SPATIAL APPLICATIONS DIVISION LEUVEN (SADL)

Final Report

The benefits and value of the Central SDI-node of Spain

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Short Description:

This report provides a summary of the study for the CNIG-ES to develop and test a methodology for quantifying the benefits or value of the central SDI-node of Spain by comparing WMS/WMTS using figures with the fee-models applied by some Member States and the feed-model applied by Google for its Google Maps API's. Moreover, also the value of the geospatial datasets downloaded is quantified based on the fee-models applied in some of the Member States.

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Executive summary

The calculation of **cost-benefits or the value of a Spatial Data Infrastructure (SDI)** and its components s an important research topic in the field of SDI, as can be observed by reviewing past and ongoing projects, scientific publications and conference communications on the subject (Barbero et al., 2019; Kruse et al., 2018). The issue is complex and far from being resolved, which affects in a negative way the strategic development of SDIs and the Spanish SDI (IDEE) in particular. In fact, the lack of a solid approach for calculating benefits and value of the Spanish SDI has also a direct impact on the collection and planning of resources for its implementation and maintenance, and hence guaranteeing its sustainability. The topic is of great interest both for the Spanish SDI, as well as for the Latin American and Caribbean SDIs and the implementation of the INSPIRE Directive in Europe.

Scope and Objectives

The major objective of this study is to **develop and test a methodology to estimate the economic benefits generated by the central SDI-node of Spain**, which is coordinated by the National Geographic Institute of Spain (IGN-ES). Benefits estimation is understood as an approximate calculation - as accurate as possible - in monetary terms of the value of the web services and data in the central SDI-node based on a set of objective considerations and criteria. The **central SDI node comprises all the SDI resources published on the web** by the same organization, IGN-ES, as coordinator of the Spanish SDI.

The benefits produced by documents, utilities, tools, links and communication channels are considered much smaller and even negligible than the **benefits derived from the use of spatial data sets and services**, therefore the study approximates the total benefits by the benefits of the use of geographic web services and geographic data. In this study the most used services, i.e. for visualization (**WMS and WMTS**), and the **datasets download** services implemented in the National Centre of Geographic Information (CNIG-ES) download centre[1] are taken into account. The contribution to the benefits of other types of services (e.g. WFS, WCS) is considered negligible and they are therefore not in the scope of this study. In practice, the most used WMTS (6), WMS (13) and downloaded datasets (4) are considered.

Approach & Methodology

The study follows **two tracks of investigation**: 1) comparing with and applying of the fee-model(s) applied by some European countries to the central Spanish SDI-node, and 2) comparing with and applying the charging – and business model of Google to the central Spanish SDI-node.

Most European countries do not apply fees for the use of geospatial web services, nor for the download and the use of geospatial datasets themselves. They follow an **open data**

[1] http://centrodedescargas.cnig.es/CentroDescargas/index.jsp

policy as is the case for the Spanish SDI (CC BY 4.0 license). Nevertheless, the study team could identify some countries who have a **fee-mechanism** in place: **Croatia, Finland, France, Slovenia, Sweden and Swiss**. Those countries were contacted and semi-structured interviews were carried out to collect information on: 1) the way they collect information regarding the use of web services for visualization (WMS, WMTS) and the number & volume of data downloads, and 2) the way the fee-mechanism works for those web services and data downloads, as well as the income that generates. For the Google model, the study team relied mostly on information and documentation found on the Google Maps platform.

The work to be performed was split in several parts. First the analysis of the use of the web services (WMS and WMTS) and the estimation of their benefits was carried out. The workflow for this part of the work is shown in Figure 1: Workflow for estimating benefits of WMS & WMTS. Second, the benefits or value of the core datasets must be estimated as well. Figure 2: Workflow for estimating benefits of data (downloads) shows this second part of the work. Each comparison required due its characteristics three different methods: A, B and C.

