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Status of National Open Spatial Data Infrastructures: a Comparison Across Continents*

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Abstract

The increasing need for geospatial information demands for well-organised management among all levels of society. A Spatial Data Infrastructure (SDI) is a multidisciplinary and dynamic instrument that facilitates access and sharing of geospatial information. The current trend towards open data initiatives is influencing the development of these infrastructures. In order to examine this effect, this article addresses the following question: what is the current state of SDI openness of four best practice open data countries Canada, The Netherlands, Australia and Brazil, and how do they compare? The question is answered through a qualitative literature study and the application of a newly developed Open SDI Assessment Framework to the countries. The Netherlands and Canada show a high performance on all assessment dimensions; data discovery, data access and data properties. Australia and Brazil show a poor open SDI performance, as they could not meet the requirements set for the assessed datasets. General conclusions of the assessment are that data is currently fragmented and scattered among the web in all four countries, which strongly negatively influences the user experience. It is crucial that a strict legal framework is embedded in a country, which ensures that current SDI objectives and propositions regarding an user-centred approach and open data availability are achieved.

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1. INTRODUCTION

Geospatial information fulfils an important role in modern day society, as most of the environmental, economic and societal challenges demand for spatial and geographical knowledge (Groot and McLaughlin, 2000; Nedovic-Budic et al., 2017). Since the 1990's public administrations worldwide have been acknowledging the need to manage the availability and access to this geospatial information through the development of Spatial Data Infrastructures (SDIs) (Dessers et al., 2011).

An SDI is a dynamic and multi-disciplinary mechanism that allows for access, reuse and sharing of geospatial information (Crompvoets et al., 2008). It aims at including people, data, institutional policy, access networks, dimensions of human resources and technical standards to form a framework that coordinates the availability and the use of geospatial information (Steiniger and Hunter, 2012; van Loenen, 2009; Rajabifard et al., 2002).

A new trend is evolving in which several countries and public administrations focus on an 'open data policy' in which governmental data, including geo-data, is freely available to use for citizens, businesses and any other groups, without any restrictions (Vancauwenberghe and van Loenen, 2018). Simultaneously, a shift is present to an 'open SDI' in which citizens, research institutions, private organizations and other businesses and non-governmental actors are recognized as key stakeholders of the infrastructure (Vancauwenberghe and van Loenen, 2018; Vancauwenberghe et al., 2018). It is aimed to involve these stakeholders in the governance and implementation of the infrastructure (Vancauwenberghe and van Loenen, 2018).

Worldwide, billions of euros are invested in the development of national SDIs (NSDIs) (Budhathoki et al., 2008). This emphasizes the relevance to investigate how SDIs are performing and to identify possible areas needing improvements. SDI assessment frameworks are a valuable tool for these investigations. Several of these frameworks have been designed and implemented (see, for example, Crompvoets et al., 2008; Grus et al. 2007; Nedovic-Budic et al., 2017). However, current SDI assessment frameworks often lack - or insufficiently cover - the reflection of recent open data developments. Therefore, this article proposes a new

improved assessment framework that integrates these recent developments into existing Open Data and SDI assessment methodologies.

The new assessment framework will be applied to the NSDI of four countries from four different continents, namely, Canada, Brazil, Australia and The Netherlands. These countries have been selected as they are one of the highest ranked open data countries for their continent, according to the Open Data Barometer (see Web Foundation, 2018). A high rank indicates that the government is performing well on publishing and the use of open data for innovative practices, accountability and social impact.

The research question addressed in this article is the following: *what is the current state of SDI openness of four best practice open data countries and how do they compare?*

This question is answered through a literature study and the application of the Open SDI Assessment Framework proposed in this article. In order to assess the openness of the SDIs of the four countries, this study will first elaborate on what an open SDI comprises. In section 2 the new Open SDI Assessment Framework is presented. In section 3 the framework is applied to the four countries and enriched with a literature study. Afterwards, a discussion is provided were the performance of these four best practice countries is compared. Finally, concluding remarks and recommendations are provided.

2. OPEN SDI

The core of an SDI consists of five components: people, geospatial data, standards, policies and access networks (including geoportals and web services). Rajabifard and Williamson (2003) considered the relationship between people and data to be one of the core components of an SDI, together with the main technological components - such as policies and standards (see also Rajabifard and Williamson, 2002; Hennig and Belgiu, 2011; Groot and McLaughlin, 2000). As technological advancements have a dynamic nature, they suggest that an integrated SDI should address issues relating to interoperability and access networks.

Over the last three decades, the concept of an SDI has evolved. This evolution can be roughly subdivided into three infrastructure generations. The first-generation SDI is producer-driven. The focus is solely national and on the supply of public geospatial data and making it available to users (Masser, 1999). In this product-

based model the main aim is linking existing and new databases to the administrative levels of the community (Rajabifard and Williamson, 2003). Consequently, user involvement is limited and involved actors are mainly national mapping organisations (NMAs) (Hennig and Belgiu, 2011). With this type of infrastructure, altering or uploading content is solely possible for the NMAs (Budhathoki et al., 2008). The second-generation SDI showed a shift towards more user-oriented strategies, enabled by the rapid development of the Internet in the early 2000's. In the second-generation, SDIs open up for cross-governmental use, e.g., between authorities that are responsible for different sectors, or between authorities at different administrative levels. The main focus of SDIs changed from data provision to the provision of web-based services (Budhathoki et al., 2008). These SDIs are process-driven – aiming to define a framework that facilitates the management of communication channels for the community to share and use datasets. Development participants are among different sectors; data integrators are also included (Hennig and Belgiu, 2011). However, the user still fulfils a passive and receiver-only role in the infrastructure (Budhathoki et al., 2008).

