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Improving environmental data use in spatial planning: A government view on the Dutch Digital System Omgevingswet (DSO)

By Tom Winter
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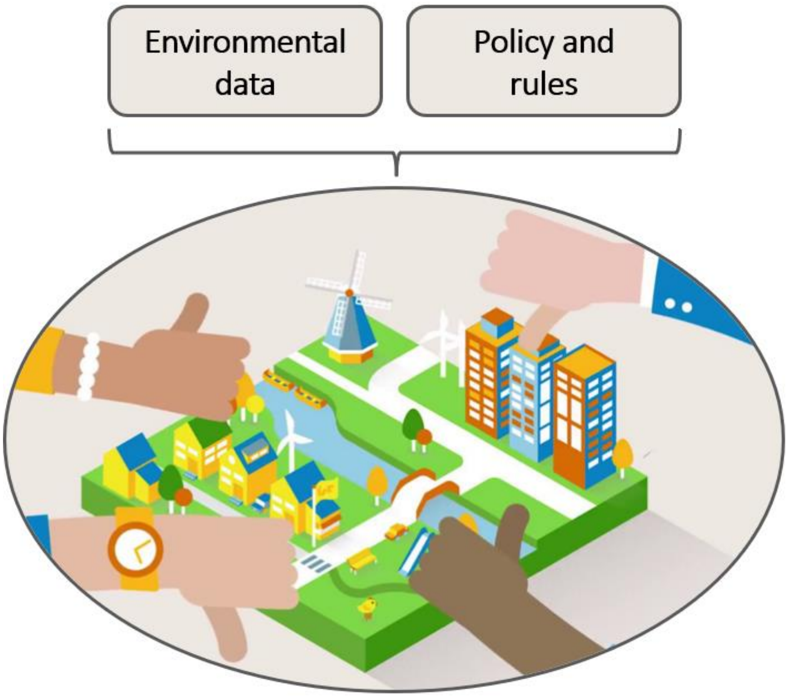

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Improving environmental data use in spatial planning: A government view on the Dutch Digital System Omgevingswet (DSO)

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Abstract

In January 2024, the Netherlands introduced the new Environment and Planning Act (Omgevingswet), which included the Digital System Omgevingswet (DSO), providing a centralized platform for spatial planning. The original vision of the DSO was to provide access to relevant rules and environmental data. The DSO would organize environmental data into ten domains, each represented by an "Information house", which is an organization that verifies and standardizes data for use in the DSO. During the development of the DSO, the concept of Information houses was abandoned to focus on other aspects of its development.

This study investigates the use of environmental data by Dutch spatial planners and permit issuers and aims to identify areas for improvement of this use. The potential of Spatial Data Infrastructures (SDIs), Spatial Knowledge Infrastructures (SKIs), and automation is highlighted. Through interviews with 17 participants, including DSO experts, spatial planners, and permit issuers, their needs, challenges, and recommendations regarding the use of environmental data are identified. Spatial planners mainly faced challenges with data fragmentation, compatibility, and visualization. Recommendations from spatial planners emphasized the need for improved overview maps and more data compatibility, indicating a preference for DSO functionalities geared towards SDIs instead of SKIs and automation. Permit issuers mainly focused on data reliability and data availability for citizens or companies before a permit is requested. Their recommendations focused on streamlining permit application processes and enhancing the user-friendliness of the portal ‘Checks’ in the DSO, which align with the potential benefits of SKI functionalities. Despite minimal support for automating decision-making, participants agreed on the value of automating simple permit checks, such as dormer windows or shed extensions. The study highlights the importance of standardization efforts and the potential benefits of Information houses in centralizing and standardizing environmental data in the long run. However, the choice to abandon Information houses and concentrate on enhancing core DSO components was probably beneficial from the government's perspective. The full potential of Information houses cannot be identified from this study since it only focused on the government, while citizens and companies might greatly benefit. Finally, future research directions include investigating specific data types required for simple permits and assessing the socio-economic benefits and risks of automation within the DSO and spatial planning in general.

Contents

1. Introduction

In 2015, the new Environment and Planning Act (Omgevingswet) has been accepted by the Dutch government. On the first of January 2024, it was implemented. This new act aims to simplify spatial planning by combining all separate laws on the subject into one. This big legislation change also includes a new digital system, the Digital System Omgevingswet (DSO). This system should provide a platform where citizens, companies, government, and all other stakeholders can quickly see locally applicable rules and environmental conditions on a map to find out what is allowed regarding spatial planning (DSO OGAS, 2020).

The significance of spatial planning in the Netherlands can be attributed to two key factors: the limited availability of land and the ongoing economic and population growth (Janssen-Jansen, 2016). In this spatial planning process, spatial data is naturally of great importance. In the Netherlands, this was already recognized in the evidence-based spatial planning practices from the 1960s to the 1970s (Janssen-Jansen, 2016). Now, different types of users from both private and public sectors increasingly demand spatial data and efficient ways of handling it (McDougall, 2010). To meet the quickly rising need for spatial data, the Spatial Data Infrastructure (SDI) has been one of the most important developments (Nedovic-Budic et al., 2011). SDIs, which generally consist of a framework of technologies, policies, and institutional arrangements, were initially developed to facilitate access to spatial data and promote its sharing (Nedovic-Budic et al., 2008). From the year 2000, SDI development shifted to more user-oriented methods called the second and third-generation SDIs (Sjoukema, 2021).

Now, after these developments in the field of SDIs, the Dutch government has shown an ambition to develop the concept of the SDI further with the DSO. Compared to the traditional function of an SDI to share data, this new system should also provide knowledge in the form of answers to questions such as: What is allowed here? Do I need a permit for construction? Will this exceed current sound regulations for the area? Such a system would approach a Spatial Knowledge Infrastructure (SKI), which is a relatively new concept in the domain of geo-information science, that was formulated by Duckham et al. (2017) as *"a network of data, analytics, expertise, and policies that assist people, whether individually or in collaboration, to integrate in real-time spatial knowledge into everyday decision-making and problem-solving"* (Duckham et al., 2017, p. 4). Much of the complexity of realizing such a system lies in processing and responding to end-user questions (Arnold et al. 2021). These user questions are often multifaceted and thus require combining multiple data types.

The need to combine data was clearly evident in the initial design of the DSO. Originally, the goal was to make the DSO a comprehensive source not just for regulations but also for information regarding the current state of the living environment. The current state of the living environment is represented by environmental data. In the DSO, environmental data would be made available in the form of ten domains (sound, air, soil, water, waste, cultural heritage, nature, external safety, construction, and spatial planning). Each domain would form its own 'Information house', which collects, validates, and standardizes environmental data to be put on a central geo-portal showing all this information as layers on a map (RIVM, 2016). Regulatory data would be available through this same portal called 'Regels op de kaart' (Rules on the map). This should be facilitated by governmental bodies delivering their regulations linked to geometry, making it possible to show which regulations apply in specific regions (Drahmann, & Huijts, 2021).

To give a short example of how environmental data can be combined with regulatory data, you can think of a company that wants to expand. It could be necessary to determine the sound load or nitrogen pollution of this expansion and that of the location, which can then be compared to maximum sound and nitrogen standards at that location to see if a permit can be granted.

Looking at the current state of the DSO it is clear that many of these original goals have not been met. An important turning point in the development of the DSO was the advice from the Bureau IT Testing (Definitief BIT-advies, 2017). It advised abandoning the concept of Information houses to make the implementation of the new act less complex. When following this advice, the Dutch government did not totally abandon the incorporation of environmental data in the DSO. Instead of Information houses, only the concept of Information products remained. These Information products will comprise of data or reports on environmental characteristics that can be uploaded to the DSO platform. They should at least be validated, but only have to be standardized when possible (GAS Informatie Producten, 2020). While this simplified the implementation of the new act, it possibly also means that environmental data is less often available in a standardized manner. This can hamper attempts to visualize (Drahmann & Huijts, 2021) or combine data, and to use it for automating spatial planning processes. These automation ambitions were often called the 'one click on the map' principle, providing you with an answer to your question regarding spatial planning with one click on the map (DSO OGAS, 2020).

Finally, it is important to note that the Dutch government plans to develop the DSO to the original ambition formulated in 2015 (Bestuurlijke reactie BIT-advies, 2020). This will start right after implementation on January 1, 2024, and follow an 'expansion agenda' that formulates which elements have first priority. One of these elements is the connection of Information products to the DSO, which shows the relevance to further research the role of environmental data use in spatial planning processes.

1.1 Research gap

The transition from Information houses to Information products potentially created a mismatch between user needs and the current state of the DSO. Additionally, a study revealed that 67% of municipal officials responsible for DSO implementation did not consider it ready for deployment by January 1st 2023 (I&O Research, September 2022). The study showed that 48% of the participants experienced insufficient ease of use for submitting spatial plans as a significant challenge. However, the study does not delve into the underlying causes of this issue, which is a critical aspect to investigate given the ongoing evolution of the DSO. It can be expected that the abandonment of Information houses left some of the original goals of the DSO underdeveloped, like the incorporation of environmental data with spatial planning. If and how this is a problem is not clear but can be deduced by researching user needs and challenges regarding the use of environmental data.

Next to this practical research gap, a scientific research gap can be identified when looking at the innovative nature of the DSO. The combination of regulatory and environmental data aiming to automate spatial planning processes shares many similarities with current descriptions of SKIs. At this stage, any attempt to develop an SKI is likely to become an SDI/SKI hybrid (Arnold et al., 2021). It is of interest to the field of SDIs and SKIs to discuss the need for automation in decision-making and the requirements to develop such automation. The current stage of DSO development poses an interesting moment now that the real consequences of automation can be anticipated more concretely. Seeing that the DSO is just beginning to explore SKI like functionalities, it is important to talk about what we want to automate and what not.

In summary, the research gap includes the potential issues arising from the abandonment of Information houses, and the unidentified perception of automation in spatial planning. These gaps show a need to research how governmental users experience the use of environmental data in spatial planning and explore potential improvements from their perspective.

1.2 Research aim and research questions

This study aims to research how governmental users experience the use of environmental data in spatial planning and explore potential improvements from their perspective. It aims to formulate specific changes or additions to the DSO that could improve this use, focusing on the potential role of automation.

For this research, the targeted user group will consist of only governmental users. Since governmental users already tested the DSO, they can provide a more informed view of it compared to those who have only used it since its implementation. Governmental users are highly involved in spatial planning and especially in combining environmental data with regulatory data, for example, in judging permit applications and making spatial plans. This enables them to discuss the potential benefits and downsides of automation to improve these processes.

The research questions for this study focus on the use of environmental data in spatial planning. They serve to fill the research gap by creating an overview of environmental data use and potential automation applications for spatial planning.

Main research question

How do governmental users of the DSO experience the use of environmental data in spatial planning, and what can help to improve or even automate this use of environmental data?

Sub research questions

1. What are the user needs regarding the use of environmental data for spatial planning?
2. What challenges do users experience in using environmental data for spatial planning?
3. What improvements could be made to the DSO to facilitate and automate the use of environmental data in spatial planning?

In the following chapter, the DSO structure is described with its strategy of incorporating environmental data. In Chapter 3, the theoretical framework is presented, which further explains the concepts of SDIs and SKIs to compare the DSO to them and link them to improvements resulting from this study. In Chapter 4, the methodology is described, substantiating the choice of interviews as the main research method. In Chapter 5, the results are presented. In Chapter 6, the results are discussed in relation to the concepts of SDIs and SKIs, the limitations are presented, and the significance of the research is discussed. In Chapter 7, the conclusion is given.

2. The DSO

This chapter gives an overview of the DSO and the systems that are expected to be used by governmental users when handling environmental data. A description of DSO components helps to put the theoretical framework in context and later formulate the methodology.

2.1 DSO user portals

The overarching goal of the DSO is to enable citizens, companies and governments to quickly see locally applicable rules and environmental conditions on a map in order to find out what is allowed in spatial planning (DSO OGAS, 2020). Three more specific goals are defined: (1) Citizens, companies, and governments should be able to consult locally applicable rules and environmental conditions; (2) citizens, companies, and governments should be able to check what rules and environmental conditions are relevant for a specific initiative in the physical living environment and request a permit; (3) different governments should be able to work together during the processing of permit applications (DSO OGAS, 2020).

In figure 1, four user portals and some important background systems are shown. Users interact with the DSO in multiple user portals (DSO OGAS, 2020). The "Omgevingsloket" is part of the DSO that is publicly available as the web portals: 'Rules on the map'; 'Checks'; 'Requests' and 'Tailor-made measures.' Next to these portals, which are used by citizens, companies, and governments, the portal 'Collaboration facility' is only used by governmental users. Not all portals are included in Figure 1 because they are assumed to be less relevant to the use of environmental data by governmental users. The following portals can be seen in figure 1:

1. On 'Rules on the map', rules and environmental data can be shown to the user. Rules come from governments, and environmental data come from Providers of environmental data (Leveranciers van Omgevingsinformatie or LvOs) in the form of Information products.
2. On 'Checks,' users can check if they need a permit or report activity by filling in a form. This form consists of applicable rules specific to their activity. These come from the register of applicable rules (RTR). APIs of Information products can automatically fill in environmental data.
3. On 'Requests', users can prepare and submit a permit request or report an activity. This is also partly pre-filled with data from Information products like in 'Checks'.
4. On the 'Collaboration Facility,' governments can collaborate among themselves and other governments on handling permit requests and spatial plans.