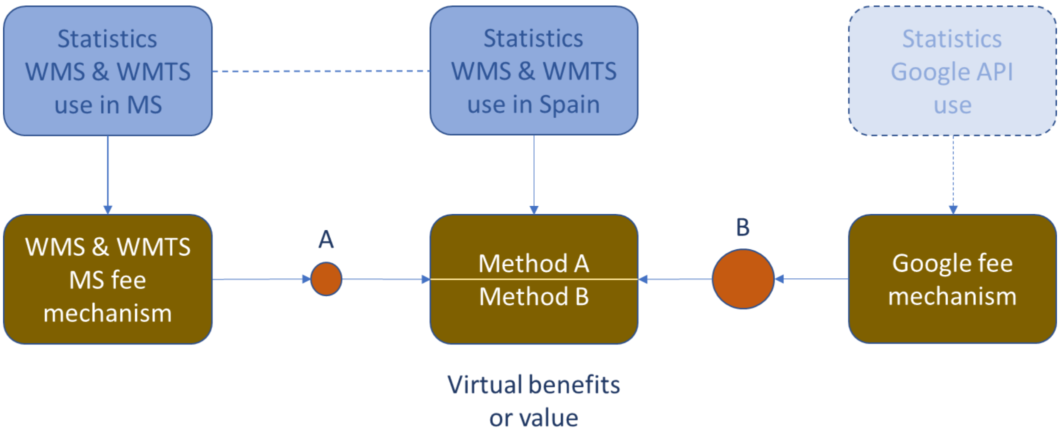

Figure 1: Workflow for estimating benefits of WMS & WMTS

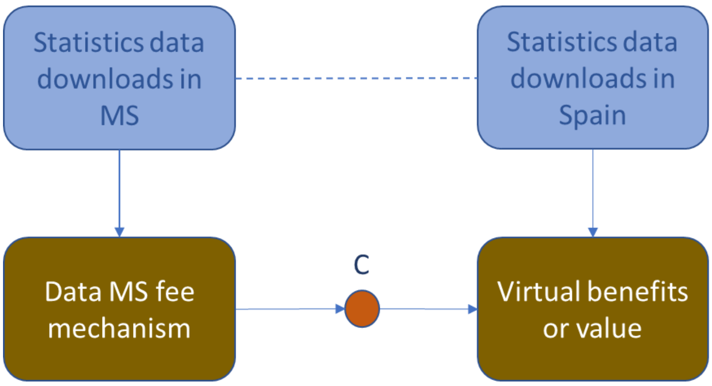

Figure 2: Workflow for estimating benefits of data (downloads)

Method A uses the information on the fee mechanisms applied in the Member States to the WMS & WMTS statistics of Spain. This starts from some assumptions and requires some parameters to be applied, but is relatively straightforward since both environments are similar, i.e. they use the same technology (hence the small red circle). **Method B** tries to link the Google fee mechanism to the Spanish WMS & WMTS use statistics. For this method, several assumptions and parameters need to be taken into account because the Google and SDI environments are not the same (hence the bigger red circle). For calculating and analysing the benefits of the data itself, only a comparison with the fee mechanism in some of the selected Member States is possible. **Method C** also requires to apply some parameters applying those on the download figures of the Spanish central SDI-node.

Findings on the Member States and the Google model

Before applying the different fee-models to the Spanish case using the three methods, it was decided to **analyse and compare the practices in the different European countries**, and to **investigate how the Google business model**, the Google Maps API ecosystem and the relate fee-mechanism **works**.

Analysis of the practices in the investigated European countries revealed first of all some **similarities and differences in their approach** regarding data and service policy: 1) all countries have experience in collecting and using statistics on the use of their services relying on different tools to do so; 2) the reasons for collecting and analysing the statistics are similar across countries (performance measurement, basis for reporting, …); 3) there are important differences in the extent to which these data are further analysed and used and 4) the extent to which these data are made available to the public varies as well.

The detailed usage figures on WMS and WMTS reveal that countries such as Spain, the Netherlands and Sweden have a performant SDI, i.e. their web services are used intensively, e.g. the total amount of requests for the whole year of 2019 and for the two types of services combined was respectively 14,9 billion, 9,6 billion and 6,3 billion. Everywhere, WMTS generate more requests than WMS.

Looking at the different MS approaches on charging for accessing data and services, we noticed that the majority of the organizations involved in the study, which all can be considered as mapping agencies, still charge for the use of services and the download of data. Most organizations have put in place a system of standard fees, which are used to determine the actual fees that need to be paid by the users. Three main parameters can be identified that are taken into consideration for determining the actual fees: **1. the types of users and/or types of use; the intensity of use and 3. the types of data**. In the estimates of the value these elements need to be taken into account as much as possible (Method A and Method C).

Google's revenue is largely made up by advertising revenue, which amounted to 134.81 billion US$ in 2019 and which is mostly generated via its search engine and its AdSense program, which places ads on millions of websites (Parr, 2010). However, Google also generates revenue through its Google Maps platform and the licensing of the different **Google API's**. How much exactly is not known. Google has many products: Maps, Routes and Places. In the context of this study, focus is on mapping, not so on routing and places. These two products are more comparable to GIS functionalities such as 'finding the fastest route to a destination' or 'geocoding'. Google Maps makes distinction between Maps and Street View. The latter is also not relevant in the context of our study. In turn, Maps offer different types of API's: Dynamic Map, Static Map, Embed Advanced Map and Embed Map.

A comparison of the four API's with the WMS/WMTS type of operations led us to focus our investigation on the **Google Dynamics Maps API** that can also visualize maps, pan/zoom (static maps can't), setting mapping parameters, using styles, display information on a location, etc. The Google fee charging mechanism is based on the **type of API** and the **intensity of use** in terms of number of monthly Map Loads. This is the starting point for estimating the value of the Spanish SDI-node.

Calculating the value of an SDI-node

The calculations were done in different ways.