The importance given to the interaction between users and suppliers shaped the new definitions and objectives of more current SDIs. Budhathoki et al. (2008) introduced a third generation of SDIs where the so-called 'produser' is central, i.e., stakeholders that both produce and use geospatial information. This type of SDIs is user-centric as the infrastructure is designed to focus on the needs of the user. The user is now involved in the development of the SDI and becomes an active information generator – using and producing data. Instead of a top-down approach that is solely driven by experts, third generation SDIs allow for a more bottom-up approach in which throughout the development process the interests of the user are always considered (de Kleijn et al., 2014). The third generation SDI is more application-driven, as knowledge on easy sharing and access to information becomes fundamental. Moreover, technological advancement in web-based services increase general expectations regarding data access and availability.

More recently, together with the worldwide open data movement, a trend is emerging in which several countries and public administrations are focusing on 'open SDIs'. 'Open' refers to open data, which is data that can be used and re-used without any restrictions. This data is (license) free, easily readable by machines and delivered in an open format. Such initiatives have strongly enhanced the availability of public data which can be used by anyone, for any purpose (van Loenen, 2018). However, in the context of open SDI, 'open data' does not only

include public data, but also private and citizen-generated data. The presence of open data may lead to, among other things, transparency of governments and businesses, efficiency in data-use, economic growth and participation of citizens in governmental decision-making (Dalla Corte, 2018).

Vancauwenberghe et al. (2018) also stressed the importance of organizing the infrastructure itself in an open manner, by encouraging participation of non-governmental actors: open participation. Open participation requires opening up the infrastructure to non-government parties (Vancauwenberghe and van Loenen, 2017). By allowing stakeholders to participate in and contribute to building the infrastructure, an open implementation can be realised. An open government is transparent and stimulates participation and collaboration (Triviño, 2016).

If initially the main aim of an SDI was to support data sharing between public bodies, this focus is now shifting towards involving the private sector and citizens as key stakeholders (Vancauwenberghe and van Loenen, 2018). This is linked to the notion that the success of open data systems depends on the extent to which the data is being used. Higher data usage translates into higher economic or social value of the data (see, for example, Vickery, 2011). In order to enable constant data circulation, users need to have access to reusable data.

3. THE OPEN SDI ASSESSMENT FRAMEWORK

In order to support a comparative assessment of SDI openness, an assessment framework needs to be provided. Vancauwenberghe et al. (2018) have introduced such a framework called the Open Spatial Data Infrastructure Assessment Framework. The framework is based on key aspects of open data infrastructures proposed by Davies (2013), namely, readiness, data and impact. This framework is considered as an inspiration to the Open SDI Assessment Framework proposed in this article, which will be used to assess the openness of the four countries in section 4.

Compared to the initial Open SDI Assessment framework, the framework proposed in this article focuses solely on the data aspect. The reason for this is the subjectivity acknowledged by the authors in the assessment of readiness and impact, which would involve the evaluation of non-governmental participation in SDI implementation and estimates of the societal and economic benefits brought by geospatial data. Such assessments lead to highly biased observations and are therefore out of scope for this article.

In the work of Vancauwenberghe et al. (2018), the data aspect assesses how available and accessible the data is for different categories of users, such as regular citizens and (non-profit) companies. It should, for example, be simple for any user to discover the data via data portals or search engines. Therefore, performance indicators for the data aspect of their framework were: findability using web search, publication on both the national geoportal and open data portal, availability of metadata in the national language and English, online availability without registration, free of charge, accessibility of data via network services, open license and published using open standards and open formats (see Vancauwenberghe et al., 2018).

For this article, the indicators in Vancauwenberghe et al. (2018) were reviewed and improvements were made to the structure and content of the data aspect. Three dimensions were introduced: data discovery, data access and data properties. 'Data discovery' focuses on the ease of finding needed data. 'Data access' covers the process of obtaining access to the data and downloading the data to a computer. The last dimension, 'Data properties', assesses the ease with which one can work with the data once it is stored on the computer. Although constructed for EU member states, the content of the EU Open Data Directive can be of great value for the analysis of countries world-wide, as it reflects current developments in open data policies. Therefore, several indicators of the new framework cover important aspects of the Directive on open data and the re-use of public sector information, also known as the 'Open Data Directive' (Directive (EU) 2019/1024).

Instead of using an indicator for network services, which looks at the availability of data for view and download, the new framework also focused on application programming interface (API) accessibility. Web APIs allow data to be easily accessed by developers, which can then use it to develop new value-adding applications. The new framework not only considers the use of multilingual metadata, but also assesses the presence and completeness of the metadata itself. Lastly, this article goes beyond assessing download availability and includes indicators on the similarity of access procedures and the presence of machine readable data formats. These indicators are used to evaluate the user-friendliness of access mechanisms and the usefulness of data itself - if the content of a dataset cannot be extracted and processed by computers the data will have lost its purpose.

For every assessment dimension indicators are defined that are used to guide the evaluation, as seen in Table 1. It was aimed to select 'SMART' indicators; representing Specific, Measurable, Assignable, Realistic and Time-bound criteria

(Doran, 1981). A score is assigned for every indicator which depends on a hands-on assessment. For many indicators this score can be a 'yes' or a 'no', depending on how compliant the dataset is to the indicator. For some indicators a more excessive score description is given, as is the case with the 'data discovery' dimension. For the assessment of registration requirements, a positive score will be assigned if no registration is needed. The reason for this is that the waiting time associated with a request for data diminishes the accessibility. The online availability and search engine scores were checked by using startpage.com as search engine. This search engine is selected as it uses Google search technology, but eliminates trackers and logs, ensuring unbiased search results for users.