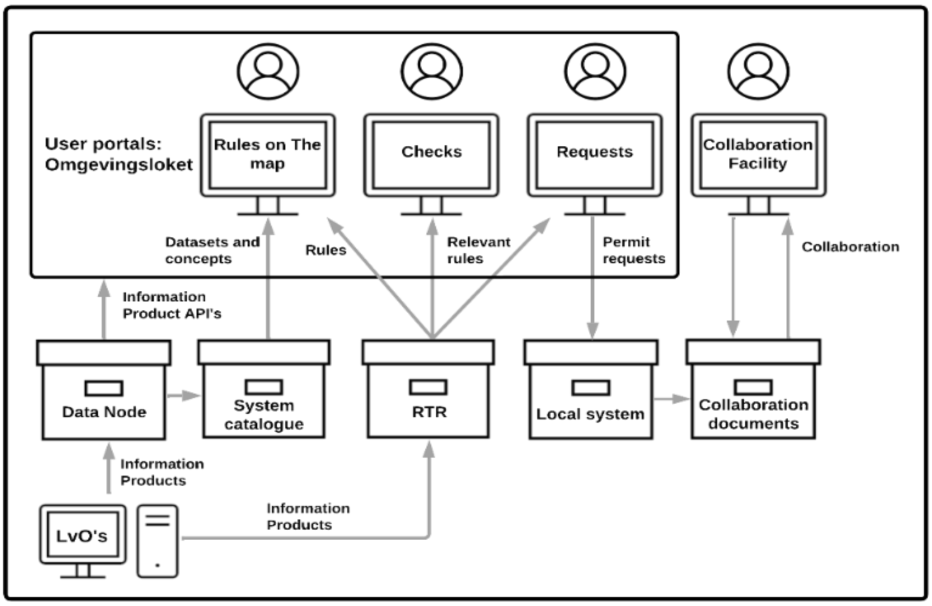

Figure 1: DSO user portals and connected systems. RTR = register of applicable rules

2.2 Environmental data in the DSO

This section provides an overview of the role of environmental data in the DSO. The initial need for environmental data in 2015 is described, and the situation before and after the abandonment of Information houses is compared. Environmental data will be published in the form of Information products, which are here described in more detail. Finally, potential issues of abandoning Information houses are hypothesized.

Information need in 2015

The user needs related to Information houses and environmental data have already been partly mapped in 8 reports, which are referred to as "Information houses (2015-2016)" (Bekker & Nikkels, 2015; Derksen et al., 2015; Kadaster 1, 2015; Kadaster 2, 2015; RIVM 1, 2015; RIVM 2, 2015; Rijkswaterstaat & Unie van Waterschappen, 2016; Rijkswaterstaat, 2016). These reports contain sections that outline a prioritization of environmental data needs, but they do not show how the data will be used and linked to spatial planning within the DSO by answering specific user questions. They were made by different organizations, which is why they all have a different structure in describing the data needs. For each of the reports, the most important data requirements are described in tables in Appendix A.

These tables function as an orientation on what ‘Environmental Data’ embodies in this study. It gives a preview of potential user needs. When available in the reports, the spatial planning applications of these data types are described in the tables.

Before and after Information houses

Information houses, as originally envisioned, were intended to be dedicated organizations, each responsible for collecting, validating, and standardizing data within their specific domain. There would be individual Information houses for the categories: sound, air, soil, water, waste, cultural heritage, nature, external safety, construction, and spatial planning. All their data would be made available in a spatial format and put on the DSO to be viewed on a map (RIVM, 2016). Besides viewing, this information would also be used to pre-fill the forms for the portal's Checks and Requests. The environmental data that Information houses produced would already be called Information products.

Now, only the concept of Information products is left in the DSO, leaving the production process to already existing governmental bodies. The producers of Information products are called Providers of Environmental data (Leveranciers van Omgevingsinformatie or LvOs). They will be governmental organizations like the National Institute for Public Health and the Environment (RIVM) and Kadaster (DSO OGAS, 2020). Another big difference is that the data at least has to be validated by the LvO’s, and does not need to be standardized as thoroughly as initially envisioned (GAS Informatie Producten, 2020).

Definition of an Information product

The current definition of an Information product is: *"Validated, processed, or combined data for a specific use within the framework of the Environment and Planning Act, meeting a recognized and agreed-upon quality level."* (GAS Informatie Producten, 2020, p. 22). The quality level states that the data needs to be available, usable, and sustainable. *"A good availability means that data, models, and calculation rules are easily findable. Good usability means that data is suitable to support processes within the framework of the Environmental Act. Good sustainability means that it is clear for what purpose this data can be used, that the data is reliable, and therefore legally usable."* (GAS Informatie Producten, 2020, p. 9). Finally, Information products may also include calculation tools to calculate data or PDF documents (GAS Informatie Producten, 2020).

Potential issues of the shift

Firstly, the shift in responsibility for producing Information products means that no organizations are specifically responsible for collecting, validating, and standardizing environmental data. So when the DSO was implemented on the 1^{st} of January 2024, most environmental data types (appendix A) were not available in the DSO. In a gradual process, the Information products that are deemed most essential will be put on the DSO. For now, four Information products are planned to be developed first. Namely, nature, sound, external safety, and public law restrictions. It is expected that the availability and accessibility of these types of data can be a bottleneck in the time span of spatial planning processes. Depending on the user, different types can be more or less important. When developing the DSO, it is important to know which data types could add the most value.

Besides the issue of data availability, some potential issues regarding data standardization can be identified. Firstly, less standardization of data formats may lead to visualization and data processing issues. LvOs are not obligated to publish in a spatial format, which can decrease the map viewing possibilities and findability of environmental data (Drahmann & Huijts, 2021). Differing data formats can lead to issues with data processing like data transformations or combinations. These issues could slow down spatial planning or increase the amount of mistakes made in the process.

Secondly, a requirement for LvOs to create broad Information products catering to diverse information needs (GAS Information Products, 2020) may lead to fewer options for automation. Currently, LvOs are encouraged to make broad Information products with multiple information sources for users to manually select from. This means that the initial plan to show in a few clicks what is allowed where will be harder to realize, and the user will still have to rely on their own or someone else's expertise to select the right regulations and environmental data.

It will be necessary to validate with the users whether the points above are actually issues or not. It could be that they do not value visualization, they might not see the benefit of more automation or possibly even prefer to select the necessary data themselves.

3. Theoretical framework

This chapter describes the concepts of spatial data infrastructures (SDIs) and spatial knowledge infrastructures (SKIs). This comparison helps to characterize the hybrid nature of the DSO as either an SDI or an SKI. Next to this characterization, the improvements coming from this study can be linked to either SDI or SKI functionalities.

3.1 SDIs and SKIs

The SDI

A Spatial Data Infrastructure (SDI) facilitates and coordinates spatial data sharing and exchange (Crompvoets et al., 2004). The SDI has been one of the most important developments to meet the quickly rising need for spatial data (Nedovic-Budic et al., 2011). Traditionally, an SDI is described with five components: *"policy, access network, technical standards, people (including partnerships), and data"* (Rajabifard & Williamson, 2001, pp. 4-5). In Figure 2, the interaction between these components is presented. Rajabifard & Williamson divided these components into two categories. The interaction between people and data is one category, and the technological components, access network, policy, and standards are a second category. These technological components are dynamic because of the rapid development of technology and the necessity to redefine rights, restrictions, and responsibilities between people and data use (Rajabifard & Williamson, 2001).

From the year 2000 onwards, the focus of SDIs shifted toward the user experience in the second and third-generation SDIs (Sjoukema, 2021). The developments in this period put emphasis on many specific SDI components for more user-oriented systems. Multiple studies state that a user-centric approach is necessary to increase the effectiveness of SDIs (Nedovic-Budic et al., 2008; Hennig & Belgui, 2011; de Kleijn et al., 2014). The newly introduced SDI services are often technological in nature. Some examples of user-oriented SDI services are discovery, visualization, downloading, coordinate transformation, processing, and uploading services (de Kleijn et al., 2014). Other important components are metadata editors, training options and help functions, integrating different types of data, and encouraging collaboration on platforms (Hennig & Belgui, 2011).

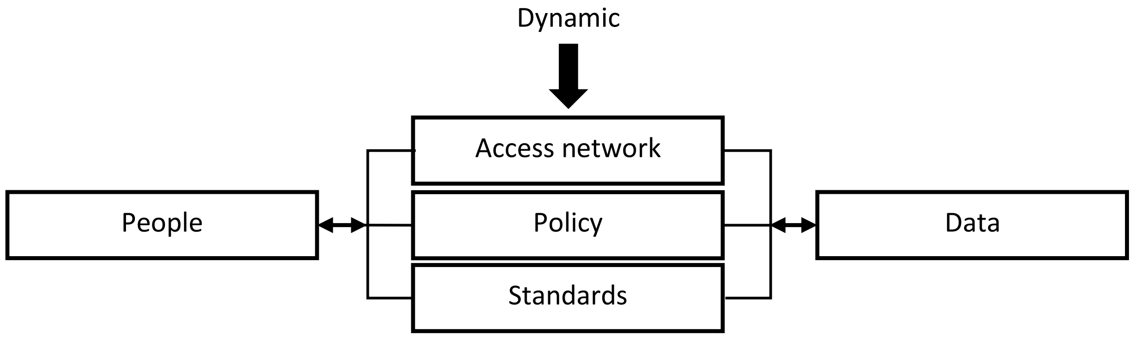

Figure 2: Model of Rajabifard showing the five spatial data infrastructure (SDI) components and their relation (Rajabifard & Williamson, 2001)

These developments align with open data principles summarized by the European Commission (2020) and used by Miletić et al., (2023) to assess the Croatian Open Data Portal. The European Commission (2020) categorized user-centric open data principles in the following 10 categories: Organize for use; Promote use; be discoverable; Publish metadata; Promote standards; Co-locate documentation; Link data; Be measurable; Co-locate tools and Be accessible.

Another set of indicators used to measure the usability of open data networks is presented by Donker & van Loenen (2017), stating that data should be *"1. known to the user (are the data identifiable and where can data be obtained?), 2. attainable by the user (can the user obtain the data, and under what conditions?), 3. Usable for the intended purpose of the user (can the user assess the quality of the data?)".*

Depending on the results of this study, either one or both of these principles and indicators might be suitable to interpret the results and propose recommendations or further research.

The promotion of open data by governments played an important role in the wide adoption of open data principles in SDIs (Sjoukema, 2021). Multiple studies in the Netherlands show that opening up spatial data results in improvements in data quality, more use, new user groups, more feedback, and very positive societal cost-benefit ratios (Sjoukema., 2021; Bregt et al., 2013; Bregt et al., 2016; Donker et al., 2017). It is important to recognize that larger municipalities in the Netherlands have significantly more resources to open up data and work on IT projects than smaller municipalities (Zuiderwijk et al., 2018), which should be considered when developing governmental IT infrastructure in the Netherlands.

The SKI

On top of the developments of user-centric SDI and open data, the spatial knowledge infrastructure (SKI) is developed in scientific literature. The SKI, which is a relatively new concept in the domain of geo-information science, was formulated by Duckham et al. (2017) as *"a network of data, analytics, expertise, and policies that assist people, whether individually or in collaboration, to integrate in real-time spatial knowledge into everyday decision-making and problem-solving"* (Duckham et al., 2017, p. 4). This definition still contains the traditional SDI components: data, policies and people, but added two components. First, "analytics" which aims to integrate data to aid decision-making and problem-solving questions to create the second new component "knowledge" (Duckham et al., 2017). In figure 3, these extra components are added to the traditional SDI components to graphically show an SKI, which again highlights the dynamic nature of the technological components.

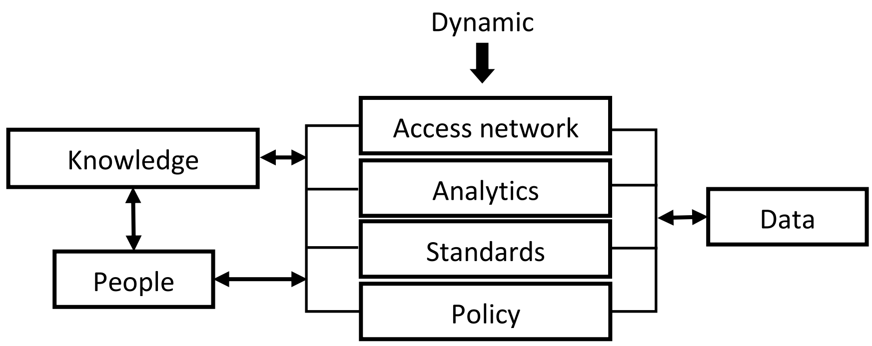

Figure 3: Simplified representation of a spatial knowledge infrastructure (SKI): based on Rajabifard & Williamson (2001) and Duckham et al. (2017).

In this definition of the SKI, the type of user has not been clearly defined. The new components aim to fill a knowledge gap with the system user, which implies a less advanced user. The SKI is expected to also provide spatial data analysis and knowledge creation for *"non-spatial experts"* (Duckham et al., 2017). This expectation can be compared to the conclusion from de Kleijn et al. (2014), stating that it takes less effort to make services for advanced GIS users compared to basic GIS users who need more user-friendly and tailored services. This also seems to be the case for SKIs, which are strongly user-oriented, requiring a complex interplay of many advanced technological aspects. Finally, it is important to note that the definition by Duckham et al. (2017) aims at decision-making aided by knowledge creation, which implies that not an automated program but a real person will still make the final decision. These developments aimed at easing decision-making should be treated carefully, considering the rapid development of technology and the necessity to redefine rights, restrictions, and responsibilities between people and data use (Rajabifard & Williamson, 2001).

SDI and SKI functionalities

The main difference between an SKI and an SDI from a functional (user) perspective is the ability of the SKI to answer user questions adapted to the user context. So, "*Instead of downloading, reformatting and manipulating data to answer a query, which is the SDI norm; the SKI includes an enveloping array of knowledge resources and processes that enable an end user to simply pose a complex question through an open interface to retrieve a response that matches their context.*" (Arnold et al., 2021, p.7).

The functionality of an SDI can be compared to Google, where the end-user needs are not predefined, and a query results in a list of answers (Arnold et al., 2021). Google does not know the exact user context and needs before a search is performed, so the result is a list of the most relevant answers from which the user can choose. This could be called a user-independent approach. The SDI functionalities correspond with the services: discovery, visualization, downloading, coordinate transformation, processing, and uploading services (de Kleijn et al., 2014).

The functionality of an SKI can be compared to monitoring services that use real-time sensors, such as weather alerts and water quality monitoring (Arnold et al., 2021). These systems, such as weather forecasts, provide an answer without users having to download and process raw data. The system knows or assumes the user context (e.g., the need for a weather forecast and a specific location) and tailors the information accordingly. This could be called a user-dependent approach. It aims to automatically fulfill all or some of the services of discovery, visualization, coordinate transformation and processing described by de Kleijn et al., (2014). Downloading and uploading are excluded because it is expected that most SKI services will be performed on a server and not on a local computer. The main SKI functionality can thus be simply called 'automation' of a combination or one of these services.

