A CHANGE OF VIEW:

Usable interface design propositions for geoportals

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Introduction

As a result of technological advances, more and more data is being generated. Following legislation such as the open data and re-use of Public Sector Information (PSI) directive, this PSI should in principle be accessible as open data. In the context of the directive, there is a focus on high-value datasets, such as Geo Information (GI) [Directive (EU) 2019/1024].

Spatial Data Infrastructures (SDIs) can be considered as a means to enable sharing of such datasets [Van Loenen, 2006]. The different SDI components and their interactions are shown in Figure 1.1 (adaptation from [Rajabifard et al., 2002]).

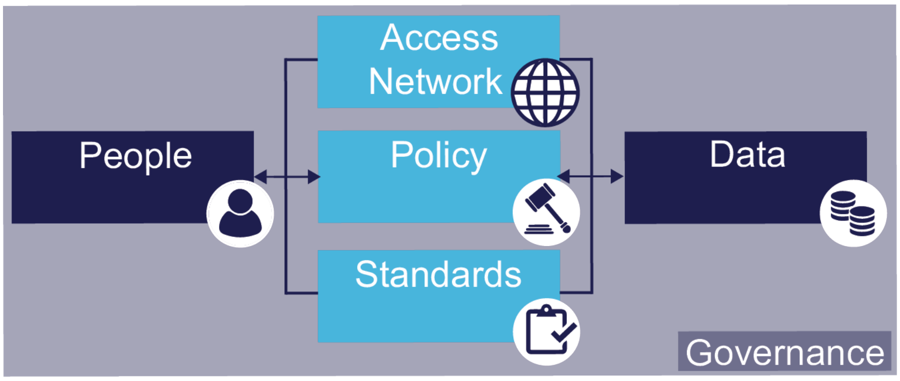

Figure 1.1: Core components of an SDI (adaptation from [Rajabifard et al., 2002]).

In the Netherlands, the scope of the national SDI should be widened from focusing on opening the data, to a focus on data (re-)use. In this widened scope, open data must be FAIR; Findable, Accessible, Interoperable and Re-useable [Penninga and Van Den Brink, 2017]. To take a step in the right direction, the access network component of an SDI, the geoportal, will be the point of focus of this thesis.

Geoportals are regarded as the way to offer *data* to the *people* [Lee, 2012], [Van Loenen et al., 2010], [Giff et al., 2008], [Maguirea and Longley, 2005]. The need for these portals and their increased maturity is reflected by an increase of interest shown in search engine results [Jiang et al., 2019]. In the Netherlands, there is also an increase in the use of geoportals visible. The running example of this thesis, the Dutch geodata platform Publieke Diensverlening Op de Kaart - “Public services on the map” (PDOK), got 0.6 billion hits in 2013. With 10.8 billion hits in 2018, and with 35 billion hits expected for 2020, massive growth is predicted [PDOK, 2019].

1.1. Motivation

Open data has the highest impact once it is being used [Van Loenen, 2018], [Koudijs, 2011], [Van Loenen, 2006]. To enable sharing and re-use of open GI, this GI must be easy to access [Kellenberger et al., 2016], [Lee, 2012], [Giff et al., 2008], achieving this is the motivation for this research.

The access process involves the traversal of the three levels of the concentric shell model as displayed in Figure 1.2 [Backx, 2003]. The first step in this model is that the existence of the data should be *known* to the user. The user has to know where the data can be obtained and should also know that the data exists. For this, the data should be recognisable and findable. Recognising the right data can for example be difficult if the name of the dataset is unexpected. The findability can for instance be enabled through a search mechanism on a data portal.

Furthermore, the data has to be *attainable*, this means it should be easy to access the data [Vancauwenberghe and Van Loenen, 2016], [Jurisch et al., 2015]; The data should be affordable and available through for example Application Programming Interfaces (APIs), downloads, or view options. The formats, licence conditions, and charges under which the data can be accessed, influence whether or not the data is available for the purpose of the user.

The last criterion is that the data should be *usable*; It should be fit for the purpose of the user [De Jong, 2019], [Van Loenen, 2006]. The data should be clear, resulting in intellectual accessibility. This can for example be achieved by providing metadata and Frequently Asked Questionss (FAQs). Characteristics such as coverage, actuality, and data format indicate whether or not the data is manageable for the purpose of the (re-)user. For the data to be usable, it should also be reliable, this includes that it should be accurate and timely [Backx, 2003].

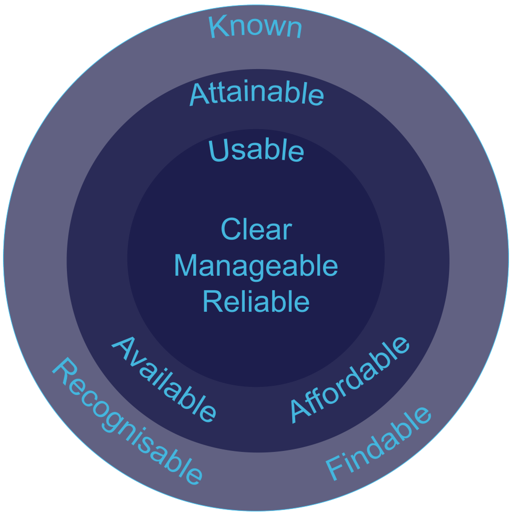

Figure 1.2: Backx' concentric model [Backx, 2003].

By interacting with the UI of a geoportal, data discovery is enabled (*known*). Furthermore, geoportals facilitate the access to GI (*attainable*). As a final step, the UI of geoportals is used to present data characteristics, which can be used to understand the data and to assess whether or not a dataset is fit for use (*usable*).

The smaller the thickness of the concentric rings, the less effort is required from the user. As a foundation for this, user-friendly, intuitive, and comprehensive geoportals UIs should be adopted [Kellenberger et al., 2016], [Lee, 2012].

1.2. Scientific relevance

A user-friendly interface is required to deal with the challenges related to assessing and accessing data, because most problems users have with computers occur as a result of poorly designed UIs [Fu, 2012]. Inadequate design often results in bad usability [Reinecke and Bernstein, 2011] and can also lead to a lack of use of a platform [Veldkamp, 2017], [Mayer et al., 2016], [Welle Donker-Kuijer et al., 2010]. On the other hand, adequately designed UIs can lead to an increase in efficiency and productivity, reduced errors, reduced training and support, and users are keener to use user-friendly systems [Van Welie, 2001].

However, it is currently unclear what can be considered user-friendly in the context of UIs of geoportals. To define this, a *user-friendliness assessment framework* will be developed during this research.

Such a framework contains a comprehensive overview of guidelines to achieve more user-friendly UI design for geoportals. Based on these guidelines, the assessment framework can be used to assess the quality of a geoportal.

Furthermore, implementation examples for (re-)design can be capture according to the framework to guide geoportal developers in implementing the user-friendly UI design elements. This results in a more standardised, user-friendly UI design for geoportals, which helps to promote their use [Lee, 2012].

Relevance for the geomatics field

As listed in the preamble of the open data and re-use of PSI directive, GI is considered to be high-value data, which should preferably be available as open data through APIs [Directive (EU) 2019/1024].

However, the current provider-driven design of UIs results in SDIs that do not meet the needs of their users. This limits both the use and value of GI.

To fully realise the potential value of GI, a user-friendly UI that satisfies the needs of its users is required. By involving specific geomatics knowledge in the development of UI design guidelines, this can be achieved.

1.3. Research challenges

This research will deal with some significant challenges.

1.3.1. Lack of consideration for use and user

Users are critical for the success of open data [Van Loenen, 2018], [Van Loenen and Welle Donker, 2016]. However, open data initiatives are still often supplier driven, with a focus on publishing data and not on use [Van Loenen, 2018], [Zuiderwijk, 2015], [Koudijs, 2011]. The statement by McLaughlin and Nichols [1994] (p. 72) that users "will probably be the most mentioned group and yet actually the least considered", is still relevant.

Van Welie [2001] introduces this problem through the analogy of a remote control and tv set; When buying the tv set, no one will ask about the remote control. Sometimes unnecessary features are included, merely because the technology allows it [Reeve and Petch, 1999]. Instead of users and their needs, technology and functionalities are the main focus points in the context of geoportal development [Resch and Zimmer, 2013]. This can make a product unnecessarily complicated [Van Welie, 2001].

In this research, there will be a focus on the user by adopting a user centred design approach.

1.3.2. Large diversity of users and a single UI

The single typical user of web systems does not exist; Users are diverse in needs, skills, and available resources [Lee, 2012]. For this reason, it is remarkably challenging to satisfy all users at once in a single design strategy [Van Loenen, 2018], [Braggaar, 2016], [Fischer, 2001].

Currently, User Interfaces (UIs) are often "one-size-fits-none", which means they are unsuitable for a large amount of users [Khan, 2018]. This also holds for open (geo)data platforms. Users encounter difficulties when they try to search, browse, and make sense of data [Parnia, 2014], they have to know what to look for. In geoportals, this is typically reserved for the geo-user [Penninga and Van Den Brink, 2017], [Kellenberger et al., 2016]. For non-geo-users, the threshold of accessing and using open geodata, which follows specific geo-standards, is too high [Penninga, 2018]. However, people who work with Geographical Information Systems (GISs) also have diverse levels of experience and even for them the portal functionalities are not always clear [NGR, 2018]. 50 % Of the participants with GIS experience did for example not rate the map interactions as easy in a study by Poplin [2015].