Table 1: Overview of the new open SDI assessment framework

Dimension	Indicator	Description
1. Data Discovery	1.1. Online availability	Data are accessible online (score: no/ through general search engine/ through portal/ other)
	1.2. Search engine score	Assessment of the easiness for which data could be found using a web search (score: no, not findable/ yes, but not within the first 10 results/ yes within the first 10 results)
2. Data Access	2.1. No registration	Data is downloadable without registration (score: no / yes)
	2.2. Free of charge	Data are available free of charge (score: no / yes)
	2.3. User restrictions	Release of the data under an open and international interoperable license (score: no / yes)
	2.4. Uniform access procedure	Procedure to access datasets are uniform/ very similar (score: non standard procedure to acces/ similar procedure to access/ standard procedure to access)
3. Data Properties	3.1. API accessible	Data is accessible through an API (score: not at all/ parts/ whole dataset)
	3.2. Machine readable	Data is machine readable (score: no / yes)
	3.3. Open formats	Data published using open standards/formats (score: no / yes)
	3.4. Metadata	Metadata documented adhering to ISO 19115 (score: no / partially / yes)
	3.5. Multilangual metadata	Availability of metadata in the national language(s) and in English (score: no / partially / yes)

4. CASE STUDIES

As proposed by Vancauwenberghe et al. (2018), for the assessment of the data dimension in each country, two high-value geospatial datasets are selected. These datasets are; a national road dataset of at least a level of detail of 1:20.000 and a national parcel dataset. These datasets are selected as they are of high-value from both a user and a provider perspective (Directive 2019/1024 appendix 1; Welle Donker and van Loenen, 2017; GOV.UK, 2013). The search terms used to find the datasets where fixed to 'road network' and 'cadastral' or 'parcel' plus either 'map'

or ‘data’ and the name of the respective country. For countries with a different national language than English, it is aimed to use a search term that is as close to the direct translation possible.

The resulting framework allows for comparison between NSDIs, but also for a clear overview of in which field changes could be made to improve the openness of the SDI. In the sections below, the new assessment framework is applied to four best practice open data countries in order to assess the openness of the SDIs.

4.1. The Netherlands

4.1.1. The Dutch NSDI

The Netherlands is ranked as the eighth most open data country worldwide in the latest edition of the Open Data Barometer and maintains a relatively stable score trend throughout all editions. While the Ministry of Internal Affairs has been responsible for the coordination of the Dutch national spatial data since 1990, the actual establishment of the NSDI was the result of many initiatives taken over the course of years. A geo-information board (*GI beraad*), representing all ministries and agencies involved in the Dutch NSDI, was launched in 2006. The governmental foundation Geonovum acts as the executive committee of the SDI, by making geo-information more accessible through the development and management of geo-standards (Geonovum, 2019).

In 2008, the Geographical Information and services for E-government in the Netherlands (GIDEON) strategy was put into place. This strategy described the basic approaches to embed the INSPIRE directive into the Dutch legislation. It aimed to “encourage collaboration in knowledge, education and innovation” (Vandenbroucke and Biliouris, 2011). In 2014, this strategy was replaced by Partners in Geo, which strives for a common vision of the government, private sector and the scientific community on the future of the geo-sector (Partners in Geo, 2014). Both the legislation of the INSPIRE directive, and policies on re-use of data from the 2013 EU Directive on the reuse of public sector information (Directive 2003/98 amended by Directive 2013/37/EU) were implemented in the Dutch SDI. This ensures that most of the national public sector information in the Netherlands is freely available for re-use in open, machine readable formats, without restrictions such as compulsory registration or copyright (Van Loenen and Grothe, 2014). In addition, public sector bodies are not allowed to exploit their intellectual property rights by imposing conditions on the re-use of the data (Vandenbroucke and Biliouris, 2011).

Moreover, the Dutch SDI is embedded in the system of 'Basisregistraties' (authentic registers). These registers are key elements of the NSDI and encompass core (geospatial) datasets, such as a national topographic dataset (BGT) and addresses and buildings (BAG). Governmental agencies are obligated to use these authentic registers. Data specifications, acquisition and maintenance of the registers are regulated by law (Besemer et al., 2006).

4.1.2. Datasets

In the Netherlands, the 'Nationaal Wegen Bestand' (NWB) is the main road network dataset. The dataset has a scale of 1:10.000 (Rijkswaterstaat, 2019). The Dutch parcel map is a cadastral map referred to as 'Digitale Kadastrale Kaart' (DKK) (Kadaster, 2019). This dataset includes parcel boundaries, street names and house numbers.

4.1.3. Data discovery

Both datasets were successfully discovered online within the first ten results of the search engine, using the search terms; 'Wegennetwerk data Nederland' and 'Kadastrale kaart data Nederland'. For the road network data, the user is directed to the PDOK portal, which offers open governmental geo-data is offered. The link of the parcel data directs the user to the national open data portal (KOOP, 2020). A second link is also present for the parcel data within the first ten results that leads to the PDOK portal.

4.1.4. Data access

Both datasets are accessible free of charge without any prior registration. The road network dataset is available free of charge under the Creative Commons CC0 1.0 Universal (CC0 1.0) Public Domain Dedication licence, meaning there are no use-restrictions. The parcel dataset is licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license, which means (re-)users can disseminate and process the data under the condition that the name of the data providers is mentioned.