Method A & C – Applying fees of Member States to the Spanish SDI

The statistics available on Spain included data on the number of requests (WMS & WMTS) and the number of downloads (of data). This means that for estimating the potential revenues for the central SDI-node of Spain we had to determine the fee for 1 single request or download. For the calculation of this fee per request/download, we took into consideration the fees currently in place in the different Member States.

In our quantitative model for applying the charging models of other countries, we also had to take into consideration the three commonly used parameters for calculating fees. For dealing with different types of users, we worked with different scenarios, which refer to a different number (or percentage) of users that need to pay a fee. For dealing with different levels of intensity of used, we calculated a fee per request, based on the applicable fees for different use levels. For dealing with different types of services and data, we performed separate calculations for WMS, WMTS and a selection of datasets.

For calculating the value of WMS and WMTS of the Spanish SDI, we applied the fee models of three other countries: Finland, France and Sweden. For each country, we worked with two different fees per request, i.e. the lowest possible fee applied in that country and the average of the lowest and highest possible fee. Finally, we also worked with different percentages of requests for which a charge is asked (100%, 50%, 10%). Table 1 shows the different parameters which were combined into many different scenarios.

Table 1: Scenarios for the comparison of WMS/WMTS with other MS

<table>
<tr><th colspan="6">Country</th></tr>
<tr><td colspan="2">Finland</td><td colspan="2">France</td><td colspan="2">Sweden</td></tr>
<tr><th colspan="6">Fee</th></tr>
<tr><td colspan="3">Minimum fee</td><td colspan="3">Average fee</td></tr>
<tr><th colspan="6">Percentage of requests actually being charged for</th></tr>
<tr><td colspan="2">100%</td><td colspan="2">50%</td><td colspan="2">10%</td></tr>
</table>

Even if only the scenarios are taken into consideration in which 10% of the requests are considered as requests that require a fee to be paid, the calculated total value of the Spanish SDI-node is very diverging, as the fees per request are very different (between countries but also within single countries). Our approach demonstrated the difficulties of estimating the fee per request, as very diverse approaches (and fees) are in place in the different countries. Based on the number of WMS and WMTS requests for the Spanish

SDI-node in 2020, the total value of the node was estimated to be between 34.000€ and 14 million €. The identification and use of different parameters allow to measure the total value for different scenarios.

For the comparison with and application of fee models for the download of data, we focused on three particular datasets: orthophotos, the topographic map and LIDAR data. For each of these datasets, we took into consideration the fees applied in two different countries. Again, we worked with different percentages of downloads for which a charge is asked (100%, 50% and 10%). Table 2 shows how these different parameters resulted in different scenarios.

Table 2: Scenarios for the comparison of data downloads with other MS

<table>
<tr><th colspan="6">Country</th></tr>
<tr><td colspan="3">Finland</td><td colspan="3">Country 2</td></tr>
<tr><th colspan="6">Datasets</th></tr>
<tr><td colspan="2">Orthophotos</td><td colspan="2">Topographic Map (1:25000)</td><td colspan="2">LIDAR data</td></tr>
<tr><th colspan="6">Percentage of requests actually being charged for</th></tr>
<tr><td colspan="2">100%</td><td colspan="2">50%</td><td colspan="2">10%</td></tr>
</table>

An estimation was made of the total benefits/value for each of the three particular datasets. Again, the different scenarios resulted in different estimations of the total benefit/value of a particular dataset. If we only look at scenarios in which fees are asked for only 10% of the total downloads, we've identified and tested two scenarios for each dataset. The first scenario is the application of the standard fee used in Finland, the second scenario is based on fees applied in Croatia (for LIDAR data and topographic maps) and in Sweden (for orthophotos). The total estimated benefit/value per dataset range between 800.000€ and 5.000.000€.

The design and testing of the approach of applying fee models of other countries not only provides us with insight on the estimated benefits/value of the Spanish central SDI-node, but also on the relevance and applicability of this approach, and how it could be further improved. The key challenge however is in the estimation of this fee per request/download since both within countries as between countries the adopted fees are very divergent, which makes the estimation – or selection – of the most applicable fee very difficult. Evidence collected on the fees applied in other countries shows that these fees are very diverse, and can to be much higher in some countries compared to other countries. Further consultations and exchange of experiences with experts and representatives from other countries will be a key element in the validation of our parameters and calculations.

Method B – Applying the Google business model to the Spanish SDI

The key question was how the Google business model can be linked and applied to the central Spanish SDI-node. Since Google Maps and SDI's are similar but yet different technological environments there are three key parameters to be considered and one assumption was made. The assumption is that a Google map load on which the Google fee system is based equals to a user session in a SDI web mapping application. Regarding, the three parameters, it was decided to rely on various scenarios based on different methodologies: 1) literature and experts opinions, 2) simple experiments and 3) calculations where relevant and feasible. First, a parameter had to be defined to make WMTS and WMS comparable, i.e. how many tiles correspond to one WMS request. Second, it had to be estimated how many tiles are visualized in one user session of a web mapping application. Three, the different price-levels of Google corresponding the intensity of use of the Google Maps were also considered.

