, however, this first time the task execution made slightly less sense due to its unexpected location. For participant 4, this task was more difficult and less sensible than the benchmark. Because (s)he did not use the search bar, (s)he had to zoom in a lot to select the BGT. Even though this was explained in the tooltip, this made the task more difficult and less sensible than the benchmark, where I requested a different dataset that did not require zooming.

7.2.4. Task 2.2: Analyse data in the viewer

For this task, the participants were asked to figure out the "plus-type" of the waterway east of the location "Muggenbeet" using the analysis functionality of the map viewer. The resulting usability metrics are shown in Table 7.8 and the corresponding navigational paths in Figure 7.9.

Observed behaviour

Participant 2 attempts to acquire feature information by clicking the right mouse button.

Participant 5 first tried to look for a way to filter the requested "waterloop" attribute in the layer dialogue. This behaviour seems to relate to more extensive GIS functionalities. The participant mentions (s)he would appreciate such a mechanism.

Evaluation of the usability metrics

Although the efficiency of this task execution is similar for the mock-up and the benchmark, most participants have a preference for the mechanism to extract feature information from the mock-up.

Table 7.8: Usability metrics related to Task 2.2: Analyse data in the viewer. The "Control" rows represent an ideal control performance.

T2.2		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:13	3	0	0	1	1
Mock-up (M) Control		**00:14**	**2 or 3**	**0**	**0**	**1**	**1**
1	B	00:53	8/3	0	0	2	4
	M	00:25	3/3	0	0	1	1
2	B	04:16*	13	0	1	3	3
	M	00:44	5/3	0	0	2	2
3	B	00:32	4	0	0	1	1
	M	00:28	3/3	0	0	1	1
4	B	01:23	6	0	0	2	4
	M	00:46	2/2	0	0	1	1
5	B	00:48	10	0	0	1	1
	M	00:53	4/2	0	0	2	3
6	B	00:43	3	0	0	1	2
	M	00:36	3/3	0	0	1	1

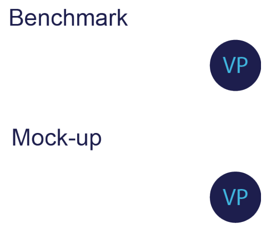


Figure 7.9: Navigational paths of Task 2.2: Analyse data in the viewer.

One participant comments it is nice that the polygon lights up upon hovering since this already indicates there are interaction possibilities. Another participant feels like the attribute names of the BGT are not self-explanatory. Because of this, (s)he appreciates the link to the BGT and IMGeo object manual.

The difficulties experienced by participant 2 and 5 are reflected by their self-reported ratings.

7.2.5. Task 3.1: Search and download unfamiliar data

For this task, the participants were asked to download a dataset containing "boormonsterprofielen" via the dataset menu. The resulting usability metrics are shown in Table 7.10 and the corresponding navigational paths in Figure 7.11.

Table 7.10: Usability metrics related to Task 3.1: Search and download unfamiliar data. The "Control" rows represent an ideal control performance.

T3.1		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:20	6	0	0	1	1
Mock-up (M) Control		**00:07**	**3**	**0**	**0**	**1**	**1**
1	B	01:05	8/6	0,40	1	2	4
	M	00:34	4/3	0	0	1	1
2	B	~~02:38~~	~~11/6~~	~~0~~	~~3~~	4	5
	M	01:17	7/3	0	0	3	4
3	B	00:55	6/6	0	0	2	3
	M	01:01	3/3	0	0	1	1
4	B	~~03:38~~	~~12/6~~	~~0,17~~	~~2~~	5	5
	M	01:16	6/3	0,2	0	1	1
5	B	02:03	10/6	0	1	2	4
	M	00:51	5/3	0	0	1	1
6	B	~~02:31~~	~~6/6~~	~~0~~	~~1~~	5	5
	M	01:04	3/3	0	0	1	1

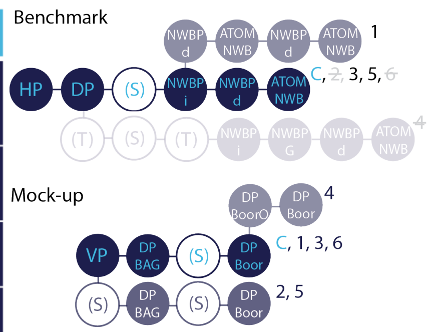


Figure 7.11: Navigational paths of Task 3.1: Search and download unfamiliar data. If a participant deviated from the control path C this is annotated with her/his identifier from Table 7.10. More frequently visited paths are less opaque.

Observed behaviour

Despite the instruction to go to the dataset catalogue page, two participants continued this task in the viewer. They first activate the requested data here, which results in additional clicks. When looking in the layer dialogue, one participant mentions (s)he does not think it is possible to get more information here since the active layer is not displayed on top of this menu.

In the catalogue, four participants did not continue finishing their keyword since `boor` already displays the right result. Another participant knew the requested dataset is part of the BRO and uses the name of the base registry as a search query. I asked the participant if (s)he did not mind the datasets being presented separately, instead of under the overarching header of a base registry. The participant mentions (s)he has no problem with this and thinks it is an advantage that this way, it is possible to directly find the right dataset without having to know what is captured under a base registry.

Evaluation of the usability metrics

Participant 1 and 4 clicked the information button next to the download option, which resulted in additional clicks. Participant 2 experienced some difficulties in going to the relevant landing page when starting from the viewer. This is also reflected by her/his self-reported measures. However, the participant said that starting from the catalogue would have made more sense and had (s)he directly started from the catalogue page, (s)he would have scored the process to be very easy and very sensible.

Two participants perceived this task to be slightly more difficult since it required them to figure out that "boormonsterprofielen" are part of the "bodemkundige boormonsterbeschrijvingen". Having to scan the page for this information is not ideal. However, they think that during a realistic use case this would not be a big issue, which shows in their self-reported metrics. All participants experienced this task to be more sensible and easier than the corresponding task of the benchmark. This is in line with the increased efficiency and task success shown by the performance metrics.

7.2.6. Task 3.2: View data

For this task, the participants were required to view the "boormonsterbeschrijving" data layer in the PDOK map viewer. This task can be used to check for the effects of memorability in viewing a dataset by comparing the resulting performance metrics to the performance metrics of the similar Task 2.1 (Table 7.6). The resulting usability metrics are shown in Table 7.12 and the corresponding navigational paths in Figure 7.13.

Table 7.12: Usability metrics related to Task 3.2: View data. The "Control" rows represent an ideal control performance.

T3.2		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:17	5	0	0	1	1
Mock-up (M) Control		00:03	1 or 2	0	0	1	1
1	B	00:31	5/5	0	0	1	1
	M	00:03	1/1	0	0	1	1
2	B	00:29	5/5	0	0	2	2
	M	00:15	1/1	0	0	1	1
3	B	00:24	5/5	0	0	1	1
	M	00:03	1/1	0	0	1	1
4	B	01:16	7/5	0	1	2	1
	M	00:03	1/1	0	0	1	1
5	B	00:54	6/5	0	0	1	1
	M	00:11	2/2	0	0	1	1
6	B	02:16	10/5	0	1	3	4
	M	00:03	1/1	0	0	1	1

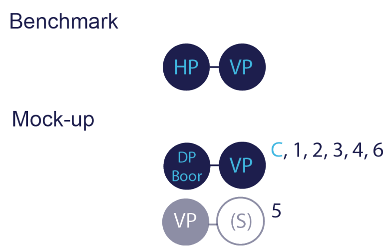


Figure 7.13: Navigational paths of Task 3.2: View data. If a participant deviated from the control path C this is annotated with her/his identifier from Table 7.12. More frequently visited paths are less opaque.

Observed behaviour

Only one participant started this task from the viewer page. The others are all already on the catalogue page and use the option to redirect to the viewer from there.

Evaluation of the usability metrics

Task 2.1 and 3.2 should be similar, however, comparing them is challenging: due to the different starting points of tasks, most participants took different paths. For the participants who already redirected from the catalogue to the viewer, the margin for improvement is too small to confirm learnability. The option to redirect from the catalogue page to the corresponding dataset in the viewer is efficient and valued by the participants. Participant 5 appreciates the keyword search option for data in the viewer, since (s)he remembered to be bothered by having to scroll and browse to the layer menu during the benchmark.

7.2.7. Task 4.1: Discover a dataset suiting specific criteria

For this task, the participants were required to find a dataset covering information of waterways with a minimum depth of 1.1 metres. The resulting usability metrics are shown in Table 7.14 and the corresponding navigational paths in Figure 7.15.

Table 7.14: Usability metrics related to Task 4.1: Discover a dataset suiting specific criteria. The "Control" rows represent an ideal control performance.

T4.1		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:13	4	0	0	1	1
Mock-up (M) Control		**00:07**	**2**	**0**	**0**	**1**	**1**
1	B	01:28	7/4	0,20	0	3	2
	M	00:22	2/2	0	0	1	1
2	B	03:24	4/4	0	1	2	2
	M	01:37	4/2	0	0	2	2
3	B	02:20	7/4	0,47	0	2	1
	M	00:47	6/2	0	2	2	1
4	B	04:54*	14/4	0,37	0	2	2
	M	02:57	11/2	0,425	0	3	2
5	B	01:38	4/4	0	0	1	2
	M	00:57	4/2	0	0	2	2
6	B	04:19	4/4	0	1	3	4
	M	02:31	4/2	0,32	0	2	2

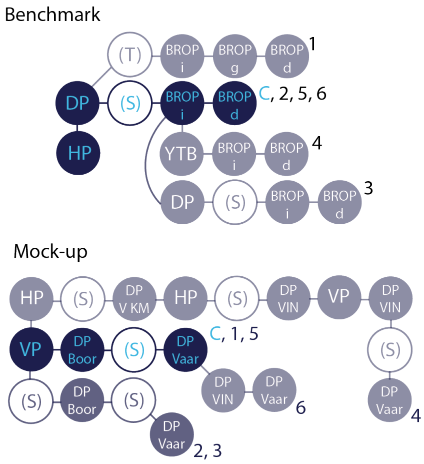


Figure 7.15: Navigational paths of Task 4.1: Discover a dataset suiting specific criteria. If a participant deviated from the control path C this is annotated with her/his identifier from Table 7.14. More frequently visited paths are less opaque.

Observed behaviour

Two participants again start this task in the viewer. Participant 3 mentioned (s)he was looking for a filter functionality in the viewer. Getting her/him on the right track required two hints. These hints would have not been required had the task instruction been clear.

Participant 4 started searching on the home page because (s)he wants to be sure to take all information captured on the portal into account during the discovery process. After picking auto-suggestions I did not implement, (s)he proceeds to search in the viewer, where (s)he mentions (s)he misses a way to go to the catalogue page directly to view more information.

Three participants did not finish their keyword as `vaar` and `vaarw` already provided results. One participant searched for the NWB.

Evaluation of the usability metrics

The participants seemed to complete this task faster with the mock-up than during the benchmark. The task execution made less sense to participants 2, 3, and 4, who expected they had to look for a function to filter everything below a certain depth value in the requested dataset. This misunderstanding made the task more complicated than intended and less comparable to the benchmark.

The additional clicks of the participants are mainly caused by starting in the viewer and selecting information here before going to the catalogue and selecting multiple datasets. Participant 5 opened and closed the advanced search options.

7.2.8. Task 4.2: Download data

For this task, the participants were required to download the dataset capturing “vaarwegvakken”. This task can be used to check for the effects of memorability in accessing a dataset by comparing the resulting performance metrics to the performance metrics of the similar Task 1.2 (Table 7.6) and 3.1 (Table 7.10). The resulting usability metrics are shown in Table 7.16 and the corresponding navigational paths in Figure 7.17.

Table 7.16: Usability metrics related to Task 4.2: Download data. The “Control” rows represent an ideal control performance.

T4.2		Time (m:s)	Clicks	Lostness	Errors	Easy (Likert)	Sensible (Likert)
Benchmark (B) Control		00:11	4 or 2	0	0	1	1
Mock-up (M) Control		00:03	1	0	0	1	1
1	B	01:39	14/4	0,84	0	3	4
	M	00:03	1/1	0	0	1	1
2	B	02:00	5/4	0	0	3	4
	M	00:05	1/1	0	0	1	1
3	B	02:22	10/4	0	1	3	2
	M	00:09	1/1	0	0	1	1
4	B	00:50	6/4	0,28	0	1	1
	M	00:03	1/1	0	0	1	1
5	B	01:38	4/4	0	0	1	2
	M	00:03	1/1	0	0	1	1
6	B	00:26	2/2	0	0	2	3
	M	00:07	1/1	0	0	1	1

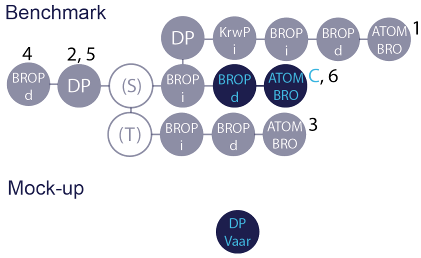


Figure 7.17: Navigational paths of Task 4.2: Download data. If a participant deviated from the control path C this is annotated with her/his identifier from Table 7.16. More frequently visited paths are less opaque.

Observed behaviour and Evaluation of the usability metrics

None of the participants experienced any problems with this task, this is reflected by the self-reported metrics. The results from Task 1.2 have very little to no margin for learnability. This shows that access to geo-web service URL and downloading is similar in the mock-up. Task 3.1 is less comparable due to the more explorative nature of that task. The same is true for a comparison between Task 4.2 in the benchmark and follow-up experiment.

7.2.9. Post questions

After performing the tasks, I asked the participants to rate several statements related to their experiences of using the mock-up. For comparison’s sake, these ratings are displayed together with the corresponding ratings of the benchmark in Figure 7.18.

P-SQ1. I am satisfied with the functionalities of the mock-up.

One participant comments (s)he thinks all information and functionality that should be present on a geoportal is available in the mock-up. The catalogue and viewer pages capture everything (s)he needs and are named clearly. Another participant agrees, and states the portal supports her/him in the processes (s)he needs it for: searching and accessing data. This confirms the relevance of the focus on the search, assess, and access processes in this research.

> Participants comment it is especially user-friendly that the data can be found with synonyms, metadata, and their actual names, added to their related base registry. One participant who made a spelling mistake, mentions did-you-mean suggestions as listed in the GUIDE would be even better than solely acknowledging the mistake.
> One of the participants specifically commented (s)he would have appreciated advanced search options during the benchmark. Upon being asked to inspect the filter options of the mock-up, (s)he thinks all relevant filters are available. Two others who clicked the filter button also comment that the possibility to use filters is nice.

Four participants comment they appreciate it that metadata is aggregated on the landing pages of the mock-up and confirm the most important information is captured. One participant specifically appreciates the link to an overview with older versions of a dataset. (S)he would like it even better if it were also possible to access older versions of datasets.
During the benchmark, one participant specifically requested more information about a dataset such as its format and size before downloading. This participant appreciates the information captured for each service option in the mock-up. Two other participants agree: it is nice to be able to know what to expect of a download.