The access procedure of the two datasets is similar. In PDOK you obtain a download link from an XML. On 'overheid.nl' you are linked to the original source of 'Rijkswaterstaat' to download the data.

4.1.5. Data properties

On the PDOK portal both the full road network dataset and the parcel data can be accessed through APIs. The API for the parcel data is accessible on 'overheid.nl'. The datasets are all provided in machine readable, open formats. On the PDOK portal, the road network data can be downloaded in either CSV, GML, JSON or as ESRI shapefile format. On both the PDOK and on 'overheid.nl' the DKK is only provided in the GML format. For different formats such as ESRI shapefiles or DX, users pay a fee. The GML format is an open, machine readable format, but the GML attributes are only available in Dutch.

Metadata is present for all the datasets. All the metadata is only available in Dutch, just like most of the instructions on the portals. The metadata is documented adhering to the ISO 19115 metadata standard.

Table 2: Assessment of the Dutch NSDI

Dimension	Indicator	Score Road Data	Score Cadastral Map
1. Data Discovery	1.1 Online availability	Through general search engine / Through portal	Through general search engine / Through portal
	1.2 Search engine score	Within the first 10 results on the result page	Within the first 10 results on the result page
2. Data Access	2.1 No registration needed	yes	yes
	2.2 Free of charge	yes	yes
	2.3 Open license	yes	yes
	2.4 Uniform access procedure	Similar procedure to access	
3. Data Properties	3.1 API accessible	yes	yes
	3.2 Machine readable	yes	yes
	3.3 Open formats	yes	yes
	3.4 Metadata	yes	yes
	3.5 Multilingual metadata	no	no

4.2. Canada

4.2.1. The CGDI

Canada is ranked second in the global Open Data Barometer, with score trends indicating continuous developments. The Canadian Geospatial Data Infrastructure (CGDI) came to existence in 1999, when the federal government of Canada

decided to facilitate a three phased funding to create a national SDI. This resulted in a program built within Natural Resources Canada (NRCan), called GeoConnections (KPMG, 2016). GeoConnections leads the CGDI by using standardised technologies and operational policies involving the integration and sharing of data (National Resources Canada, 2019).

In Canada, governance of geospatial information management operates as a collaboration between governments (federal, provincial and territorial), industry, the academic community and the public. Even though many of the provincial government parties have been working close together with NRCan, it is not mandatory for any of the parties to participate in the agreements. Consequently, the CGDI is not 'anchored' in the legislative framework of the country. No strict legal framework is present for the institutional arrangements and infrastructure in the field of geo-data. Rather, the management of geospatial information is facilitated through relationships based on collaboration and through strong partnerships (United Nations, 2014).

In 2013, GeoConnections constructed a "Team Canada" scenario to guide a new Pan-Canadian Geomatics Strategy, which acknowledges the need of shared leadership for the geomatics field of Canada. This scenario describes the ideal future of the geomatics field, which involves a clear relation between the public and private sectors and where the role of the government is to enable that the private sector can optimally function within a policy framework (KPMG, 2016). Policy development with a focus on user-needs is currently ongoing (KPMG, 2016). In addition, open data policies have been adopted by a growing number of Canadian governments, supported by the Open Government Directive and the Open Government License. However, these policies solely focus on governmental data.

4.2.2. Datasets

The dataset covering the Canadian road network is the "National Road Network". This dataset has a scale of 1:10.000 and contains road and ferry connection segments and punctual entities such as junctions and toll points (Open Canada, 2018a). The national parcel data is called 'Canada Lands Digital Cadastral Data' (NRCAN, 2017) and comprises datasets made according to survey plans recorded in the Canada Lands Survey Records. As a result, the scale may vary between 1:1000 and 1:10000 depending on the parcel sizes.

4.2.3. Data discovery

Both datasets were online available and present within the first 10 results of the search engine using the search terms ‘road network data Canada’ and ‘cadastral map data Canada’. However, many different links were returned for many different data portals and websites, all providing similar, but not exactly the same, data. Relevant data seemed to be scattered over several portals and many irrelevant datasets were also returned.

The National Road Network data was available through both the general search engine and the Open Government geoportal. The parcel data was only available through the search engine. However, the link provided by the search engine did lead to a government-owned website (NRCAN, 2017).

4.2.4. Data access

Both datasets where downloadable without registration and free of charge. In addition, they both have an ‘Open Government License – Canada’. This license is fine-tuned frequently and is specifically designed to encourage users to freely use data under as less conditions as possible. Under this licence the user is free to “copy, modify, publish, translate, adapt, distribute or otherwise use the information in any medium, mode or format for any lawful purpose” (Open Canada, 2019). This also includes commercial purposes.

The procedure to access the two datasets is similar but not equal since the road network data was directly accessible from the Open Government portal and the parcel data was not. The NRCan website where the parcel data was found does not have the same buttons as the Open Government data portal. However, the same license applied, and both links lead to FTP directories with a similar structure from where the data could be downloaded. In addition, for both datasets no request forms had to be filled out.

4.2.5. Data properties

The Open Government data portal uses CKAN, which is a feature-rich registry system. CKAN’s Action API is used and is an RPC-style API that reveals all of the main features of CKAN to API clients. In this way, all the datasets on the Open Government portal are completely accessible through an API (Open Canada, 2018b). However, the parcel data was not present on this portal, and this dataset was not available through an API on the NRCAN website.

Both datasets are machine readable. Except for unzipping the downloaded data folder, no preparation by the user is needed. This makes the data interoperable, both technically and semantically. The road data is available in KMZ and shapefile format and the parcel data is available in DWG and shapefile format. For both datasets the metadata is present and adherent to ISO:19115. In addition, the metadata is provided in English and French.