To deal with the "one-size-fits-none" approach, the UI of geoportals can be implemented within a so-called Adaptive Hypermedia (AH) approach. Such adaptive interfaces offer a solution by anticipating what the individual user requires. This can lead to an improved user-friendliness of the system.

1.3.3. Maze of information

More data is being published, which means it becomes increasingly challenging for users to find relevant information [Veldkamp, 2017], [Janssen and Van Den Hoven, 2015], [Te'eni and Feldman, 2001]. Users need a way to filter this relevant information to prevent them from losing their way in all the content [Khan, 2018], [Van Loenen et al., 2010].

How data is published on a geoportal can affect the way users can access and use data [Van Loenen and Welle Donker, 2016], [Zuiderwijk, 2015]. In a portal with a clear, user-friendly interface, this process is more straightforward [Zuiderwijk, 2015].

1.3.4. Lack of consistent design regime

In the context of geoportals, inadequate design among others involves the fact that many portals are currently implemented in inconsistent ways in terms of design, usability, functionality, interaction possibilities, map size, and symbologies [Resch and Zimmer, 2013] due to a lack of a consistent portal design regime.

This is not only an issues within the portal itself, it also leads to a lack of interoperability between different geoportals. This is undesirable because it might confuse users, who desire recognisable visual aspects and feel of a system [Chincholle et al., 2013], [Resch and Zimmer, 2013].

Implementation guidelines listed in a user-friendliness assessment framework can result in more standardisation and interoperability.

1.3.5. Data fragmentation

To suit different types of users, there are several different geodata access channels available in the Netherlands [Penninga and Van Den Brink, 2017]. Two national, well-established channels are the catalogue service Nationaal Geo- Register - "National Geo Registry" (NGR) and the Dutch national geodata platform PDOK. Furthermore, other organisations such as local governments also adopt their own platforms.

The fact that not all data is yet published through a single central data platform such as PDOK, can hinder data access. This data fragmentation causes confusion and affects the findability of datasets [Welle Donker et al., 2019], [Braggaar, 2016], [Van Loenen, 2006]. It would be easier if there is one single central geoportal serving as a one-stop-shop [Braggaar, 2016], [Giff et al., 2008].

This research is not focused on reducing fragmentation. However, it is possible to link the different access channels such as NGR to PDOK more evidently. Furthermore, an increase in user-friendliness can lead to an increase in use of PDOK. This increase in popularity could for example be an incentive for local governments to publish their spatial data on PDOK, which will result in less fragmentation and more possible data access.

1.4. Reading guide

In this thesis, a graduation plan is described. First, related work and the knowledge gap are discussed (Chapter 2). In line with this, the research questions, aim, and scope of this research can be listed (Chapter 3). The research questions dictate the research methodology (Chapter 4), which will be executed according to a time planning (Chapter 5). Finally, an overview of the required tools is provided (Chapter 6).

2
Related work

In this chapter, an overview of related research is provided. This related research can be divided into research related to open (geo)data portals (Section 2.1), research into UI design (Section 2.2), research into usability (Section 2.3), and research into Adaptive Hypermedia (AH) (Section 2.4). To conclude, the knowledge gap will be discussed (Section 2.5).

A tabular overview of the literature review is provided in Annex A.1.

2.1. Open (geo)data portals

There are many frameworks and methods available to monitor and measure the performance of SDIs. However, these frameworks are not always focused on open data platforms with functionalities similar to PDOK. Different platforms have varying levels of maturity and are designed for different purposes, as is for example described by Crompvoets [2006]. Portals are often solely a catalogue service, whilst platforms often provide additional support next to offering the actual data.

This means not all aspects of the current assessment frameworks are suitable criteria for the full range of platforms and portals. For this reason, the aspects relevant for this research need to be selected carefully.

Requirements for open data infrastructures [Zuiderwijk, 2015], [Zuiderwijk et al., 2013], open data policies [Vancauwenberghe and Van Loenen, 2016] and open data portals [Elvira, 2018], [Marta, 2016], [Carvalho and Lafuente, 2015], [Parnia, 2014], are all communicated by the UI of the portal.

Because of this, these researches all cover elements that could be considered in a user-friendly UI assessment framework. Examples of these requirements involve the need for available and usable help systems, example use cases, metadata, and accessibility of the data.

Not many practical examples are available, however, in the context of open data portals, Zuiderwijk [2015] provides practical examples in a prototype and Parnia [2014] uses wireframe diagrams.

Geoportals

Geoportals are a specific type of (open) data portal, they have a clearinghouse functionality.

In general, geoportals are very technical and not easy to use. This may relate to a lack of focus on the presentation of the information that happens through the UI [Veldkamp, 2017].

Portal performance through tasks

To evaluate the quality of a geoportal from the perspective of the user, participants can be asked to perform certain tasks, such as searching for specific kind of GI.

This methodology is for example adopted by He et al. [2012] and Van Loenen et al. [2010].

Another possible method to asses the clearinghouse status, involves an evaluation based on measurements related to twelve key characteristics, as is done by Crompvoets [2006]. Some of these characteristics should be communicated by the UI, which means they might be relevant for the research described in this thesis. This for example includes the level of (meta)data accessibility and the use of maps for searching [Crompvoets, 2006].

2.2. User Interface (UI) design

The UI involves the communication of system functionalities to its users. Related research specifies requirements to ensure that the UI fulfils such interactions in a user-friendly way.

2.2.1. General UI requirements

Examples of required functionalities that could be part of the assessment framework involve error handling, the navigation of the users through the system, and system feedback about the state of a process [Guntupalli, 2008], [Shneiderman, 2004].

Furthermore, the behaviour and appearance of the UI should be consistent and simple [Parnia, 2014]. Presenting the content in a meaningfully structured visual hierarchy is part of this [Carvalho and Lafuente, 2015].

Several theories on the presentation of the content can be used to achieve a pleasing appearance of the UI. Examples involve the theory of colour harmony or the golden section ratio, which have proven to be pleasing to users on a general level [Fu, 2012].

2.2.2. UI requirements following heuristics

Websites from the Dutch government and the European Union are obliged to follow certain heuristics that are meant to make their content more accessible and usable for a wider range of users [Welle Donker-Kuijer et al., 2010]. Currently, these heuristics are often based on the Web Content Accessibility Guidelines (WCAG) [WCAG, 2019], which is a W3C recommendation. By following such heuristics, the design elements from the assessment framework can be implemented in a more usable way.

2.2.3. UI requirements based on research related to geoportals

Critical factors for the success of clearinghouse development within the context of the UI for example include the availability of view services, communication channels, access without registration, and user-friendly interfaces with clear terminology in general [Crompvoets, 2006].

Some of the usability problems related to these factor need to be taken into consideration in the UI user-friendliness assessment framework. This includes issues such as inactive contact buttons and language barriers, which could influence the user-friendliness of the UI [Van Loenen et al., 2010].

Other examples for example relate to map interactions. Users should for instance be able to specify the desired geographic extent of a dataset [He et al., 2012]. During such an interaction, the system should provide sufficient feedback to the user. Furthermore, the navigation through the system should be recognisable [Kellenberger et al., 2016].

Additional preferences that are discovered in previous research related to the UIs of geoportals include more general requirements such as the size of buttons, and the contrast between the text and the background [Resch and Zimmer, 2013].

2.3. Measuring usability

Measuring the user-friendliness of the UI can be done by measuring the usability.

Generally speaking, usability evaluation metrics involve the effectiveness, efficiency, and satisfaction of the design [Veldkamp, 2017], [Parnia, 2014], [Resch and Zimmer, 2013], [Reinecke and Bernstein, 2011], [Chiew and Salim, 2003], [Van Welie, 2001]. There are many metrics available to measure the User Experience (UX), which relates to the perceived usability, these are for example covered by Joo [2017], Roth [2017], Pekkanen [2015], and Tullis and Albert [2013].

The parts of the usability that is relevant to measure in this research, involves task performance measures such as speed and error rate [Tullis and Albert, 2013]. Self-reported metrics, which can be used to extract subjective user preferences related to the UX, are also relevant [Resch and Zimmer, 2013], [Chiew and Salim, 2003].

Usability of geoportals

Within the context of map-based geoportals, Resch and Zimmer [2013] developed a questionnaire containing such self-reported metrics. Certain questions, such as whether or not the participants are satisfied with the search dialogues, or which functionalities they generally use, can be of relevance for the research presented in this thesis.

Related research shows that the usability of geoportals can be different for different types of users.

For the case of RO-Online[1], there is for example a difference between the performance of geo and non-geo users. In this research, a group of fifteen respondents was considered. Five rated themselves to be proficient geo users. Based on task performance, these respondents averagely ranked fifth. The others got a ninth rank on average [Veldkamp, 2017].

2.4. Adaptive Hypermedia (AH)

The fact that the different intended users of PDOK have different needs, represents a challenge in the UI design, since these different needs cannot all be served within a single UI [Welle Donker et al., 2019], [Van Loenen, 2018]. A concept called AH can contribute to solving the challenge of the current "one-size-fits-none" approach, and can help users find their way in the "maze of information" of the web [Khan, 2018].