One participant experienced issues with the controls of the map viewer. Because of this, I asked her/him to click the help button. Although (s)he tends to not do this in real life, (s)he thinks the support mechanism in the map viewer of the mock-up is helpful.

P-SQ2. It was easy for me to use the mock-up.

Two participants appreciate the responsiveness of the search functionality. The use for this is supported by that not all participants completed their search keywords (e.g. `boorm` instead of `boormonsterprofiel`).

P-LQ3. The use of the mock-up is self-explanatory.

One participant appreciates the arrow icon indicating a drop-down.
Three participants comment they like the two different search bars in the map viewer. However, the location of the search bar for the data is not ideal. Without the placeholder, two participants think this search bar seems to be unrelated to the map. Two others do think the placeholder explains it sufficiently. Both the front-end developer and one participant also think it is intuitive that the same search bar is always used for searching datasets.
Even though four participants looked for an option to redirect from a dataset in the viewer to a specific landing page, none of them used it. This indicates this option is not prominent enough.

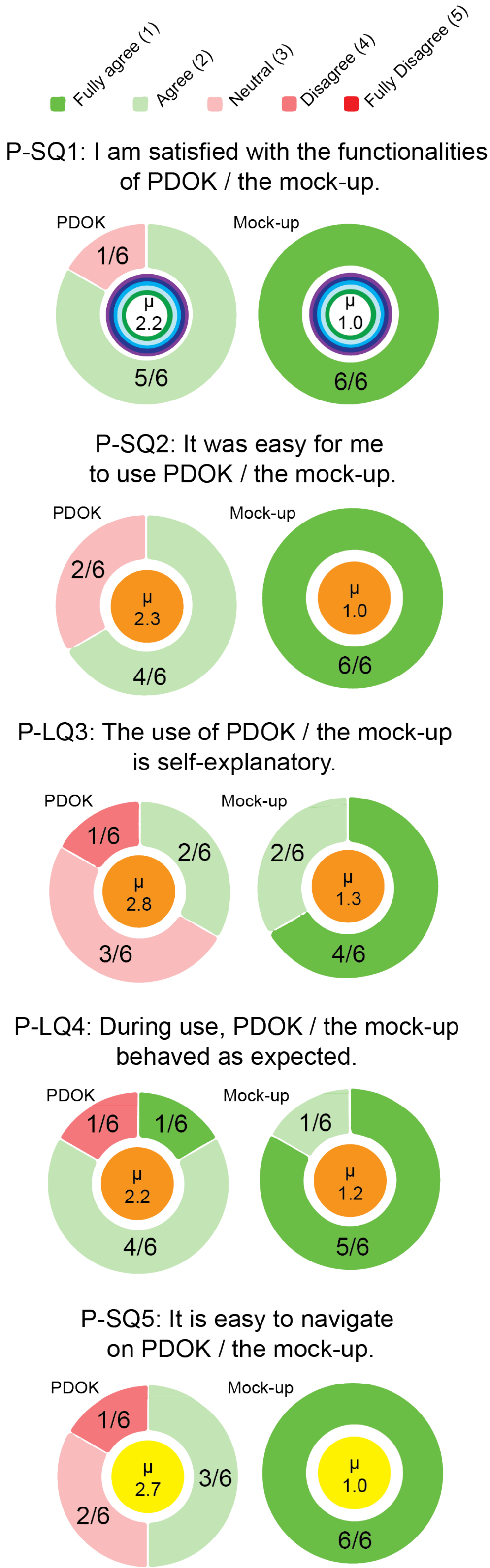
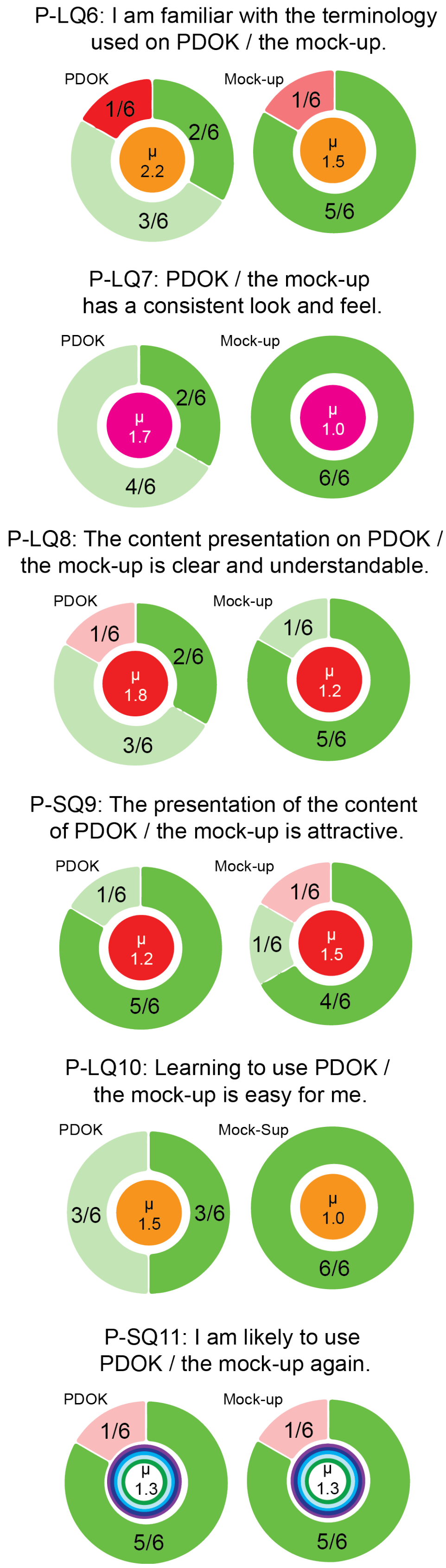


Figure 7.18: Ratings participants accounted to statements regarding the benchmark and the follow-up ranging from fully agree to fully disagree (continued on the next page).



P-LQ4. During use, the mock-up behaved as expected.

One participant comments (s)he did not expect the catalogue page search mechanism to immediately refresh and select the top search result upon key input. Although unexpected, (s)he comments the mechanism is clear after using it.
Two participants think active data is not clearly differentiated in the viewer.

P-SQ5. It is easy to navigate on the mock-up.

The front-end developer mentions (s)he appreciates the navigational structure of the mock-up. The menu bars of websites often capture many small, scattered elements. Prominently listing the most frequently used elements such as the viewer and the catalogue prevents confusion. The other participants agree. One of them recalled the "community" header to the GeoForum confused her/him during the benchmark. In the "support" drop-down of the mock-up, it is no longer obtrusive.
Two participants comment they like being able to search for data through both the catalogue and the map and that these pages work together.
During the benchmark, one participant especially appreciated the dataset landing pages of PDOK. However, even this participant prefers the solution implemented in the mock-up.
The link to more metadata on NGR of the mock-up indicates to the participants they are redirected. This makes the navigation process more predictable.

P-LQ6. I am familiar with the terminology used on the mock-up.

The front-end developer is still not comfortable with the terminology but rates the mock-up slightly better than the benchmark.

P-LQ8. The presentation of the content on the mock-up is clear and understandable.

Three participants note they are positively surprised they did not have to scroll on the landing page. This results in a clear overview. Upon being asked if the UI of the mock-up is not too busy because of this, two of them agree that there is indeed a lot of information captured. However, they do not think this is cumbersome since the subdivision of the elements and their placement is clear.

The front-end developer agrees; (s)he thinks people who visit this page are looking for more information, which is what they get. Two others agree it is nice basic metadata is aggregated on a single page, although they do comment that at the first use, scanning the page is more tricky because of it.
One participant appreciates it that the possible access options are all displayed together.
Four participants comment positively on the data previews being part of the search results, as this helps them assess what data to expect. Two of them also like the icons of the themes.

P-SQ9. The presentation of the content of the mock-up is attractive.

Two participants comment they like the size of the access buttons because it captures their attention and is easy to point at. Another participant thinks the cyan looks pretty and that it draws attention to the different access options.
One participant comments the UI of the mock-up feels fresher and more modern than the one from the benchmark. The front-end developer also thinks the interface looks recent and thus sustainable. The home page is clear and clean; the search bar is a very prominent feature. (S)he expects this supports almost all use cases of the portal. Nonetheless, (s)he thinks the rounded corners of the buttons and the icons that tend to fill the buttons to the corners are less modern. Furthermore, (s)he comments the layer dialogue of the map viewer is not very scannable since the different options are not separated. For this reason, (s)he rates the mock-up to look neutrally attractive. One participant thinks the catalogue page looks a little too busy.
Two participants think the object information dialogue can feel a little busy since there are many different attributes. One of them suggests a different justification to make the features more scannable.

P-SQ11. I am likely to use the mock-up again.

For geo-professionals, using PDOK was already almost inevitable due to the sheer amount of data that is published. Only the participant without geo-knowledge scored neutral. This did not change for the mock-up; (s)he does not expect to need this kind of portal, however, the mock-up does invoke a feeling of trust that (s)he would manage to find data easily and fast would (s)he need to use it.

Net Promoter Score (NPS)

Participants are also asked how likely they are to recommend PDOK to their colleagues on a scale from zero to ten. These ratings can be used to calculate the NPS, as is displayed in Equation 7.1.

$$NPS = \%Promoters - \%Detractors \tag{7.1}$$

Promoters give a score of 9 or 10, detractors score below 6, all other scores are passive. The NPS values per participant for the benchmark and the mock-up are provided in Table 7.19.

Table 7.19: NPS scores of the benchmark compared to the mock-up.

NPS	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6
Benchmark	8	10	7	8	10	8
Mock up	9	10	8	9	9	10

The benchmark already scored a NPS of 33.3%. For the mock-up, the NPS is 83.3%. The participant without geo-related knowledge would recommend it to a colleague who could need to work with GI. One participant rates the benchmark higher than the mock-up. At first, (s)he wanted to give the mock-up a 10 as well, however, (s)he changed her/his answer saying a 10 is not realistic.

One of the participants incorporated a comparison between the different portals of the Netherlands in her/his NPS score for the benchmark. According to this participant, all these portals have their strengths and weaknesses. When asked if the mock-up captures these strengths, (s)he confirms this.

7.2.10. General findings: Comparison of the benchmark and the mock-up

Generally speaking, a more efficient UI is preferable for a geoportal. This is confirmed by an expert from PDOK, who mentions that one of the most frequent complaints PDOK gets is that users dislike all the clicking required to get to the point they want to be at. In this sense, the mock-up following the GUIDE is an improvement. To get to a dataset, for example, the number of clicks is diminished from four to two compared to PDOK. Furthermore, the expert thinks the catalogue page of the mock-up looks attractive and clearly structured. (S)he suspects such a catalogue page would be suitable for novice GIS specialists or users from municipalities. More experienced users are expected to care less about the portal itself and more about efficient access of the data. Since most tasks require fewer clicks and time when using the mock-up, this is theoretically supported.

However, whether or not the mock-up design is favourable also depends on if users are satisfied and if they are likely to achieve an optimal score. To test the latter, comparing the time and the number of clicks between the benchmark and the mock-up should be done in several ways. Take, for example, Task 1.1: for the benchmark, the optimal number of clicks to achieve this task equals six clicks. For the follow-up experiment, the preferred information can be retrieved with three clicks. If a participant scores perfectly in the benchmark (six clicks) and needs more clicks than strictly necessary in the mock-up (say five clicks), there are two ways to interpret the results:

1. the mock-up is more usable since it required fewer clicks,
2. or the benchmark is more usable since the mock-up required more clicks than optimal.

The second interpretation requires a relative comparison of the amount of time and clicks. For this, I consider all clicks or time exceeding the optimum value. Dealing with percentages would be unfair for a design which requires fewer clicks. Furthermore, I consider both the median and the sum of all participants for each metric. The resulting values are displayed in Table 7.20.

Table 7.20: Results of the quantitative performance and self-reported metrics of the benchmark compared to the follow-up experiment. ■ Cyan cells indicate a higher usability for the mock-up, ■ lavender cells indicate equal usability, and ■ navy cells indicate the benchmark has higher usability.

Lower values are more usable		Absolute time	Time more than optimal	Absolute clicks	Clicks more than optimal	Lostness	Errors	Ease of use	Sensibility
T1.1	Median	B: 01:54 M: 00:26	B: 01:32 M: 00:18	B: 8 M: 3	B: 2 M: 0	B: 0,17 M: 0	B: 1 M: 0	B: 2,5 M: 1	B: 3,5 M: 1
	Total	B: 10:56 M: 02:25	B: 08:44 M: 01:37	B: 51 M: 16	B:15 M: 0	B: 1,11 M: 0	B: 5 M: 0	B: 16 M: 7	B: 20 M: 6
T1.2	Median	B: 00:08 M: 00:05	B: 00:02 M: 00:02	B: 1 M: 1	B: 0 M: 0	B: 0 M: 0	B: 0 M: 0	B: 1 M: 1	B: 1 M: 1
	Total	B: 00:48 M: 00:43	B: 00:12 M: 00:25	B: 6 M: 7	B: 0 M: 1	B: 0 M: 0	B: 0 M: 0	B: 6 M: 6	B: 6 M: 6
T2.1	Median	B: 00:24 M: 00:17	B: 00:15 M: 00:12	B: 7,5 M: 3	B: 2,5 M: 0,5	B: 0 M: 0	B: 0 M: 0	B: 1,5 M: 1	B: 2 M: 1
	Total	B: 04:31 M: 03:38	B: 03:37 M: 02:08	B: 46 M: 22	B: 16 M: 7	B: 0,66 M: 0	B: 0 M: 0	B: 11 M: 8	B: 13 M: 8
T2.2	Median	B: 00:50 M: 00:40	B: 00:37 M: 00:27	B: 7 M: 3	B:4 M: 0	B: 0 M: 0	B: 0 M: 0	B: 1,5 M: 1	B: 2,5 M: 1
	Total	B: 08:35 M: 03:52	B: 07:17 M: 02:34	B: 44 M: 20	B: 26 M: 4	B: 0 M: 0	B: 1 M: 0	B: 10 M: 8	B: 15 M: 9
T3.1	Median	B: 02:17 M: 01:02	B: 01:57 M: 00:55	B: 9 M: 4,5	B: 3 M: 1,5	B: 0 M: 0	B: 1 M: 0	B: 3 M: 1	B: 4,5 M: 1
	Total	B: 12:50 M: 06:03	B: 10:50 M: 05:21	B: 53 M: 28	B: 17 M: 10	B: 0,57 M: 0,2	B: 8 M: 0	B: 20 M: 8	B: 26 M: 9
T3.2	Median	B: 00:42 M: 00:03	B: 00:25 M: 00:00	B: 5,5 M: 1	B: 0,5 M: 0	B: 0 M: 0	B: 0 M: 0	B: 1,5 M: 1	B: 1 M: 1
	Total	B: 05:50 M: 00:38	B: 04:08 M: 00:20	B: 38 M: 7	B: 8 M: 0	B: 0 M: 0	B: 2 M: 0	B: 10 M: 6	B: 10 M: 6
T4.1	Median	B: 02:52 M: 01:17	B: 02:39 M: 01:10	B: 5,5 M: 4	B: 1,5 M: 2	B: 0,1 M: 0	B: 0 M: 0	B: 2 M: 2	B: 2 M: 2
	Total	B: 18:03 M: 09:11	B: 16:45 M: 08:29	B: 40 M: 31	B: 16 M: 19	B: 1,04 M: 0,75	B: 2 M: 2	B: 13 M: 12	B: 13 M: 10
T4.2	Median	B: 01:38 M: 00:04	B: 01:27 M: 00:01	B: 5,5 M: 1	B: 1,5 M: 0	B: 0 M: 0	B: 0 M: 0	B: 2,5 M: 1	B: 2,5 M: 1
	Total	B: 08:55 M: 00:30	B: 07:49 M: 00:12	B: 41 M: 6	B: 19 M: 0	B: 1,12 M: 0	B: 1 M: 0	B: 13 M: 6	B: 16 M: 6

95 Of the 128 possible fields of Table 7.20 indicate that the usability of the mock-up outperforms the usability of the benchmark. There are only five cases in which the benchmark seems to outperform the mock-up. The three cases in Task 1.2 are challenging to assess since only participant 6 performed a variant of Task 1.2 in the benchmark that is comparable to the follow-up experiment. The two cases in Task 4.1 could be influenced by how I stated the task description for the mock-up session. Two participants mentioned this caused them to believe they had to perform a more complex filtering problem instead of consulting metadata, resulting in some confusion that was unrelated to the UI.