SDI and SKI technologies

Here, two technical characteristics that set the SKI apart from the SDI are described: one concerning the data itself and one concerning how it is accessed. First, the *"semantic enrichment"* of data is one of the key challenges of developing an SKI (Ivánová et al., 2020). The concept of semantically enriched data originates from the Semantic Web coined by Berners-Lee et al. (2001), which can be described as a web of data in which machines are able to use the data's meaning within its context. This can be done by embedding the meaning of the data into the data itself in a machine-readable format (Ivánová et al., 2020). Guidelines for these data requirements are formulated in the FAIR principles, which stand for: findability, accessibility, interoperability, and reuse. They aim to enhance the ability of machines to automatically find and use the data (Wilkinson, 2016). To make the data machine-readable, the Resource Description Framework (RDF) is used, which is a way to structure data so that questions in natural language can be answered with it. For this study, the exact RDF structure is not relevant; it is explained in detail by Ivánová et al. (2020). However, it should be clear that data in RDF format is an important requirement for SKI functionalities (Ivánová et al., 2020). This requirement can serve as a feasibility check of potential SKI functionalities for the DSO.

The accessibility of data in an SKI also differs from an SDI. In an ideal situation, all data used in an SKI is made available to the web instead of storing it in closed catalogs which are only accessible via dedicated web portals and user input (Arnold et al., 2021). Currently, quite some SDIs still function with these closed catalogs (van den Brink, 2019; Arnold et al., 2021). Considering the wide range of different SDIs, it is unsurprising that even geospatial experts often do not know where to start when searching for spatial data (van den Brink, 2019). Making data available to the web, advocated by Arnold et al. (2021), can also be called making it *"crawlable"* (van den Brink, 2019).

When looking at the technical characteristics of an SKI the difference to the SDI is less clear than for the functionalities, and they overlap with technologies already implemented in current SDIs. The following section will compare the DSO to SDIs and SKIs to put it on the spectrum between these different types of systems. This can help to find potential improvements in literature when either SDI or SKI functionalities are required by the users of environmental data.

3.2 Comparing the DSO to SDIs and SKIs

At this stage, any attempt to develop an SKI will likely become an SDI/SKI hybrid (Arnold et al., 2021). This section will show how this hybrid nature is present in the DSO by highlighting its resemblances to SDIs and SKIs. The distinction between a user perspective and a technical perspective is used to describe these resemblances.

The DSO from a user perspective

From a functional (user) perspective, the DSO still strongly resembles an SDI. It works in a user-independent approach by providing a set of relevant search results as an answer to a search request on 'Rules on the map'. This way of working is reflected by the ambition to create broad Information products (GAS Information products, 2020). *"In practice, this means a response with relatively much data from which the recipient can make a selection for each question"* (GAS Information products, 2020, p. 27). This does not fulfill the initial ambition of 'one click on the map' to provide the user with answers to questions like: what is allowed here? Do I need a permit for construction? It shows how this part of the DSO does not contain the SKI components *"analytics"* and *"knowledge".*

The combination of data by pre-filling permit application forms in the DSO could be argued to contain the new SKI components *"analytics"* and *"knowledge".* By pre-filling permit applications, the DSO aims to accelerate the process of spatial planning (DSO OGAS, 2020) and shows a clear distinction from SDIs, which mainly aim to provide data and not to use it in processes specific to the end user's context. In the pre-filling process, the end user's context is defined depending on the DSO portal and the location of the permit application. It shows a more user-dependent approach and could be called a form of knowledge creation. However, it is still far removed from the combination of data to create truly novel insights like a direct yes/no answer to a permit request. Besides that, it is still unclear to what degree this automatic form-filling will be made possible for all Information products that will be added in the upcoming development period of the DSO.

The DSO from a technical perspective

On a technical level, the DSO has aspects resembling both SDIs and SKIs. One major aspect resembling an SDI is the fact that Information products are not required to be only machine readable. For example, PDF formats are still allowed (GAS Information products, 2020). On the other hand, the required metadata of Information products is quite extensive, including versioning, a data description, data quality judgement, target group description, supported data exchange formats, supported data visualization standards, spatial reference, and a link to source data (GAS Information products, 2020). Finally, the metadata needs to be saved in RDF format, which is quite important as explained in the previous section. All these requirements open up future possibilities to create SKI functionalities that need proper quality assessment, user context dependency (Arnold et al., 2021,) and data linking with RDF data formats (Ivánová et al., 2020).

Another important technical aspect of the DSO that resembles an SKI is the ambition to make all Information products available on the web (GAS Information products, 2020). Considering that many SDIs currently do the same, it could be contested that this makes the DSO more like an SKI. However, it is an important requirement for SKI functionalities. By opening up like this, the goal is to push the market into creating tools that use this data (GAS Information products, 2020).

4. Methodology

This chapter compares different research methods and substantiates the choice of interviews as the main method. Next to that, it describes the targeted user group and interview structure. Finally, the data analysis is explained.

4.1 User Experience Research Methods

Other studies have already created methodologies for the development of SDIs from a user perspective. They can be used as inspiration for this study. The paper from Hennig & Belgui (2011) describes a method for user-centric SDI development including five steps: (1) selection of a method to support user-centric SDI development; (2) identification of users; (3) identification of user types; (4) Identification of user needs; (5) open recommendations to aid user-centric SDI development. The paper from de Kleijn et al. (2014) starts by identifying the technical skill level and objectives of users, which is then followed by connecting the user objectives to necessary technical SDI components. In this study, the user base was already narrowed down to governmental users from the start. However, from here onwards, roughly the same steps as Hennig & Belgui (2011) were followed: (1) methodology selection; (2) further characterization of user types, (3) identifying user needs, challenges, and recommendations; (5) linking the results to SDI or SKI functionalities and the potential need for Information houses. So, first, a suitable research method for determining user needs, challenges, and recommendations should be selected.

User needs or requirements are studied in the field of user experience research, which is fundamentally about understanding people, the domain, and technology (Baxter et al., 2015). User needs refer to the features a product should have or how it should perform from the users' perspective (Baxter et al., 2015). User experience research, which often aims to determine user needs, is applied in a broad range of disciplines, some examples are human-computer interaction, product design and development, and psychology (Allam et al., 2013), or more concretely the development of mobile devices, software, and websites (Baxter et al., 2015).

When researching user experience, objective measures can be task execution time and the number of clicks or errors, but these alone are not enough to research user experience as a whole which includes how the user feels about the system (Allam et al., 2013). This is why user experience research should often include qualitative data collection (Baxter et al., 2015) and the subjective ideas of users (Allam et al., 2013). Common research aims are collecting general data, gathering opinions and perceptions, identifying user problems, determining user needs, prioritizing needs, generating ideas, etc. (Geyer et al., 2018). For these aims, a variety of methods exist, including diary studies, interviews, surveys, card sorting, focus groups, and field studies (Baxter et al., 2015).

4.2 Methodology selection

Interviews were chosen as the main methodology for this study. When choosing a method, it is necessary to reconsider the research aim, which is to find out how environmental data is used by the government in the process of spatial planning and to formulate specific changes or additions to the DSO that could improve this use, with a specific focus on the potential role of automation.

To obtain these potential improvements and perceptions, interviews or surveys seem to fit well. Observing people working with the DSO would cost too much time, which cancels out diary studies and field studies. Constructing a comprehensive picture of user experience requires individual insights and opinions (Allam et al., 2013), which shows that focus groups are less suitable, because these attribute less attention to individual users, and opinions could be influenced by group discussions. An interview is suitable for obtaining detailed information and perceptions from individual users (Baxter et al., 2015), which is also indicated by Geyer et al. (2018), showing that interviews were most often used for defining user needs and challenges. Finally, surveys could be a good addition, but would be more suitable when people have built up more experience with the DSO. So, for this study a semi-structured interview style is chosen. A semi-structured interview uses a list of questions but allows for spontaneous follow-up questions. Other interview styles, like structured interviews, follow a predetermined list of questions, while unstructured ones do not. A semi-structured interview style is chosen because this increases flexibility and also allows for comparison afterwards because all relevant questions were covered equally for each participant (Lichtman, 2014). In this study, interviews were held in person or online. Both were recorded with Microsoft Teams for sound recording and automatic transcription.

4.3 Interview target group

This study distinguishes three participant types to create a broad picture of the use of environmental data in spatial planning. From here on, the term' participant' is used instead of ‘user’ because not all participants were DSO or environmental data users. Also, DSO experts were interviewed for a more technical view on potential improvements.

Participant types:

- DSO experts
- Spatial planners
- Permit issuers

DSO experts

For this study, a DSO expert is defined as someone who works on the DSO development, or its IT processes. Their perspectives are valuable to get a more technical view of potential improvements of the DSO. Users of the DSO can tell us a lot about the functional requirements, as described in Chapter 4. DSO experts can potentially help to get an overview of technicalities and background processes that are required for future DSO developments.

Spatial planners

Spatial planners are defined as those involved in making environmental visions (omgevingsvisies) and zoning plans (omgevingsplannen). It is important to note that these visions and plans are not made inside the DSO, but only have to be uploaded. The environmental vision outlines a long-term vision of the functions of different areas and how the municipality intends to develop and protect its living environment (Geonovum, 2023). The zoning plan includes the regulations for the physical living environment that aim to work towards the environmental vision. Spatial planners are included because it is assumed they use environmental data. So they can help to highlight important environmental data types that are maybe less prominent in permit application processes.

Permit issuers

Permit issuers judge whether a permit application can be granted. They are often involved in judging reports (meldingen), which comprise many cases in the DSO. This study focuses on permit applications since these are often the more complex cases involving multiple environmental data themes. Besides the responsible municipality or province, local environmental agencies are often involved during permit applications. In this participant group, people who are strongly involved in the permit application process but are not literally a permit issuer were also included. Examples are permit application quality assessment or support for applicants.

Sample selection

The participants were contacted through email and LinkedIn. A snowball method (Lichtman, 2014) was applied before and after the interviews by letting each new contact link me to other colleagues or departments for further interviews.

4.4 Operationalization and Interview Structure

The interview questions are made based on the research questions and potential issues of the shift from Information houses to Information products (see section 2.2). The first potential issue is the low availability of environmental data and the potential difficulties in finding or accessing the required data, leading to delays in spatial planning. The other issues can be a result of a lower standardization degree. These are issues like challenging data access, less data visualization, and problems with data processing and automation. Through the experiences and expertise of the participants, the prominence of these potential issues will be checked. The questions are carefully formulated in an open manner to avoid bias by steering the conversation.

The user needs, and perception of SKI functionalities can be derived from the user needs to be related to the functional aspects of the DSO described in section 4.2. Shortly put, the perceived need for a real person between the data and a decision is assessed. The questions will focus on the participant's perception of automated form filling in the portals 'Checks' and 'Requests' and automation in general. It tells us something about the suitability of *"broad Information products providing a list of potential sources"* (section 4.2).

Interview structure

One interview structure is used for the environmental data users, who are spatial planners and permit issuers. Another set of questions was made for the DSO experts because they do not use the DSO and environmental data like the other participants. All the interview questions can be found in Appendix B. The interview structure for environmental data users has five steps. Each of these steps is here briefly described.

Interview steps:

1. Introduction (research background, interview goal, user type)
2. User needs (data availability and importance)
3. User challenges (experiences and potential issues)
4. Recommendations (open recommendations)
5. Close off (link to colleagues or departments for interviews)

In the first step, the background of the research is explained, and the term environmental data is defined. Next, the goal of the interview is introduced. Finally, the background of the participants in spatial planning and their experience in using the DSO is defined, which is used to specify the user type.

The second step aims to identify necessary types of environmental data and their importance. This gives a baseline to work from and can already tell us something about the first issue regarding data availability and the potential delays in spatial planning.

The third step aims to identify the challenges of using environmental data in spatial planning by asking more specifically about the potential issues (see section 2.2). It starts with open questions asking about issues of using environmental data in general to avoid bias. After these questions, more targeted questions are asked regarding the potential issues of data availability and standardization related issues like: data access and visualization, data processing and automation.

The fourth step is open to avoid bias by steering the conversation. It asks for recommendations, and follow-up questions are asked to specify the recommendations.

In step five the interview is closed off, and connections are made to other colleges who could be relevant to this research.

4.5 Results analysis

Transcribing

After each interview, the transcript was made by correcting the automatic transcript of Microsoft Teams with the recording. The transcripts were made in a word-by-word manner. It is important to note that the transcribing process can be seen as the start of the analysis phase since you already start by familiarizing yourself with the content and deriving meaning from it (Braun & Clarke, 2006). This increases the circularity of analysis in contrast to linearity, which ensures that the data is interpreted multiple times over a longer period and not only once after data collection. Circular data analysis is generally considered a better analysis practice because it improves the researcher's ability to identify concepts and to link them between different observations (Braun & Clarke, 2006; Lichtman, 2014).

Coding

Throughout the interview, the covered topics do not necessarily follow the exact line of questioning of the three research questions. The aim of coding in this study is to extract parts of the interview that are relevant to specific themes, which can then later be related to one or multiple of the research questions. The general structure of a coding process goes from codes to sub-themes to main themes (Braun & Clarke, 2006) or from codes, to categories to concepts (Lichtman, 2014).

When coding, you can code with an inductive or deductive approach. Inductive coding infers the themes from the data itself and deductive coding creates themes from a theoretical base or with specific research questions in mind (Braun & Clarke, 2006). Generally, coding starts with a high number of initial codes that are *"sorted"* by your own judgement in the case of inductive coding and *"sieved"* by predefined categories in the case of deductive coding (Lichtman, 2014). For this study, a mix of deductive and inductive coding was applied. The first coding step was deductive, the second step inductive, and the third step deductive again. This approach is further explained in the coding framework below.

The iterative coding steps as described by Lichtman (2014) show a clear overlap with the thematic analysis phases described by Braun & Clarke (2006), as they both have a strong emphasis on revising the created codes and themes increasing the circularity of your analysis, which will also be applied in this study.