An AH system provides users with more suitable content based on their characteristics or tasks. Through the implementation of AH, it would no longer be necessary to make trade-offs in a single UI design. Instead, different, more suitable versions of the content are offered to suit the needs of the different individual users. Specified rules indicate the conditions under which this adaptive behaviour can be applied [Khan, 2018]. The required information to follow these rules can be extracted by asking the user directly, through interference from their behaviour, or by external information provided to the system [Reinecke and Bernstein, 2011], [Fischer, 2001].

2.4.1. Development of AH systems

The so-called "authoring" process of AH, involves the preparation and maintenance of the AH system. This process can be very challenging [De Bra and Ruiter, 2001] and is often a point of research. Khan [2018] for example developed a visual adaptive authoring framework. Another example is the Adaptive Hypermedia Architecture (AHA), which focuses on providing user guidance through conditional, additional explanations, and link hiding [De Bra et al., 2003].

Reducing the cost of development and increasing consistency can be done by re-using base elements of the system [Viloria and Lezamab, 2019]. This approach will be attempted during the research described in this thesis.

Current focus for AH systems

Currently, most adaptive systems are focused on educational purposes [De Bra and Ruiter, 2001]. The AH system developed by Khan and Mustafa [2019] for example, considers effective and engaging learning. AH has proven to be useful to support the needs of a group of learners by displaying more relevant content [Khan, 2018].

There is also research available on the use of adaptation in video games. Patterson [2014] for example, looks into a method to adapt to and recognise different play styles. Within his research, there was no discrete differentiation between players. This made categorising players with supervised machine learning challenging.

Automated adaptation

There is also related research available on machine learning to automatically extend the AH system elements and to deal with the cold start problem related to the lack of initial adaptation data. An example of such research is the intelligent conceptual model based on neuron networks described by Tmimi et al. [2018].

2.4.2. Pros and cons AH

Showing users more relevant options can lead to higher user satisfaction [Khan, 2018], higher efficiency, and fewer errors. Users find adaptive versions significantly easier to use and more attractive [Reinecke and Bernstein, 2011].

In the task-based adaptation approach adopted by Te'eni and Feldman [2001], users performed better in terms of execution times and accuracy in the adaptive site. This is assumed to be related to its increased compatibility. However, for more difficult tasks, the perceived complexity of the adaptive site was higher and users were less satisfied.

[1] https://ruimtelijkeplannen.nl

Users may value their control, a consistent appearance, and adaptive functionality [Te'eni and Feldman, 2001]. This possible trade-off is important to consider during the research described in this thesis.

2.5. Knowledge gap

The first knowledge gap bridged by this research involves the combination of general evaluation criteria for open (geo)data portals and user-friendly UIs.

In research related to assessing the performance of open (geo)data portals, the UI and the user-friendliness is often neglected. The portal assessment of Open Data Maturity presented by Cecconi and Radu [2018] for example overlooks the UI. This is a missed opportunity because the UI translates the system functionality to the user. As a crucial factor in communication, the UI has to be considered when assessing geoportals. The user-friendliness assessment framework that will be developed during this research can be used for this.

Additionally, current heuristics for website usability can be difficult to use and are prone to information overload due to their size.

In a sense, most of these guidelines are also not comprehensive, because they are often more concerned with how the information is delivered than with finding and comprehending the content. This means that guidelines such as “clear, precise language” are rare as opposed to guidelines such as “Keep pages simple and easy to understand” or heuristics involving the correct implementation of programming languages.

Furthermore, the validation of the heuristics often seems to be non-existent, which means their effectiveness is generally unknown [Welle Donker-Kuijer et al., 2010].

Added to the lack of comprehensive, usable guidelines, there seems to be a lack of concrete implementation examples related to such guidelines. This research will provide a comprehensive overview of implementation examples based on the user-friendliness assessment framework, which will be validated by real potential users.

Last but not least, research applying adaptive UIs in the context of geoportals is lacking, which introduces an additional area of improvement for this research.

3
Research questions and scope

In this chapter, the research questions and research aim will be discussed (Section 3.1). This is followed by a description of several definitions (Section 3.2) and the research scope (Section 3.3).

3.1. Research questions

The following research question is central to this research:

"What user interface design elements increase the user-friendliness of physical and intellectual human-computer interaction with 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 physical and intellectual access involving aspects such as search functionality, semantics, and metadata. Physical access concerns the ease of finding and accessing a dataset. Intellectual access involves the ease of understanding or using the information [Van Loenen, 2006].

To assess which design elements lead to an increase in user-friendliness, possible design propositions should be obtained. For this reason, Subquestion 1 is asked:

"What are design propositions for a user-friendly geoportal interface?" (1)

Subquestion 1 will be answered from diverse perspectives by asking the questions listed in Subsubquestions 1.1, 1.2, and 1.3:

"What characteristics of user-friendly (geoportal) interfaces are mentioned in the literature?" (1.1)
"What user-friendly interface design characteristics are implemented in other (geo-)portals?" (1.2)
"What are (PDOK's) user-friendly interface design characteristics according to experts and users?" (1.3)

Subquestion 2 addresses the provision of structural implementation examples of the design propositions listed in Subquestion 1.

Note that intellectual and physical accessibility depend on the capabilities of the user [Van Loenen, 2006]. The use of AH can help to ensure that the implementations are usable for these different capabilities.

"How can these design propositions be implemented as design elements?" (2)

Research aim

The aim of this research is to enable the development of more user-friendly UIs of geoportals, which should assist users to find, retrieve, and understand the available data in an interoperable, efficient way. This involves the development of a user-friendliness assessment framework for the UI of geoportals, which will also fill the current knowledge gap in quality metrics for the UIs of geoportals.

Furthermore, the implementation examples resulting from the user-friendliness assessment framework can act as guidelines for more user-friendly (re-)design of a UI of a geoportal. This way, the framework can be a foundation for decisions around what UI elements should be implemented in which situation.

3.2. Definitions

Several elements should be defined to describe the scope of this research.

Geoportals and platforms

Portals are defined to be an access or entry point. Accordingly, a geoportal can be seen as an access point to spatial data [Jiang et al., 2019], [Giff et al., 2008].

This is in line with the following definition from Resch and Zimmer [2013] (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 inadequate formats to further process them in a professional workflow."

PDOK can be referred to as a geoportal. However, PDOK also offers functionalities more related to a data platform, such as feedback options, example use cases, and so on. During the remainder of this thesis, the terms geoportal and platforms are used interchangeably. Both terms are meant to relate to a system similar to PDOK in terms of available functionalities.

Access

The term "access" is assumed to involve data acquisition through downloads, APIs, or geo-web services such as Web Map Service (WMS) or Web Feature Service (WFS). Access to data also involves data visualisations and previews on for example the map viewer of the portal.

User Interface (UI)

Within this thesis, the UI is assumed to consist of the available services, the graphical representation, and the enabling information such as documentation [Guntupalli, 2008], [Nilsson and Ottersten, 1997], [Rantzer, 1997].

User Experience (UX)

UX design involves all aspects of social interaction between the UI and its users [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].

The indirect or external factors of performance that are part of the UX, are not within scope for this research. Examples of such factors are the download speed, the speed of the helpdesk and the amount and quality of the datasets [Yan and Guo, 2010], [Guntupalli, 2008].

However, the UI design influences the UX [Roth, 2017]. As a consequence, some UX metrics can be used to measure the perceived usability of the UI [Tullis and Albert, 2013].

Human Computer Interaction (HCI)

In this thesis, human-machine interaction is used interchangeably with HCI to describe the communication between users and a system through a UI. Note that other sources often use a broader definition to describe the field of HCI. HCI is for example also mentioned in contexts involving a wide spectrum of UX design aspects beyond the use of the UI [Fischer, 2001].

Measuring user-friendliness

User-friendliness and usability are used interchangeably in this thesis. It is assumed that user-friendliness is measurable with usability metrics. In general, usability metrics constitute criteria that capture how effective, simple, or intuitive interactions with the UI are [Resch and Zimmer, 2013], [Haklay and Tobón, 2003].

Personas

A UI design in which the skills and expectations of the users are considered enables successful communication [Guntupalli, 2008]. A good way to do this is by using personas. These fictional users help guide the design by setting a target of a potential user instead of trying to design for everyone at once [Pruitt and Grudin, 2003].

3.3. Scope

The focus of this research is on the UI of geoportals such as PDOK. The context of the research will be the SDI user, or more specifically, the users of PDOK. This is a broad group, covering many different types of users [Welle Donker et al., 2019].

To establish the scope of this research, several design choices are made.

3.3.1. Selection of user types

There is a vast diversity in the characteristics of different users of platforms such as PDOK. In short, PDOK is used by both public and private sector users; Ministries and universities, individuals, both large and small organisations, all use data from PDOK [Welle Donker et al., 2019].

These different users have different needs, interests, objectives, and experience [Zuiderwijk, 2015], [Parnia, 2014], [Guntupalli, 2008] and require different design goals [Shneiderman, 2004].

Within the scope of this research, it is not SMART, Specific, Measurable, Assignable, Relevant and Time-bound ([Doran, 1981] as cited by [Haughey, 2014]), to consider all possible users. For this reason, a selection of users whose characteristics will be considered is made based on the personas of PDOK. These personas are constructed and validated based on market research [PDOK, 2019].

In accordance with the needs of PDOK, this research will be focused on the characteristics of the *developer / GIS specialist* and the *web developer*. Previous market research related to the NGR confirms these are relevant user groups. Of the users of NGR 17% are software developer, this is 48% of the private sector users. 5% Of the user does not have experience with GIS, of the private sectors users, this is 16% [NGR, 2018].