In 28 of the 128 cases, the benchmark and the mock-up perform equally well. There are only three cases in which such equal results did not correspond to optimal scores. These all occurred in Task 4.1.

The big differences in time and number of absolute clicks between the benchmark and the mock-up for Task 4.2 are also due to a not completely fair comparison. This is caused by the changes in the interface; at the end of Task 4.1, participants are on the dataset landing page where they need to be for Task 4.2. However, for the benchmark, several different datasets are captured on this page. As a result, only one of the participants noticed the required dataset straight away. All others went back to the catalogue to search for the dataset. On the mock-up overlooking the presences of a dataset on the separate landing pages is impossible. Although this is preferable, it is less fair for comparing the results.

All in all, the results presented in Table 7.20 indicate the usability of the mock-up in terms of both performance metrics and self-reported metrics exceeds the benchmark. This suggests the implementation of the design elements of the GUIDE in the mock-up indeed results in a more user-friendly design.

The scores are supported by the qualitative comments of the participants. The front-end developer does not remember PDOK and could not make the comparison. But the other participants indicated they preferred the mock-up over the benchmark. Participant 6 performed the follow-up experiment straight after the benchmark, so (s)he could compare the benchmark to the mock-up more closely. When asked, (s)he states that the mock-up makes more sense: (s)he would visit a portal to quickly find data and (s)he feels like the mock-up allows users to find, view, and access data efficiently. On the benchmark, significantly more clicks and scrolling are required to achieve the same thing and it feels more uncertain if the required information is present on the more textually rich pages. Furthermore, (s)he thinks the navigation is improved on the mock-up as it is more clear what each click redirects to.

For the self-reported metrics, additional evaluation is possible based on the usability merit of Chiew and Salim [2003]. Here, values are assigned to ratings of strongly agree (1), agree (0.75), neutral (0.5), disagree (0.25) and strongly disagree (0). The usability point is the sum of the merit divided by the number of questions, where a level between 0 and 0.2 is bad, between 0.2 and 0.4 poor, between 0.4 and 0.6 moderate, between 0.6 and 0.8 good and between 0.8 and 1 excellent [Chiew and Salim, 2003].
A boxplot of the results of this merit for both the benchmark and follow-up session is shown in Figure 7.21. With a median value of 0.95, the mock-up scores excellent, whereas the benchmark scored good with a value of 0.69.

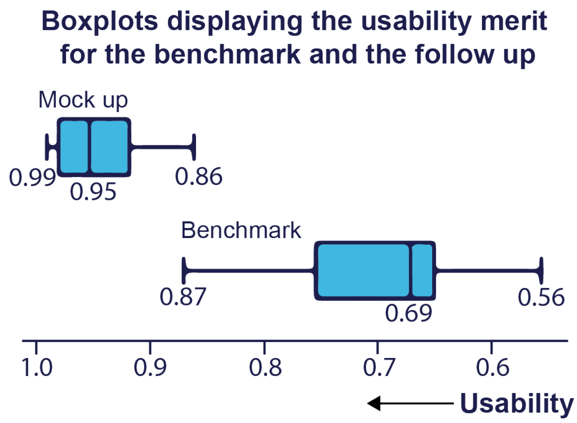


Figure 7.21: Boxplots showing the performance of the benchmark and mock-up in terms of the usability merit of Chiew and Salim [2003].

To see if there is a significant difference between the scores, I performed a hypothesis test. Since the data is normally distributed and the samples are of the same participants, a paired T-test is suitable. My hypothesis is that the mock-up has higher usability than the benchmark.

With a P-value of 0.0012 (since 0.0012 < 0.05), this hypothesis is confirmed with 95% certainty. Because some ratings participants provided for the mock-up seem unrealistically high to me, I also performed a paired T-Test under different conditions. Here, I replaced the benchmark ratings of the substitute participant 6 (who scored 0.56) with the initial participant (who scored 0.78). Furthermore, I replaced all scores of the mock-up with the lowest value (0.86). This results in a P-value of 0.017. Since 0.017 < 0.05, the hypothesis still holds with 95% certainty.

Such a result supports that it seems likely that the implementation of the UI design characteristics as listed in the GUIDE results in a more user-friendly UI in terms of satisfaction and learnability. However, not all design elements of the GUIDE are tested, since the participants did not use these naturally during the task execution.

7.3. Reflection follow-up user session

The usability scores of the mock-up seem very high, maybe even unrealistically so. Especially participants 1, 3, and 6 are very positive: except for one or two cases, they rated the mock-up perfect scores. The main reason behind this could be that the mock-up is more specifically designed around the tasks participants were asked to perform during the user sessions than was the case for the benchmark. This would not necessarily make the experiment less representative since these tasks are corresponding to the tasks users realistically want to execute on a geoportal.

7.3.1. Biases

Possible biases are another explanation for the high usability scores. The benchmark could have caused the participants to become more experienced for the tasks of the follow-up experiment. However, because there are two months between both sessions, this is assumed to be of minimal influence. Furthermore, all but one of the participants had prior experience with PDOK, whereas they are first-time users in case of the mock-up. This seemingly would put the mock-up in a disadvantageous position.

A more likely explanation for the high ratings of the mock-up could be an effect called designer bias (see Courage and Baxter [2005]). This bias can manifest in me wanting to hear positive things about the UI I developed, causing me to interpret the results too positively. However, by carefully transcribing and aggregating the comments of the participants, I assume I managed to prevent this.

The fact that the participants know I am the designer of the mock-up could also have caused them to be more positive because they want to be kind to me. However, since I also performed the benchmark as a more "neutral" facilitator, and since the participants are all professionals, these effects are assumed to be negligible. What I expect to be of more influence, is that I am no professional facilitator. It was challenging for me to remain neutral, especially in case a participant complimented me. Although I tried not to, I can imagine I might have subconsciously influenced the ratings of the participants with my content responses to their comments.

A way to be sure if the results are unbiased is to perform a more elaborate usability experiment with a neutral facilitator. The current small sample size also makes the results less statistically sound.

7.3.2. Unclear tasks and unfair comparison

During the benchmark, the tasks instructions seemed to be clear. Because it is easier to assess if task instructions are clear in person, having to perform the follow-up session digitally complicated things. For the follow-up experiment, I attempted to keep the descriptions and tasks similar. Despite my efforts, some challenges occurred.

- For Task 2.1, the dataset selected in the benchmark is available at all zoom levels, whereas the one from the mock-up is only available when zoomed in. Because of this, selecting the dataset in the layer dialogue required more effort during the follow-up session than during the benchmark.

- For Task 2.2, participant 5 assumed (s)he needed to filter a specific attribute in the viewer, instead of clicking the "waterway" for feature information.

- Two participants started Task 3.1 and 4.1 in the viewer, whilst discovering more information about datasets is more sensible in the catalogue. Theoretically, this should work. However, since this mechanism to go to a landing page from the viewer was not prominent enough, starting in the viewer made the task more challenging than it was supposed to be. During the benchmark, this was less of an issue since searching via keywords in the viewer was impossible.

- Task 4.1 felt insensible to two participants. They expected to have to filter a part of the dataset.

7.3.3. The importance of the UI

The higher usability scores of mock-up compared to the benchmark shows the participants (subconsciously) value the improved interface. However, during the benchmark, all participants with geo-related knowledge already acknowledged they would use PDOK again. This indicates that even with its original interface, the use of PDOK is promoted. Does this mean the interface does not matter at all? No, not necessarily. It does indicate the original UI of PDOK is good already. However, it is very likely that in case of a bad UI, use is not realised to its full potential.

What do the users think? The participants with geo-related knowledge mention they appreciate the large amounts of data offered on geoportals. They also state that the UI of the mock-up makes the portal more usable, which makes the process of acquiring the data more efficient, pleasant, and suitable. However, the most important thing is the information being available, only then the data can be (re-)used. This could suggest the UI is not as important to users as initially assumed. However, although users might not be consciously aware of the importance of the UI, their actions show something else. An example of this is the participants commenting during the benchmark that they would normally resort to Google if they cannot find something. Users leaving a geoportal for Google indicates the UI of that portal is lacking in providing users with what they need. One participant even mentions that the company (s)he works for has developed a tool that prevents them from having to access the BGT from PDOK. Had the interface of PDOK supported her/his needs for this process, such a workaround would not have been necessary.

7.4. Re-evaluation of the mock-up

Based on the comments and behaviour of the participants in the follow-up study, I could have performed another iteration of implementations on the mock-up. At first, this might seem to indicate that the design elements covered by the GUIDE leave room for improvement as well. However, the areas in which the participants experienced problems with the UI of the mock-up, all had one thing in common: the participants interpreted the UI in such a way that the mock-up was not fully in line with the GUIDE. This shows that a framework such as the GUIDE is less valuable without the corresponding implementation examples.

Since the UI design process is iterative, the development of suitable implementation examples requires re-evaluating previous designs by performing additional user sessions. Due to time constraints, it was not possible to implement and test supplementary comments within this research. Instead, I use this section to elaborate on three major suggestions for improvement, some minor suggestions, and some plausible suggestions that leave room for discussion.

Major suggestion 1: A more sensible location for the search bar for data in the map viewer

One of the more prominent usability issues of the mock-up revolves around the location of the search bar for data in the map viewer. This contradicts with the GUIDE (see, for example, the Gestalt laws). Instead of in the navigational header, this search bar is expected in the map view, close to the layer dialogue (see, for example, Figure 7.22). Another option would be to improve this functionality by integrating the search bar in the layer dialogue (see Figure 6.32).

Note that the front-end developer and one other participant acknowledge that using the same search bar on the same location for all data related searches is intuitive. To maintain this consistency, the search bar on the catalogue page can also be moved out of the navigational header.

Major suggestion 2: A more prominent display of active map layers

Furthermore, two participants could not easily recognise the active layers in the map viewer. For them, it would be beneficial to display what layers are active in a more prominent way. One way to achieve this is by including an active layer dialogue (see Figure 6.32).

Major suggestion 3: A more prominent option to redirect from the map viewer to the catalogue

Another larger usability issue involved the participants overlooking the redirection option from the viewer to the catalogue. This option could be shown more prominently for all layers in an active layer dialogue. Other solutions involve presenting this option more noticeably in the visual hierarchy on its current location whilst increasing the white space, or to make it available in the list of dataset search results (see Figure 7.22).

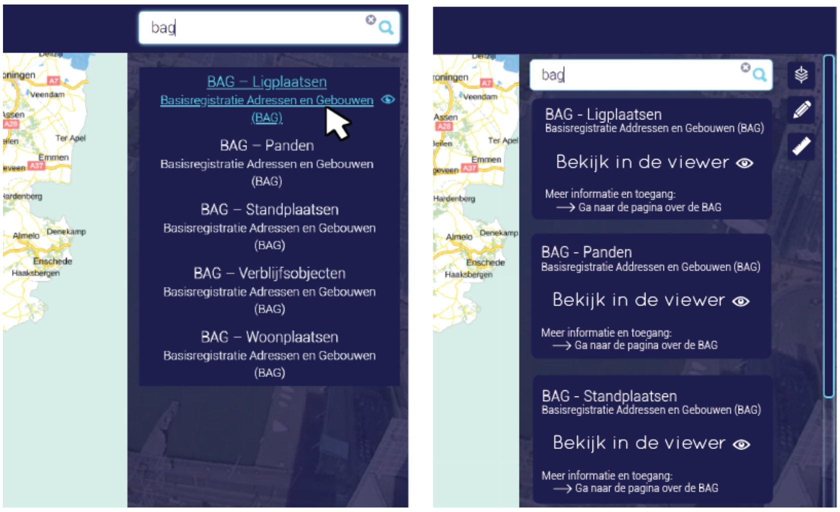


Table 7.22: Possible changes related to the position of the search bar for data in the map viewer. The original implementation is shown on the left, and the possible improvement on the right.

Minor suggestions

Some other more minor suggestions include the request of one participant to capture the contact utility link in the support drop-down. Furthermore, it is possible to display feature information upon both left and right mouse button clicks and to automatically confirm a keyword after clicking an auto-suggestion.

Additionally, one participant mentions it would be nice to zoom to the location of the user in case a dataset is only available on a large scale map view and the full country level cannot be shown as default. In the mock-up, I decided to zoom in on Apeldoorn, where the head office of PDOK is located. An advantage of zooming to the location of the user, is that the user is familiar with this location, making it easier to assess the suitability of the data from here. This is supported by that several of the analysed geoportals offer a button with which users can zoom to their location.

Plausible suggestions

Other requests leave room for discussion. One participant, for example, suggested changing the order of the items in the menu bar of the home page; instead of the order "support – viewer – catalogue", (s)he would expect a left to right order of "catalogue – viewer – support" based on the importance of the processes. However, I picked the current order to be visually pleasing with the support drop-down. Another participant thinks the catalogue page is too busy and suggests this can be resolved by using navy backgrounds for the search results, only showing the currently selected or hovered items as a preview image. Asking more users for their opinion could be a way to make a more well-founded decision regarding these issues.

7.5. Summary: Evaluation of the design elements

The user-friendliness of the elements captured in the GUIDE can be assessed by comparing the results of performance and self-reported usability metrics of a benchmark experiment to a follow-up experiment performed with a mock-up following the GUIDE. Based on this comparison, the usability of the mock-up seems to exceed the usability of the benchmark. Since the mock-up is based on design elements that are listed in the GUIDE, this indicates these elements indeed result in a more user-friendly geoportal UI.