The combined methods led to the following scenarios for the different parameters:

- Number of tiles / WMS request: 16, 24, 30, 36
- Number of tiles / user session: 326, 450, 500
- Fee-levels: 7 US$, 5.6 US$ (the latter was not used in the calculations because of the 'lower' volumes in the SDI

In addition it was decided to take into account an exchange parameter when calculating values for different years, and also the credit mechanism of Google was taken into account. This led to the following scenarios for the different parameters.

Table 3: Scenarios for the comparison with the Google Business Model

<table>
<tr><td colspan="60"># of tiles / WMS map</td></tr>
<tr><td colspan="15">16</td><td colspan="15">24</td><td colspan="15">32</td><td colspan="15">36</td></tr>
<tr><td colspan="60"># of tiles / user session</td></tr>
<tr><td colspan="20">326</td><td colspan="20">450</td><td colspan="20">500</td></tr>
<tr><td colspan="60">Fee per 1000 user sessions (In €)</td></tr>
<tr><td colspan="60">7 US$</td></tr>
<tr><td colspan="12">5,85€</td><td colspan="12">6,25€</td><td colspan="12">5,93€</td><td colspan="12">6,21€</td><td colspan="12">6,33€</td></tr>
<tr><td colspan="12">2020</td><td colspan="12">2019</td><td colspan="12">2018</td><td colspan="12">2017</td><td colspan="12">2016</td></tr>
<tr><td colspan="60">Fixed credit of 1.996€</td></tr>
</table>

Applying the different scenarios lead to the following results: a minimum benefit/value of the 6 WMTS and 13 WMS of 355.646€ based on 16 tiles/WMS and 500 tiles/user session, and a maximum benefit/value for the same web services of 891.144€ based on 36 tiles/WMS and 326 tiles/user session (2019 figures). Moreover, the figures were analysed for different years: from 2016 to 2020. While the period 2016-2017-2018 showed a relative stable value, this value was raising quickly in 2019 and 2020 as can be seen from the figure below.

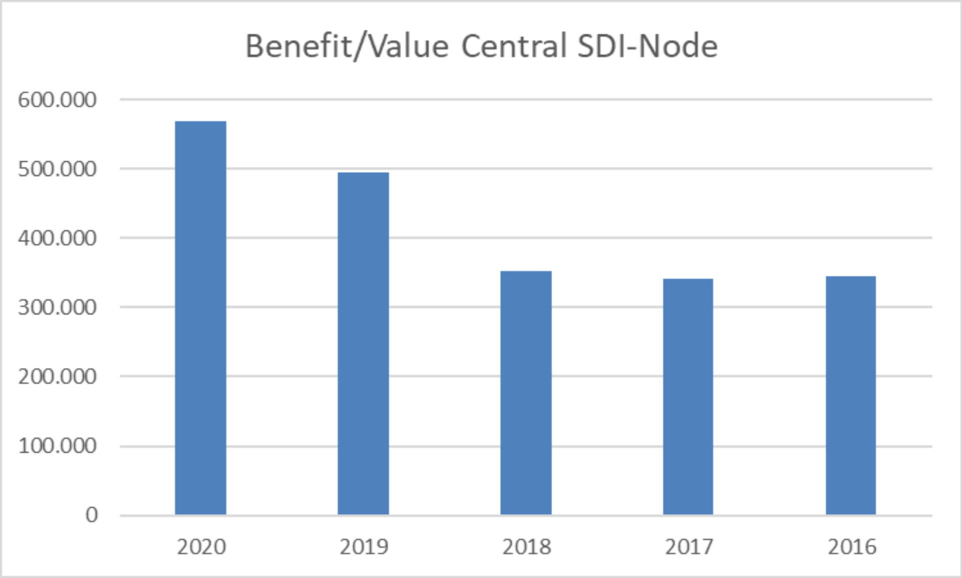

Figure 3: Evolution of the benefits of the SDI-node based on 24 tiles/WMS and 450 tiles/session

The figures allow to draw some preliminary conclusions and key observations.

- The factor that has the biggest impact on the benefits or value is the number of service requests. When these numbers are rising, then the benefits are rising as well.
- The richer the central-node is, i.e. the more WMTS and WMS there are, the more requests this will generate, and thus also more value. However, it should be noted that this depends on whether the services are 'used', this means are embedded in (new) applications.
- If the approach and methodology would be applied to the full Spanish SDI, taking into account key web services from other federal nodes and also the regional SDI-nodes, the value would of course even much bigger.
- From the more detailed figures, it becomes also obvious that some services generate more value than others. In fact four services are popping-out.
- It is also interesting to compare the results on the benefits with the estimated costs of the Spanish SDI: the annual Return on Investment (RoI) seems to be between 1/6 and 1/4.
- Two parameters are influencing the results mostly: the number of tiles per WMS map and the number of tiles per user session. They can be changed based on new insights.