The developer personas can be subdivided in Sjors and Klaas, and a web developer. Sjors has a curious "do-it-yourself" attitude, whilst Klaas is more goal-oriented. The web developer does not have much technical knowledge [PDOK, 2019].

The GIS specialist is familiar with the specific geomatics related jargon, but can for example have different levels of experience with the portal interface and GIS [NGR, 2018].

Note that by following the methodology of this research, other personas could theoretically be taken into consideration in future implementations.

3.3.2. Selection of functionalities

Geoportals can offer a wide range of functionalities. However, some of these functionalities are more common than others. Typically, users of open data visit a geoportal when they want to discover datasets that are relevant for their needs [Jiang et al., 2019], [He et al., 2012], [Giff et al., 2008]. For data discovery, *search functionality* is required. Of the search methods that are often possible in geoportals, keyword search is the most preferred option, followed by geo search on a map. The least favoured option is a category search [Resch and Zimmer, 2013].

Furthermore, *data visualisation mechanisms* are essential to help users assess, understand, and utilise data [Kukimoto, 2014], [He et al., 2012].

Next to discovery and data visualisation, geoportals should also enable *data access* for further analysis [Resch and Zimmer, 2013], [Masó et al., 2011], [Giff et al., 2008]. This is in line with the aim of PDOK, in which the data access is highly valued [PDOK, 2019].

Only the UI design related to common functionalities such as data discovery, visualisation, or access, will be a point of focus during this research.

3.3.3. Selection of datasets relevant for this research

At the time of writing, PDOK hosts 142 datasets. Within the scope of this research, not all of these can be considered. In agreement with PDOK, the datasets that could be interesting for testing purposes are selected:

- Basisregistratie Grootschalige Topografie - "Base registry large scale Topography" (BGT): detailed topographic maps on a scale from 1:500 to 1:5000 containing buildings, roads, water, railways and vegetation. Available as WMS, Web Map Tile Service (WMTS), Tile Map Service (TMS), WFS, and as download in the Geographic Mark-up Language (GML) format.

- Basisregistratie Ondergrond - "Base registry sub-surface" (BRO): includes data about the use of the subsurface environment, subdivided in so-called "registration objects" such as "Cone Penetration Tests" (geotechnisch sondeeronderzoek) or "groundwater monitoring wells". Available as WMS, WFS, and downloadable in the GML format through ATOM services.

- Basisregistratie Adressen en Gebouwen - “Base registry Address and building information” (BAG): includes data about all addresses and buildings in the Netherlands. Examples of available attributes include the building year, building contour, purpose of use, and location on the map. Available as linked open data, through RESTful APIs, WMS, WMTS, TMS, and WFS.

- Nationaal Wegen Bestand - “National roadmap data” (NWB): the main road network dataset at a scale of 1:10.000. Available as WMS, WFS, and downloadable in the GML format through ATOM services.

The BRO, a new base registry, was especially suggested to be a point of interest. This dataset is also interesting to consider because it is not supplied by the Dutch cadastre, but by TNO. For the same reason, the NWB, which is supplied by Rijkswaterstaat, is interesting to consider.

Previous research of PDOK suggests the applicability of the selected datasets for the *developer / GIS specialist* and the *web developer* [PDOK, 2019].

GIS specialists for example want to show all buildings built before a certain year. For this, the BAG is of relevance. Web developers want to display parking locations, routes, or office locations. For this, the BGT background maps could be useful.

3.3.4. Functional requirements

This research will solely cover functional user requirements for the UI related to the selected user types, functionalities, and datasets. Such functional requirements entail what users want and need from the UI of the geoportal [Zuiderwijk, 2015].

Note that such a design choice is a limitation of this research since in reality the usability will sometimes be constrained by non-functional, technical requirements such as the download speed of a dataset.

Furthermore, in the real world, different users also value different data characteristics. This research solely focuses on the communication of these characteristics to enable users to assess whether or not the data is fit for their use case before access. In other words, non-functional requirements in terms of data content are also assumed to be fulfilled and the data users need, is assumed to be available on the portal.

4 Methodology

In this chapter, the methodology that will be adopted to answer the research questions is described.

A flowchart visualising the relationships between the different chapters and the methodology that will be part of the final thesis is displayed in Figure 4.1.

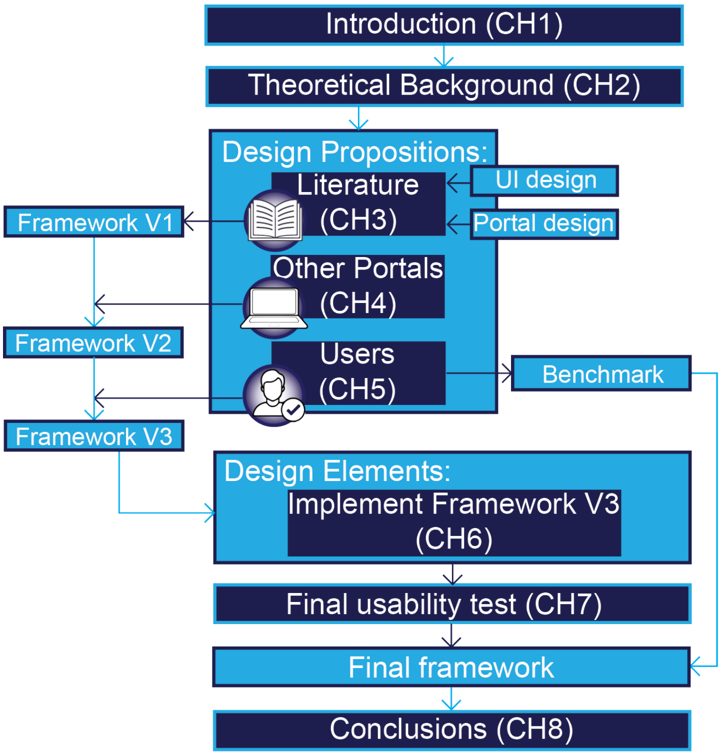

Figure 4.1: Flowchart displaying the relationship between the different chapters of the final thesis.

Following the workflow as shown in Figure 4.1, theoretical background research into UI design is used as a foundation for this research (Section 4.1). After this, the development of design characteristics is analysed from diverse perspectives (Section 4.2). This includes a literature review, desk research involving other (geo)portals, and user interviews related to the running example PDOK. Based on the synthesis of the combined findings, a framework containing possible design propositions is developed. The feasible design propositions are implemented in a mockup as design elements again with a focus on PDOK as a case study (Section 4.3). A final usability experiment using this mockup leads to an answer to the main research question (Section 4.4).

This methodology is in many ways similar to a general UI design workflow. One way to explain this, is through an adaptation of the Delta method, which is used to describe the necessary components for the UI design process. A visual adaptation of the Delta method is provided in Figure 4.2 (based on [Rantzer, 1997]).

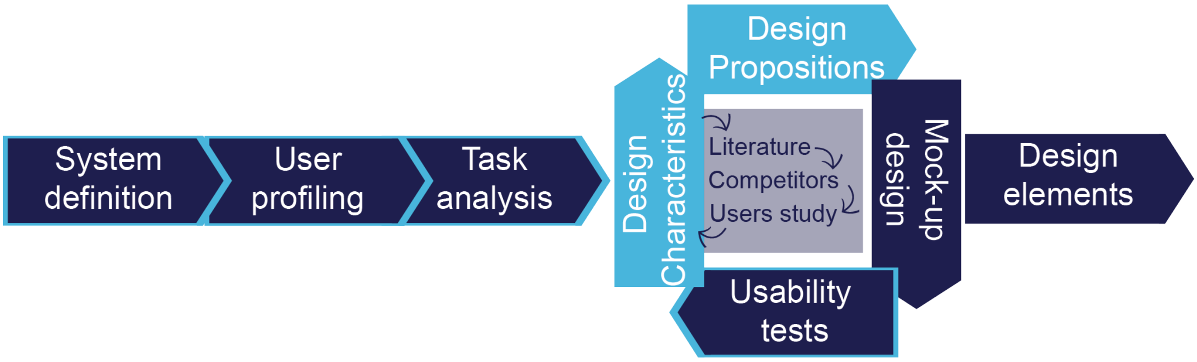

Figure 4.2: Visualisation of the correspondence of the methodology that is adopted during this research based on the Delta method (adapted from Rantzer [1997]).

4.1. Theoretical background research

For the first step of this research, it is required to look into background information related to UI design, as will be provided in Chapter 2 of the final thesis.

4.1.1. User centred UI design process

By considering the needs, requirements, and constraints of users in the design process, the system will be more suitable for the user.

The iterative UI design process of a design solution involves design evaluation, specification of the context of use, and specification of the requirements.

Personas can be used to decide for whom the design will be. *Task analysis* involves the possible steps a user can take during system use.

4.1.2. UI

The UI involves the communication of system information to the users. To enable this, it uses the graphical representation, interaction with available services, and information including enabling information such as documentation.

4.1.3. (Perceived) usability

In this research, metrics that assess the (perceived) usability of a system are used to determine the user-friendliness of the UI.

According to International Organization for Standardization (ISO) 9241-11, usability consists of effectiveness, efficiency, and satisfaction. This definition can be extended with learnability, memorability, and error occurrence.

Perceived usability and UX

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.