8
Conclusions

With this research, I aimed to develop a guidance framework for user-friendly UIs for geoportals. This aim is covered by the following research question:

"What user interface design elements determine the user-friendliness of physical and intellectual human-computer interaction with geoportals?"

By performing a literature study into user-friendly geoportal UI design characteristics, assessing best practices of existing geoportals in a desk research, and carrying out two user sessions, I developed a scientifically sound guideline for the development and assessment of geoportal UIs: the Geoportal User Interface Design Evaluator (GUIDE). The GUIDE (summarised in Figure 8.1) supports user-friendly *physical interaction* (navigation, search mechanisms, and access mechanisms) and *intellectual interaction* (system interaction, communication mechanisms, metadata, and help mechanisms). The content presentation and consistency of the design support both physical and intellectual interaction.

Content presentation
- CP1 Use of harmonious colours.
- CP2 Balanced placement of the content.
- CP3 Consideration of ergonomics.
- CP4 "Scannable" content.
- CP5 Support for flexible background maps.
- CP6 Visualisations of the data.

System interaction
- SI1 Error handling and preventing.
- SI2 Responsiveness and system status visibility.
- SI3 Relatable semantics in terms of symbology, linguistics, and controls.

Navigation
- N1 Provide direct ways to do tasks (allow shortcuts).
- N2 Provide navigational aids.

Search mechanisms
- S1 Keyword search for (meta)data and locations.
- S2 Different (meta)data search possibilities.
- S3 Enable more intuitive search.
- S4 Allow filtering of the search results.
- S5 Allow sorting of the search results.

Access and upload mechanisms
- A1 Provide data access.
- A2 Provide (meta)data available in various formats.
- A3 Provide tools for analysis and processing.
- A4 Provide tools for system integration.
- A5 Allow users to subscribe for updates or news.

Communication mechanisms
- CM1 Allow sharing of (map view) pages.
- CM2 Collaboration system between users and providers.
- CM3 General contact information.
- CM4 Contextual contact button linked to a form or chat.

Metadata
- M1 Accessibility conditions of the data.
- M2 Availability of standardised metadata.
- M3 Data governance model.
- M4 Information about the portal.
- M5 Links with other data and information sources.
- M6 Quality indicators.
- M7 Semantics (layer legends and data attributes).
- M8 Structure of the data (data model, service level, etc.).
- M9 Topic and distinctive description of the data.

Help mechanisms
- H1 Audience-oriented sections.
- H2 Support for data use.
- H3 Support for geomatics related knowledge.
- H4 Support for portal use.

Consistency
- C1 Consistent appearance.
- C2 Consistent behaviour.
- C3 Consistent semantics.

Figure 8.1: Summarised overview of the elements of the GUIDE.

To evaluate the GUIDE, I compared a usability benchmark to the usability of a mock-up implemented in accordance to the GUIDE. The findings resulting from this comparison suggest that the elements listed in the GUIDE as implemented in the mock-up result in a more user-friendly geoportal UI. In the adopted usability metric that covered 128 fields related to performance and self-reported metrics, the mock-up outperformed the benchmark in 95 fields. This improvement was confirmed by qualitative comments of the six participants of the usability sessions and by the experts of PDOK.

In the introduction, I asked you to imagine yourself in the role of a GIS specialist looking for a specific type of GI. The GUIDE supports developers of geoportals by providing guidance on the UI design for three major tasks users want to execute on the portal:

1. searching data,
2. assessing if data is fit for a use case,
3. and accessing data.

An example capturing the pages you need to perform these tasks with the mock-up is displayed in Figure 8.2. Compared to the benchmark, a desirable increase in efficiency is achieved by integrating the pages related to the most frequent use cases on a single page.

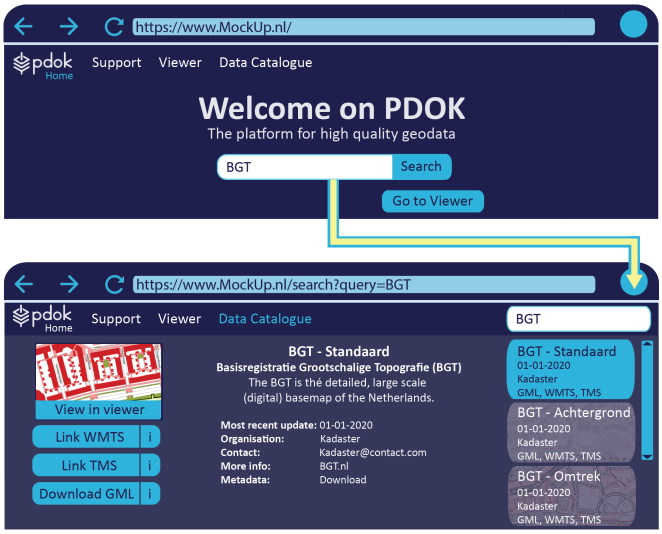


Figure 8.2: Schematic overview of using the mock-up.

Although different users are likely to require different things from a UI, and only six users and two user types are considered, this research indicates the design elements in the GUIDE are a suitable general fit; a one-size-fits-most that can be used as a starting point for future design.

Even if GI is openly available, users do not necessarily manage to find, obtain, and thus use it. By applying the design elements listed in the GUIDE, more user-friendly UIs of geoportals can be achieved, supporting users in the process of searching, assessing, and accessing GI. This helps to facilitate (re-)use and, correspondingly, increases the value of the GI.

However, from a scientific perspective, there are research limitations that leave room for improvement (Section 8.1), and the foundation I provided with the GUIDE and the corresponding mock-up establishes a full new research agenda (Section 8.2). In line with the GUIDE, this research also reveals societal recommendations for geoportal UI development (Section 8.3).

8.1. Research limitations from a scientific point of view

Both the research scope and the reliability of the results are narrowed down because I had to conduct this research in a limited amount of time and with limited prior knowledge. Future research can expand and improve on this.

8.1.1. Limitations user sessions

During my research, I had to establish a foundation. This required me to include explorative experiments and qualitative comments in the user sessions, making such sessions time-consuming to perform, process, and analyse. Because of this, I could only include a limited number of participants. This resulted in less statistically sound quantitative values.

Generalising based on a small sample size should be prevented to acquire representative results and to filter outliers. For this reason, I recommend additional research involving user sessions with more participants of a wider range of user types to extend my initial re-evaluation of the GUIDE.

For user sessions in future research, I would also recommend performing a large scale pilot to prevent comprehension issues with the tasks. Furthermore, it would be best to perform user sessions with a more experienced, neutral facilitator to avoid any facilitator related biases.

8.1.2. Limitations implementation examples from existing portals

In this research, I used a combination of literature review and a sample of five different portals as a support for decisions related to implementation examples. For future research, I would recommend increasing this sample size to achieve more statistically sound results. Additionally, it would be possible to investigate well-performing general websites. I did not consider such websites, because they do not contain all parts a geoportal should have. However, for the general UI design, it would very well be possible to learn from general implementations.

For the content presentation, for example, not only fonts, colours, and the location of elements, but also suitable sizes and spacing could be analysed into more detail. Based on my initial analysis, it seems likely that what sizes and spacing look good and work well, depends on more factors than just the text size. More in-depth research considering a larger number of variables could help to see if it is possible to establish patterns for this.

8.2. Recommendations from a scientific point of view

The GUIDE can be the foundation for a new research agenda focused on the user-friendliness of geoportal UIs. Such future research could, among others, involve the topics I describe in this section.

8.2.1. User-friendly semantics

Higher compatibility with the mental model of the user can increase the usability of a UI. This can be achieved by implementing suitable semantics in terms of adopted symbols, terminology, and controls. In this thesis, I discussed possible examples of such user-friendly semantics. However, more extensive research is required to be able to conclusively state what semantics are most suitable to which users. This could, for example, involve in-depth research into patterns regarding popular semantics of existing portals. Future research should also include the reasoning of these existing portals behind adopting certain semantics. Moreover, I recommend presenting different semantics to users to see how they interpret them.

Furthermore, suitable semantics can in some cases be established by a card sort experiment [Tullis and Albert, 2013]. To determine suitable dataset themes, for example, participants can be asked to group a selection of cards capturing datasets that are available on a portal. Based on the most frequent groups and the names users assigned to them, themes can be created.

User-friendly dataset themes

The themes that can be used to search datasets could also benefit from research into suitable semantics. For theme-based browsing to work, it should be clear what data is captured in each category and the categories should be recognisable. All four of the participants who used themes during the benchmark session, acknowledge they currently have several issues with this: themes can be unclear, seem to overlap, or are too limited. At the moment, different portals all adopt different themes. Future research can be focused on establishing a suitable standardised set of themes with matching icons.

8.2.2. User-friendly search mechanisms

At the time of writing, PDOK hosts 192 datasets. To still enable users to find the right dataset for their needs with this amount of data, the search mechanism on the portal should be user-friendly. In the GUIDE I captured search mechanisms should be intuitive in that users should be enabled to find data by searching for synonyms and (meta)data elements. This involves adding tags to the data in suitable semantics. Future research can be focused on this.

The adopted sorting mechanism is also of influence for the findability of the data. Sorting on relevance, for example, can be desirable. This relevance could include the popularity, which can be defined based on the number of downloads or views of a dataset. Moreover, the importance of a keyword matched to a tag can be considered. In the case of a fuzzy search, the best match can be presented first. To deal with equally good matches, it would be an option to assign importance values to each tag. These values can, for example, be based on use statistics capturing how frequent a dataset is combined with a certain keyword. Related research regarding user-friendly search mechanisms is already available, however, a suitable solution for geoportals is yet to be investigated.

8.2.3. User-friendly supportive mechanisms

During this research, I solely looked into the three main processes users want to perform on a geoportal: searching, assessing, and accessing data. Several mechanisms listed in the GUIDE could be used to provide support during these processes. This mainly involves the *communication mechanisms* and *help mechanisms* but also the tools for data analysis. In this research, I solely determined what mechanisms should be available. However, something being available does not automatically mean it is user-friendly. For future research, I would recommend looking into the user-friendliness of different types of implementations of the support mechanisms listed in the GUIDE.

This can be attempted by taking a similar approach as I did in this research, involving literature review, studying existing implementations, and testing with users. However, instead of focusing on the UI in general, future research could go into the details of specific support mechanisms.

Although I touched upon this by asking users to rate the design characteristics listed in the GUIDE, I would also recommend to further look into the relevance of certain support mechanisms to assess if users realistically use them. The need for this is reflected by that only one of the participants initiated looking into the support mechanisms during the user sessions. This could be due to the nature of the session, in which participants did not see the need for support mechanisms because I provided hints. However, three participants also stated they were unlikely to consult a manual when using the portal.

8.2.4. Towards adaptive UIs

The users of geoportals are diverse, and it is challenging to suit their diverse needs in a single static interface. Adaptive UIs can be used to fit the individual needs of users. Possible options for adaptive interfaces for geoportals are listed more extensively in Annex A. Within this research, I did not manage to overcome certain challenges related to the process of achieving this.

Storing the data

Recognising reoccurring users who are unwilling to create an account is challenging. Cookies can be removed, and dynamic IP addresses change. Future research might shed new light on possibilities to prevent the adaptation being limited to a single session.

Acquiring preferences

To provide users with adaptive content, they are often grouped in stereotypes based on shared characteristics. Collaborative filtering can then be used to provide users with content preferred by similar users. PDOK (and likely most other portals as well) already has data from previous market studies covering the wants and needs of their different personas. This data can be used to establish stereotypes.

Differences in preferences for user-friendly content presentation, navigation, semantics, or supportive mechanisms for different personas, can additionally be uncovered by future research.

Furthermore, future research can shed new light on possibilities such as real-time testing of the preferences of users in a/b tests.

Linking preferences to implicit behaviour

Explicit stereotyping is, for example, possible with a button on the home page. Semi-explicitly, users can be grouped into the corresponding stereotype if they visit a specific audience-oriented section. Within this research, I did not manage to discover any relations between the implicit browsing behaviour of a user type and their specific preferences for the UI. Additional research with a larger sample size could provide a more definitive answer in whether or not these patterns exist.

Furthermore, there might be significant individual differences in preference within a single stereotype. For this reason, the user model can also be extended with the personal preferences of a user. The frequency of clicks can, for example, be associated with such personal preferences regarding filters or access mechanisms.

8.2.5. Fine-tuning the GUIDE as assessment framework

Another possible topic for future research would be to evaluate the quantitative scores assigned to the elements of the GUIDE to assess existing geoportals. Rating portals with the GUIDE to assess what score ranges can be considered good, satisfactory, and unsatisfactory could be part of this.

8.3. Recommendations from a societal point of view

With 14.4 billion hits in 2019 and with 35 billion hits expected for 2020, users display interest in the Dutch geoportal PDOK [PDOK, 2019]. However, during the benchmark, several participants stated they would usually resort to Google in case they experienced issues with a task.

Geoportals are supposed to be a one-stop-shop for GI. Within such a one-stop-shop, users would ideally find everything they need to discover, assess, and access GI [Braggaar, 2016], [Koudijs, 2011], [Giff et al., 2008]. With users using workarounds such as Google to get to the individual pages of the portal, geoportals apparently do not yet fulfil their goal.

My study shows geoportals can be more usable if they implement the UI design elements as listed in the GUIDE. Even the alleged best practises I analysed during this research (PDOK and the geoportals of France, Ireland, Norway, and Luxembourg) do not comply to all aspects of the GUIDE yet, so there is room for improvement.

Users seem to especially appreciate efficiency of use in terms of spend time, and number of clicks and page visits. The catalogue page of the mock-up increases this efficiency by integrating all possible tasks a user could want to execute on a portal on a single page. I would recommend all geoportal developers to consider this integration, to make their geoportals more efficient and thus more user-friendly. Beyond the scope of the UI, integration can be even taken a step further by tackling the challenge of fragmentation. Three participants of the user sessions acknowledged they did not like having to redirect for information, and the experts from PDOK also confirm this is undesirable. In line with this, related research covers that data fragmentation causes confusion and affects the findability of datasets [Welle Donker et al., 2019], [Braggaar, 2016], [Van Loenen, 2006]. It is easier if there is a single geoportal displaying all required information, serving as a true one-stop-shop [Braggaar, 2016], [Giff et al., 2008].

During my research, I noticed there is lots of possibly valuable information and documentation available related to the GI offered on PDOK, NGR, and Data.overheid. However, on the landing pages of these portals, contextual links to these external sources are rarely provided. To make sure users are aware of valuable external information sources and tools, contextual references are desirable. This includes references to websites of the base registry or dataset covering more elaborate information and tools such as the BAG viewer. For the datasets I analysed, PDOK, for example, only lists a link to such a website on the landing page of the BRO. Additionally, GitHub pages and dataset catalogues containing documentation are often available, but not linked. To link to more general tools, a service page as provided on PDOK makes sense. At the time of writing, this page is incomplete; services such as NL Maps and Verbeterdekaart.nl are not accessible via PDOK.