Coding framework

Here the initial codes and coding steps for this research are explained. In Table 1, the coding framework is presented. The coding process flows from left to right. This is a form of hierarchical coding which is suitable when aiming to answer specific questions or test specific hypotheses. Since this research started with specific research questions and a theoretical background, a deductive approach was applied in the first coding round to select those pieces of text specifically relevant to the questions.

In code hierarchy 1, the first theme of the piece of text is given deductively. These themes were constructed by combining the research questions, the potential issues discussed in Section 2.2, and the literature discussed in Chapter 3. In code hierarchy 2, a more detailed description is given deductively or inductively. The deductive part of this code was prepared beforehand based on very general descriptions and the potential issues discussed in section 2.2. During the coding process it appeared to be insufficiently categorized, so the codes of code 2 are mainly coded inductively. In code hierarchy 3, the codes in hierarchy 2 were deductively fitted to either 'Needs' (related to requirements of performing the work), 'Challenges' (when no direct solution was proposed), or 'Recommendations' (when a direct solution was proposed to a challenge). This distinction is sometimes difficult to make, but it helps to answer the research questions.

Table 1: Coding framework. I.C. = Inductive code, E.D. = environmental data

Code 1: Themes	**Code 2: Description**	**Code 3: Link to research question**
User Type	Permit issuer	N.A.
	Spatial planner	
	DSO developer	
DSO portal use	Rules on the map	
	Checks	
	Requests	
	Collaboration facility	
Environmental data importance	Important	Need/Challenge/ Recommendation
	Not yet important	
	Not important	
	I.C.	
Information house target group	Citizens	Need/Challenge/ Recommendation
	Companies	
	Government	
	All	
	I.C.	
Environmental data types	One of: Soil, construction, air, spatial planning, nature, water, sound, external safety, I.C.	Need/Challenge/ Recommendation
DSO user friendliness	I.C. (think of required tools or very specific functionalities like making maps transparent)	Need/Challenge/ Recommendation
Availability and access of data	Potential issue: slowing of processes	Need/Challenge/ Recommendation
	I.C.	
Visualization	Potential issue: visualization of E.D. important	Need/Challenge/ Recommendation
	Potential issue: visualization of E.D. not important	
	I.C.	
Combining data	Potential issue: combining E.D. important	Need/Challenge/ Recommendation
	Potential issue: combining E.D. not important	
	I.C	
Automation	Potential issue: Positive view	Need/Challenge/ Recommendation
	Potential issue: Nuanced view	
	Potential issue: Negative view	
	I.C.	
Standardization	I.C.	Need/Challenge/ Recommendation
Open data principles	One of: Organize for use, promote use, be discoverable, publish metadata, promote standards, co-locate documentation, link data, be measurable, co-locate tools, be accessible, I.C.	Need/Challenge/ Recommendation

5. Results

This chapter presents the results of the coded interviews. For each sub-research question, the resulting code 1 themes and code 2 descriptions are presented. This approach aims to ensure a good alignment of the results with the use of environmental data and to facilitate easier comparison and linking of findings across different themes.

Interviews overview

In total 15 interviews were held with 17 people. In Table 1, all interviews are listed along with the participant type. Three DSO experts were interviewed. For both the spatial planners and the permit issuers, one interview was held with two participants, adding up to 6 spatial planners and 8 permit issuers being interviewed.

Table 2: List of interviews and participant types. (Not in chronological order)

Participant(s) employer	Participant type
Kadaster	DSO expert
Municipality	DSO expert
Water Board	DSO expert
Municipality	Spatial planner
Municipality	Spatial planner
Municipality	Spatial planner
Environmental agency	Spatial planner
Environmental agency	Spatial planner
Environmental agency	Permit issuer
Municipality	Permit issuer
Municipality	Permit issuer
Environmental agency	Permit issuer
Environmental agency	Permit issuer
Environmental agency	Permit issuer
Province	Permit issuer

5.1 Needs

This section describes the themes (code 1) and corresponding code 2 descriptions that belong to the category of needs, which are shown in Table 3. For each theme, the needs regarding the use of environmental data are explained based on these descriptions.

Table 3: Themes and code 2 descriptions for needs

Code 1: Theme	Code 2: Description	Frequency
Environmental data importance	Important	18
	Not important	9
	Permits only checked against zoning plan	8
	Less important for spatial planning	2
	Especially needed for complex projects	3
	Speed of permit dependent on initiator	3
Information house target group	Companies	16
	Citizens	15
	Government	9
	All (companies, citizens and government)	6
	Government knows where the data is	8
	Municipalities need less external advise	3
	DSO use: mostly government and companies	7
	Knowledge for citizens: flood risk, sound etc.	2
Environmental data types	Importance dependent on area	2
	Important: Air	4
	Important: External safety	9
	Important: Nature	7
	Important: Noise	18
	Important: Physical parameters	3
	Important: Smell	2
	Important: Soil	20
	Important: Spatial planning	6
Availability and access of data	Data from initiator	3
	Data from internal / online systems	20
	Data from area specific research	19
Visualization	Important	10
	Not important	3
Combining data	Combining needed	16
	Combining not needed	8
	Adding / combining different types	4
Automation	Positive	26
	Nuanced	17
	Negative	13

Environmental data importance

Environmental data is important for spatial planning and permit issuance. However, it's not seen as the main obstacle in the planning process. The issues related to handling environmental data were more often regarded as a side issue compared to dealing with policy and rules. Basic location data like building heights and aerial imagery are used daily, and more detailed data is needed depending on the area or permit type.

With spatial planners, asking about the importance of environmental data did not result in one coherent answer, reflecting the complexity and broad range of tasks involved in making zoning plans. All environmental data types need to be considered, but for a large part the zoning plan is a legal plan. When relevant, the current state of the physical living environment can be considered in making zoning plans and environmental visions, but it is not essential for all aspects.

"The zoning plan is a legal plan checked against environmental legislation, so the exact current environmental data may not be so important, I think. It's about whether they're relevant to the choices you have to make in the plan." (municipal spatial planner).

It is expected that this will change now that a bigger emphasis is put on data about the physical living environment.

"The physical living environment will come in the future [aimed to be included more in spatial planning]. Currently, data about water quality or bird breeding is not yet included in zoning plans" (municipal spatial planner).

For permit issuers, depending on the type of permit, environmental data can be relevant or not. The majority of permit applications involve minor changes to the physical environment, requiring only checking against applicable rules or very specific environmental data. On the other hand, more complex permit applications, often real estate projects, do require environmental data.

"For dormer windows and extensions to sheds, you naturally don't need data on soil and sound, and those are the most common permit applications. And for the other part of real estate or other large constructions including zoning plan activity (bestemming) changes to "living", then you do need that data again. But that's perhaps only 30% of applications." (municipal permit issuer).

The initiator of an activity (a company or citizen) is responsible for showing that they will not surpass environmental norms. This is also the first way in which permit issuers obtain data: through the provision of the initiator. For other aspects, the permit issuer will retrieve environmental data from GIS portals or ask advice from another governmental body with more expertise on that specific theme. Overall, environmental data provided by the government was deemed essential but not the most important factor for a timely permit application judgement, which still depends mostly on the data provided by the initiator.

"I think that generally, the processing time of a procedure depends more on the data that an initiator provides and the completeness thereof than on the availability of the data of various environmental aspects." (environmental agency permit issuer).

Information house target group

Most participants regarded Information houses as relevant to all target groups. However, they often first mentioned citizens or companies as primary target group, after which they mentioned government. The overall perception was that spatial planners have least to gain from the concept of Information houses since they often do not need to use environmental data of the current state of the living environment, and when they do, they know where to find it.

"It's just available. Yeah, people who know their stuff can find it, let's put it that way." (environmental agency spatial planner).

Besides that, spatial planners do not benefit from companies and citizens having more direct access to environmental data, which is the case for permit issuers. Even though citizens are a major target group, it was expected that the average citizen will not benefit that much, since they are not often involved in spatial planning. The average permit issuer likely spends more time in the DSO portals than the average citizen. Adding up the small time gains from many citizens (or companies) having more direct access to governmental data could accelerate the first stage of the permit application process of determining what is known and what needs further research.

"You're just missing a lot of information, and that means that the permit issuers have to contact the applicant for what is missing. Yeah, there's so much time and delay involved in that, and we all want to be able to make a decision as quickly as possible, so every party benefits from just submitting that form completely and correctly the first time. And then the process can just get started." (provincial permit issuer).

"And then we can ask for advice early. Then we know if additional research or advice is needed. When we only have that data later, we would have to ask for advice, and then wait two weeks until you, to put it bluntly, wait two weeks until you have your advice. And then you hear, yeah, there's something going on there and you need additional research. I want to see this clearly from the start." (environmental agency permit issuer).

Within government, information houses are perceived as especially relevant to municipalities that are most directly in contact with citizens, and they regularly need to ask for advice from environmental agencies, to whom the required data is often quickly available.

"If you could have that [all data directly available for environmental agencies] accessible in rules on the map, that would save people time, for instance, those not working at an environmental agency, like the municipalities, who have to seek advice for everything." (environmental agency permit issuer).

Environmental data types

All types of environmental data required by spatial planners and permit issuers can be placed in one of the categories of Information houses (Appendix A: soil, construction, air, spatial planning, nature, water, sound, external safety). Often, it can be stated that all aspects are equally important. All of them need to be given attention by either spatial planners or permit issuers, but between the participant types, the types do differ in importance. Besides that, their importance is strongly linked to the area, for example, how urban or rural it is. In a more urban area, sound issues are more relevant, whereas nitrogen deposition can be more relevant in rural areas.

"I think we have relatively little trouble with nitrogen standards in the city center because we're far enough from nature reserves. We haven't experienced anything significant contributing to nitrogen deposition in the natural areas yet, and that's where it becomes an issue for a small municipality close to nature reserves. For sound the inverse is true" (municipal spatial planner).

For spatial planners, the importance of the different types is less clear. Most of them stated to use all types equally, but most often, sound, air, and physical parameters like building and ground level heights were mentioned as being important.

The most evident distinction between the two user groups can be found in the importance attributed to soil data. The permit issuers all stated soil data to be significant to their work. Especially information about soil pollution is frequently used. None of the spatial planners specifically mentioned soil to be of more significance than other types. Besides that, nature was also more often regarded as important by permit issuers.

Two themes that were generally regarded important by both groups were sound and external safety. Sound has the most direct impact on the livability of a location compared to other factors that are also important but less directly influencing people's senses.

"I also think it's actually the most important factor for the quality of life of a particular place, of a particular building. Whether the air quality is poor, you don't notice it immediately as a resident, while noise has a direct effect on people. So noise is really the most important factor." (municipal spatial planner).

Availability and access of data

As stated for the code 'Information house target group', the spatial planners struggled the least with environmental data availability. Permit issuers more often stated problems with availability and access to environmental data, which was mentioned multiple times as a problem mostly experienced by municipal permit issuers.

Four general ways of obtaining environmental data are identified. First, internal GIS systems are used to access general information like building heights, sound loads, sewer system locations, and more. Secondly, web portals like 'Atlas van de Leefomgeving' and area-specific ones like 'Atlas van Overijssel' are often used to obtain general information that is available on larger scales. Thirdly, when an activity becomes more complex, detailed research is required. Examples include smell or sound loads calculated by environmental agencies, soil reports, animal species occurrence reports, and AERIUS calculations (nitrogen deposition) provided by bureaus hired by the initiator. Depending on the area, information from previous reports can be reused, given that the data is still current.

"It definitely happens that there's already information available for certain locations. Research may have been conducted a few years ago, but then the question arises: is that research still current enough?" (environmental agency permit issuer).

For soil, reports can be more often re-used on business terrains compared to residential areas because businesses often require this kind of reports.

"Certainly at companies, soil surveys are often known. For residential properties, it's often not known. With companies, there are often potentially soil-threatening activities, which necessitate a soil survey." (environmental agency permit issuer).

These types of reports are mainly used in the process of permit application, but spatial planners also use them to justify deviations from the zoning plan. All these kind of reports need to be interpreted by someone qualified to determine the reliability and relevance for that specific development, so the data from the reports cannot be directly used without an expert. This is especially relevant when the reliability of a report is questioned, which is something that happens occasionally.

"You can imagine that with calculations, you can work towards a certain result so that the desired outcome comes out by adjusting the knobs in the background. And we try to understand that. So I'm not saying it always happens, but it does occur occasionally." (environmental agency permit issuer).

A fourth way of gaining information about the environment is to look at the granted permits at that location. This is not a direct measurement of environmental data but is an important indicator used by spatial planners and permit issuers to determine whether environmental boundaries are reached.

Visualization

For visualization, the distinction between complex and simple activities was perceived as a determining factor for its relevance, where the complex ones have more to gain from visualization.

"Quite often, because many data aspects are important in determining whether something can or cannot be done, and yes, only with small requests that are less impactful, visualization plays a smaller role." (environmental agency permit issuer).

For both spatial planners and permit issuers, visualizing data is especially important when comparing the current situation with a potential new one to see whether a new activity fits in the physical environment. For this, especially the Basic Registration of Addresses and Buildings (BAG), and building heights were deemed useful.

Combining environmental data

The relevance of combining different types of environmental data is clear for spatial planners. When a change in zoning plan or environmental vision needs to be justified, all environmental aspects are relevant and must be considered.

"Then it's also a sum in the justification that needs to be written about why a development is good, why it complies with the legislation. You have to combine all that information into a complete narrative and final decision." (municipal spatial planner)

"For me, they're all essential, as they determine, for example, whether a house can be built somewhere." (environmental agency spatial planner).

A common situation in which this is necessary, is adding up values to come to the cumulative environmental burden of certain aspects. For example, combining air quality and sound load to calculate the health burden of an area.

"Air quality determines 80% of the health burden. So, if you add sound to air, then sound would also have some effect, but air quality is the determining factor." (environmental agency spatial planner).

The relevance of combining environmental data is less clear for permit issuers. As stated before, the majority of permits require minimal use of environmental data, but when it concerns a more complex matter like real estate projects, combining is always necessary.