User sessions

To measure the (perceived) usability, user sessions can be conducted involving for example surveys, interviews, card sorting, or task-based observations. In such sessions, the system performance in terms of usability can be evaluated. Furthermore, user sessions can be used to gather user requirements such as the design characteristics relevant to this research.

4.1.4. AH

Different users have different needs. To suit these needs, AH can be used to present more personalised content suiting these different needs.

During the AH system development process, it should be encoded how data should be acquired and interpreted.

Advantages and limitations of AH

Showing users more relevant options can lead to higher user satisfaction, higher efficiency, and fewer errors. A lack of (perceived) consistency and unwanted changes are challenges related to adaptive UIs.

4.2. Design characteristics from diverse perspectives

For this research, the possible UI design characteristics are acquired from diverse perspectives. This matches the iterative nature of the UI design process [Nilsson and Ottersten, 1997].

The methodology that will be adopted is a deductive, top-down approach. In this specific approach, a hypothesis about possible design characteristics is acquired through a literature review. These findings will be validated and extended through a desk study involving other geoportals and through a user session [Fu, 2012].

4.2.1. Literature review

There is related research available on UI design and geoportals. This research will be used to establish the initial version of the assessment framework. The entries of the assessment framework will all belong to one of the categories of the UI; The available services, the graphical representation, and the enabling information such as documentation.

Example entry of the assessment framework

An example of a possible entry in the assessment framework in the category of enabling information is provided in Table 4.3. In the context of this methodology description, this example is used to indicate what the assessment framework will look like.

The preferred implementation of design characteristics can depend on certain user characteristics. If this is the case, the use of AH can help to ensure that each user is offered the implementation that is most suitable for them.

Table 4.3: Example of an entry in the user-friendliness assessment framework based on [Elvira, 2018], [Roth, 2017] ,[Marta, 2016], [Braggaar, 2016], [Carvalho and Lafuente, 2015], [Jurisch et al., 2015] [Zuiderwijk, 2015], [Parnia, 2014], [Zuiderwijk et al., 2013], [Guntupalli, 2008], [Van Loenen, 2006], [Courage and Baxter, 2005], [Van Welie, 2001], [Dayton et al., 1997], [Rohlfs, 1997], [Smith, 1997].

Design characteristic	Implementation suggestions	Sources
Availability of help mechanisms and documentation Mentioned in: [Elvira, 2018], [Guntupalli, 2018], [Roth, 2017], [Marta, 2016], [Braggaar, 2016], [Carvalho et al., 2015], [Jurisch et al., 2015] [Zuiderwijk, 2015], [Parnia, 2014], [Zuiderwijk et al., 2013], [Van Loenen, 2006], [Courage et al., 2005], [Van Welie, 2001], [Dayton et al., 1997], [Rohlfs, 1997], and [Smith, 1997].	Data manual (User's manual listing tools & guidance for data usage)	[Elvira, 2018], [Zuiderwijk et al., 2013], [Marta, 2016], [Parnia, 2014]
	Discussion forum (for example through social media) & help desk	[Elvira, 2018], [Braggaar, 2016], [Marta, 2016], [Zuiderwijk, 2015], [Zuiderwijk et al., 2013]
	Examples of data applications and use	[Elvira, 2018], [Marta, 2016], [Zuiderwijk, 2015], [Parnia, 2014]
	FAQ	[Elvira, 2018], [Marta, 2016], [Braggaar, 2016], [Carvalho et al., 2015], [Parnia, 2014], [Zuiderwijk et al., 2013]
	Glossary with terms & definitions	[Marta, 2016]
	Portal manual or Wiki	[Guntupalli, 2018], [Marta, 2016], [Braggaar, 2016], [Zuiderwijk et al., 2013]
	Tips & hints (such as visual clues about functionality [Smith, 1997])	[Zuiderwijk et al., 2013], [Nilsson et al., 1997]
	Tutorials	[Elvira, 2018], [Marta, 2016], [Parnia, 2014], [Zuiderwijk et al., 2013]

4.2.2. Desk research involving other geoportals

It is helpful to examine the strengths, functionalities and unique features of other geoportals to learn from their design choices [Courage and Baxter, 2005]. This way, insights into existing designs can help describe design characteristics for future design [Fedorowic et al., 2014], [Simpson, 1997].

Using pointers from other portals for the implementation of design characteristics will also help to enable consistency and interoperability between different portals [Scholtz, 1997].

Expected procedure

A two-sided approach will be adopted to acquire design characteristics from other portals. In the first place, other geoportals are analysed in desk research according to the initial findings of the literature review. Based on the conformity of the portal with this initial framework, the better performing factors can be recognised and related to implementation examples.

Furthermore, new design characteristics can be discovered by evaluating how other portals handle tasks related to discovering, assessing, and accessing data.

Portal selection

Before it is possible to start the desk research, it must be decided which portals will be part of the analysis. At the time of writing, there is no list of user-friendly geoportals available. For this reason, other selection criteria are required.

These other measures are available in the form of ratings for open data portals, open data readiness, or geospatial readiness of a certain country. Such measures are usable, when assuming that countries with high open data and geospatial readiness 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. Because these countries should have similar legislation, culture, and country type as the Netherlands, the use types are also assumed to be more similar.

According to Open Data Maturity [Cecconi and Radu, 2018], the Open Data Barometer [2016], Geobuiz [2018], and Open knowledge international [2016], these countries are rated as displayed in Table 4.4.

Table 4.4: Open 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]. Ireland ranks first in the Open Data Maturity. However, because this specific assessment does not focus on geodata, the actual geoportal might be less promising.

In the Open Data Maturity EU28 scores, all the portals mentioned in Table 4.4 get an average rating of 63%. When looking at 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. Again note that these scores reflect the open data portals and not necessarily relate to the geoportals.

Based on the information displayed in Table 4.4 and an initial visual assessment, the portals that will be considered during this research are selected. In the first place, the portals of France[1] and Ireland[2] will be considered. 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.

One of the aims of the research presented in this thesis is to gain interoperable and standardised interfaces of geoportals. For this reason, more general, international open data portals could also be of interest. Accordingly, it could be interesting to also assess international, European portals if time allows it. The Infrastructure for Spatial Information in Europe (INSPIRE) geoportal[5], and the European open data portal[6] can for example be selected in line with this idea. Since both of these portals relate to Europe, they do stick to the European scope. This is important, because European users are more likely to be equivalent to the Dutch users of PDOK, than for example Asian users would be.

4.2.3. User session

To increase use, the user should be involved in the open data process [Van Loenen and Welle Donker, 2016]. For this reason, additional design characteristics and the usability of PDOK are empirically assessed by observing and interviewing users during a user session.

Courage and Baxter [2005] suggest that a proposal for usability sessions is required to structurally plan the activity. For the usability sessions conducted during this research, these proposals are provided in Annex A.2.

Expected procedure

The user session of this part in the methodology will lead to two results; A benchmark of the initial status of PDOK, and the perspective of potential users on the user-friendly UI design characteristics.

The benchmark of the initial status of PDOK involves comparing the current geoportal to the current assessment framework, a brief evaluation of comments on the GeoForum[7], and a usability experiment. This will help validate the effect of the UI design elements that will be implemented based on the assessment framework.

Usability experiment

The selected methodology for the usability experiment is a so-called mixed-method approach. In this approach, both qualitative and quantitative research elements are combined.

With quantitative research, relationships between variables can be assessed by for example statistically comparing closed-answer survey results. Qualitative research concerns how and why things happen [Pekkanen, 2015], [Fu, 2012]. This allows for a more thorough understanding of a phenomenon by examining contextual behaviour [Fu, 2012], [Van Loenen, 2006].

During the usability experiment, participants will be observed while they perform tasks. They are then asked to quantitatively rate their experience. A semi-structured interview related to these ratings

[1] https://www.geoportail.gouv.fr
[2] https://geohive.ie/
[3] https://www.geoportail.lu/en/
[4] https://www.geonorge.no/en/
[5] https://inspire-geoportal.ec.europa.eu/
[6] https://www.europeandataportal.eu/en/homepage
[7] https://geoforum.nl

is used to uncover and elaborate on particular issues participants encountered and where they think there is room for improvement. This can provide relevant information of which the researcher has not initially thought [Fu, 2012]. The choice for a semi-structured interview relates to the fact that, unlike a structured interview, it allows the freedom to go into issues. Semi-structured interviews still allow comparison of the results. This is more challenging for open interviews, which could lead to completely different directions.

User requirements experiment
A card sorting experiment will be performed to gather additional user requirements related to the design characteristics. Card sorting can be useful to evaluate the users' mental model regarding system elements [Tullis and Albert, 2013].

During the card sort, the participants will be invited to express their opinion about elements in the current user-friendliness assessment framework. Based on their comments, the framework can be refined.

Participant selection

To acquire realist results and for the design to fit the target group, user sessions must be performed with actual users who match the intended personas [Mishra, 2013], [Roto et al., 2011], [Dayton et al., 1997].

Larger sample sizes increases the confidence level, but smaller sample sizes are more SMART for this research [Tullis and Albert, 2013]. For this reason, convenience sampling, with a smaller, less representative sample size, will be performed [Courage and Baxter, 2005].

Different sources recommend different sample sizes. Some state six to eight people of each user type should be recruited [Courage and Baxter, 2005], [Rohlfs, 1997], others suggest at least four from each group [Tullis and Albert, 2013], or keep it broad by suggesting three to ten participants would be sufficient for usability testing [Poplin, 2015]. Generally speaking, recruiting new participants can stop once the amount of new information starts to become limited [Courage and Baxter, 2005], [Rohlfs, 1997]. This depends on the homogeneity of the target market [Rohlfs, 1997].