To achieve a more user-friendly geoportal, I recommended capturing relevant documents and information that are currently scattered over various sources in their related context on the geoportal. By clustering these scattered elements, the geoportal will become even more of a one-stop-shop, bringing us one step closer to a better fitting UI for a wider range of users.

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A

A change of view: Adaptive user interfaces for geoportals

ABSTRACT

Satisfying the diverse needs of the different types of users of geoportals in a single user interface (UI) is a goal worth pursuing to increase the access to open geodata. Adaptive UIs represent a possible way to achieve this, by establishing higher compatibility between the user and the interface.

However, currently, there is no model available which describes how Adaptive UIs can be implemented in the context of geoportals.

In this paper, this gap is bridged by creating such a conceptual model based on literature review. In this model, catering help when required, storing preferences for recommendation and filtering purposes, and task recognition for navigational support are covered.

1 INTRODUCTION

Users are keener to use systems with a user-friendly user interface (UI) [33], [102], [64], [109], [90], [59]. In the context of geoportals, an increase in use can maximise the portal's effect [46] by leading to more access to open geodata, which in turn results in more use and a higher impact of this data [99], [52], [98].

However, the diverse perspectives of the different user groups of web-based systems might conflict [21] since individuals may differ in characteristics such as level of expertise or preferences [111], [94], [4], [55]. This is also true for the users of open (geo)data portals [115], [74], [37], [99], [101], [39]. Such diverse characteristics require different design goals [88], [58], which are nearly impossible to satisfy in a single design [99], [11], [32].

As an alternative for the traditional one-size-fits-none approaches [47], [11], [13], adaptive hypermedia (AH) systems automatically adapt their displayed content or style of interaction to better suit the inferred situation or characteristics of the user [91], [64], [72], [4], [92]. By guiding the user [49], [4], adaptive behaviour can for example help to overcome problems related to information overload, orientation [8], [49], and comprehension challenges [27], [28]. Because of this, the adaptiveness can improve the usability of the system in terms of efficiency [92], effectiveness, and satisfaction [67], [91], [47], [27], [4].

Related research on this topic shows, for example, what the behaviour of users could mean. Such as that the time spent on a page, the amount of scrolling and a combination of time and scrolling are found to have a strong correlation with explicit interest [67]. Other research is focussed on what can be adapted based on this information, such as, providing recommendations [17], [35] or help when required [43], [68]. Furthermore, different adaptation techniques and their opportunities are researched [49], [14]. Annotations can, for example, distinguish several states of relevance, whilst avoiding challenges related to incorrect maps and link stability [13]. Added to this, there is research available related to assessing the performance of adaptive systems. Such as that the use of stretchtext can increase the speed and quality of user comprehension of the content [14] and that adaptive presentation can result in users answering comprehension questions faster and with better comprehension [9]. Other studies show that adaptive versions with annotation resulted in less navigational overhead to achieve the same educational goal [13]. Furthermore, casual users stay longer if adaptive navigation support is provided [13], which indicates an increase in interest [56], [60], [2], [67]. In the task-based adaptation approach adopted by [92], users performed better in terms of execution times and accuracy in the adaptive site. However, for more difficult tasks, the perceived complexity of the adaptive site was higher, and users were less satisfied. The perceived usability of UIs adapted based on the cultural background of users caused an increase of performance in terms of fewer errors, fewer needed clicks, and more speed. Users found the adapted version easier to use and more attractive [80].

To the best knowledge of the author, research on the possibilities for adaptive geoportal interfaces seems to be unavailable. To bridge this gap, a conceptual model capturing possible implementations of adaptive behaviour for the UI of geoportals will be presented in this research in line with the following research question:

"What could be a conceptual model for the implementation of adaptive UIs for geoportals?"

To do this, in the first place the state of the art of (adaptive) UI design will be analysed in Section 2. Furthermore, a literature review will be performed according to the methodology as is described in Section 3. This results in the findings presented in Section 4, which can be combined into the main contribution of this research discussed in Section 5: a conceptual model for adaptive geoportal UI design.

2 STATE OF THE ART (ADAPTIVE) UI DESIGN

The UI is the communication layer between the system and the user, which allows the user to interact with the content of a webpage [45], [84], [15], [33], [4], [64]. Literature review reveals that the UI consists of three main elements: the graphical representation (1), interaction with available services (2), and information (3), including enabling information such as documentation [37], [71], [79].

The UI should be compatible with the user, their tasks and the product itself [74], [37]. To achieve this, UIs can be made adaptive to the needs and preferences of their users [91], [64], [32].

2.1 User modelling

To understand and adapt to the needs of a user, a user model (UM) is required [80], [22], [27], [13], [14], in which information about the users, or tasks and related interactions can be managed [14], [91], [11], [55]. For adaptive systems, user modelling involves predicting user characteristics based on interactions of the user with the system [4], [87], [50], [55], [67], [17], [64], [72], [75]. These characteristics can, for example, involve the knowledge, interest, goals, background, preferences, or the current context of the users' work related to their device or physical conditions such as the day of the week [14], [27], [28], [11], [13]. Individual traits such as cognitive factors or learning styles could also be of influence, however, for these aspects it is often unclear what is worth modelling and they can be hard to deduce [11], [14]. The UM should be limited to elements that have a direct use for adaptation [22], [14], [41].

In general, certain user actions related to events or conditions can trigger changes in the UM, which contains rules that trigger personalised adaptation of the UI [80], [26], [75], [77], [50].

UMs can, for example, be based on feature-based, stereotype or overlay models. More advanced techniques such as Bayesian Networks and Fuzzy Logic can be applied to deal with the uncertainty of concepts in the UM, for example, by assigning probabilities to certain types of occurrences of triggers [14].

2.1.1 Feature-based models. Characteristics of the user are modelled and maintained in the UM [14]. This type of model can have varying granularity and corresponding complexity.

2.1.2 Stereotypes. User can be grouped by calculating the probability they belong to a certain stereotype. Adaptations suitable to the most probable stereotype can then be presented to them [43], [14]. Since stereotypes make predictions about users based on little evidence [82], they can be used to initialise individual feature-based models to avoid cold-start issues [14], [64]. In this sense, the stereotypes do not have to be completely accurate, they provide a foundation which can be overridden once more specific facts are available [82].

2.1.3 Overlay models. The user is typically characterised in terms of assumptions about the knowledge of a user in relation to domain concepts compared to the ideal knowledge of an expert [41], [14].

Overlay models can sometimes be too simple since the state of the user knowledge is never an exact subset of expert knowledge. A bug model can be used to also model possible misconception and genetic models reflect the development of user knowledge. Practical use of both these models is limited due to their complexity [14].

2.2 Methods for adaptation

Within the context of the characteristics of geoportal users (discussed into more detail in Subsection 4.1), adaptive behaviour can mainly relate to help based on knowledge, or recommendations based on interest or intention.

2.2.1 Knowledge (Help system). Adaptive behaviour can help to deal with varying levels of expertise of different users. A reaction, such as providing a hint or a chat functionality pop-up [67], or different versions of the content, can be displayed depending on an attached level of expertise [47]. The knowledge of a user can be represented in binary [43] or a scalar scale [14]. Experts and novices are stereotypes which are often related to this [27], [32].

Knowledge can differ for different parts of the domain [14] and knowledge is not only related to the domain, but also to the platform. New visitors for example browse different than repeating visitors, whose increased proficiency in working with the interface [96], [72] results in a reduced amount of pageviews and a shorter session time [72]. Determining the probability a user knows a concept can therefore be based on the different strategies experts and novices use to complete tasks [111], [72], [43]. Another possibility would be to use the interactions of the user with help systems [43].

The background of a user also implies knowledge about the domain such as experience in a certain area [43] or jargon implied by a profession [14], [44] and can reveal previous experience with similar systems and the domain, both of which are indications for proficiency [96].

2.2.2 Interest or intention (Recommender systems). It is important to display information relevant for the user's needs [108], [84], [15], [115], [37], [66], [1]. Recommender systems determine the interest, preferences, or goals of a user based on their behaviour, and rank suggestions or information based on this [60], [18], [11], [75], [4]. This helps to prevent users from getting lost due to information overload and filtering problems [114], [35], [47], [105], [4], [32] [8], [49], [37], [15], and to make locating and retrieving relevant information more efficient [35], [11].

Based on similarities of the current navigation sequence and expected navigation sequences related to tasks, the task and related goals of a user can be deduced [43], [68], [4], [14], [32], [92]. This information can then be used to make recommendations of links that help guide the corresponding execution [68], [11], [4], [77], [32], [76], [102]. Such recommendations in the form of navigation support let users achieve their goals faster, reduce navigation overhead, and increase satisfaction [13].

Recommendations can also be provided in the form of autosuggesting. The general idea behind autosuggesting is to identify routines and preferences based on previous interactions [75]. Such a functionality avoids the need for lots of shortcuts [7] or filling re-occurring fields in a form [7], [55] to complete an action and can make more frequent tasks simpler to perform.

The process of determining a suitable recommendation can be content-based or based on collaborative filtering [38].

For content-based filtering, each item is represented by a descriptor [55], which, for example, consists of keywords. The user profile consists of the interest of the user based on aggregated descriptors related to past interactions or a weighted overlay of the concept domain. Items with a similar profile to the user profile can be used to adaptively rank or filter information [112], [2], [105], [17], [55], [14]. If a user, for example, views dataset X with theme Y, the interest in both X and Y increases [26]. The recommendations can also be based on generalisations of existing rules, such as if users prefer a certain coverage for dataset A, they would also like this for dataset B [75], [64].

Collaborative filtering relies on recommendations related to past usage of like-minded users, for example of the same stereotype [63], [17], [13], [55], [105]. In general, collaborative filtering involves the assumptions that if user A has a similar preference to user B, then the probability exists they have other corresponding preferences [75], [17]. Collaborative filtering is a possible way to deal with the cold start of new users [50], [7].

A combination of content-based and collaborative filtering results in a more reliable performance with fewer drawbacks. However, it is more challenging to keep such an approach understandable for the users [105].

2.2.3 Taxonomy of adaptation techniques. A taxonomy of adaptation techniques, such as showing and hiding specific content [43], is for example provided by [11] who separated adaptive presentation and adaptive navigation support. [49], [14], and [12] later extended this with a category for content adaptation. A taxonomy containing elements discussed in related research is shown in Figure 1.

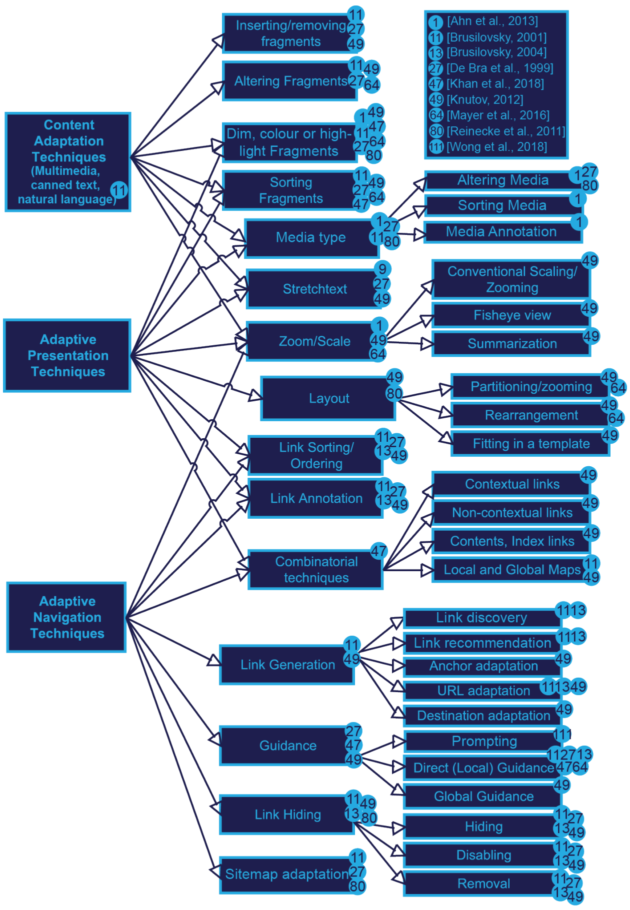

Figure 1: Taxonomy of possible adaptation techniques (adapted from [49]).

The possible adaptation of media types [27], [11], [1], [80] is not captured by [49]. However, this addition can be relevant since users learn more deeply from words and pictures than from words alone [94], [105] and images can evoke the urge to want to see more [51]. As a downside, having users split their attention between two information sources can increase cognitive load. This can possibly be handled by adapting the type of media. Furthermore, the interpretation can be adaptively supported by annotating parts of a visualisation depending on where users are reading [94].

2.3 Challenges related to adaptive systems

There are several challenges related to adaptive behaviour. User modelling can for example be complicated due to a possibly limited amount of information deduced in each session [50], [17], [63], [60] and in general, there is a fear that intelligent systems might disturb users [80]. This can relate to:

2.3.1 Undesirable changes. Next to incorrect modelling of user preferences, another cause of undesirable changes lies in misinterpretations of implicit user traces [91]. Links can for example be clicked by mistake instead of out of interest [18] and thoughtless clicking through content does not mean it is understood [22].

2.3.2 Lack of control. Users value the feeling of being in control [112], [2], [7], [114], [102], [92], [32], [88], [74]. However, adaptive systems are often uncontrollable [4]. An example of this is the trade-off that might occur between offering navigational freedom and link overload [29], [13]. Direct guidance through "next" or "teach me" buttons can for example become an issue if users do not want to follow this suggestion [13]. If a service offers control, this can result in higher perceived efficiency and overall satisfaction [31], [58]. Furthermore, an increased sense of (perceived) control can reduce privacy concerns [114].

2.3.3 Lack of transparency. The increasing complexity of UMs under current developments, such as, data mining, neural networks and deep learning leads to less understandable system behaviour [91], [2], [4], [26]. This is a worrying development since users value transparency [112], [75] and can be discouraged by unexpected changes and behaviour [88], [92], [114]. For this reason, a lack of understanding results in a loss of control and trust in the recommendation [2], [105].

2.3.4 Lack of consistency. Learnability, recognition, and intuitiveness of the system are of importance to decrease the chance of mistakes and to enable users to finish a task more quickly [84], [101], [74], [102], [37], [88]. To achieve this, the appearance of the page [74], [65], [37], [88], [20] the behaviour of the system [106], [74], [65], [37], [88], [25], [74] and the semantics [57], [88] should be consistent [58], [92] and in line with the mental model of the users [65], [2], [13], [32].

The flexibility of adaptive systems can reduce memorability and might lead to errors [74], [102], a higher cognitive load [72], confusion [41] and higher perceived complexity [92]. With link hiding or removal, users can for example be discouraged when they can no longer use previously available content [13]. This means there is a trade-off between consistency and adaptive behaviour.