"It's either not relevant at all, for example with a dormer window, but when you're talking about new housing development, you often have multiple aspects to consider. It's not often that you only need sound, it's often also about the soil. When it's necessary, it's with the slightly bigger projects, and then it's always a combination." (municipal permit issuer).

Automation

Overall, the perception of automation can be described as positive but careful. Most participants recognized at least some potential benefits, but at the same time also stressed the need to carefully think about what to automate and what not. In this consideration, data reliability was most often mentioned as the determining factor. On one end of the spectrum, a participant stated the need for human contact and just plain common sense as reasons for not automating:

"They also need that personal contact instead of everything through data and their computer. They come because they want to speak to someone. Sometimes common sense is needed too, sometimes there's more than just data." (municipal permit issuer).

On the other end, a participant stated they would be happy if their job was replaced by automation in 10 years:

"But in 10 years, when the zoning plan is in place and indeed the puzzle pieces fit in well and are delivered properly, then I won't be needed anymore. And, actually, I hope that's the case, because it would be nice. Of course, you might still need help from time to time, but the actual hand drawing work, GIS work, won't be necessary anymore if you standardize it well." (municipal spatial planner).

Most other participants were happy to welcome a bit more automation under the often stated condition that the used data is reliable. A few participants stated the condition that a final human check will always be necessary.

5.2 Challenges

This section describes the themes (code 1) and corresponding code 2 descriptions that belong to the category of challenges. They are shown in Table 4. For each of the themes, the challenges regarding the use of environmental data are explained based on these descriptions. As can be seen in Table 4, fewer themes were categorized under 'Challenges.' This is mainly because code 2 was classified as a challenge when no direct solution was proposed, which rules out DSO user-friendliness issues, which are all concrete recommendations.

Table 4: Themes and code 2 descriptions for challenges, E.D. = environmental data

Code 1: Theme	Code 2: Description	Frequency
Availability and access of data	Data fragmentation	16
	Not enough information pre-request	15
	Municipalities need more E.D.	10
Visualization	Too much information on Rules on the map	3
	No more color coding of functions	5
Combining data	Before combining comes policy and rules	6
Automation	Data reliability	10
	Misuse or unwanted activities	6
	Dilemma between broad and specific data	3
Standardization	Data reliability and versioning	14
	Harmonize terms	11
	Data as PDF	6
	Complex API profile	2

Availability and access of data

As explained before, spatial planners often already know where to find the required environmental data. Most of the challenges spatial planners pointed out were thus related to data access and standardization. For example, they experience challenges with fragmented data and not being able to directly add data to each other when calculating environmental burdens.

"So we are encountering now that the information is very fragmented. Also, it's not standardized, so the type of information you receive varies depending on the internal or external partner. And reliability is also a concern." (municipal spatial planner).

Data availability was more often considered a challenge for permit issuance. This challenge can be observed at multiple stages. First, the initiator of a project is required to deliver information. Incompleteness of permit applications was the most often mentioned challenge by permit issuers. The challenge at this stage lies in making environmental data that is already available to the government available to the initiator.

"All those datasets already exist somewhere, and those parties just need to start providing them in a different way. And in places where those datasets don't exist, there's likely a need for them." (DSO expert).

A good example of data that is often already available to the government is data from previous reports or data that is relatively static over time. For example, soil reports or the locations of trees, gas tanks, sewage pipelines, and sound loads can indicate the need for extra insulation measures. Having data like this available from the start can save municipal permit issuers time they usually spend on figuring out whether they need to ask for advice or request additional research on the area.

"Then you actually come to the point where rules on the map could also be used like how we use our GeoWeb

[a commercial application] to be alerted in advance that you know something is going to happen here. Then you also know how to deploy advice when you're going to ask for advice, or you immediately request data from the initiator to further substantiate it, and that saves permit issuers a lot of time, I think." (environmental agency permit issuer)

"And if we had more information about what's going on there, including noise, which is really quite important, then we could assess it ourselves a bit earlier without that link being made to the environmental service. That would save time." (municipal permit issuer)

For this to work, the data needs to be up to date and detailed which is another challenge discussed at 'standardization'. In the second stage, information that needs to come from the government is gathered. At this stage, the challenges related to asking for advice or reports can both take up a lot of time. When asking for advice, mostly the same problems of data fragmentation and standardization as described above are applied. When additional information from reports is required, there is not a lot a permit issuer can do to speed up the process. Most of the reports that were mentioned were related to soil pollution or animal species occurrence. It can take several weeks to 1.5 years respectively to do the required research.

"Maybe still a soil investigation is necessary. So often there is not a complete application at the time of submission. That means you have to ask for additional information. You message them, you give them a deadline. That could be, for example, 4 weeks." (permit issuer environmental agency).

"Starting 1-1.5 year in advance is necessary because you also have to deal with bats. But the nature and landscape team mainly does very large projects, for which a lot of time is needed either way." (provincial permit issuer).

Visualization

A challenge that spatial planners mentioned was the amount of information currently layered on top of each other in Rules on the map. The information a user currently sees is not filtered because many rules do not yet have annotations attached to them. Annotations are links attached to rules or data. They state its relevance for specific activities. The underlying issues leading back to policy making is further explained in 'Combining data'. Adding to this challenge of unfiltered data is the often-mentioned challenge that spatial functions, previously called 'destinations' (destemming), are not color-coded anymore because standardization of these colors is not mandatory under the new environmental act. Multiple spatial planners and permit issuers stated they would like this decision to be reversed.

"And the color coding, you don't have that anymore, it's no longer mandatory. I always found that very helpful, I'm just visually oriented. Because if you glance at a plan map and you see yellow, well, that's mainly residential." (environmental agency spatial planner).

Combining data

Only one code from hierarchy 2 falls into the category of challenges; the rest can be found at '6.3 Recommendations'. The complexity of combining rules with environmental data. They also mentioned that it would have been helpful to have examples of zoning plans and a few more guidelines for making them.

"So, the challenge for us is that colleagues from the environmental department don't know how to transform the information into rules. And we, on the other hand, don't have as much knowledge of that data as the colleagues from the environmental department do. So, I think that's the biggest challenge." (municipality spatial planner).

In this process, applicable rules need to be connected to environmental data values. This can be a very time-consuming process of translating domain knowledge to combine specific data values to rules that a municipality wants to include in the zoning plan. According to spatial planners, digitization and automation would not be a benefit to this process; rather, it requires knowledge transfer between experts.

“We have spent hours and hours together in a room so that the people from soil could explain to us what was there, and so that we could explain to them what the rules were. I don't think you can simply make that digital.” (municipal spatial planner).

Automation

The most often mentioned challenge standing in the way of automation was ensuring data reliability. Both spatial planners and permit issuers stated data reliability as a main challenge. When asked about certain types of data that can be more easily trusted, participants generally had a hard time thinking of something they would easily trust to be filled in automatically. The challenge of data reliability is not only relevant for automatic processes. Also when a person interprets data, mistakes can be made with its currency or validity.

“The Basic Registration is a good example. Nobody doubts that, but there are also errors in it. That's just the way it is. You can also make changes to it, and sometimes things don't match up, so it's always a bit uncertain. However, reliability is one of the most important things, and there's still some steps to take before people really have full confidence in a new system.” (municipal spatial planner).

It is important to determine which datasets can be trusted and which not. A telling example was given by a permit issuer wanting to re-use data from a soil report. Before they could re-use it, an expert was required to judge its relevancy and currency. This shows that often it is not as simple as just updating a database regularly, sometimes expert judgement is required.

“That research was conducted a few years ago, but then the question arises: is that research still current enough? That's something a soil advisor would assess.” (environmental agency permit issuer).

Another challenge often mentioned was the intentional misuse of automation or unwanted effects as a result of too many activities being approved. It was expected that automated decision-making could potentially be exploited or overused when people know certain things are not checked. For example, by ignoring the value of nature and causing excessive building activities.

"In automatic procedures, we can say, be aware, you may still need a permit from the province for Natura 2000 activities. Because nitrogen is released into nature there. Well, if they don't apply for it and the province doesn't oversee it, as is often the case. Yeah, then we just don't have control anymore whether things are demolished without considering the species. (environmental agency spatial planner).

“The permit issuer already has difficulties to determine if you need that permit. So I don't know if we have a system in place that is so well-structured to determine that based on the text: I want to put a dormer on my house. And if we immediately link the permit to that, then a lot of construction will take place.” (municipal permit issuer).

Standardization

All parties involved in spatial planning and permit issuance have their own terms, rules, and even software. This provides flexibility but also increases complexity. It shows a contradiction in the new environment and planning act, which decentralizes, but at the same time, sets out goals for the DSO that require far-reaching standardization and collaboration between different governmental bodies. The spatial planners generally did not view this flexibility as something that helped them. For example, they would have liked an example of a zoning plan and preferred the re-implementation of color coding standards for functions (bestemmingen). Besides these examples, four reoccurring challenges of standardization were identified. These are harmonization of terms, data reliability and versioning, data as PDF, and complex API profiles.

Firstly, harmonization of terms between municipalities and different governmental layers is a challenge that stands in the way of effective use of environmental data. This issue was mainly brought up by DSO experts and spatial planners when they were required to combine data of multiple types over larger areas. This issue was perceived as mainly challenging for municipalities.

"The system catalog actually tries to bring together the semantic side, so concepts, activities, tasks, the relationships. That's difficult because concepts are all made by the authorities themselves. There's a desire for them to harmonize. Well, that's going to take a few more years." (DSO expert).

Secondly, to determine the reliability of data it needs to be possible to see how current the data is, which requires proper versioning. Multiple participants stated that data is often not properly registered and updated.

"Sometimes it is described in the metadata. That's an important point. And at least in our own system, I just notice that sometimes map layers are used once and then not updated anymore. Of course, that's a bit detrimental." environmental agency permit issuer)

"Yeah, a lot of capacity is lost because we all register things somewhat half assed and then have to manually check and see how things really are. It just wastes a lot of time." (environmental agency spatial planner).

Thirdly, the use of PDF's for submitting spatial plans can lead to accuracy and interpretation challenges when making the translation from what is seen on the PDF to a geo-referenced file.

"Sometimes you just get a PDF of something. So, that means that at some point, someone drew with a marker with a thick line. Then I have to turn it into a thin line [in GIS software], which is prone to human interpretation errors." (municipal spatial planner).

Finally, one DSO expert mentioned that the Information products delivered by Providers of Environmental Data (LvOs, described in Chapter 2) require complex API profiles. This is an obstacle when aiming to make a lot of Information products be used to automatically fill fields in 'Checks' and 'Requests'. It was suggested to make the API profiles less complex, but the tradeoff here would be that by doing so part of the complexity is shifted to the user.

"Multiple parties have said that the requirements are quite complex and asked whether they can't be simpler. Well, partly no and partly yes, we can try to find a middle ground, with the downside that part of the complexity ends up again with the users. If you have a very tight surface, so you know exactly: I can ask this question, I will get an answer. That makes it very easy to show it in the viewer" (DSO expert).

Shortly put, the work put into making these complex API profiles takes away complexity for the user because Information products will be able to answer more specific questions. Essentially it is a dilemma between broad Information products catering to many different needs and specific Information products used to answer targeted questions.

"If you create very narrow information products tailored to a specific question, then it's easy. If you have a question, well, you have your answer. But if you then want to ask a slightly different question, then you have a problem. I think this is about finding a balance between creating very specific interfaces where you're only allowed to ask one question and broad information provision" (DSO expert).

An example of a broad Information product could be a database on external safety, including gas tanks, firework deposits, and the areas around them which are potentially impacted when explosions or leaks occur. An example of a specific information product could be a dataset of all houses with asbestos on their roofs. Such a dataset could answer a direct question like: Do I have to take extra measures because my roof contains asbestos? And: is extra research required to determine this?

5.3 Recommendations

This section describes the themes (code 1) and corresponding code 2 descriptions that belong to the category of recommendations. They are shown in Table 5. For each of the themes, the recommendations regarding the use of environmental data are explained based on these descriptions.

Table 5: Themes and code 2 descriptions for recommendations, E.D. = environmental data

Code 1: Theme	Code 2: Description	Frequency
Environmental data types	Already known data	27
DSO user friendliness	Copy from previously filled fields	7
	Better connect Checks and Rules on the map	5
	Make zoning plan transparent	3
	Zoom in/out further	2
	Draw lines across jurisdictional boundaries	1
Availability and access of data	Permitted situation and reporting's on map	8
Visualization	3D Idea's	4
	Make overview maps	5
Combining data	Filter data by relevance for activity	6
	Decision tables for connecting rules and E.D.	5
	Combine forms of different governments	4
Automation	Link Information products to local software	2
	Suitable for simple permits	4
	Prevent mistakes and need fewer people	9

Environmental data types

For this theme, the code 2 description 'Already known data' was applied when a participant stated some data to be quickly available and potentially suitable for automatic filling. For most types, the participant stated not blindly trust the data, or that expert judgement is still necessary. The data types can thus be seen as a starting point of Information products that indicate to the initiator whether certain measures are necessary or extra research in the area is needed. The data types and relevance to specific questions can be found in Table 6. The questions are constructed from the participant's proposed automation applications. Overall it can be observed that they relate to determining if a permit is necessary or if extra research and measures are needed. So, the required data and these questions are especially relevant to the portal 'Checks'.

Table 6: Data types potentially used for automation and relevant questions

Known or easily accessible data type	Relevance to questions	Location
Sound load	- Do I need extra insulation for a new building at this location?	Atlas van de leefomgeving
Water levels and the resulting space under bridges	- Can a boat still pass under the bridge? What is the minimal space between the bridge and the water?	Peilbesluit
Building height	- Does this building I want to build fit in the local context? (depending on local rules)	AHN, or more specific in internal systems
Pipelines	- Is there a pipeline at this location, and do I need a permit to dig here?	Register external safety
Gas tanks (dangerous objects in general)	- Are there already too many gas tanks in this area? Is this building with: minors, the elderly, the sick, or large amounts of people too close?	Register external safety
Second world war bomb maps	- Is extra research to the soil necessary?	Internal systems of municipalities
Tree locations and properties	- Do I need a permit to cut this tree?	Internal systems of municipalities
Monumental properties	- Do I have to take extra measures because my house is a monument?	Internal systems of municipalities
Roofs with asbestos	- Do I have to take extra measures because my roof contains asbestos? - Is extra research required to determine this?	Internal systems of municipalities
Soil pollution from reports	- Is extra research to the soil necessary?	Internal systems of municipalities
General soil information Ground level height	- Do I likely need a stronger foundation or strengthen the current one? - Will this location likely experience soil subsidence? - Will this location likely flood?	Dino Loket AHN

DSO user friendliness

The recommendations that fall into the category DSO user friendliness are mostly straightforward functionalities currently missing in the DSO. Five of these directly apply to the use of environmental data and are here explained in Table 7.