For this research, at least three people from each user group will be interviewed. It is estimated that this amount is both SMART and sufficient to acquire a generalised representation of reality for the benchmark whilst involving the most common opinions about user-friendliness design characteristics. If the results deviate too much and time allows it, more participants should be involved in the sessions because this will make the research more conclusive.

Users of the same user type can still have diverse characteristics and varying needs. For this reason, it is realistic to recruit participants within a broad spectrum of characteristics. This way, all their different requirements can be considered.

For the GIS specialists, geo-related knowledge is a must. However, the level of experience with GIS and PDOK may vary. For the developer persona, one developer related to Sjors and one related to Klaas can be selected. It is also possible to recruit a participant without much technical knowledge. This will be most in line with the web developer persona.

Recruiting a web developer as a participant also has added value because this participant can be considered to be an expert on UI design. Evaluating a design with feedback from an expert is regarded as beneficial [Purao et al., 2008].

4.3. Implement design propositions

The implementation phase of the methodology of the thesis is used to provide concrete examples of the implementation of UI design elements to geoportal developers. Additionally, implementing design elements is required to be able to evaluate their effect, which will be described in Section 4.4. AH will be considered to adjust the implementation of design elements to the needs of specific user types.

Generally speaking, the implementations should be SMART within the research scope. Furthermore, within the scope of PDOK, dealing with re-design should also be considered. This re-design can be challenging, because users are already accustomed to the current version of PDOK. Changes should be implemented with care, to minimise required learning [Rohlfs, 1997].

There are several possible approaches to implement findings. For this research, a mockup is used. Alternatives such as paper sketches and wireframe models would be insufficient. They can help to evaluate ideas, but cannot be used to assess actual usability.

In certain instances, the mockup design for this research will not include functional elements. In other cases, for example for the selected datasets and tasks, the mockup will represent a working prototype to enable usability testing. When users click one of the access buttons (download, geo-web services, or API), the download of a `.txt` will start to indicate the completion of the access process. It is not necessary to link the actual data, because this is no longer part of the UI design.

4.4. Test design elements

To validate the user-friendliness of the implemented design elements, a similar usability test as described in Subsection 4.2.3 will be performed, preferably by the same participants. With the results of this follow-up experiment, the performance of the newly implemented design elements is comparable to the performance of the original version of PDOK. The research proposal for this session is displayed in Annex A.2.

The elements that perform well during this final usability test will be labelled design elements. Together, these design elements can be captured in the user-friendliness assessment framework. The elements of the final assessment framework can be visualised using colour codes on sample pages of the portal, an example is shown in Figure 4.5.

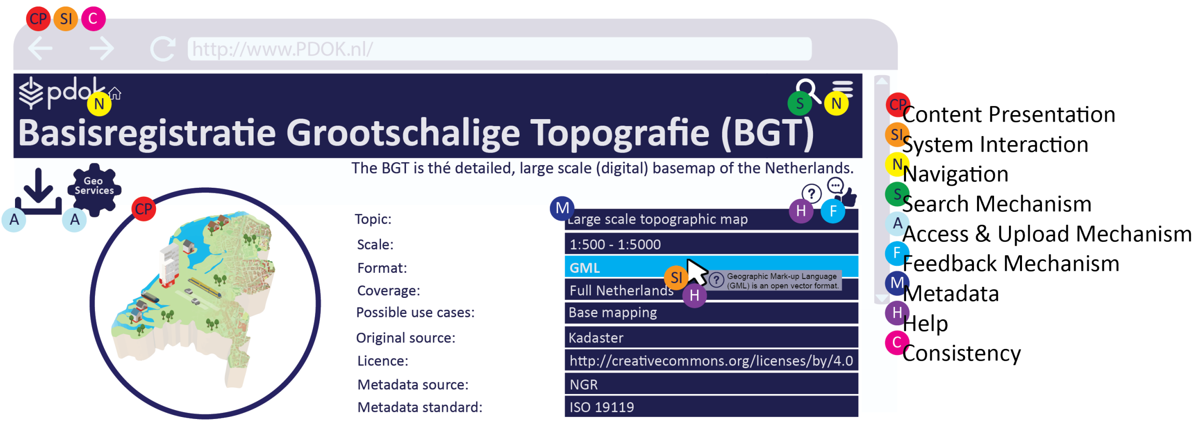

Figure 4.5: Visualisation of the assessment framework of some possible implementation examples. Note that this image is just an indication, the end result is very likely to be different and might have little or no resemblance to this image.

5
Time planning

In this chapter, a scheme of the division of the workload of this graduation research is presented in a summarised form in Figure 5.1.

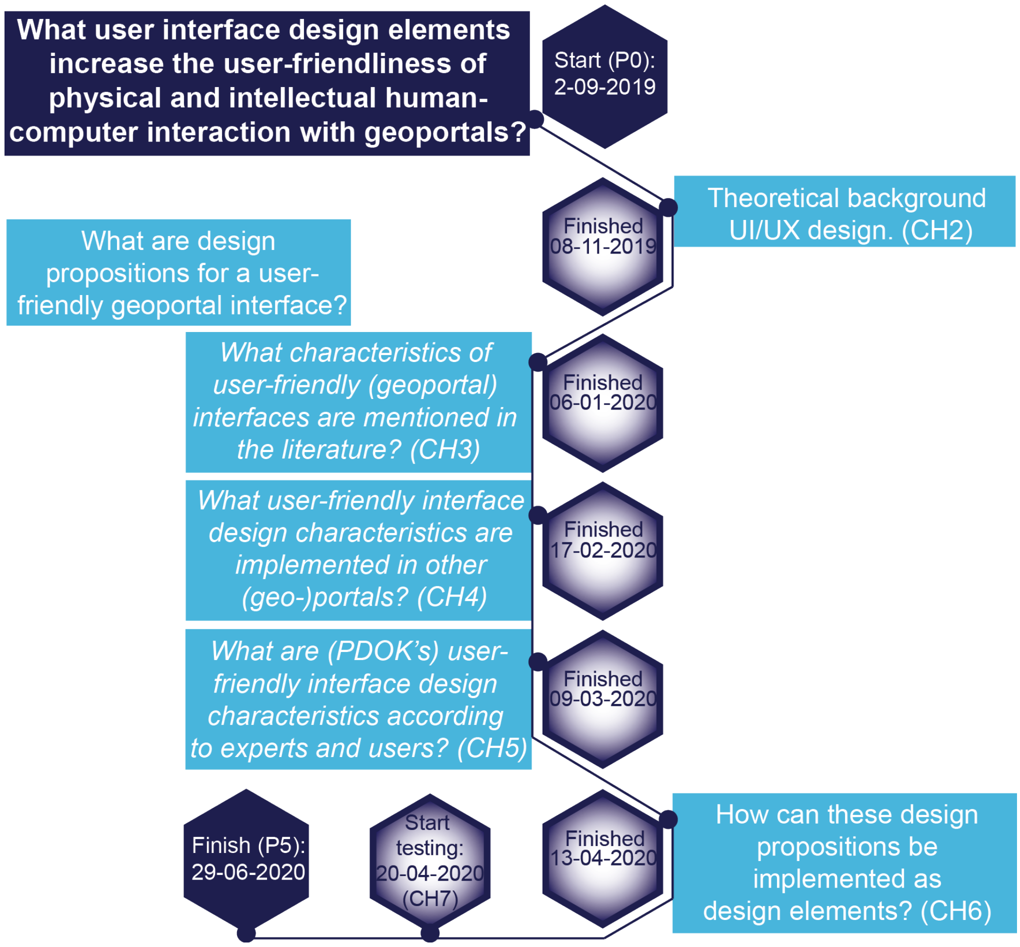

Figure 5.1: Summary of the time planning which envisions the way the workload of this graduation project will be spread related to the research questions.

In Annex A.3, a Gantt chart containing a more in-depth time planning is provided.

6 Tools and datasets used

The tools and datasets that are expected to be required for this research are listed in this chapter.

In the first place, background information provided by PDOK is already used to establish a system analysis about the different users of PDOK and their needs.
Furthermore, the initial PDOK platform will be used for benchmarking purposes.

In order to create a clickable mockup in which user-friendly UI components are implemented, HyperText Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript will be used. There are many tools, such as AdobeXD, Sketch, or UXPin, that are more intuitive to work with for a beginner. However, implementing basic aspects of AH is expected to be challenging with these tools. To allow more control during the design process, going back to basics with HTML, CSS, and JavaScript seems to be the most suitable plan of approach.

The Open Broadcaster Software tool[1] will be used to capture where participants click and to measure the time they need.

[1] https://obsproject.com/welcome

A

Annex

A.1. Tabular overview literature review

In this annex, a tabular overview of the related work is provided in Table A.1.

Table A.1: Tabular overview of the related work chapter (continued on the next page).