2.4 Challenges resolved?

In research by [31], adaptable menu interfaces are found to be preferred over static and adaptive versions. Such findings suggest that a mix between adaptive and adaptable systems, in which users can actively influence adaptations [64], [4], [32], can be of use to deal with the challenges mentioned in Section 2.3.

Adaptive systems can be made adaptable when they allow users to explicitly set preferences [28] or introduce changes [32]. It should, for example, be possible to allow users to change the content of their UM in a preference manager or customisation panel [64], [14], [1],

[80], [32], [114]. This requires transparency around what the system assumes about the interests of the users, why this is, and what the matching adaptation rules are [26]. A well-known example is the "because you viewed dataset X" approach [105]. In the research by [112], users appreciated such a visible task model. Next to changing the assumptions of the system, users should also be enabled to guide the adaptation, for example by checking boxes for adaptation rules they perceive to be relevant [26] or by indicating when they would want a prompt [111].

This can increase control [64], [114], [2], [105], [4], exploration [105], satisfaction [105], [74], [2], [2], transparency [114], [2], effectiveness [1], [105], trust [114], [2], a safer feeling [58], [114], and allows correction of unsuitable adaptations [80].

A downside of adaptable systems is the effort required by a user. Furthermore, adaptability can increase complexity. For this reason, the customisation panel should be optional and easy to use [32]. Another option would be to consult users for changes in a pull-based approach [67], [114], however, it should be minded that this might also harm the user experience [88], [114]. In general, editable UMs must be used with caution, because users who do not have the required background to make well-founded decisions regarding changes may harm the performance of the system [64], [114], [2]. In the research by [2], a negative correlation was discovered between system performance and the amount of UM changes by a user. However, provided that users can distinguish good and bad system performance, it is assumed that immediate feedback about the effect of their proposed changes will allow better decision making [2].

3 THE CONCEPTUAL MODELLING METHODOLOGY

Adaptive systems can be defined by answering the questions displayed in Figure 2 (based on [49]). These questions will dictate how the ideas behind the conceptual model for adaptive geoportal UIs were found in, and inspired by literature.

The answer to the "why" question relates to the motivation for this research, which involves dealing with the current, not very user-friendly, one-size fits none approach of geoportal UIs. Based on related research into methodologies for adaptation, it is already analysed "how" it is possible to adapt (Subsection 2.2). To answer the "what" question, the state of the art of geoportal UI design needs to be considered (Subsection 4.1) the different kind of traces users leave when using a geoportal can be used to answer the "to what" question (Subsection 4.2). Together with the adaptation rules of "when" (Subsection 4.3) and the application areas for "where" adaptation can be applied (Subsection 4.4), this can be combined into the desired conceptual model (Section 5).

4 RESULTS

4.1 UI design geoportals

A geoportals is an access point for spatial (meta)data [44], [34]. There are several types of portals with varying types of functionalities, some do not offer additional services [8], others offer functionalities more related to a data platform such as feedback options, example use cases, and so on. In this paper, the term geoportal

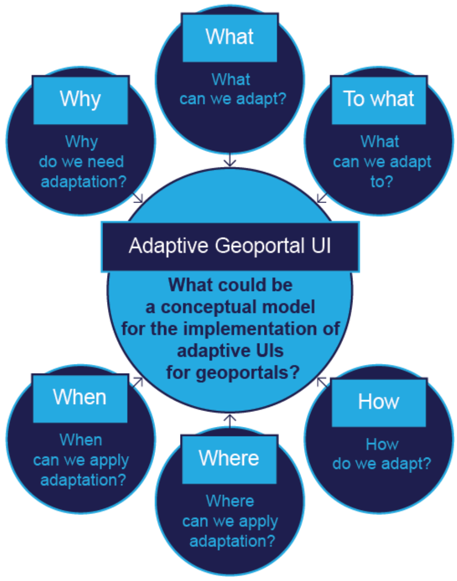

Figure 2: Questions to define an adaptive system based on [49] related to the main research question of this research.

refers to a system similar to Dutch geodata platform PDOK[1] in terms of available functionalities.

This is in line with the following definition from [81] (p. 1019): "A geo-portal is a web-based system that allows users to discover particular geo-datasets by looking into the associated metadata, to portray the data on a map, and to retrieve the data in adequate formats to further process them in a professional workflow."

Most commonly, users visit a geoportal when they want to discover datasets that are relevant for their needs [44], [34]. This means search functionality is required. Furthermore, data visualisation mechanisms are essential to help users assess, understand, and utilise data [40], [54] and access to data is required for further analysis [81], [62], [34].

The UI of the portal enables interaction of the users with these functionalities to search, assess, and access data. Based on previous research, UI design characteristics with potential for adaptive implementations related to geoportals should be selected, which is described in Subsection 4.4.

4.1.1 UM characteristics. The users of (open) geodata portals have diverse characteristics [115], [74], [37], [99], [101], [39] which can be used for UM purposes.

Within the limited time frame of this research, it is infeasible to acquire initial requirements of all possible geoportal users. Consequently, this research will only consider possible requirements for the GIS specialist (a geo-professional) and a developer user type, which is in line with recent developments on PDOK.

In general, the skill level of the user with the UI and the domain are important user characteristics. These need to be separated, since professional first-time users still have little knowledge of the

[1] www.pdok.nl

interface [88]. Portal users encounter difficulties when they try to search, make sense, and access data [74]. In geoportals, this is easier for the geo-user [78], [46]. However, even people who work with Geographical Information Systems (GISs) have diverse levels of experience [69]. This can be related to a characteristic such as "declarative geo-knowledge", which is related to concepts [43], [22], [14], [68]. The same is true for concepts related to the developer, covered by "declarative developer-knowledge".

Unclear portal functionalities are related to a lack of procedural knowledge, which is related to actions [43], [22], [14], [68]. This is covered by the characteristic "procedural knowledge".

For recommendation purposes, interest plays a role as opposed to knowledge [1]. In relation to this, different users can have different preferences regarding data and their access such as the theme, coverage, actuality, data attributes, aggregation level, data format, data service level (view, download, geo-web services, or API), data size, completeness, consistency, the available metadata, language, and semantics [107]. These preferences and interests can be stored in the UM.

Another possible characteristic is the purpose of use. For geoportals, this purpose is indicated by the place of the user in the information value chain [101]. In this context, there is a distinction between suppliers, intermediary users and end-users. The intermediary users can be subdivided into categories of aggregators, enablers, developers, and enrichers [108], [99], [107]. Open data is most often used for both commercial and non-commercial intermediary purposes. However, due to the dynamic nature of the market, most re-users seem to use open data for more than one specific purpose [108]. Incorporating such possible short-term changes is prone to noise and can skew standard models [50]. For this reason, the purpose of use itself has not been incorporated in the UM. However, the current task of the user can be detected to provide navigational support.

The behaviour, knowledge, and interest and intentions of geoportal users can be interrelated, which can be used to make certain assumptions in the UM based on generalised stereotypes. If users for example access their data through APIs, this will increase their declarative developer-knowledge, as will be the case for declarative geo-knowledge for users who use geo-web services. This can even relate to different preferences in datasets. GIS specialists want to perform analysis, such as showing all buildings in a city built before a certain year, this requires different datasets than a web developer, who wants to display parking locations, routes, or office locations.

4.2 Collecting user data

Collecting data related to user preferences and behaviour in order to trigger adaptations is a main challenge for adaptive systems [93]. There is a trade-off between doing this either explicitly or implicitly [38], [43], [60], [18], [4], [112], [114], [27], [41], [32], [80]. Explicit means, require more effort from the user, however, non-intrusive, implicit traces collected during use are harder to interpret [18], [22]. A combination of both means is often most efficient [38], [60].

4.2.1 Explicit. Explicit data collection involves the users directly telling the system what they think [60]. An example of this involves having users fill a questionnaire as a way to gather initial data for user modelling [43], [80], [27], [76], [67]. Typical information covered in such questionnaires involve questions about abilities [67], background, or users can pick pre-defined goals [14]. Furthermore, users can be asked to rate (proposed) adaptations or recommendations [67], [18], [112], [1], [4], [55], [32]. A downside of this type of explicit feedback is that users do not like mandatory questionnaires [53], [93] and asking feedback can be intrusive [4]. Additionally, explicit data can be biased since users might be only motivated to provide information in case something went wrong [60].

Less intrusive explicit data collection can be related to preferences directly entered by the user [4], [55], [35] such as when they bookmark certain pages [60], [105] or rate content. It is also possible to store filters previously set by a user [43]. This is beneficial since users are likely to find setting manual filter parameters tedious [55]. Furthermore, users can be allowed to tag datasets under alternative names, which can enhance linguistic clarity, querying functionality [108], [74], [15], [61], [42], [20], and the accuracy of recommendations [17], [105]. Based on collaborative filtering, such personal tags can be used to establish official keywords for data search and to some degree make the natural language of the content more suitable [64].

4.2.2 Implicit. Implicit data acquisition is constrained by the input equipment of the user. For geoportals, this is most often limited to traditional low-level input which involves mouse clicks [11], [43], [56], [67], [114], [68], [50], hovering [80], cursor movement in general [77], [60], [67], [75], keyboard input [87], [43], [60], and scrolling interactions [60], [67], [50]. Even the type of input keywords for search can provide information [38], [60], [14]. Related to these interactions, the pages accessed [48], [87], [38], [77], [2], [50], [72], [27], [4], [19], [22], [75], and the time spent on a page [72], [48], [11], [87], [38], [77], [67], [22], [2], [50], [72], [19], are statistics which are often mentioned.

New types of information are acquired by aggregating the collected data. This, for example, involves deducing the frequency of visits [48], [87], [38], [77], [43], typical entry and exit pages [77], and navigational patterns [87], [38], [68], [4], [110], [114], [72]. Frequented paths between pairs of pages can be used to establish interdependent domains [48], [87], [38], [77], this can be helpful for recommendation purposes [63], [14], [29].

The limited options for user input in the context of geoportals do not leave room for recent developments of more extensive data acquisition based on multimodal input in the area of intelligent UIs [73]. However, especially eye tracking data is often mentioned to deduce attention patterns [22], [18], [67], which can be used to improve efficiency and satisfaction [18]. To some degree, the mouse cursor movement could be a substitute for this [77], [67].

4.3 Defining adaptation rules

Implicitly, adaptations can be triggered based on the behaviour of a user [67]. Related research reveals several possibilities for rules that describe this.

4.3.1 Knowledge. Timing can be a measure to reveal the efficiency of task completion [47], [96], [80], [92], [102], [90], [88]. For this reason, timing can also be used to measure the ease of use of a system [47], [115], [102] and the ability of the user to perceive the content [94]. Based on perceptual theories or previous interactions, longer than average, abrupt pauses in interaction can be discovered, which can be reasons to provide help and rate users to be less experienced [68], [47], [67], [88].

When using time in such a way, it is key to account for possible inactivity during browsing sessions [87]. Activity, for example indicated by scrolling or mouse movement, can be used to check if the user is still using the system [56], [60]. If a user has visited a page and they spent a realistic amount of active time with the content, this can influence their knowledge [27], [14]. The knowledge of a user is dynamic in the sense that users can learn and forget [5], [14]. The more frequent these visits are, the more likely it is the user is familiar with the presented concepts [43].

Furthermore, inappropriate or suboptimal usage such as inefficient command sequences, frequent searches [68], or users going back in the navigation [77] indicate a need for assistance [4], [68], [55]. Questions a user has in relation to a certain topic can be used to determine where additional help could be appreciated [43].

4.3.2 Interests or intention. Visit frequency can be a metric for interest [19], [87], [47] and user engagement [87], [77], or the intention of a user [60]. "Frequent" can for example be defined as at least in 40 % of the sessions [87], possibly with higher weights to more recent data [19]. If a user uses a certain option more frequently, it can be assumed this option is preferred and suiting adaptations such as shortcuts can be provided [38], [77]. Content labels, such as described by [47], can indicate similarity, which can be used for the recommendation of similar pages [4], [67].

Time spent on a page can also be a measure for engagement or interest [56], [60], [2].

Users spending time on a recommended page [2], or clicking the recommended content are means to evaluate the adaptation [2], [41]. However, if recommended items are easier to access, this can introduce a certain bias known as a filter bubble, in which only the recommended items will be explored, which will then be recommended even stronger [26], [41].

4.3.3 Initialisation. At the first use, the UM should be initialised. Based on the fact that most geoportal users use the portal infrequently [101], the assumption can be made that most users are novice using the platform and their "procedural portal knowledge" can be initialised as such [88], [25].

If provided, explicit background information can be related to a stereotype covering assumptions based on average preferences and "declarative knowledge" in a certain domain of users with a similar background. If there is no explicit information provided, the average information of all users can be used.

4.4 Defining application areas

The application areas of adaptations in relation to the UI elements of geoportals and possible methods of adaptation (as listed in Subsection 2.2) are discussed below.

4.4.1 Knowledge. Possibilities for adaptations in relation to the knowledge of the user are displayed in Figure 3.

Knowledge	
Adaptations by	**Mentioned by**
The amount of options displayed in the **content presentation**	[80], [88], [15], [74]
Use of relatable semantics during the **system interaction** by: • Allowing tagging • Avoiding unfamiliar jargon and acronyms (declarative)	[84], [20], [102], [36], [90], [74], [65], [113], [98], [6], [70], [64] • [61], [15], [74], [62] • [104], [15], [113]
Organisation of the **navigation** structure.	[88], [64]
Provide **help** in the preferred context: • In relation to the data (declarative) • In relation to the use of the portal (procedural)	• [30], [116], [61], [74] • [30], [61], [10], [116], [40], [37]

Figure 3: Adaptivity related to knowledge.

4.4.2 Interest or intention. In the context of geoportals, interest or intention can result in adaptations related to dataset recommendation purposes, navigational support, and storing preferences in settings for autosuggestions. This is displayed in Figure 4.

Interest and intention	
Adaptations by	**Mentioned by**
Support flexible **content presentation** and store preferences: • Colour changes or removal • Zoom content (button or text size)	[81], [88] • [106], [88], [4] • [97], [15] [115], [81], [40], [88], [102], [90], [4]
Convey visual hierarchy in **content presentation** for recommendation purposes (to guide users through the portal) with: colour, font, contrast, placement, size, markers	[97], [3], [10], [15], [115], [95], [66], [88], [20], [102], [83], [90], [64], [51], [49], [11], [13], [1], [27], [47], [111]
Efficient **navigation** is preferred. This can be achieved by recommending shortcuts of a detected or most used task	[3], [15], [106], [74], [37], [88], [70], [90], [6], [89], [72]
Autosuggestions of filter preferences for data **search**	[16], [30], [61], [10], [115], [74], [98], [86]
Autosuggestions of sorting preferences for data **search**	[69], [3], [10], [115], [74], [116], [24], [23]
Recommend relevant data during the data **search** process	[30], [10], [61], [74]
Show preferable data **access** method: view, download, API, or geo-web services in preferred format	[42], [44], [108], [16], [30], [69], [10], [61], [101], [74], [52], [24], [100], [115], [46], [116], [103]
Show the relevant **metadata**	[10], [61], [101], [107], [115], [74], [108], [46], [101], [30], [74], [116], [44], [24]

Figure 4: Adaptivity related to interest or intention.