Possible improvements to the model

Some issues were encountered during the application of the three Methods (A, B and C). They are briefly discussed here and potential improvements are suggested.

Applying Member State fee model to the Spanish SDI-node (Method A and C)

- An important parameter in most fee models is the intensity of use, which strongly determines the fees that actually need to be paid by different user organizations. In case of a higher total amount of requests, the fee per request will be lower. The current approach looks at the lowest possible fee and the average between the lowest and the highest possible fee. Alternative approaches can be considered to better take into consideration all possible fees and/or the actual importance of the different fee levels (i.e. which fee levels are most applied).

- Another relevant parameter identified in our study was the distribution of user organizations across type of users, since many countries have adopted a fee model in which specific user groups – government, research, education – need to pay no or a lower fee. In our current approach we deal with this parameter by working with different scenarios expressing different percentages of requests actually being charged for. Also here further refinements are possible.
- For the calculations of the value from downloads of data, we focused on a selection of three datasets. For an estimation of the overall value related to the downloads of data, it is important to take into consideration all datasets. An important challenge here – even with a small selection of datasets - is the identification of identical or similar datasets in other countries, as there always will be small differences between similar datasets in different countries (which also might influence the fee or value of the dataset).

Applying the Google Business Model to the Spanish SDI-node (Method B)

- The fact of using figures on number of requests of WMTS and WMS is logic: the more the services are used, the higher the value or benefits are. Also, calculating the benefits or value of just one node of the SDI based on key services seems acceptable.
- On the other hand, the approach tries to make figures on WMTS and WMS comparable, which is also acceptable (Google is also tiles-based). It should be noted however, that in the current approach we 'upgrade' or put a higher 'weight' on the WMS. One could also argue that you need to 'downgrade' or put a lower 'weight' on the WMTS.
- One could argue that you have to just use the request figures 'as-is', without recalculating. WMTS are often seen as more 'valuable' (more performant, providing a lot of information).
- The estimations for the number of tiles in a WMS map remains relevant but might need some more testing. Although several methods were used to come up with different values for this parameter, this could be further improved and checked.
- Also for the number of tiles in a user session, the values remain good estimates. However, as is the case for the parameter 'tiles per WMS map' this value will largely depend on the user, the way the WMTS is set-up, etc.
- Another element in the equation is the current assumption that a user session in a web mapping viewer corresponds (1-on-1) with a Google map load. It can be considered as a good proxy, but still we need to understand that a Google dynamic map is in reality a bit more complex than what is being done with a WMS and WMTS in the context of an SDI.
- Overall, all figures and the results of the calculations should be used with care, it is not hard mathematics, rather estimates.

Recommendations

The overall approach proved to be working relatively well and generates some interesting results. That does not mean improvements can be made to the model, not that this approach is 'final'. What follows are the most important recommendations emanating from the study: they relate to the data/information collection, the methodology and possible improvements, as well as how the resulting information can be used.

1. Extending the analysis from one SDI-node to other SDI-nodes;
2. Improving the analysis of apps and applications;
3. Getting better insights in the Google mechanism and business model;
4. Harmonized data collection on the use of web services in different Member States;

5. More information (including qualitative information) on charging mechanisms and fees;
6. More advanced and extended experiments will lead to better results.

Content

Table of figures

Table of tables

Table of acronyms

API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
BTN	Base Topográfica Nacional de España
CC BY	Creative Commons Attribution
CHF	Swiss Franc
CNIG-ES	National Centre of Geographic Information
CODIIGE	Executive Board of the Geographic Information Infrastructure of Spain
DGU	State Geodetic Administration of Croatia
DTM / MDT	Digital Terrain Model
DWG	Abbreviation for Drawing, Autodesk file type
ELF	European Location Framework
BE, ES, FI, FR, HR, NL, SE, SI	ISO abbreviation for Belgium, Spain, Finland, France, Croatia, Netherlands, Sweden and Slovenia
EU	European Union
GIS	Geographic Information Systems
GML	Geographic Markup Language
GRB	Grootschalig Referentie Bestand / Large Scale Reference Database
GT IDEE	Working Group IDEE
HRM	Human Resource Management
HTML	Hypertext Markup Language
IBERPIX	Visualizador de Mapas e imágenes
ICT	Information and Communication Technology
IDEE	Spatial Data Infrastructure of Spain (*Infraestructura de Datos Espaciales de España*)
IGN-ES	National Geographic Institute
INSPIRE	Infrastructure for Spatial Information in Europe

kn	Croatian Kuna
KPI	Key Performance Indicators
LiDAR	Light Detection and Ranging
KB/ MB / GB / TB	KiloByte/ MegaByte / GigaByte / TeraByte
MIG / MIG-T	INSPIRE Maintenance and Implementation Group (Technical)
MS	Member State
MTN	National Topographic Map (series) of Spain
N/A	Not Applicable
NMA	National Mapping Agency
OGC	Open Geospatial Consortium
OWS	OGC Web Services
PDOK	Publieke Dienstverlening Op de Kaart / Public Service on the Map
PNOA	National Plan for Aerial Orthophotography
REST(ful)	Representational State Transfer
ROI	Return On Investment
SCN	National Cartographic System
SDI / NSDI	Spatial Data Infrastructure / National SDI
SEK	Swedish Kroner
SIGN	Viewer of IGN-ES
SKU	Stock Keeping Unit
SLA	Service Level Agreement
SOA	Service Oriented Architecture
TCP/IP	Transmission Control Protocol / Internet Protocol
TIFF / .tfw	Tag Image File Format and .tfw file format
TMS	Tile Mapping System
URI	Uniform Resource Identifier
URL	Uniform Resource Locator