Research focus	Source	Outcome relevant for this research
Requirements for open data infrastructures to support provision and use of open data	[Zuiderwijk, 2015], [Zuiderwijk et al., 2013]	Requirements such as available help mechanisms, metadata, accessibility in form of view or download service and examples of use cases that are listed in these sources, are communicated by the UI. Such elements should be considered in the user-friendly interface assessment framework.
Tools and instrument used to monitor and evaluate performance of the open data policies (in the context of governance)	[Vancauwenberghe, 2016]	
Requirements for open government data portals to enhance transparency, privacy and information quality	[Marta, 2016]	
Requirements for open spending portals to enhance citizens engagement	[Elvira, 2018]	
Assessment possibilities for geoportals from a user perspective	[Van Loenen et al., 2010]	The research describes tasks to search for geoinformation to assess the portal. This can be used within this thesis. Some usability problems that are mentioned also need to be handled in order for the portal to be user-friendly (for example inactive contact buttons and language barriers).
Evaluation measures (GeoTest) for the usability of geoportals	[He et al., 2012]	Different tasks described to test the usability (such as keyword search for a dataset) can be used in this research. Requirements for the portal such as being able to specifying a geographic extent for the data and the availability of a manual are also of importance.
Assessment of the perceived usability of the RO-Online geoportal on their communication and visualization of land use plans	[Veldkamp, 2017]	The communicational aspect this research looks into is the core purpose of the UI.
Assessing the usability of map-based geoportals	[Kellenberger et al., 2016]	List criteria specific to the interaction with map-based geoportals such as map navigation and system feedback to the user.
Website usability evaluation tool (WebUse)	[Chiew et al., 2003]	The usability evaluation measures include for example learnability, control and satisfaction, and can also be adopted to measure the user-friendliness of the UI in the context of this thesis.
Measures for the user experience (UX)	[Joo, 2017], [Roth, 2017], [Pekkanen, 2015], [Tullis, 2013]	The UX is partly determined by the UI. For this reason, measures for the UX help to measure the user-friendliness of the UI. The part of the UX that is relevant to measure in this thesis involves task performance measures for usability, such as speed and error rate.
Measures for the UX in map-based geoportals	[Resch et al., 2013]	Next to general UX measures, concrete examples to deal with issues in the UX, such as changing the size of buttons and the contrast of text, are also mentioned. These examples can contribute to the user-friendliness of the UI.

Research focus	Source	Outcome relevant for this research
Strategies for effective human computer interaction	[Shneiderman, 2004]	The examples stated about the interaction between the user and the system should be ensured by the UI in a way that is as user-friendly as possible. Examples are the error handling, the navigation of the users through the system and system feedback about the state of a process.
Qualities of good UI design	[Guntupalli, 2008]	
Aesthetics in UI design	[Fu, 2012]	Information about the use of colour and the presentation of the content in a way that has proven to be pleasing to users on a general level.
Data portal UI design strategies	[Carvalho et al., 2015]	Next to more general requirements, such as the availability of FAQs, the research also lists requirements for the presentation of the content, such as the use of a visual hierarchy.
Task-based UI design	[Van Welie, 2001]	Looks into implementation examples ("design patterns") of UI design elements from the perspective of different tasks
Data portal UI design strategies	[Parnia, 2014]	Here requirements for consistent behaviour and appearance, and that the look of the system should be simple, are listed. However, Parnia (2014) does not deeply go into how the visual presentations and aesthetics of the UI could be used to communicate elements such as available metadata. Parnia (2014) does provide some examples in the form of a wireframe model.
AHA! Adaptive Hypermedia for all kinds of web-based applications	[De Bra et al., 2003], [De Bra et al.,2001]	The general concept of AH.
AH instructional system for effective and engaging learning	[Khan et al., 2019]	Examples of implementation of AH.
Player modeling based on both playstyle and motivation (assessed in a survey)	[Patterson, 2014]	Examples of implementation of AH. For this research, there was no discrete differentiation between players. This made categorising players with supervised machine learning challenging.
Improving Performance, Perceived Usability, and Aesthetics with Culturally Adaptive User Interfaces	[Reinecke et al., 2011]	Providing users with adaptive interfaces can result in higher efficiency, fewer needed clicks and fewer errors. Users find adapted versions significantly easier to use and more attractive.
Testing the effectiveness of task-based adaptation of goal-directed browsing in terms of performance and satisfaction	[Te'eni et al., 2001]	The results indicate that adapted sites improve performance, but not overall satisfaction in a task-based adaptation. Users performed better in terms of execution times and accuracy in the adapted site, which is assumed to be related to its increase compatibility. However, the perceived complexity of the adapted site was higher than the non-adapted when working on more difficult tasks. Users may value their control, a consistent appearance and adaptive functionality.
Conceptual model based on neurons to make a smart system that can learn new elements and solves the cold start problem of AH, in which not enough initial information is available for adaptation	[Tmimi et al., 2018]	The idea to develop the system in such a way that new elemens can be learned, is relevant for this research.
Ranking webpages to meet custom user needs based on automatic learning	[Viloria, 2019]	Reducing the cost of development and increasing consistency by reusing base elements of the system.

A.2. Proposal user sessions

In this annex, proposals for the user sessions are provided. For the first benchmark session, this is done in Figure A.2.

The proposal for the follow-up usability study is displayed in Figure A.3.

Table A.2: Proposal for the benchmark usability session (continued on the next page).

Proposal User Session 1	
Introduction & History	PDOK is the Dutch platform for open geodata. The key features op 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.

Proposal User Session 1	
Methodology	**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.
User profile	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.
Recruitment	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.
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): 24-01-2020 to 31-01-2020 • Possible dates for the session: 10-02-2020 to 21-02-2020

Table A.3: 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

A.3. In-depth time planning

In this annex, an in-depth time planning of the project is provided.[1, 2]

In Figure A.4 the planning for the first quarter is provided. In Figure A.5 the planning for the second quarter is provided. In Figure A.6 the planning for the third quarter is provided, and in Figure A.7 the planning for the fourth and final quarter is provided.

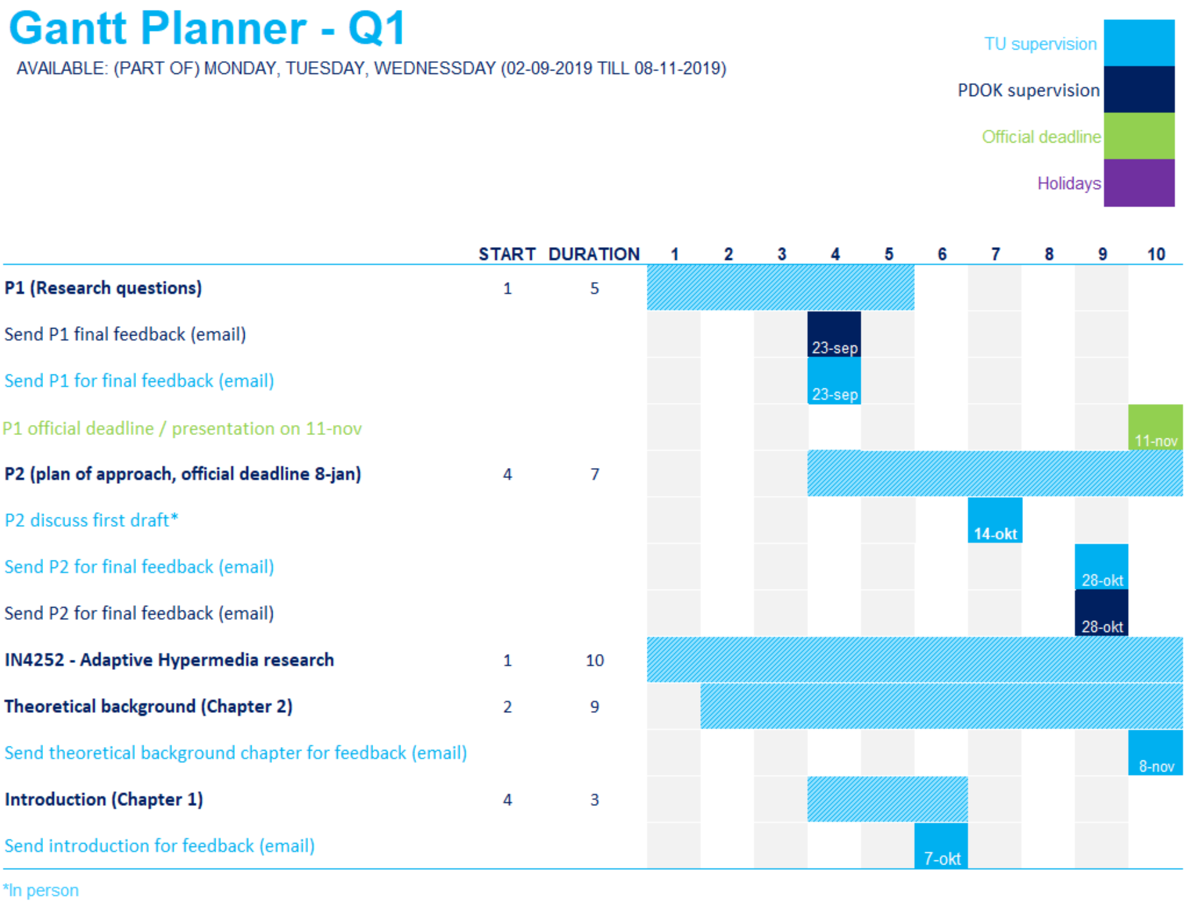

Figure A.4: Time planning which envisions the way the workload of this graduation project will be spread for the first quarter.

[1]Note that after each meeting, the exact date of the next appointment will be determined.
[2]The dates in this planning are considered to be guidelines. Currently, the project is progressing according to plan.