5 RESULTING CONCEPTUAL MODEL

The conceptual model for the implementation of adaptive geoportal UIs is displayed in Figure 5. Next to the implicit measures mentioned in the figure, users can voluntarily add information such as their background for stereotyping purposes or check presets for autosuggesting.

6 CONCLUSION

In this paper, a conceptual model for the implementation of adaptive UIs for geoportals has been presented based on literature review. The UM in this context captures the knowledge of users in different related domains and their use of the interface to provide help in the relevant context, and the interest and intention of these users in terms of storing preferences for recommending data and filtering purposes, and task recognition for navigational support. Capturing this information can be done explicitly on a voluntary basis, or implicitly.

Conceptual model			
Knowledge	Low score adaptations	High score adapt.	Implicitly based on
Declarative developer knowledge	Less jargon, familiar terms and labels • (content adaptation) [88]	Jargon •	Active time spent on a page in a certain context
Declarative geo knowledge	Addition explanations • (e.g. via stretchtext or upon mouse hover) [14], [64], [27], [81]	No additional explations •	Context of the previous use of help systems Context of previously visited pages
Procedural knowledge	Less densely packed display with minimal options • [88] Many specific cues • [88] Logical, hierarchical organisation • [88] Tutorial videos for workflow • [68], [88] Hint functionalities in context • [32]	Interface with maximal options • Non-distracting feedback • [88], [64], [70], [37] Shortcuts • [88], [64]	Active time spent on a page in general Efficiency of clicking behaviour Frequency of use
Interest or intention	Adaptations	Implicitly based on	
Data recommendations •	Show recommendations by sorting of content or links, direct guidance [27], [13], [11], [64], [49] or other display of the visual hierarchy	Content based or collaborative filtering	
Navigation support •		Current pattern of clicks and frequent actions	
Store preferences •••		Explicit settings (previous actions) or collaborative filtering	

Figure 5: Conceptual model adaptive geoportals based on a GIS specialist and developer user type.

6.1 Recommendations

The theory described in this paper provides a basic foundation for the implementation of adaptive UIs in the context of geoportals. Since this research does not go into detailed user requirements and matching adaptations, there is room to elaborate on this for future research. Furthermore, future research might allow to include different types of users than the GIS specialist and the developer discussed in this paper.

All this would benefit from a more user-centred design approach, which requires consulting the intended users to make the adaptive system design better fit the target group [65], [85]. By observing how these users use the system and acquiring their requirements during user requirement sessions as described by [23], such behaviour and requirements can be linked to more specific adaptation rules and more in depth applications of the general conceptual model described in this paper.

The actual implementation of the adaptive behaviour in the context of geoportals will allow for usability studies as described by [96], which are required for evaluation purposes.

To deal with the trade-offs between the implicit and explicit acquisition of user data, it can be argued that, next to the implicit measures, it can be beneficial to allow users to voluntarily change their UM to help deal with the challenges listed in Subsection 2.3. Customisable, adaptable system behaviour as a possible ways to accommodate this, is mentioned in Subsection 2.4. Evaluating and specifying these assumptions for the context of geoportals would be another topic for future research.

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B
Selecting geoportals for desk research

At the time of writing, there is no list of user-friendly geoportals available. For this reason, I used ratings in the Open Data Maturity [Cecconi and Radu, 2018], the Open Data Barometer [2016], Geobuiz [2018], and Open knowledge international [2016] to select well performing countries. Such measures are valid, when assuming that countries with high open data and geospatial maturity are likely to have a proper geoportal. Note that this assumption will not be valid for all possible cases.

The focus for the portal selection is on Northern European countries relatively closely located to the Netherlands (see Table B.1). Because these countries should have similar legislation, culture, and country type as the Netherlands, the use types are also assumed to be more similar.

Table B.1: Open (geo)data readiness of Great Britain, Ireland, Norway, Sweden, Denmark, Germany, Belgium, Luxembourg, and France related to the Netherlands according to Open Data Maturity [Cecconi and Radu, 2018], Geobuiz [2018], the Open Data Barometer [2016], and Open knowledge international [2016].

Open Data Maturity	Open Data Barometer	Global Open Data Index	Geobuiz
Ireland (1)	UK (1)	Great Britain (2)	Germany (2)
France (3)	France (3)	France (4)	UK (3)
Luxembourg (6)	The Netherlands (8)	Norway (5)	France (5)
The Netherlands (10)	Norway (9)	Ireland (10)	The Netherlands (10)
UK (11)	Denmark (12)	Denmark (11)	Sweden (12)
Belgium (15)	Sweden (14)	The Netherlands (20)	Belgium (15)
Germany (17)	Germany (15)	Sweden (21)	Denmark (18)
Sweden (23)	Ireland (26)	Belgium (22)	Norway (25)
Norway (24)	Belgium (29)	Germany (24)	Ireland (-)
Denmark (28)	Luxembourg (-)	Luxembourg (-)	Luxembourg (-)

Note that there is a big difference in rating between the different sources. This is related to the use of different assessment criteria. The Open Data Maturity for example, takes open data portals into account. However, they do not specifically focus on geodata, as is the case for the Geobuiz [2018].

In the Open Data Maturity EU28 scores, all the portals mentioned in Table B.1 get an average of 63%. For the defined country scores that are provided by users, Ireland (80%), France (80%), and Luxembourg (78%) have the highest scores. The Netherlands has a score of 70%, followed by Sweden (67%), Belgium (65%) and the UK (64%). Norway (55%), Germany (54%), and Denmark (40%) score the lowest. Note that this reflects the open data portals and not necessarily relate to geoportals.

During this research, I will consider the portals of France[1] and Ireland[2]. Because the geoportal of Luxembourg[3] looks promising, their portal will also be incorporated. Furthermore, the portal of Norway[4] could be worth assessing. The portal of Sweden would be a more likely choice, but this portal seems to be only available in the national language. This is also the case for France, but the scores of France are high enough to attempt translation.

The lower score of the UK in the Open Data Maturity, and the fact that their geoportal is under development at the time of writing, resulted in the decision not to consider their portal in this research.

The role of the Netherlands (PDOK) as running example goes beyond the desk research.

[1] https://www.geoportail.gouv.fr
[2] https://geohive.ie/
[3] https://www.geoportail.lu/en/
[4] https://www.geonorge.no/en/

C
Proposals user studies

Courage and Baxter [2005] suggest creating a research proposal to structurally plan a user session. In this annex, such proposals for the user sessions of this research are provided. For the benchmark session, this is displayed in Figure C.1 and for the follow-up usability study in Figure C.2.

Table C.1: Proposal for the benchmark user study (continued on the next page).

Proposal User Session 1	
Introduction & History	PDOK is the Dutch platform for open geodata. The key features of the platform include: • Several options to search for datasets (discovery) • Several options to access datasets (view, download, web services or API) Based on market research the different personas of PDOK are established. User requirement sessions, which included interviews, workshops and co-creation sessions with the developer persona, have already been performed. The results of these sessions lead to improvements on PDOK. Meetings with developers are organised, an infographic is created, and the findability on the platform is improved due to enhanced keyword search options. This document contains a proposal for an additional user session with both the developer, and the GIS specialist persona. The session involves the observation of the participants while they perform tasks, an interview based on these observations, and a card sort activity.
Objectives, Measures & Scope of Study	**Observing participants** while they perform tasks is a valuable sources of information. Usability metrics such as the task completion time, completion rate or error rate, indicate the level of user-friendliness. **Interviews** can help to uncover new usability issues. They can provide relevant information of which the researcher has not initially thought. By keeping the interview **semi-structured**, it is possible to follow up on so called “markers" of situations or events that users recall, whilst still keeping the structure required for comparison between different participants. **Card sorting** is a usability technique that helps to discover the users’ mental model of an information space. The activity proposed in this document has several purposes: • Benchmark the usability of the current version of PDOK. This is done by observing how participants perform tasks. After the task performance is complete, the participants are also be interviewed about their experiences. • Evaluate and cluster design characteristics that are currently available. This is done during the card sorting phase and the interview. • Acquire additional user-friendly interface design characteristics for each user type. This is done by the card sort and the interview. The following data will be collected: • Demographic information (determine the type of user based on: frequency of use PDOK, GIS experience, API experience). • Quantitative performance of the participants based on usability metrics (measured whilst observing them perform tasks). • Qualitative suggestions and feedback of participants based on their task performance. This can results in additional design characteristics. • Alternative terminology identified by participants. The information collected from this activity will be used to make the user interface of PDOK more user-friendly for the selected user groups.

<table>
<tr><th colspan="2">Proposal User Session 1</th></tr>
<tr><td>Methodology</td><td>Tasks: the tasks participants will perform relate to 4 datasets of PDOK (one from each the BGT, BRO, BAG, and NWB). The tasks will involve either accessing or assessing a specific dataset based on either limited or elaborate instructions.
Interview: during the interview participants are asked to rate their experience and explain the decisions they made when performing the tasks.
Cards: each interface design characteristic will be represented on an individual card. Participants have to arrange and group these cards. They are allowed to add cards, remove cards, and write alternative terminology on each card.

Procedure: the session can be performed on various locations and times depending on the availability of the participants. The period in which the activity will be performed ranges from 10-02-2020 to 21-02-2020.
1. Participants will start with performing the first pre-defined task. This task is both presented in written text, and explained by the facilitator. The facilitator will clarify any unfamiliar terms.
2. Participants are interviewed about the first task.
3. Step 1. and 2. will be repeated for every task. (about 60 minutes)
4. The facilitator explains the card sort activity. Participants may read the cards and ask questions. (about 5 minutes)
5. Participants may re-name, add or remove cards at any time in the process.
6. Participants may sort cards into “groups that make sense to them”. There is no wrong way to do this. (about 20 minutes)
7. After sorting, participants may name each group. (about 5 minutes)

The usability will be measured based on task completion time, task success, the amount of errors, the amount of clicks (“lostness”), memorability and learnability, and satisfaction.
The results of the card sort will be analysed using cluster analysis and / or a dendrogram.

Based on the findings, the interface design characteristics can be redefined.</td></tr>
<tr><td>User profile</td><td>Participants must meet one of the following criteria in order to participate:

Developer (does not necessarily have geo-knowledge):
• Developer without much technical knowledge (web developer).
• Technical developer with curious “do-it-yourself” (Sjors).
• Technical, goal oriented developer (Klaas).

GIS specialist:
Varying levels of experience with open data, GIS, and PDOK.</td></tr>
<tr><td>Recruitment</td><td>Participants who are expected to meet on of the required profiles are sent an email. In this email, they will be asked whether or not:
• They think they indeed meet the profile.
• They would be willing to participate during the listed period.
• They would object to being recorded.

A total of 6 participants is required.</td></tr>
<tr><td>Requirements PDOK</td><td>• Review and approval of this session proposal.
• Review and approval of the experiment.</td></tr>
<tr><td>Proposed Schedule</td><td>• Develop the session: 06-01-2020 to 24-01-2020
• Recruit participants: 06-01-2020
• Prepare session (print cards, test set-up): 24-01-2020 to 31-01-2020
• Possible dates for the session: 10-02-2020 to 21-02-2020</td></tr>
</table>

Table C.2: Proposal for the follow-up usability session.

Proposal User Session 2	
Introduction & History	This document contains a proposal for a follow up user session with the participants of session 1. The session involves the observation of the participants while they perform tasks, and an interview based on these observations.
Objectives, Measures & Scope of Study	The activity proposed in this document has the purpose to evaluate the usability of the new version of PDOK. This is done by observing how participants perform tasks. After the task performance is complete, the participants will be interviewed about their experiences. The following data will be collected: • Demographic information (frequency of use PDOK, GIS experience, API experience) • Quantitative performance of the participants (measured whilst observing them perform tasks). • Qualitative suggestions and feedback of participants based on their task performance. The information collected during this session will be used to assess whether or not the implementation of certain design characteristics mentioned in session 1 made the user interface of PDOK more user-friendly for the selected user groups.
Methodology	**Tasks**: the tasks participants will perform are the same as in session 1. **Interview**: during the interview participants are asked to rate their experience and explain the decisions they made. **Procedure**: the session can be performed on various locations and times depending on the availability of the participants. The period in which the activity will be performed ranges from 20-04-2020 to 01-05-2020. 1. Participants will start with performing the first pre-defined task. This task is both presented in written text, and explained by the facilitator. The facilitator will clarify any unfamiliar terms. 2. Participants are interviewed about the first task. 3. Step 1. and 2. will be repeated for every task. (about 60 minutes) The user performance will be noted using the same measures as in session 1.
User profile	Preferably, session 2 will be conducted with the same participants as session 1.
Recruitment	During the recruitment of session 1, participants are asked whether or not they would be willing to participate in 2 sessions. A total of 6 participants is required. If it is not possible to find participants who want to participate twice, different participants with a similar profile as used for session 1 will be recruited.
Requirements PDOK	• Review and approval of this session proposal. • Review and approval of the experiment.
Proposed Schedule	• Develop the session: 06-01-2020 to 24-01-2020 • Recruit participants: 06-01-2020 • Prepare session (print cards, test set-up): 10-04-2020 to 17-04-2020 • Possible dates for the session: 20-04-2020 to 01-05-2020

D

Content of the benchmark user session

Questions, metrics and tasks user session CH5*

*Since PDOK is Dutch, the instructions and questions of the user session will be in Dutch.
This document shows the *original questions* in Dutch, and a translated version.

Demographics

D1. What is your occupation?
Wat is uw vakgebied?
Free text answer: (•••)

D2. Do you have experience working with GIS?
Heeft u ervaring met het werken met GIS?
Yes: ○ No: ○ A little: ○

D3. Do you have experience using APIs?
Heeft u ervaring met het gebruik van APIs?
Yes: ○ No: ○ A little: ○

D4. Do you have experience working with PDOK?
Heeft u ervaring met het gebruik van PDOK?
Yes: ○ No: ○ A little: ○

Metrics

The following metrics will be captured for each (sub)task:

Effectiveness: *task success*
Pass: ○ Fail: ○

Error prevention: *amount of errors*

Efficiency: *task completion time*
Time from first cursor movement till task completion

Efficiency: *amount of clicks*

Efficiency: *lostness*
Number of pages visited
Number of unique pages visited

Task specific statements

The following statements need to be ranked after each (sub)task:

SQ1. This task was easy. *(Satisfaction)*
[Veldkamp, 2017], [Kellenberger et al., 2016], [Poplin, 2015], [Zuiderwijk, 2015], [Te'eni et al., 2010]
Deze taak was gemakkelijk.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

LQ2. It made sense to me how I could do this task. *(Learnability)*
[Te'eni et al., 2010], [Kellenberger et al., 2016], [Poplin, 2015], [Zuiderwijk, 2015], [He et al., 2012], [Courage et al., 2005], [SUS]
Het was logisch voor me hoe ik deze taak kon uitvoeren.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

LQ2.1 If not, where would you like (more) help, instructions or hints?
[Chiew et al., 2003], [SUMI], [WAMMI]
Zo nee, waar zou u graag meer hulp, informatie of aanwijzingen krijgen?