VAT	Value Added Tax
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
WMTS	Web Map Tile Service

1. Introduction

In this introductory section the background and context of the study are explained, and the objectives and scope defined.

1.1 Context and background

The National Centre of Geographic Information[2] in Spain (**CNIG-ES**) was created as an Autonomous Body by Law 37/1988 (article 122) under the Ministry of Transport, Mobility and Urban Agenda, formerly the Ministry of Development[3]. The Statute of the CNIG-ES, assigns, among others, the function of producing, developing and distributing of the products and services carried out by the National Geographic Institute (**IGN-ES**) and the Centre itself, as well as those of other official bodies of which it is a distributor.

The CNIG-ES is also responsible for coordinating the implementation of the INSPIRE Directive (2007/2 / CE) in Spain, and of the organization of the Spatial Data Infrastructure of Spain[4] (**IDEE**). From this perspective CNIG-ES has also the responsibility – through its Director - to participate in the INSPIRE Maintenance and Implementation Group (INSPIRE-MIG), and to chair the Executive Board of the Geographic Information Infrastructure of Spain (**CODIIGE**) and of the IDEE Working Group (GT IDEE).

The CNIG-ES has **four lines of activity** in the field of Geomatics, particularly related to web services serving geographic information, interoperability and ICT:

- To respond to the organizational and practical needs that arise throughout the implementation of procedures for the production of geographic data, metadata, web services and associated tasks in accordance with the INSPIRE Regulations and Rules;
- To co-ordinate, from a strategic and organizational point of view, with the rest of the members of the MIG all aspects of the INSPIRE implementation and maintenance process;
- To promote the transfer (of part) of the organizational solutions generated at European level during the application of the INSPIRE Directive to the Latin American environment;
- To lead the coordination and organization of IDEE, together with the other members of CODIIGE, both at a practical and technological level, as well as at the theoretical and strategic level.

In this context, the **calculation of cost-benefit balances** of a Spatial Data Infrastructure (SDI) node is currently one of the important research topics, as can be observed by

[2] https://www.ign.es/web/ign/portal/qsm-cnig

[3] It is currently regulated by the Royal Decree 1637/2009 of 30th of October (BOE N°271 of 10th of November), which modifies the Statute of the CNIG, approved by the Royal Decree 663/2007 of 25th of May (BOE N°134 of 5th of June), and by the Royal Decree 953/2018 of 27th of July (BOE N°183 of 30th of July.

[4] https://www.idee.es

reviewing the past and ongoing projects, scientific publications and conference communications on the subject (Barbero et al., 2019; Kruse et al., 2018). The issue is complex and far from being resolved, which affects in a negative way the strategic development of the Spanish SDI and IDEE in particular. In fact, the lack of a solid approach for calculating benefits and value of the Spanish SDI has also a direct impact on the collection and planning of resources for its implementation and maintenance, and hence guaranteeing its sustainability. The topic is of great interest both for the Spanish SDI, as well as for the Latin American and Caribbean SDIs and the implementation of the INSPIRE Directive in Europe.

1.2 Objectives and scope of the study

The major objective of this study is to **develop and test a methodology to estimate the economic benefits generated by the central SDI-node of Spain**, coordinated by the National Geographic Institute of Spain (IGN-ES). Benefits estimation is understood as an approximate calculation - as accurate as possible - in monetary terms of the value of the web services and data in the central SDI-node based on a set of objective considerations and criteria. The **central SDI node comprises all the SDI resources published on the web** by the same organization, IGN-ES, as coordinator of the Spanish SDI.

The benefits produced by documents, utilities, tools, links and communication channels are considered much smaller and even negligible than the benefits derived from the use of spatial data sets and services, therefore the study approximates the total benefits by the benefits of the use of geographic web services and geographic data. In this study the most used services, i.e. for visualization (**WMS and WMTS**), and the **datasets download** services implemented in the National Centre of Geographic Information (CNIG-ES) download centre[5] are taken into account. The contribution to the benefits of other types of services (e.g. WFS, WCS) is considered negligible and is therefore not in the scope of this study.

The study does not include other SDI-nodes than the IGN-ES one, so spatial datasets and services from other data custodians/providers of the SDI are not assessed.

The study is not a full-blown cost/benefits study either. In practice it means that the study only looks to the benefits (or value) side, not the costs side.