Table 3: Assessment of the Canadian NSDI

Dimension	Indicator	Score Road Data	Score Cadastral Map
1. Data Discovery	1.1 Online availability	Through general search engine / Through portal	Through general search engine
	1.2 Search engine score	Within the first 10 results on the result page	Within the first 10 results on the result page
2. Data Access	2.1 No registration needed	yes	yes
	2.2 Free of charge	yes	yes
	2.3 Open license	yes	yes
	2.4 Uniform access procedure	Similar procedure to access	
3. Data Properties	3.1 API accessible	yes	no
	3.2 Machine readable	yes	yes
	3.3 Open formats	yes	yes
	3.4 Metadata	yes	yes
	3.5 Multilingual metadata	yes	yes

4.3. Australia

4.3.1. The Australian SDI

Australia is among the most open countries according to the Open Data Barometer, placing sixth in the global rankings. The country has been pursuing the establishment of a national SDI since 1996 (Kelly and Searle, 2009). These ambitions eventually led to creation of the Australian SDI (ASDI), with the goal to provide a 'transparent supporting structure for spatial decision making and information access, that will be used on a regular basis by all members of society' (ICSM, 2008). There are two main parties concerned with the ASDI, namely Geoscience Australia (GA) and the Australia New Zealand Land Information Council (ANZLIC). GA is a public sector organisation that performs geo-scientific research and advises on geo-scientific topics (Geoscience Australia, nd). Next to

these responsibilities, GA is the government's custodian of geological and geospatial data.

ANZLIC is an intergovernmental organisation that provides leadership in the collection, management and use of geospatial information in Australia and New Zealand (ANZLIC FSDF 2019). ANZLIC sponsors the Foundation Spatial Data Framework (FSDF) initiative, which provides a common reference for the congregation and maintenance of foundation level Australian and New Zealand geospatial data. It aims at serving the widest possible variety of users (ANZLIC FSDF, 2019).

Australia has a national open data portal (Australian Government, 2019), which is currently in a beta phase. This website is owned by the Australian government and provides a central source of Australian open government data. On this portal, anonymised public data is published by federal, state and local government agencies. Next to the national open government data portal, several state specific open geo-data portals are present.

4.3.2. Datasets

The Public Sector Mapping Agency (PSMA) of Australia provides both the national road network dataset and the national parcel dataset, but they are not available free of charge (PSMA Australia, nd). The metadata on these datasets is not openly available and no budget is present for this research to purchase the data, which limits the possibilities to further assessment.

ANZLIC provides a national roads dataset called Geodata Topo 250K Series 3, which is an aggregation of data collected by several jurisdiction sources and has a scale of 1:250k (Geoscience Australia, 2006).

In addition, ANZLIC describes a dataset containing national land parcel boundaries (PSMA Australia, 2010). However, no open national parcel dataset was available. As the paid national dataset is an aggregated version of all open state parcel datasets, the choice was made to focus on one of the open state parcel datasets; the cadastral data of Queensland (Natural Resources, Mines and Energy, 2019). This state is selected as it has one comprehensive dataset with all cadastral data, while some of the other states have the data spread out over different datasets.

The table below shows the results of the assessment of the Geodata Topo 250K Series 3 and the cadastral data of Queensland. It should be noted that these

datasets do not fulfil the requirements set for this assessment, as the scale of the road dataset was not detailed enough (not 1:20k), and the parcel data did not cover the whole of Australia. This results in diverging assessment scores. Therefore, the content should solely be considered as informative and resulting scores will not be presented in the discussion section of this article.

4.3.3. Data discovery

Discovery of the road network data through startpage.com with the search terms 'Road Network Data Australia' was possible, but not within the first 10 results. The parcel map was successfully discovered using the search term 'Cadastral Data Queensland'.

The road data could be found through the national open data portal and national geoportal, but the state parcel data was not findable on these portals. The parcel data was discoverable through the state open data portal (Queensland Government, 2019a) and state geoportal (Queensland Government, 2019b).

4.3.4. Data access

The road network data is accessible without prior registration. The parcel data of Queensland did require the user to provide an e-mail address, but no account had to be created. Both datasets are free of charge. Both datasets are licensed under the Creative Commons, specifically the CC-BY 4.0 license. This means that the data can be copied and redistributed in any medium or format, and that it can be adapted for any purpose. The processes to obtain the datasets were similar, even though they were accessed through different data portals.

4.3.5. Data properties

Neither of the datasets are available through an API, although the Australian government has stated it considers APIs important for data availability (Australian Government, 2015). The data is provided in formats that are machine readable, but the parcel map is only downloadable in a proprietary format. The metadata of both datasets is documented adhering to specific Australian/ New Zealand standards based on the ISO:19115. The metadata was all provided English.