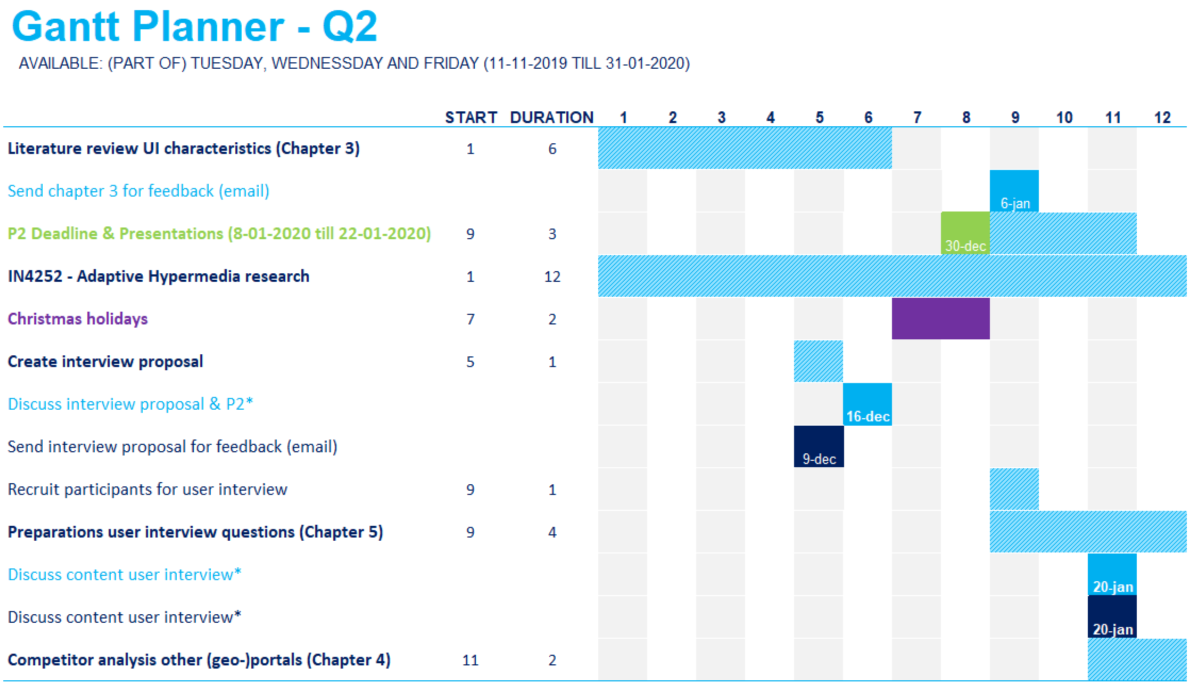

Figure A.5: Time planning which envisions the way the workload of this graduation project will be spread for the second quarter.

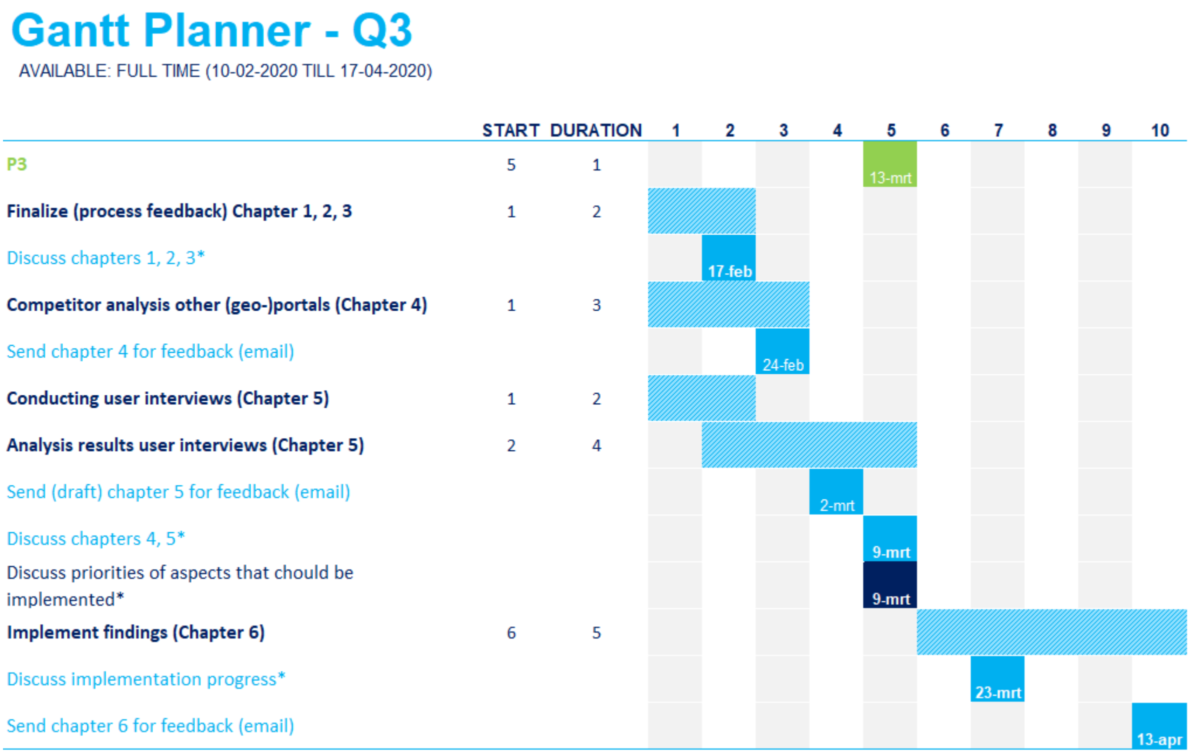

Figure A.6: Time planning which envisions the way the workload of this graduation project will be spread for the third quarter.

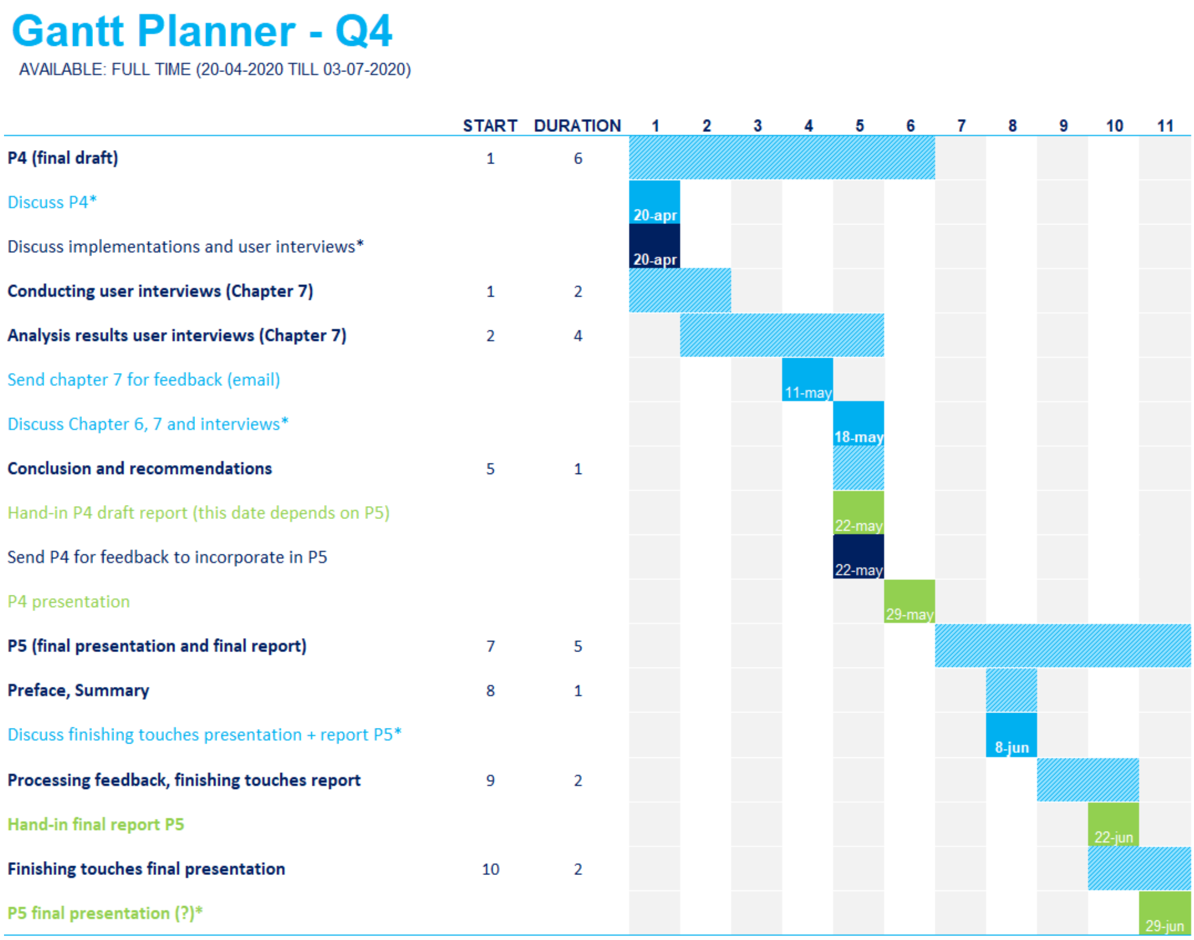

Figure A.7: Time planning which envisions the way the workload of this graduation project will be spread for the fourth and final quarter.

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