There are **two scenarios** that are investigated to this respect:

1) An estimate of the benefits of the Central SDI-node of Spain by comparing and applying data policies (and related fees) applied by some of the SDIs in the **Member States** that charge for the use of web services and/or data to the central Spanish SDI-node;
2) An estimate of the benefits of the central SDI-node of Spain by applying the **Google** charging or business model to the use of web services for visualizing.

Following, more specific objectives can be derived from the overall objective:

[5] http://centrodedescargas.cnig.es/CentroDescargas/index.jsp

- To investigate existing *approaches for monitoring the use of geospatial data through services* and for charging fees for accessing and using these data and services;
- To *compare these different approaches* and identify the key criteria applied for defining charging fees;
- To *apply the approaches* from other countries *to the SDI-node of Spain* in order to estimate the potential benefits of this SDI-node;
- To investigate how the *Google Maps system* and its components work and *how it can be compared with the use of web services for visualization* in the context of an SDI;
- To *apply the rules of the Google business model* to estimate the benefits in terms of value of the use of SDI visualization services;
- To *evaluate both methodologies* for estimating the benefits of an SDI.

1.3 Structure of the document

The document is structured as follows. **Section 1** consists of this **introductory section** including the background and context, and the objectives and scope of the study. **Section 2** explains the **approach and methodology** of the study: the general approach including key definitions of terms used, the methodology for quantifying the benefits or value of the central SDI-node of Spain, and the workflow and different steps followed by the study. **Section 3** provides a detailed description of the findings of the analysis of how the **Google business model** works and how a selection of **Member States** collects data on usage of their infrastructure and the data policy/policies they apply. **Section 4** links the practices and data from the Spanish SDI-node with those from the Member States and Google, by explaining the key parameters and how the calculations were performed, and by **discussing and interpreting the results** obtained. Finally, in **Section 5**, general **conclusions** are drawn and some **recommendations** are formulated.

2. Approach and methodology

In this section, the general approach for the study is explained, as well as the method for quantifying the benefits and the overall workflow for doing so.

2.1 General Approach

In the general approach, key definitions and terms used throughout the document are defined and explained. Moreover, the exact meaning of the central SDI-Node of Spain is clarified, as well as the general approach for the two parts of the study – the scenario in which the Spanish SDI is compared with licensing practices of some of the EU Member States and with the Google business model.

2.1.1 Key definitions and terms used

Application Programming Interface (API) - is a computing interface that defines interactions between multiple software intermediaries. It defines the kind of calls or requests that can be made, how to make them, the data formats that should be used, the conventions to follow, etc. It can also provide extension mechanisms so that users can extend existing functionality in various ways and to varying degrees. An API can be entirely customized, specific to a component, or designed based on an industry-standard to ensure interoperability. Through information hiding, APIs enable modular programming, allowing users to use the interface independently of the implementation (Wikipedia, 2020).

Data download – is occurring when a user is taking a copy of (part of) a dataset on their own or another computer. So the difference with WMS and WMTS is that here features are transmitted, not images. Different mechanisms can be used such as the OGC WFS, or Atom Feed. Different formats for data transfer might be used (e.g. GML). The size of the files will influence the complexity and performance of the download.

Data transfer – In Service Oriented Architectures, web services are transferring data over the web. This is not necessarily in the form of a copy of (parts of) datasets (data download), but might also be in the form of a map, a figure, an information record. Data transfer refers to all these kinds of exchange, also called message exchange (Josuttis, 2007). In the context of this study, data transfer is important in the sense that it provides an indication of the intensity of use of the Internet (network). Even if WMS/WMTS do not provide (a copy of) the data themselves, data are transferred in the form of e.g. images (which can be expressed in MB or GB).

Map Load – This is a term used by Google. A Google map load is counted when a map is initialized on a web page (Globema, 2018). User interaction with a map after it has been loaded (e.g. panning, zooming, switching map layers) does not generate additional map loads (Google, 2020). In that sense it can be seen as a kind of user session.

Request/Response - A message exchange pattern where a service consumer or client (usually an application) sends a request message and expects an answer. There are synchronous and asynchronous requests/responses (or request/callback message exchange pattern). In the latter, the service user does not block or wait for a response (Josuttis, 2007). Sometime this term is also used as a synonym for a service call, or service 'hit'. The number of requests is a key variable in this study and in the context of OGC Web Services (OWS) it refers to requests for a map (getMap), or part thereof (getTile), or for information about an object (getFeatureInfo).

Service Oriented Architecture (SOA) - There are various definitions for SOA. Some specify only that it is an approach for architectures where the interfaces are services. However, in a more specific sense, SOA is an architectural paradigm for dealing with business processes distributed over a large and heterogeneous network of existing and new systems that are under the control of different owners (Josuttis, 2007). The key concepts of SOA are services, interoperability, and loose coupling. The key components of SOA are the infrastructure, architecture, and processes. Web Service is not a synonym for SOA. Web Services are one possible way of realizing the infrastructure aspects of SOA. In the context of this study we only focus on a web-based SOA.