Table 4: Assessment of Australian NSDI

Dimension	Indicator	Score Road Data (Scale 1:250k)	Score Cadastral Map (State Queensland)
1. Data Discovery	1.1 Online availability	Through general search engine / Through portal	Through general search engine / Through portal
	1.2 Search engine score	Yes, but not within the first 10 results	yes
2. Data Access	2.1 No registration needed	yes	no
	2.2 Free of charge	yes	yes
	2.3 Open license	yes	yes
	2.4 Uniform access procedure	Similar procedure to access	
3. Data Properties	3.1 API accessible	no	no
	3.2 Machine readable	yes	yes
	3.3 Open formats	yes	no
	3.4 Metadata	yes	yes
	3.5 Multilingual metadata	yes	yes

4.4. Brazil

4.4.1. The INDE

Brazil maintains the third position in Latin America and the 18th position in the global ranking of the Open Data Barometer. Studies aiming at standardization of the production of geospatial data from Brazil's federal institutions started in 2003. This led to the establishment of the 'Infraestrutura Nacional de Dados Espaciais' (INDE) in 2008, based on the action plan of the National Committee of Cartography (CONCAR). It has three main objectives: promote ordering of geospatial data from governmental organizations, promote use and production of geospatial data by standards approved by CONCAR and prevent double efforts and resource waste in acquisition of geospatial data. These objectives are fulfilled by the Brazilian Directory of Geospatial Data (DBDG), which can be accessed through the Brazilian portal of geospatial data – 'SIG-Brasil' (INDE, 2019).

The Decree 6.666/08, that led to the creation of INDE, ensures that institutions of the federal executive branch are responsible for publishing their geospatial data and related metadata.

In August 2014, the importance of providing specific standards and agreements on open spatial data was acknowledged by means of an Institutional Plan for Open and Spatial Data. These documents aim at supporting the development of technologies related to public management as well as providing citizens with public information that can be promptly reutilized in digital applications (Ministério da Justiça e Segurança Pública, 2017).

In recent years, the government of Brazil has made a manifold of other commitments that guided the development of the NSDI. Examples of these are; the Open Government Partnership, the Law of Information Access and the establishment of the National Open Data Infrastructure. These commitments represent key moments showing the country's willingness to improve government transparency and information access.

4.4.2. Datasets

For the national road network of Brazil, no datasets could be detected that met the scale requirements set for this assessment of at least 1:20k. The national road network of Brazil is a collection of the federal, state and municipal road network data. The complete dataset contains information on roads, rails and waterways. INDE provides direct access to the federal road network (1:25000), which falls under the responsibility of the National Department of Transport Infrastructure (DNIT, 2019).

Selection of the parcel dataset for the assessment of the Brazilian NSDI presented a problem, as no unified cadastre exists. Therefore, the cadastral map for the city of Belo Horizonte (1:2000), which is present on INDE's website, was used for the assessment of the parcel data (Prodabel, 2010).

It should be noted that both datasets do not meet the requirements set for the assessment – the results are therefore of an informative nature, with the scores not being present in the discussion session of this research.

4.4.3. Data discovery

The search terms used to discover the date were 'Sistema Nacional de Viação Brasil' for the road network data and 'Dados cadastrais Belo Horizonte' for the

parcel data. The road network data was available within the first 10 results of the search engine but was not available on the SIG geoportal. The search engine link referred to the website of the responsible organization DNIT.

The parcel data was not discoverable through the search engine but was detected in the SIG geoportal. In this portal the user is redirected to the portal of Belo Horizonte; the responsible municipality.

4.4.4. Data access

For both datasets, no registration was needed, and the content could be visualized and downloaded free of charge. Licensing information was not easily found. For the road network data, no license type was provided in the metadata. Even after searching the road dataset on the national open data portal (Governo do Brasil, 2020), where license information is present for many other datasets, no information could be retrieved. Concerning the cadastral dataset, only copyright information was specified in the metadata. When searching for the dataset on the portal of the Belo Horizonte municipality, a mention to Common Creative Attribute 4.0 could be found. However, it was unclear if this applied to the dataset itself.

The procedures to access the datasets were different. While the road network data could be directly retrieved from the DNIT website, the parcel data could only be downloaded using INDE's viewer.

4.4.5. Data properties

While the national open data portal is powered by CKAN, none of the datasets were found using its API functionality. Only the cadastral data could be accessed through an API, provided by the SIG geoportal. Both datasets are machine readable and available in open formats. The national road network is provided via XML and shapefile formats. For the cadastral dataset, one has the option to download CSV, KML, and shapefiles.

Although INDE's portal allows access to metadata for all available documents – including both datasets -, the information is not well organized. In the metadata catalogue section, the user has the option to download the metadata in PDF or ISO:19139 compliant XML format. Nevertheless, when opening the file, crucial information - concerning legal constraints and geospatial representation, among others - is missing.

The metadata of the road network data is next to Portuguese also partly available in English. However, the translation of the text fragments is poor. When considering the cadastral data, the translation to English is almost non-existent.

Table 5: Assessment of Brazilian NSDI

Dimension	Indicator	Score Road Data (1:25k)	Score Cadastral Map (Belo Horizonte)
1. Data Discovery	1.1 Online availability	Through general search engine	Through portal
	1.2 Search engine score	Within the first 10 results on the result page	no, not findable
2. Data Access	2.1 No registration needed	yes	yes
	2.2 Free of charge	yes	yes
	2.3 Open license	no	yes
	2.4 Uniform access procedure	Non standard procedure to access	
3. Data Properties	3.1 API accessible	no	yes
	3.2 Machine readable	yes	yes
	3.3 Open formats	yes	yes
	3.4 Metadata	partially	partially
	3.5 Multilingual metadata	partially	no

5. DISCUSSION

The resulting scores of the application of The Open SDI Assessment Framework are presented in table 6. Both Australia and Brazil did not receive any scores in the final table, as these countries did not fulfil the requirements for the road network dataset as the scales were less detailed than 1:20k, and the parcel dataset, as the datasets did not have a national coverage. This corresponds to a poor performance of these two countries on the assessment. On the contrary, The Netherlands and Canada scored well in all three dimensions.