LQ2.2 If not, how would you prefer to do this task?
[Zuiderwijk, 2015], [Resch et al., 2013]
Zo nee, hoe zou u deze taak liever uitvoeren?

LQ2.3 What triggered you to execute this task the way you did?
[Courage et al., 2005]
Wat was voor u van invloed om de taak uit te voeren zoals u nu gedaan heeft?

Task 1

You want to access the BGT.
U wilt de BGT raadplegen.

T1.1 What is the original publication date of the BGT?
Wat is de publicatiedatum van de BGT?
A: 2015-03-24

Questions:
T1.1-SQ1
T1.1-LQ2

T1.2 Download the BGT from “Delft”.
Download de BGT van “Delft”.

Questions:
T1.2-SQ1
T1.2-LQ2

Task 2

You want to access the BAG.
U wilt de BAG raadplegen.

T2.1 The dataset places of residence is part of the BAG, view it with the “PDOK viewer”.
De dataset woonplaatsen is onderdeel van de BAG, bekijk deze met de “PDOK viewer”.

Questions:
T2.1-SQ1
T2.1-LQ2

T2.2 In which place of residence is “Kleine Huisjes” located?
In welke woonplaats ligt “Kleine Huisjes”?
A: Kloosterburen

Questions:
T2.2-SQ1
T2.2-LQ2

Task 3

You want to access a map of the Dutch road network.
U wilt de Nederlandse wegenkaart raadplegen.

T3.1 Try to download a map of the Dutch road network via the dataset menu.
Probeer de Nederlandse wegenkaart te downloaden via het dataset menu.

Questions (memorability of T1.2):
T3.1-SQ1
T3.1-LQ2

T3.2 Try to visualise the so-called waterway surfaces on the “PDOK viewer”.
Probeer de zogenaamde vaarwegvlakken weer te geven op de “PDOK viewer”.

Questions (memorability of T2.1):
T3.2-SQ1
T3.2-LQ2

Task 4

You are looking for a model regarding the Dutch soil to 500 metres depth.
U bent op zoek naar een model van de Nederlandse bodem tot op 500 meter diepte.

T4.1 Which dataset is useful for this purpose?
Welke dataset zou je hiervoor kunnen gebruiken?

Questions:
T4.1-SQ1
T4.1-LQ2

T4.2 Try to download the dataset that covers groundwater monitoring.
Probeer de dataset met betrekking tot grondwater monitoring te downloaden.

Questions (memorability of T1.2 and T3.1):
T4.2-SQ1
T4.2-LQ2

General statements

P-SQ1. I am satisfied with the functionalities of PDOK. *(Satisfaction)*
[Kellenberger et al., 2016]
Ik ben tevreden met de functionaliteiten van PDOK.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-SQ1.1 If not, what challenges did you experience? How would you like to change this?
Zo nee, welke uitdagingen heeft u ondervonden (zoekfunctionaliteit, PDOK viewer)? Hoe zou u dit willen veranderen?

P-SQ2. It was easy for me to use PDOK. *(Satisfaction)*
[Khan, 2018], [Zuiderwijk, 2015], [Van Welie, 2001], [WAMMI], [SUS]
PDOK was voor mij eenvoudig te gebruiken.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-LQ3. The use of PDOK is self-explanatory. *(Learnability)*
[Zuiderwijk, 2015], [He et al., 2012]
Het gebruik van PDOK spreekt voor zich.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-LQ3.1 If not, what particular elements seemed unclear?
[Kellenberger et al., 2016]
Zo nee, welke specifieke elementen waren onduidelijk?

P-LQ4. During use, PDOK behaved as expected. *(Learnability)*
[Chiew et al., 2003], [WAMI]
Tijdens het gebruik reageerde PDOK zoals verwacht.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-LQ4.1 If not, in which cases not?
Zo nee, in welke gevallen niet?

P-SQ5. It is easy to navigate on PDOK. *(Satisfaction)*
[Kellenberger et al., 2016], [Chiew et al., 2003], [WAMMI]
Navigeren door PDOK is eenvoudig.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-LQ6. I am familiar with the terminology used on PDOK. *(Learnability)*
[Zuiderwijk, 2015], [Chiew et al., 2003]
Ik ben bekend met de terminologie die gebruikt wordt op PDOK.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-LQ6.1 If not, what terminology would be more suitable for you?
Zo nee, welke terminologie zou meer passend zijn voor u?

P-LQ7. PDOK has a consistent look and feel. *(Learnability)*
[Chiew et al., 2003], [SUS], [SUMI]
PDOK heeft een consistent uiterlijk en gevoel.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-LQ8. The presentation of the content on PDOK is clear and understandable. *(Learnability)*
[SUMI], [WAMMI]
De presentatie van de gegevens op PDOK is duidelijk en begrijpelijk.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-LQ8.1 Why? Is the content logically organised for you?
[WAMMI], [Chiew et al., 2003]
Waarom is dit? Zijn de gegevens volgens u logisch georganiseerd?

P-SQ9. The presentation of the content of PDOK is attractive. *(Satisfaction)*
[Reinecke et al., 2011], [Chiew et al., 2003]
De presentatie van de gegevens op PDOK is aantrekkelijk.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○
P-LQ9.1 What do you (dis)like (Colours, structure, images)?
Wat spreekt u aan? Wat spreekt u juist niet aan?

P-LQ10. Learning to use PDOK is easy for me. *(Learnability)*
[Zuiderwijk, 2015], [Chiew et al., 2003], [SUS]
Het is eenvoudig voor mij om PDOK te leren gebruiken.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-SQ11. I am likely to use PDOK again. *(Satisfaction)*
[Tullis et al., 2013], [SUMI], [SUS]
Het is waarschijnlijk dat ik PDOK nog eens ga gebruiken.
Fully agree: ○ Agree: ○ Neutral: ○ Disagree: ○ Fully disagree: ○

P-SQ12. How likely is it that you would recommend PDOK to your colleagues? *(Satisfaction)*
[NPS], [SUMI]
Hoe waarschijnlijk is het dat u PDOK aan een collega zou aanraden?
0: ○ ←——→ 10: ○

Additional remarks

A1. For what purposes could you use PDOK for your job? *(Characteristics AH)*
[Tullis et al, 2013], [Resch et al., 2013], [Scholz, 1997]
Voor welke doeleindes zou u PDOK voor uw werk kunnen gebruiken?
A1.1 What functionalities would you require for this?
[Resch et al., 2013]
Welke functionaliteiten zijn hiervoor nodig?

A2. Would you mind creating a personal account for more personalised functionality?
[Veldkamp, 2017]
Zou u een persoonlijk account willen aanmaken voor meer gepersonaliseerde functionaliteit?

A3. Would you like a feature to communicate with data publishers
and other users about the data?
[Veldkamp, 2017], [Zuiderwijk, 2015]
Zou u interesse hebben in een mechanisme om met de bronhouder van de data en andere gebruikers te communiceren over de data?
A3.1 If yes, what kind of feature?
Zo ja, wat voor soort mechanisme?

A4. Do you have any further remarks?
Heeft u verder nog opmerkingen?

E

Content of the follow-up user session

Questions, metrics and tasks of the user session analysed in Chapter 7. The metrics and statements listed in Annex D are also applicable for this follow up experiment.

Task 1

You want to access the BAG
U wilt de BAG raadplegen.

T1.1 What is the update frequency of the BAG?
Wat is de herzieningsfrequentie van de BAG?
A: maandelijks

Questions:
T1.1-SQ1
T1.1-LQ2

T1.2 Access the WMS URL of the BAG.
Zoek de WMS link van de BAG op.

Questions:
T1.2-SQ1
T1.2-LQ2

Task 2

You want to access the BGT.
U wilt de BGT raadplegen.

T2.1 View the “Standard” BGT in the “PDOK viewer”.
Bekijk de “Standaard” BGT in de “PDOK viewer”.

Questions:
T2.1-SQ1
T2.1-LQ2

T2.2 What is the plus type of the object with bgt-type waterway east of “Muggenbeet”?
Wat is het plus-type van het object met bgt-type waterloop ten oosten van “Muggenbeet”?
A: Kanaal

Questions:
T2.2-SQ1
T2.2-LQ2

Task 3

You want to see where drilling tests took place.
U wilt in kaart brengen waar booronderzoeken hebben plaatsgevonden.

T3.1 Try to download a dataset which contains drill sample profiles.
Probeer een dataset met boormonsterprofielen te downloaden via het dataset menu.

Questions (memorability of T1.2):
T3.1-SQ1
T3.1-LQ2

T3.2 Try to visualise this dataset in the “PDOK viewer”.
Probeer deze dataset weer te geven op de “PDOK viewer”.

Questions (memorability of T2.1):
T3.2-SQ1
T3.2-LQ2

Task 4

You are looking for waterways with a minimal depth of 1.1 metre.
U bent op zoek naar vaarwegen met een minimale diepte van 1.1 meter.

T4.1 Which dataset is useful for this purpose?
Welke dataset zou u hiervoor kunnen gebruiken?

Questions:
T4.1-SQ1
T4.1-LQ2

T4.2 Try to download the dataset containing waterway surfaces.
Probeer de dataset met vaarwegvakken te downloaden.

Questions (memorability of T1.2 and T3.1):
T4.2-SQ1
T4.2-LQ2

F

Cheat sheet for the initial GUIDE from Chapter 3

In Chapter 4 and Chapter 5, colour codes and abbreviations are used to refer to the design characteristics of the initial version of the GUIDE established in Chapter 3. The cheat sheet listed in this annex can be used as a support when reading these chapters.

Content presentation

- CP1 Use of harmonious colours.
- CP2 Balanced placement of the content.
- CP3 Consideration of ergonomics.
- CP4 Full screen map availability.
- CP5 "Scannable" content.
- CP6 Support for customisation of the display.
- CP7 Visualisations of the data.

System interaction

- SI1 Control over the system.
- SI2 Error handling and preventing.
- SI3 Responsiveness and system status visibility.
- SI4 Relatable semantics in terms of symbology, linguistics, and controls.

Navigation

- N1 Provide direct ways to do tasks (allow shortcuts).
- N2 Provide navigational aids.

Search mechanisms

- S1 Data recommender system.
- S2 Different (meta)data search possibilities.
- S3 Display of the active search criteria.
- S4 Allow filtering of the search results.
- S5 Allow tagging data for search.
- S6 Allow sorting of the search results.
- S7 Suggestion functionality for more intuitive search.

Access and upload mechanisms

- A1 Allow registration for additional functionality.
- A2 Pages that print properly.
- A3 Minimal memory loading.
- A4 Provide (meta)data available in various formats.
- A5 Provide data access.
- A6 Provide tools for analysis and processing.
- A7 Provide upload facilities.
- A8 Allow users to subscribe for updates or news.

Feedback mechanisms

- F1 Allow discussion and sharing among users.
- F2 Provide a data request mechanism.
- F3 Provide a mechanism for users to provide feedback.

Metadata

- M1 Accessibility conditions of the data.
- M2 Availability of standardised metadata.
- M3 Data governance model.
- M4 Links with other data and information sources.
- M5 Quality indicators.
- M6 Semantics of the data attributes.
- M7 Structure of the data (data model, service level, etc.).
- M8 Topic and description of the data.

Help mechanisms

- H1 Audience-oriented sections.
- H2 Contact form and/or contact information.
- H3 Data manual or Wiki.
- H4 Discussion forum and help desk.
- H5 Examples of applications of the data.
- H6 FAQs.
- H7 Portal manual or glossary.
- H8 Tips and hints mechanisms.
- H9 Tutorials.

Consistency

- C1 Consistent appearance.
- C2 Consistent behaviour.
- C3 Consistent semantics.

G

Cheat sheet for the re-evaluated GUIDE

Content presentation

- CP1 Use of harmonious colours.
- CP2 Balanced placement of the content.
- CP3 Consideration of ergonomics.
- CP4 "Scannable" content.
- CP5 Support for flexible background maps.
- CP6 Visualisations of the data.

System interaction

- SI1 Error handling and preventing.
- SI2 Responsiveness and system status visibility.
- SI3 Relatable semantics in terms of symbology, linguistics, and controls.

Navigation

- N1 Provide direct ways to do tasks (allow shortcuts).
- N2 Provide navigational aids.

Search mechanisms

- S1 Keyword search for (meta)data and locations.
- S2 Different (meta)data search possibilities.
- S3 Enable more intuitive search.
- S4 Allow filtering of the search results.
- S5 Allow sorting of the search results.

Access and upload mechanisms

- A1 Provide data access.
- A2 Provide (meta)data available in various formats.
- A3 Provide tools for analysis and processing.
- A4 Provide tools for system integration.
- A5 Allow users to subscribe for updates or news.

Communication mechanisms

- CM1 Allow sharing of (map view) pages.
- CM2 Collaboration system between users and providers.
- CM3 General contact information.
- CM4 Contextual contact button linked to a form or chat.

Metadata

- M1 Accessibility conditions of the data.
- M2 Availability of standardised metadata.
- M3 Data governance model.
- M4 Information about the portal.
- M5 Links with other data and information sources.
- M6 Quality indicators.
- M7 Semantics (layer legends and data attributes).
- M8 Structure of the data (data model, service level, etc.).
- M9 Topic and distinctive description of the data.

Help mechanisms

- H1 Audience-oriented sections.
- H2 Support for data use.
- H3 Support for geomatics related knowledge.
- H4 Support for portal use.

Consistency

- C1 Consistent appearance.
- C2 Consistent behaviour.
- C3 Consistent semantics.

H

Reproducibility of this research

Although most related research I used as input for this thesis will remain available and attainable based on their Digital Object Identifier (DOI). The analysed geoportals are continuously adapting and will not always remain in line with what I analysed in the period between 27-11-2019 and 09-01-2020.

In this thesis, I elaborately documented the process for coming up with the GUIDE and the mock-up. However, I decided to not openly provide the HTML, CSS, and JavaScript code behind the mock-up. The reason for this is that my code only works under certain specific system requirements and my solutions are not of high quality or innovative (in fact, I used many examples from w3schools). Professional front-end developers would do a better job. For this thesis, coding is used to prototype and not as a goal. The mock-up itself does have great value as an implementation example. For this reason, I included many visualisations of the mock-up in this thesis. A video displaying a process of searching assessing, and accessing data on the benchmark (PDOK) compared to the mock-up can be viewed at: https://youtu.be/rQ82oMsWK8Y.

To prevent this thesis from getting too long, I aggregated the elements that contributed to the development of the GUIDE and the corresponding mock-up. For the user sessions, for example, I only provided a summary instead of a full transcription. For the privacy of the participants, I did not maintain the screen captures of the user sessions.

For more details or the code you can contact me: linkedin.com/in/celinejansen97/.