Table 7: User friendliness issues

DSO portal	User friendliness issue
Checks and Requests	Participants stated they would like data in 'Checks' and 'Requests' to be copied to fields later in the form, to prevent filing in the same thing multiple times. When resolved, this can increase the effectiveness of environmental data and prevent mistakes in the process of filling in a long and tedious form "When I go through the permit check myself, I also notice that there are a lot of duplications in the questions asked by the environmental counter. So some questions can later just be skipped. As a permit issuer, it can also be advantageous because an applicant, for example, spends less time on an application. I think if you're working on something for a long time, at some point, you'll start to rush through the questions." (environmental agency permit issuer).
Checks and Requests	It was recommended a few times to start the checks portal within a map in which the proposed situation can be drawn. This would allow for direct checking against the zoning plan and possibly even the current permitted situation. This recommendation is in line with general needs expressed by permit issuers and spatial planners to get a digital geo-referenced drawing of a spatial zoning plan change or permit application.
Rules on the map	An issue mentioned multiple times is the option to make the zoning plan transparent. In Rules on the map this is currently not possible and is required to check the zoning plan against satellite imagery.
Rules on the map	A functionality that would help, is the ability to zoom in and out more in Rules on the map. Zooming in can be necessary to request a permit on a very narrow area and zooming out can be necessary to visualize permit requests that apply to a larger area like a province "It's the same with the local railway; we would like to have the scale of that map much larger, so that you can zoom in much more. That would really add a lot of value. And the other way around as well: we also receive requests from the wildlife management unit of the province of Utrecht. They have to apply for a certain permit for the whole province or a large part of the province and for that you really need to be able to zoom out, which is not possible because there is simply a limit." (permit issuer province).
User application in the DSO (undefined in the interview)	Currently, when planning to construct a cable and drawing its location, the line cannot cross jurisdictional boundaries, requiring you to deliver multiple drawings that hopefully connect correctly. A tool outside of the DSO was proposed to make it possible to draw across the boundaries of jurisdictional areas. This can potentially be combined with the second item in this table in an external drawing tool connected to the DSO.

Availability and access of data

For this theme, only the code 2 description 'permitted situation and reporting's on map' fits into the category of recommendations. Many spatial planners and permit issuers mentioned how helpful it would be to have an overview of granted permits on a map. Multiple improvements in using environmental data could be derived from this application. Firstly, the environmental burden on a location can be calculated by adding up the granted permits and associated environmental impacts. This is currently already possible in some systems available to environmental agencies, but having an overview of permits or currently running permit procedures in one system could save spatial planners and permit issuers a lot of work in manually putting them together.

"Systems where the licensed activities that cause, for example, odor emissions or a safety contour, are entered. Yeah, and you can retrieve that information from there. However, these are all separate systems where you enter the basic data separately again. It would be great if it could all be done in one system." (environmental agency spatial planner).

"An overview of the permits already granted in a certain area. That's also something permit issuers look at, like: "We're considering granting permission for this activity, where the damage to protected animals and plants is limited as much as possible, but actually, if permission has already been granted in the past or in the vicinity of that area, then there are cumulative effects." (province permit issuer).

Secondly, if this data is already available pre-request when using the portals 'Checks' and 'Requests', it can be used to prevent overlapping activities when drawing in the boundaries in the system.

"An additional map layer where they draw the ongoing projects, so that it's also included in the permit check. If someone draws something and then if it doesn't intersect with physical objects, but it does intersect with a project area, then you also receive a notification: "Sorry, that's not possible here anymore." (DSO expert).

Visualization

The ability to visualize the physical environment or granted permits in a 3D environment was viewed as a potentially great improvement to quickly judge a situation. Some cities like Rotterdam are already working on this development and many state its great potential. A good application can be to assess permit applications more easily compared to the current norm with PDFs.

"We now receive a PDF field of the drawing. Yeah, that's just a flat drawing, and it says, "This will be 8 meters high." But if you had all of that in 3D, it would save us a lot of assessment work." (municipal permit issuer).

The ability to create overview maps within the DSO was expressed multiple times as a potentially helpful tool. Particularly, the ability to select different layers of information for an overview of the area could be helpful to spatial planners. A good example would be the option of selecting only a specific function (bestemming) in Rules on the map.

"Or perhaps you could even easily generate maps from it. That would also be nice. That you highlight certain functions." (municipality spatial planner).

This recommendation reflects the challenge discussed in the previous section: Many find Rules on the map chaotic due to the amount of data layered on top of each other. Being able to manually make more selections would be especially helpful to spatial planners. For an average user or project initiator, this might not be enough. It would be better if the information was filtered depending on the activity they check or request.

Combining data

Spatial planners and DSO experts both stated, to make effective use of environmental data, the policy and resulting rules need to be goal-oriented, meaning that they should be tailored to what is possible in relation to the physical living environment represented by environmental data. A common method to combine the two is a decision table. This is a Table in which one axis is the conditions, and the other is the values or environmental data. These tables can help to structure the link of rules to environmental data, and they also make it easier to apply changes in rules.

"If you now want to adjust the regulations, I only need to adjust my model or table. This automatically updates my applicable rule in the permit check, and automatically updates my legal text as well." (DSO expert).

When stating it like this, it is made to look very easy. However, in practice, making such specific rules is, for a large part, dependent on the policy made in zoning plans. The complexity of zoning plans needs to be translated into rules, so in order to effectively combine environmental data with rules you already have to start with making policy aimed at doing so.

"You just have to be careful now when drafting policies, to make them simple enough to turn into an applicable rule. Because what you see a lot now is that policies are spread across different environmental documents. So, zoning plans have many exceptions upon exceptions upon exceptions. So if an applicable rule is complex, it's also a reflection of how complex your policy is." (DSO expert).

Automation

In general, the points brought forward by participants showed they believed in the automation of simple actions like determining if previous reports are available or showing the locations of trees, sewage pipelines, and other objects or characteristics that are relatively static over time. These types of data can especially be helpful in the portal 'Checks', to speed up the process for simple permits. For a final decision, most participants agreed that a person needs to be involved.

"I see it as something good, except for in Requests. I think the starting point where you can see what's going on with just a click on the map and what is allowed, and then the button "Here you can apply", is a very ideal image. But to immediately get the permit is impossible I think." (municipal permit issuer).

Automation was perceived to be less suitable for spatial planners. For example they value flexibility in decision making, for example when slightly deviating from the rules to make something possible that the local community or municipality is pursuing.

"It becomes very black and white, because then it strictly adheres to the rules, now if something just doesn't fit, you can still present it to the politicians. Sometimes you can allow a little more." (municipality spatial planner).

The only way in which spatial planners mentioned to potentially benefit from automation would be if Information products can be linked to the software they use for making zoning plans. Since the DSO has an open data policy and actually encourages companies to make use of the data for tools, this is a very likely and realistic recommendation.

"I would probably prefer to link it to the software where you create the plan. Information regarding noise or something. And you link that to your software and you create a working area somewhere, and you immediately get a warning: Watch out, the noise here is very high. Or watch out, there is something in the ground. That seems more useful to me than putting it in the DSO." (municipal spatial planner).

Finally, three main groups of benefits of automation can be identified in the results, namely: time gains, fewer people having to work on simple things and preventing mistakes in the process.

"I think automation would make everything easier. Ultimately, it would also result in fewer mistakes because people make mistakes too." (environmental agency permit issuer).

"If you don't have to fill in all those questions in 'Checks' again for other authorities if it can be somewhat automated, that would definitely save time and eliminate the chance of people filling it differently. So, that would prevent misunderstandings." (environmental agency permit issuer).

"Then you need fewer people, and you still need the people who make the plan and look at the environmental burdens. But you probably need fewer building permit issuers." (environmental agency spatial planner).

6. Discussion

The results of this study differ between the participant types, which is why they are discussed separately. First, the main results are summarized and discussed in relation to the theoretical framework per participant type. Especially the challenges and resulting recommendations linked to either SDI and SKI functionalities are discussed. Secondly, the limitations and potential improvements of this study are discussed. Finally, the discussion ends by presenting the scientific relevance within the fields of SDIs and SKIs, and the practical relevance for the development of the DSO.

6.1 Main findings

Main findings spatial planners

The main findings for spatial planners are summarized in Table 8. Their challenges of environmental data use are mostly related to data fragmentation, data compatibility, and problems with visualizing large amounts of data in one overview. These challenges can, in a way, be attributed to the omission of Information houses. As also pointed out by Drahmann, & Huijts (2021), who expected data visualization to become a problem if Information houses were not realized. The challenges of data fragmentation, compatibility, visualizing indicate that data is often 'known' but not always quickly 'attainable' and easily 'usable', according to the indicators from Donker & van Loenen (2017). Spatial planners knew where to find the data, but it is fragmented over many different portals which takes time to navigate. In order to be more useful, the data should also have compatible formats, and its quality should be clear through its *'timeliness and update frequency'*. The following part of this section discusses the suitability of SDI and SKI functionalities in addressing these challenges.

The challenges of data fragmentation, compatibility and visualization mainly show a need for web-GIS functionalities, which in turn can be developed more easily when traditional SDI components: people, access network, policy, standardization, and data (Rajabifard & Williamson, 2001), are properly developed. The SDI services described by Kleijn et al. (2014) seem to be sufficient in addressing these challenges since they include discovery, visualization, downloading, coordinate transformation, processing, and uploading services. For these services to work, the data should also be 'usable', which requires proper standardization, and for proper standardization, policy is required to set standards. However, a contradiction is present in the new Environment and Planning Act, which decentralizes for the sake of flexibility but simultaneously sets goals for the DSO that require far-reaching standardization and collaboration between different governmental bodies. Overall, the results suggest that spatial planners need standardization more than flexibility. For example, they experienced a lack of color coding standards, challenges with making rules that incorporate environmental data, and expressed a need for examples of zoning plans. These challenges show how the DSO has limited guiding value in the process of combining environmental data with rules. Finally, given the observation that SKIs require an interplay of many technological aspects already present in SDIs (as discussed in section 3.1), prioritizing standardization to facilitate the services described by Kleijn et al. (2014) appears more logical than developing SKI functionalities for spatial planners, especially considering spatial planners' doubts regarding the necessity of such functionalities.

When looking at the challenges of data fragmentation and compatibility, the new SKI components 'analytics' and 'knowledge' (Duckham et al., 2017) are not that suitable compared to SDI functionalities to address them. Especially in making zoning plans, implementing SKI functionalities will be complex because of the important role of the location and user context in SKIs (Arnold et al., 2021) and the need for extensive exchanges with domain experts in making zoning plans. Overall, these issues also cast doubt on the suitability of developing an SKI for spatial planning decisions, also because spatial planners most often need to combine many environmental data types for one location and discuss with colleagues, making automation less suitable. However, to aid decision-making, the automation of the visualization service by 'analytics' and 'knowledge' creation could add value. For example, by showing relevant environmental data related to a specific activity or function (bestemming). Finally, because of the current lack of Information products, even these SKI functionalities regarding visualization are likely limited at first. Considering the important role of using RDF formats (Ivánová et al., 2020), these SKI-like functionalities cannot be made until more Information products are available meeting these requirements.

Table 8: Summary of most important results for spatial planners

Theme	Summary
Environmental data importance	- In general, the use of environmental data was viewed a side issue compared to dealing with policy and rules - The importance of environmental data for spatial planners is not clearly characterized by the results and was shown to be strongly area-dependent, reflecting the complexity of making zoning plans. - All environmental data types need to be considered in making a zoning plan, but largely, it is a legal plan checked against environmental legislation. - It is expected that environmental data will play an increasingly important role in making zoning plans and environmental visions.
Information house target group	- Main target group: citizens and companies - Spatial planners were not expected to first benefit from Information houses, but the challenges they experience with data fragmentation and compatibility show they can benefit from centralization and standardization. For example, by using Information products in software to make zoning plans or by having more compatible data.
Environmental data types	- All data types are relevant for spatial planning. Depending on the area and activity different types are important.
Availability and access of data	- Spatial planners report few problems with data availability and more with data access. They struggle with data fragmentation across many systems and web portals. - Having a spatial overview of the permitted situation and currently running permit applications would greatly help the process of calculating environmental burdens on an area.
Visualization	- Creating an overview in Rules on the map is deemed challenging due to the lack of color coding and too much layered information. - Selecting specific functions (functies/bestemmingen) and being able to zoom in/out more in Rules on the map would improve this. - Having 3D functionalities would be a big improvement to check future developments with the current physical environment.
Combining environmental data	- The biggest challenge for spatial planners using environmental data lies in making the link between rules and environmental data. This process requires qualitative assessments between domain experts. - When a change in zoning plan needs to be justified, often all environmental aspects are relevant and need to be combined or added up to calculate the environmental burden or area suitability.
Automation	- Most participants see full automation as impossible for spatial planning decisions. However, it can help to highlight important aspects early on in the process. For example, by highlighting high sound loads, polluted soils, or air quality parameters in the software for making zoning plans.

Main findings permit issuers

The main findings for permit issuers are summarized in Table 9. Data provided by the initiator was perceived as the most important factor for a timely permit application process. However, the process after a permit application is when the actual work of a permit issuer starts. In this process, data fragmentation can be considered a main challenge. Next to data fragmentation, ensuring data reliability was also perceived as an important challenge, which is in line with the literature on open data portals and SKIs stating that the reliability of data should always be communicated to the user (Donker & van Loenen, 2017; Arnold et al., 2021).
The challenges show that for permit issuers, data is almost always 'known', but not often easily 'attainable' and 'usable' according to the indicators from Donker & van Loenen (2017). Permit issuers know where to find or request the data, but often face data fragmentation over different portals and experience delays in obtaining data when asking for advice from other organizations. When they have the data, its reliability can often be questioned. The following part of this section discusses the suitability of SDI and SKI functionalities in addressing these challenges.