The scores assigned in tables 4 for Australia and table 5 for Brazil can be considered as informative and do help to understand the structure and current status of the national SDIs. In order to include all four countries in the discussion, knowledge gained during application of the framework to all four countries is

considered, while keeping the deviations of Australia and Brazil from the requirements for the datasets in mind.

During application of the framework to the four countries, several differences between the national SDIs became apparent, which are considered to be noteworthy. The following paragraphs will discuss them separately. Hereafter, remarks will be made on the applied methodology.

Table 6: Results of application of The Open SDI Assessment Framework

Indicator	The Netherlands		Canada		Australia		Brazil	
	Road data	*Parcel data*	*Road data*	*Parcel data*	*Road data*	*Parcel data*	*Road data*	*Parcel data*
1. Data Discovery								
1.1 Online availability	Through general search engine / Through portal	Through general search engine / Through portal	Through general search engine / Through portal	Through general search engine	N.A.		N.A.	
1.2 Search engine score	Within the first 10 results on the result page	Within the first 10 results on the result page	Within the first 10 results on the result page	Within the first 10 results on the result page				
2. Data Access								
2.1 No registration needed	yes	yes	yes	yes	N.A.		N.A.	
2.2 Free of charge	yes	yes	yes	yes				
2.3 Open license	yes	yes	yes	yes				
2.4 Uniform access procedure	Similar procedure to access		Similar procedure to access					
3. Data Properties								
3.1 API accessible	yes	yes	yes	no	N.A.		N.A.	
3.2 Machine readable	yes	yes	yes	yes				
3.3 Open formats	yes	yes	yes	yes				
3.4 Metadata	yes	yes	yes	yes				
3.5 Multilingual metadata	no	no	yes	yes				

5.1. Discoverability and user experience

Canada and The Netherlands score high on discovery; most of the data can be retrieved from both search engines and portals. However, when the user is taken into consideration, searching for the data often resulted in a confusing experience. In The Netherlands, a recent survey on open data users has identified fragmentation of data as one of the biggest barriers related to discoverability (Welle Donker et al., 2019). Data belonging to a certain domain is found across different portals, making it difficult for users to choose. In the case of Canada, many different links were returned for many different data portals and websites, all providing similar, but not exactly the same, data. Relevant data seemed to be scattered across portals and many irrelevant data was also returned. Findability and accessibility are key factors in allowing reuse of data. This research has shown fragmentation of data across portals to be a recurring challenge that needs

addressing in all four countries, regardless of the SDI generation attributed to the NSDIs. In fact, the countries show characteristics of several SDI generations. These gradations could also be used to guide further developments.

5.2. Importance of legislative frameworks

Laws guaranteeing access to public sector information positively impact the development of open SDIs. When considering the movement towards more user-centric and interoperable infrastructures, policies on the reuse of information should also be examined. Canada has recognized this by designing the Open Government Licence, which aims at removing restrictions on the reuse of published government data (United Nations, 2014). However, this initiative does not ensure abidance of the organisations responsible for the implementation thereof. A similar situation is observed in Brazil. The national law of access to information does not mention the rights and obligations of publishers regarding use and re-use. This leads to a questionable practice in the country: many institutions impose licenses as they see fit. The definitions used are often vague or ambiguous, exposing users to risks when redistributing or modifying data (de Carvalho Freitas et al., 2018). According to Welle Donker et al. (2019), The Netherlands also copes with problems regarding reuse of data, as many requests for data are still made based on the Law of Public Information Access (*Wet openbaarheid van bestuur*). This means that not all wanted data are findable or accessible openly through portals.

5.3. Impact of government systems

In Canada, Australia and Brazil, the access to information laws only provide access rights to information under control of federal government institutions. As such, state and municipal organizations are not obliged to provide their information under federal laws. In Canada, even though many of the provincial government parties have been working close together with NRCan, this lack of legally binding agreements leads to the CGDI not being ‘anchored’ in the country. In Brazil, the federal arrangement combined with the territorial dimensions of the country leads to similar challenges. Many activities between different hierarchical government institutions are interconnected. This leads to problems regarding technological, financial and human resources. Many of Brazil’s municipalities simply do not have the resources to maintain proper SDIs (Borba, 2017). As such, integration between data from different layers of governmental levels becomes difficult. Even when funding is available, bodies in charge of maintaining datasets might decide that the costs do not allow publishing the data free of charge. This is the situation in

Australia, where the national road network and parcel datasets are aggregates of state level datasets. These smaller datasets are processed by the Public Sector Mapping Agency and offered as a national product, for a fee. Such a funding model has a strong impact on SDI openness.

In The Netherlands, the creation and maintenance of a road-network of 1:10.000 and parcel dataset is the responsibility of a national governmental organization ensuring nation-wide harmonized datasets (Van Loenen, 2006).

5.4. Methodology limitations

Although application of the assessment framework resulted in insights in the openness of SDIs in four countries, the developed methodology has several limitations. Firstly, the Open SDI Assessment Framework used in this research uses a limited number of indicators. Extension of the amount of indicators will result in a more comprehensive analysis that can lead to new insights in Open SDI performances. In example, indicators assessing user experience could be included. For instance, the experience for different types of users can be considered; is the data easily discoverable, accessible and usable for a GIS specialist, a developer and a layman? Another example; in the data properties dimension the indicator API accessible only considers the presence of an API, while it can also be relevant to check whether the underlying mechanisms of the APIs are standardized, allowing easy access for the user.

Moreover, the aspect of ‘open participation’ was not considered in this framework. The focus of SDI development should not just be on opening up data, but on the potential for re-use as well. A truly open SDI should allow the user to produce and share data themselves and to participate in the decision-making process. Furthermore, for the application of the assessment framework, only two high-value datasets were considered. If different datasets were to be included, it is possible that deviating results would have been presented. For example, when considering the accessibility of the datasets for Brazil in table 5, it is stated that no registration is needed. However, a recent study by Araújo et al. (2018) found that many of the datasets used by developers in Brazil still require registration through the ‘access to information’ portal. In this case a request can take up to ten days to be validated, hampering the accessibility.

In addition, when more than two datasets were to be tested, the results of the application of the framework will become more reliable and therefore of a higher

value. In example, the results of the application of the framework to the Brazilian NSDI and the Australian NSDI are now omitted from the end results, as no datasets were detected that met the set requirements. However, when more different types of datasets where to be included in the research, it is possible that resulting scores would be present for these two countries.

Furthermore, no budget was available for this research to purchase datasets when needed. Consequently, even though the PSMA does sell the road and parcel data for Australia that is required for this research, these datasets could not be used and less suitable alternatives were found. However, it is believed that this limitation did not affect the main findings of this research.

Another important limitation to this study is that the four different countries were assessed by four different people. Even though the assessment criteria are believed to be SMART, slight differences in interpretations are unavoidable.

Moreover, reinterpretation of the effect of certain indicators could lead to other results. In example, registration requirements were scored positively if no registration is needed. However, registration may help understand the need of (re-)users and lead to better data quality and availability. Therefore, the proposed scoring could deviate when assessed by other people.

Even though a considerable effort was put in gaining high quality results, these limitations should be taken into account when considering the reliability of the findings. Nevertheless, the selected methods are considered to be of sufficient quality for the purpose of this research. The methodology used, a combination of a literature study and applications of the Open SDI Assessment Framework, can be applied to other countries worldwide to get a simplified overview of the current state of their national SDI, and to detect where in the infrastructure there is room for improvement.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

This article addresses the research question: what is the current state of SDI openness of the four best practice open data countries and how do they compare?

It can be concluded that even though all four countries score high on the Open Data Barometer, results of The Open SDI Assessment Framework are not

completely in line with these scores. The Netherlands and Canada show a high performance in data discovery, access and properties, however both countries display limitations by providing fragmented and scattered data. This limitation was also observed in Brazil and Australia. Furthermore, the high amount of data requests in The Netherlands based on the Law of Information Access indicates that a part of the geo-information desired by Dutch users is not yet openly available. In addition, Canada's NSDI framework which is based on non-commitment and therefore is not enforced, strongly limits the achievement of the set open-data goals for the national SDI. Improvements need to be made to diminish the non-committal nature, in example by introducing a strict legal framework.

These findings lead to a general conclusion that it is crucial that a legislative framework is created and embedded in a country, which ensures that current objectives and propositions regarding a user-centred approach and open data availability are achieved. This legislative framework should lay down rules that need to be followed by all layers of government, companies, industry, the academic community, the public and all other involved parties in the NSDIs. In addition, organisations should be appointed which check for compliance of the involved parties to the legislation. This is more urgent than ever given the current COVID-19 outbreak. Many government institutions may have realised right now how important it is to have geospatial data sets well organised and easily accessible across countries to improve decision-making and react to emergency situations like the current one.

When solely considering the final results of the application of the framework within the limits of the set data requirements, Australia and Brazil show a poor performance on Open SDI, as none of the required datasets were available. However, as the design choices for this assessment strongly influence the outcomes of the framework application, these conclusions can be a bit too strict. Further assessment of alternative datasets allowed for a deeper understanding of the current status on openness of the national SDIs.

The federal arrangement combined with the territorial dimension provides a limitation to proper NSDI development and management in Brazil. In addition, gaps in legislation in Brazil results in questionable practices on licensing, limiting re-use of the data. Lack of technological, financial and human resources ensures that many of Brazil's municipalities do not have access to the resources needed to maintain proper SDIs. This holds back the integration between data from different layers of governmental levels. Regardless the availability of funding, Australia also

fails to integrate high value datasets and to publish it on a national level, free of charge. Even though state level datasets are freely available, aggregates of these datasets, leading to national coverage, are offered for a fee by the Public Sector Mapping Agency.

Overall, it can be concluded that the four best practice open data countries, The Netherlands, Canada, Brazil and Australia, substantially differ in performance on SDI openness. Even though there is room for improvement in The Netherlands and Canada, these two countries outperform Brazil and Australia in terms of data discovery, data access and data properties.

6.2. Recommendations

Several recommendations can be made for further research. Firstly, the addition of extra indicators, such as indicators examining user experience and open participation, could be added to the Open SDI Assessment Framework to allow for a more comprehensive analysis of the countries. In addition, the extension of different types of datasets to be assessed per country can provide more reliable scores and therefore a better representation of the current status of openness of the national SDIs.

Furthermore, as the amount of data required to deliver a national coverage depends strongly on how large the country is, a more valid comparison of open NDSI performances can be made between countries of equal size. In further research, country size should be taken into consideration.

Moreover, federal or decentralized systems tend to be problematic for the dissemination of homogeneous data at a national level. However, despite being a federal government, Canada scores high on SDI openness. Further research could examine the reasons behind this success.

Finally, this paper focused on the assessment of the performance of the open SDI in four countries. Whereas currently SDIs arguably are still in the hands of the public sector, more and more geospatial data is nowadays owned by the private sector. This has strong implications on the availability, accessibility and reusability of such data and as a consequence on the performance of the SDIs. More insight is required in the role private and volunteered data in SDIs may play and how open access and reuse of these data and services could or should be to optimise the performance of an SDI.

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