Just as for spatial planners, the challenges regarding data fragmentation and data reliability mostly relate to traditional SDI components: people, access network, policy, standardization, and data (Rajabifard & Williamson, 2001), and less to the newly added components 'analytics' and 'knowledge' for SKIs (Duckham et al., 2017). The challenges of data fragmentation and accessibility could be addressed by the SDI services described by de Kleijn et al. (2014): discovery, visualization, downloading, coordinate transformation, processing, and uploading services. The 'discovery' and 'uploading' services together could be valuable in tackling the challenge of data fragmentation. However, proper policy for standardization of data formats and versioning of uploaded data is required to also make the data usable, making the 'uploading' service more complex. With the results that showed proper versioning and data documentation to be challenging and often lacking, policy that sets these standards appears to be even more important.

The results show how SKI functionalities are perceived to be mainly beneficial to citizens: to them data is not always 'known' and 'attainable'. The recommendations focused on helping initiators by making the portal 'Checks' more user-friendly, mainly by automatically copying answers to fields later in the form and automatically filling in environmental data. Because of the specific nature of the questions for simple permit checks, not many environmental data types need to be combined. These specific applications ensure that the user's context is defined, which is one of the most important requirements of SKI functionalities (Arnold et al., 2021). So, starting with automating these simple permit checks is currently the most realistic way to use environmental data and create the first SKI functionalities for spatial planning. Additionally, these simple SKI functionalities seem to be the most suitable application in general, seeing that the combination of environmental data and interaction between experts is increasingly relevant for more complex permit applications. Experts need to judge data quality, consider its relevance, and combine it with other data to come to a conclusion.
Finally, considering the important role of using RDF formats (Ivánová et al., 2020), SKI functionalities for combining data for complex permits cannot be made until more Information products are available meeting these requirements. Even when these are available, the results show that automating processes for these complex permits is not preferred by permit issuers. Besides full automation, another option would be to provide answers ranked to the relevance and currency of the data used (Arnold et al., 2021). A permit issuer could be provided with multiple automatic permit judgement options from which they can choose the one most suitable.

Table 9: Summary of most important results for permit issuers

Theme	Summary
Environmental data importance	- In general, the use of environmental data was viewed a side issue compared to dealing with policy and rules - The importance of environmental data for permit issuers strongly depends on the type of permit. The majority of permits (dormer windows, extensions to sheds, small demolitions) require limited to no environmental data and can quickly be checked with the rules. Environmental data is always required for bigger projects like real estate and excavations. - Environmental data provided by the government was not seen as the most important factor for a timely process. That depends mostly on the data provided by the initiator. To speed up the process of the permit application, a focus on data that the initiator requires to submit seems to add most value.
Information house target group	- Main target group: citizens and companies - Within government, especially municipal permit issuers are expected to benefit from Information houses. Value can be added to data by constructing datasets on soil pollution, sound load, etc., with more information on their 'expiry date' and documentation on its use for specific permit applications. - The permit application process can be accelerated most when initiators know from an early stage what they exactly need to deliver and have access to the required data.
Environmental data types	- All environmental data types are relevant for permit issuance. Depending on the permit and location, different types are important.
Availability and access of data	- Improving data availability and access to initiators can add the most value. You can think of the availability of previous reports or data and characteristics that are relatively static over time. Having this data available from the start can save municipal permit issuers time they usually spend on figuring out whether they need to ask for advice or request additional research on the area. - When additional information from reports is required, the process cannot be accelerated easily. - A spatial overview of the permitted situation would help with checking the environmental/spatial parameters of a new permit.
Visualization	- Visualizing new permit applications in a georeferenced or even 3D environment can significantly improve the process of checking them against the local rules and environmental data.
Combining environmental data	- The simpler permit types require minimal use of environmental data, but when it concerns a more complex matter like real estate projects, combining different types is always necessary.
Automation	- Automation can benefit simple actions like determining if previous reports are available or showing the objects or characteristics that are relatively static over time. These data types can especially be helpful in the portal 'Checks' for simple permits. - Data reliability was perceived as the main challenge standing in the way of automation. Proper documentation and versioning were recommended.

6.2 Limitations

For this study, 17 people were interviewed in 15 interviews. Three DSO experts, 6 spatial planners, and 8 permit issuers were interviewed. Overall, the results are more conclusive for permit issuers than for spatial planners. Nearing the end of the interviews with permit issuers, most answers clearly fitted the general picture. This was less the case for spatial planners, of which the answers diverged more until the last interview, which can likely be attributed to participant type differences within the group of spatial planners. Two participants advised on making zoning plans as environmental experts, two participants wrote the literal text of zoning plans, one participant checked if the zoning plan followed environmental legislation, and one participant was a technical zoning plan drawer. The variety of different functions logically also makes for less agreement between the answers. In future research, this could be prevented by conducting more interviews per type of spatial planner.
For the permit issuers, the variety in functions can be mostly characterized by being either a municipal or environmental agency permit issuer. Between these two, the type of work overlapped more so than for spatial planners. This shows that more definitive conclusions can be drawn for permit issuers. Finally, this research did not include citizens and companies, so a definite conclusion regarding the need for Information houses cannot be drawn. Especially because citizens and companies are the main target group according to the participants.

In addition to the sample size, the generalizability of the study needs to be discussed. All participants worked in a relatively urban area or a big municipality. The results showed how different the environmental data needs can be between regions. For example, the relevance of sound in urban areas compared to the relevance of nitrogen deposition in rural areas. This shows how the results regarding data type importance should be viewed through the lens of an urban context. Next to the data types, also the availability and accessibility of data can be different for larger urban municipalities compared to smaller municipalities, often having fewer resources and data available (see section 4.1). The fact that few challenges with data availability were experienced can be potentially attributed to this difference.

Finally, the creation of interview questions and data analysis inevitably created some bias. Especially the hypotheses based on standardization issues could have steered the deductive codes and consequential results toward those related to standardization and automation. Another factor increasing bias is that only one person was involved in the coding process. To minimize bias, the interview questions were formulated broadly at the start of a new topic, after which the interview was narrowed down to more specific themes. The choice to inductively code the second round of coding also aimed to reduce bias, and codes were relocated or renamed when going through them for the second and third time, improving the quality of the codes. However, even with these practices, the focus on Information houses possibly prevented other needs, challenges and recommendations from coming up. The idea that environmental data is required is an assumption woven through the research. Other recommendations, for example, those stating that the old situation before the New Environment and Planning Act was preferred, could be underexplored.

To improve this study design a few points could be beneficial. First, including small rural municipalities would have made the study representative of a larger part of the Netherlands. Second, more spatial planners should have been interviewed. The option of taking surveys was considered but not chased because the DSO is new, and not a lot of experience has been built up with its use, which decreases the effectiveness of a survey sent to many people whose background is not known. For future research, a survey among spatial planners and permit issuers on their use of environmental data can provide valuable insight into which types of environmental data could be of value in pre-filling or provide a more quantitative instead of qualitative conclusion on the perception of automation for spatial planning. Finally, having a second person help with coding would have improved the reliability and quality of the codes.

6.3 Scientific and practical significance

Automation for spatial planning

The scientific relevance of this study first presents what was perceived as potentially suitable for automation, representing the suitability of SKI functionalities in spatial planning. Secondly, it discusses the requirements of creating an SKI for spatial planning.

Looking at the perception of automation by spatial planners and permit issuers, it can be concluded that decision-making is not preferred in an automated way. The need for experts, discussion and the importance of the location and user context (Arnold et al., 2021) show why. Combining rules and environmental data to make a decision about the physical environment often involves expert judgement of data reliability, discussion of its relevance and some room for flexibility outside of the rules. Apart from automation in visualization, like showing relevant data depending on the permit or development, the results show a limited need and use for SKI functionalities in the day-to-day work of spatial planners and permit issuers. This aligns with how Duckham et al. (2017) describe the SKI, stating that knowledge creation should aid decision-making, but not that it should perform decision-making itself.

However, the results do suggest a need for SKI functionalities among citizens during simple permit requests (dormer windows, extensions to sheds, small demolitions). Particularly showing if additional research is necessary or providing input data for such additional research could add value, which was also concluded by a previous report on the user needs of Information houses (RIVM, 2017). The questions in Table 6 pose good examples like: Do I need a permit to cut this tree? Or, does my roof contain asbestos and do I need to take extra measures when demolishing? These are very specific questions, which show options for SKI functionalities and a ‘user-dependent system’ (p. 11). These suggested needs are in line with conclusions from de Kleijn et al. (2014) stating that: *“The greater the discrepancy between the users’ spatial thinking skills and their technical knowledge, the more effort is required in the development of these services”.* They state that it takes less effort to make services for advanced GIS users than for basic GIS users who need more user-friendly and tailored systems. This conclusion, and this research indicate the potential need for SKI functionalities for citizens.

Next to identifying what is currently perceived as suitable for automation, this study sheds light on the requirements of creating an advanced SKI for spatial planning. As described in section 3.1, SKIs require a complex interplay of many advanced technological aspects. However, most of them overlap with general SDI technologies like data versioning, uniformity through standardization, linking data, and web publishing. It shows how the creation of an SKI is strongly dependent on a proper SDI basis. Only the need for machine-readable data is strictly necessary for SKIs (Ivánová et al., 2020). But even the incorporation of machine readable data is often seen in SDIs, showing that the technological requirements of SKIs are highly similar to those of current SDIs.

Research into the potential needs of citizens and companies for SKIs is of scientific interest to the domain of geospatial-data science and SKIs, which is in line with Drahmann & Huijts (2021), highlighting the importance of a citizen's perspective for the development of the DSO. Additionally, research into the socio-economic cost-benefit of automating simple permits can be a valuable first indication of the societal benefits of SKIs. These studies can focus on whether, indeed, fewer people are required, if fewer mistakes will be made and if the process of application is accelerated and whether these outweigh the high costs of development. When these automation functionalities are realized, the research can be validated with real-world observations of socio-economic benefits. These studies should always consider potential negative results of automation, like misuse of automatic systems and unwanted side effects (section 5.2), like ignoring the value of nature or excessive building activities. These risks and the dynamic nature of the technological components of SDIs and SKIs (Rajabifard & Williamson, 2001; Duckham et al., 2017) show the necessity to redefine rights, restrictions and responsibilities between people and the data use (Rajabifard & Williamson, 2001).

Does the DSO need Information houses?

This study only considers the governmental view on Information houses, and not the potential usefulness for citizens and companies. So, a definitive judgement about the necessity of Information houses cannot be made. However, it is possible to assess the impact on the governmental aspect of environmental data use in spatial planning.

The hypothesized issues of abandoning Information houses (section 2.2) can be used to make this assessment. The results show that, while data availability is generally satisfactory, challenges with data access, visualization, and processing are frequently experienced. More specific issues included data fragmentation, reliability concerns due to poor documentation, the lack of color coding, a lack of filtering in mapping tools, and resource constraints for Providers of Environmental Information to make new Information products. These results show a potentially valuable role of Information houses in serving as neutral organizations taking a lead in data centralization and standardization efforts. However, it's crucial to recognize the bias towards the use of environmental data (section 6.2). Environmental data use is just one facet of spatial planning and is often perceived a side issue compared to dealing with policy and rules. Additionally, participants generally perceive Information houses as primarily serving citizens and companies.

It should be noted that the results in this study represent a very early assessment of the DSO and the use of environmental data in spatial planning. Recent publications by the Dutch government and the VNG highlight the growing importance of incorporating environmental data in decision-making processes for spatial planning (BZK, 2023; VNG, 2023), potentially intensifying the demands of data access, visualization, and processing. So, for a long-term vision of the use of environmental data by the government, it could be worth reconsidering the concept of Information houses. But, in the short term, the decision to abandon Information houses and focus on other aspects of DSO development seems to have been a smart move from the government's perspective.

Practical recommendations for the DSO

In order to promote the use of environmental data for pre-filling, it is important to have a look at the widespread dissatisfaction with the portal ‘Checks’, which is understandable, seeing that the promised functionality of ‘one click on the map’ is not realized. Taking this in account, it might be worth considering developing a few specific Information products to show that the background systems work and are ready to be ‘filled’. Next to showing that the technology is available and working, having an early example can potentially motivate municipalities in harmonization efforts and specifying their need for other Information products. Additionally, the issue of specifying pre-filling possibilities also highlights the importance of further research into specific data types required for simple permits. It can be of great value to the development of Information products to have an overview of data types required in simple permits, which is essentially an elaboration on Table 6.

Finally, one important practical recommendation for the DSO is to create a tool that shows currently running and granted permits. Both spatial planners and permit issuers state this will be of great value, especially when combined with a system for drawing new permits or calculating environmental burdens from granted permits. A previous report on the user needs of Information houses came to this same conclusion (RIVM, 2017). Other practical recommendations on the user-friendliness of the DSO can be found in Table 7, which shows issues experienced by the participants.

7. Conclusion

The objective of this study is to find out how environmental data use is experienced by spatial planners and permit issuers for making zoning plans and judging permit applications. It aims to formulate specific changes or additions to the DSO that could improve this use with a specific focus on the role of automation. The following main research question is answered: How do governmental users of the DSO experience the use of environmental data in spatial planning, and what can help to improve or even automate this use of environmental data?

To partly answer this question, the abandonment of Information houses and its impact on governmental use of environmental data is assessed. After the abandonment of Information houses, the DSO has limited guiding value in combining environmental data with rules. Most is left to supply and demand by letting 'Providers of Environmental Information' provide source data and requiring municipalities to point out fields they would like to fill automatically in 'Checks' and 'Requests'. This observation, in combination with the experienced challenges of data fragmentation, standardization, and the production of Information products, shows that the concept of Information houses still has value in taking a more centralized lead. Especially considering the likely growing importance of environmental data in decision-making, the concept of information houses should be considered for a long-term strategy. However, with Information houses perceived as serving citizens and companies, and environmental data not being the main factor in spatial planning compared to policy and rules, the decision to abandon Information houses and focus on other aspects of DSO development seems to have been a smart move from the perspective of the government.

Next to this conclusion on Information houses, this study also characterizes the use of environmental data in relation to the needs for SDI or SKI functionalities to provide a more targeted answer to the main research question. The experiences of spatial planners and permit issuers show a limited need for SKI functionalities for decision-making in their day-to-day work. The participants mainly faced data availability, fragmentation, compatibility, and visualization challenges, which can be addressed with SDI functionalities. The SDI functionalities mainly require proper standardization and policy. Currently, only for visualization of data before a decision is made, SKI functionalities were trusted to be of value for the participant's work.
The participants stated that automation can help citizens submit more complete and correctly filled permit applications. The potential benefits of automation for simple permits like dormer windows, extensions to sheds, and small demolitions were highlighted in their recommendations, particularly in showing if additional research is necessary or providing input data for such additional research. For example, to determine if your roof contains asbestos or if extra insulation is required due to local sound loads. The current DSO structure is ready to answer this kind of questions; the only things required are the addition of Information products and annotations to rules. Suppose that more SKI functionalities are to be developed, a strong SDI basis is necessary, seeing that many of the technological requirements of an SKI overlap with those of SDIs. Finally, considering that information products on sound, nature, and external safety will soon be added to the DSO, the next need among permit issuers is soil data and, for spatial planners, air quality data. However, the interviews only included urban spatial planners and permit issuers, potentially creating a bias toward these themes.

Further research could identify the specific data types and Information products to be developed for soil, air, and other environmental data types, focusing on simple permits. Additionally, research into the need for SKI functionalities among citizens is of scientific interest to the domain of SKIs. Finally, research into the socio-economic benefits and costs of automating simple permits can be a first indication of the societal benefits of SKIs. When these automation functionalities are realized, the potential real-world observations of socio-economic benefits can be validated. Research in this direction should always include the risks of automation, like ignoring the value of nature or excessive building activities.

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Appendix A: Information house data requirements 2015

Table 10: Environmental data need – Soil. (Rijkswaterstaat. 2016, pp. 13-14)

Soil	
Data requirement	**Description**
Soil structure	Load-bearing capacity of the subsurface, especially for large constructions like buildings and infrastructure. Ensures that structures do not settle or cause damage to others' property. Utilizes models and subsurface information for strength calculations during the design phase. Relevant for: Assessing the soil's bearing capacity for constructing a skyscraper, using subsurface data to design stable foundations.
Environmental hygiene quality	Environmental hygiene quality of soil, groundwater, and water bodies. Aimed at preventing or removing contamination in the soil caused by human activities. Relevant for: Soil pollution from industrial activities, groundwater contamination from leaking tanks, cleaning up contaminated sites.
Minerals and geothermal	Two components: Geothermal energy extraction and mining. Includes the use of underground space for purposes like waste storage and carbon capture. Relevant for: Geothermal heating systems, deep-sea mining for minerals, underground waste storage facilities.
Excavations	Commercial surface mining up to 100 meters deep on land and at sea. Also includes other excavations for spatial and infrastructural developments. Spatial and infrastructural excavations fall under the jurisdiction of provinces. Relevant for: Sand and gravel extraction for construction, excavations for building infrastructure like roads and buildings.
Underground space utilization	Spatial planning aspects of the subsurface. Requires good information on chemical, physical, and biological aspects of the soil for effective planning. Consideration of how various subsurface characteristics affect planned functions, such as groundwater reserves for drinking water or geothermal energy. No existing system for function designation in the subsurface. Relevant for: Balancing competing functions like reserving groundwater for drinking water and using it for geothermal heating; planning underground utilities or transportation networks.

Table 11: Environmental data need – Construction (Kadaster1. 2015, pp. 16-18)

Construction	
Data requirement	**Description**
Completion dossier (Opleverdosier)	The completion dossier contains, from the moment of realization of a construction, the information from the permit application and information about what has been realized. Including: Permit Application Information: Copies of the original permit application and approved permits. Specifications regarding the permitted construction activities. Technical Drawings: Construction drawings and floor plans of the completed structure. Details of structural elements, installations, and other technical aspects. Materials and Specifications: List of materials used and their specifications. Certificates or test results of materials if relevant.
Building regulations	These regulations are designed to ensure the safety, health, sustainability, and functionality of buildings. The Information product Building Regulations aims to make this building regulation accessible and understandable in such a way that it becomes possible to calculate and quantify these regulation rules.
Permit-free constructions/buildings	All permit free buildings (not rule free, so building regulations have to be followed but no permit is necessary). Or locations where no permit is necessary to build.
Digitalization support	Conversion of non-digital or partially digital building drawings to BIM standards. BIM (Building Information Modeling) refers to the creation of digital construction models or Building Information Model (the construction information model). This involves a digital model that represents a virtual depiction of the building, where geometry and information are linked. It is constructed from various objects such as a window, a roof, and a wall, along with associated information like their technical properties and relationships with other objects.

Table 12: Environmental data need – Air (RIVM. 2015. pp. 23-25)

Air	
Data requirement	**Description**
Calculation tool	Calculation of air quality depending on a specific project and time frame
Air quality next to roads	Distinction is made between: roads in cities, main road network and point sources
Background concentrations	Nitrogen dioxide; Fine particles: PM10 and PM2.5; Ozone; Sulfur dioxide; Carbon monoxide; Carbon monoxide p98; Benzene.
Meteorology	Wind speeds, temperature, air moisture.

Table 13: Environmental data need - Spatial Planning (Kadaster 2. 2015. pp. 14-15)

Spatial Planning	
Data requirement	**Description**
Planning	Theme maps: Where is what allowed and what is allowed where?
Public-law restrictions	Is there a groundwater extraction area adjacent to my garden? Is there a restriction on my plot under the Aviation Act?
Private-law restrictions	Is there a right of way applicable? Or is there an easement established on this plot? If so, by whom? Is there a cable or pipeline in this plot, and if so, who owns it?
Aesthetic Information	Where can I build without aesthetic restrictions, and where does a more stringent aesthetic policy apply?
Local regulations	Overview map of where I can and cannot place posters. Where does each parking policy apply?
Permit Applications	What types of permit applications are filed where? Have permit applications been submitted for, for example, dormers in a specific neighborhood?
Granted Permits	Where have various types of permits been granted? Which permits are not in line with the underlying zoning plans?
Jurisprudence	Has there been a previous legal process for this industrial area regarding the establishment of a business from a higher environmental category than formally allowed in the zoning plan?
Reports/Tolerance Matters	What tolerances apply to the land adjacent to my backyard?
Lease	Which areas are leased? Which leasing regulations apply to which area?

Table 14: Environmental data need – Nature (Bekker & Nikkels. 2015. pp. 31-32, pp. 70-71)

Nature	
Data requirement	**Description**
Area restrictions	Insight into the (proximity of): - Natura 2000 areas: Bird and habitat directive areas - Nature Network Netherlands NNN (formerly: Ecological Main Structure EHS) - Local regulations (provincial, municipal) - Zoning plans and structure visions, designation "Nature" - Management plans
NDFF Datasets Species (view/download) available	Individual observations of specific species: Amphibians, daytime butterflies, leafy and liverworts, breeding birds, lichens, dragonflies, non-breeding birds, reptiles, vascular plants, fish etc. Source: https://www.ndff.nl/overdendff/toepassingen/onderzoeksvolledigheid/
Opportunity map 3B And complete	Insight into the likelihood that a species could occur in an area for which no current observations are known. It indicates whether a species might occur more frequently than is apparent from the current known observations recorded in the National Database for Flora and Fauna (NDFF).
Nature Route Planner	Intended for the applicant of an environmental permit where an ecological assessment is required and for those involved in the processing of such a permit application. It assists applicants and processors with questions like: "How do I know if an ecological assessment is required?", "In which phase should ecological data be available?", and "How long do these procedural steps take?"

Table 15: Environmental data need Water (Rijkswaterstaat & Uni van Waterschappen. 2016. pp. 33-38), text in bold is important in the short term (Informatiehuis Water voor de Omgevingswet. 2017. p. 18)

Water	
Data requirement	**Description**
Surface water	Information on: - **Surface water quality** - **Surface water temperature** - **Water levels or flow in volume per second** Relevant for: - Dredging / deepening, Structures (artificial constructions), Excavation of watercourses, Recreational facilities, Construction in riverbed
Space and water	Information on: - Rainwater - Seepage - Rainwater storage Relevant for: - Urban Planning Developments, Infrastructure Developments, Activities related to the construction of water storage
Marine	Information on: - Water quality - Seabed - Sediment - Nature on seabed Relevant for: - Gas and oil extraction, Surface mineral extraction, Dredging, Wind energy, Cables and pipelines, Discharge (at sea)
Wastewater	Information on: - **Discharge amounts, types and locations** - **Map of sewage system** Relevant for: - Direct discharge of wastewater in: Surface water, In or on the soil - Indirect discharge of wastewater, Discharge of effluent from a wastewater treatment plant, Overflow of urban wastewater
Water safety	Information on: - **Water safety constructions: flood defenses** Relevant for: - Modification and construction of water defense, Construction, modification, or removal of structures on, in, along, and beneath the water defenses, River widening, Construction outside dikes
Groundwater	Information on: - **Groundwater quantity** - **Groundwater quality** (macro-parameters and natural processes) - **Groundwater extractions** Relevant for: - Extraction, e.g.: Drinking water extraction - Infiltration, e.g.: Recharge dewatering, Irrigation water - Energy storage (open and closed ground energy systems): Borehole Thermal Energy Storage (BTES) - (Subsurface) infrastructure

Table 8: Environmental data need – Sound (RIVM 2., 2015. p. 40)

Sound	
Data requirement	**Description**
A tool that calculated the sound load for outside places	The average sound/sound level in decibel at a location
A tool that calculated the sound load for inside buildings	The average sound/sound level in decibel in a building
Sound sources	Locations of sound sources: - Different types of roads (traffic) - Industrial areas - Trains, trams and metro - Fly paths - Restaurants, café's, bars and clubs

Table 9: Environmental data need – External Safety (Derksen et al., 2015. p. 28)

External Safety	
Data requirement	**Description**
Risk sources	- Specific activities or companies - Airbases - Pipelines - Transport routes
Vulnerable objects and measures	Objects: - Buildings - Crowded roads - Public transport infrastructure - Population dense areas The options for disaster management in specific areas
Environmentally harmful activities	An activity that may cause adverse effects on the environment, other than a discharge activity to a surface water body or a discharge activity to a purification plant or a water abstraction activity Examples: - Applying fertilizer on or in the soil - Soil remediation - Dredging - Building a wind turbine - Specific digging activities Source: https://iplo.nl/regelgeving/regels-voor-activiteiten/milieubelastende-activiteiten-hoofdstuk-3-bal/

Appendix B: Interview questions

Environmental data users

Step 1: Introduction (10 min)

1. *Explain the interview (duration: about 1 hour):*
   - *How I came to the topic: from Information Houses → explain term environmental data*
   - *Goal: to identify the use of environmental data to find out how the DSO can be improved.*

2. Can you describe your involvement in processes in or for the DSO?
   - Employer and number of years of experience in spatial planning
   - How much have you already worked or tested in the DSO, and in which portals?

Step 2: Data requirement (10 min)

1. What types of environmental data do you need for your work?

2. How important is environmental data in your work?
   - How often do you use environmental data?

3. Can you describe what types of environmental data are most important to your work?
   - Can you give some examples where this data is needed?

Step 3: Data usage and challenges (30 min)

1. Can you describe some of the challenges of using environmental data in your work?
   - In which program, which data types, which processes, which parties involved?

2. Which target group would benefit most from Information Houses?

Potential issues of the shift

3. How would the availability of more standardized environmental data affect your work?
   - Taking into account that Information Products: Nature, noise, external safety and public law restrictions will be developed first. What else is needed?

4. How do you obtain the environmental data you need?
   - Via: Web portals (intern/extern), API or download

5. How big is the role of data visualization in finding data?
   - How often and how do you visualize environmental data?

6. To what extent are you involved in transforming or combining environmental data?
   - How often and how do you combine environmental data?

7. What would you prefer in regards to automation of spatial planning processes?
   - Would you prefer an automated answer or one from a person assessing the data? Why?

8. Which aspects of your work could be automated and which not?

Step 4: Recommendations (5 min)

1. What would you change or add to the DSO to improve the use of environmental data?

Step 5: End (2 min)

Thanks for the interview. Do you have questions for me? Link to colleagues for an interview.

DSO experts

Step 1: Introduction (10 min)

1. *Explain the interview (duration: about 1 hour):*
   - *How I came to the topic: from Information Houses → explain term environmental data*
   - *Goal: to identify the use of environmental data to find out how the DSO can be improved.*

2. Can you describe your involvement in the DSO?
   - Employer and number of years of experience

Step 2: Information houses (10 min)

1. What do you think are the consequences of abandoning Information Houses for the use of environmental data in spatial planning?
   - For permit issuance?
   - To create environmental visions/plans?
   - Impact on availability, accessibility, quality of environmental data?

2. What are the pros and cons of broad Information Products? (as described in 2.2)

Data usage and DSO portals (15 min)

1. How is environmental data currently used in the DSO?

2. How will environmental data be used in the DSO after the expansion?

3. What adjustments or additions to the DSO do you think could improve the use of environmental data in spatial planning?

4. What is currently the role of "Rules and Map" in the use of environmental data?
   - Do you think this should be extended? What would it take?

5. To what extent is it possible to pre-fill data during permitting processes?
   - Do you think this should be extended? What would it take?

Standards (15 min)

1. Which open data standards are applied in the DSO?
   - Do you think this should be extended? What would it take?

2. Which standards can improve the use of environmental data in the DSO?

3. How does the data format of environmental data in the DSO affect its use?
   - What do you think about the fact that Information Products can also be uploaded as PDFs?

4. How "crawlable" is the data in the DSO? (accessible to search engines)
   - Do you think this should be extended? What would it take?

Step 5: End (2 min)

Thanks for the interview. Do you have questions for me? Link to colleagues for an interview.