Transmission Control Protocol/Internet Protocol (TCP/IP) – is a standard Internet communication protocol that allows digital computers to communicate over long distances. The Internet is a packet-switched network, in which information is broken down into small packets, sent individually over many different routes at the same time, and then reassembled at the receiving end. TCP is the component that collects and reassembles the packets of data, while IP is responsible for making sure the packets are sent to the right destination (Rosencrance et al., 2021).

Tiles and Tiling – The OGC WMTS type of service is working with tiles and apply tiling schemas (OGC, 2010). These are pre-defined images of 2D maps. Tiling can be done in different ways and at different levels based on different resolutions. The clients will mosaic the tiles obtained from the server and then clip the set of tiles into a final image (Digital Globe, 2013).

Tile Map Service (TMS)[6] - is a specification for tiled web maps, developed by the Open Source Geospatial Foundation. The definition generally requires a URI structure which attempts to fulfil REST principles.

User – In the context of this study a user is defined as a person that uses one or more TCP/IP addresses to access applications and or web services over the web. The notion of user can also apply to an entire organization, called in this study user organisations. User organisations are also relevant in the context of data and service policies which usually apply to entire organizations, not individual users. Users can be known, e.g. when there is a registration system, but in the context of SDI's that is usually not the case. In general, one can state that we do not know the identity of users of an SDI. TCP/IP visits are often used as a proxy for users of a system. Unique TCP/IP addresses provide an indication of the number of unique users, while TCP/IP visits provide an indication of the number of user visits.

[6] https://wiki.osgeo.org/wiki/Tile_Map_Service_Specification

User session / user visit – A user (TCP/IP address) might access a portal or any other web application several times. A user session in this context is defined as the start of using the interface of a web application at a certain point in time to use the functions provided (e.g. visualize layers, querying spatial objects, panning and zooming …) and the end of using the interface by quit the application at a certain point in time. During such a session, the user can/will perform many requests, including WMS & WMTS requests.

Web Mapping application (client) – Is an application accessible via the web that makes use of data through web services and or API's. A geo-portal for example contains usually a web mapping application to showcase the geospatial data available in the portal. Other, more dedicated, applications might support particular work processes by combining and visualizing certain geospatial data layers together. In many web mapping applications WMS and WMTS are used so the application is requesting multiple getMap's. Each time the user is zooming, panning, etc. one or more requests might be sent to the server.

Web Map Service (WMS) – Is an interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The map is being prepared at the server-side. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc.) that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not (OGC, 2006). WMS can have different types of operations such as getCapabilities, getMap and getFeatureInfo. The figures about requests of a WMS are including any of those types of requests over a period of time (month, year). Most requests however will be of type getMap.

Web Map Tile Service (WMTS) - can serve map tiles of spatially referenced data using tile images with predefined content, extent, and resolution. The big difference with WMS is that the tiles are prepared/processed and stored beforehand, so no processing at the time of the request is needed. This makes WMTS very performant. The usage figures of WMTS reflect the total number of tiles requested, so each tile visualized corresponds to one request (OGC, 2010).

2.1.2 Defining the central SDI-Node of Spain

This study is focusing on the benefits of the central SDI-node of Spain. There are several interconnected concept here.

First, the Spatial Data Infrastructure (SDI) in a country might consist of several tightly or loosely interconnected SDI's corresponding to different levels of authority and/or thematic domains. For example, in Belgium, which is a federal state, there are 4 official SDI's which are loosely interconnected: the SDI in Flanders, Wallonia and Brussels reflect the regional level, while the Belgian Federal SDI represents the federal level. In other countries there also exist thematic SDI's such as in Germany or Romania to name just a few. In Spain, you have a similar situation: each of the 17 Regions has a more or less developed SDI and also the National level has a well-developed SDI, consisting of several parts. They are all very well interconnected.

In the context of this study we do not take into account the Regional SDI's, but looked at the national level of Spain.

Second, most SDI's form an extended network of interconnected organizations to share, exchange and use geospatial data. Different organizations might have different roles. This is illustrated in Figure 4: A SDI as a network of organization to access, share and use geospatial data. In most SDI's there is a coordinating body (or organization) that has the role to bring together different geospatial data providers, to collect user requirements and feedback, prepare and steer legal and institutional arrangements, etc. The network will always consist of a series of data providers (that might publish and distribute their own data), many user organizations that use the geospatial data in different contexts (they are often not know), and usually also several organizations that are both user and data provider (e.g. an environmental agency). Moreover, there might be organizations that are service providers, sometimes these are third parties (companies) that take the data from data providers and publish them on their behalf. Finally, there might be a dedicated so called 'geo-broker' that plays a central role by supporting data harmonization, publishing of the data in the form of one or more web services, developing and offering applications, including a central data portal and web mapping viewer. Sometimes the role of central coordinator and geo-broker are combined.

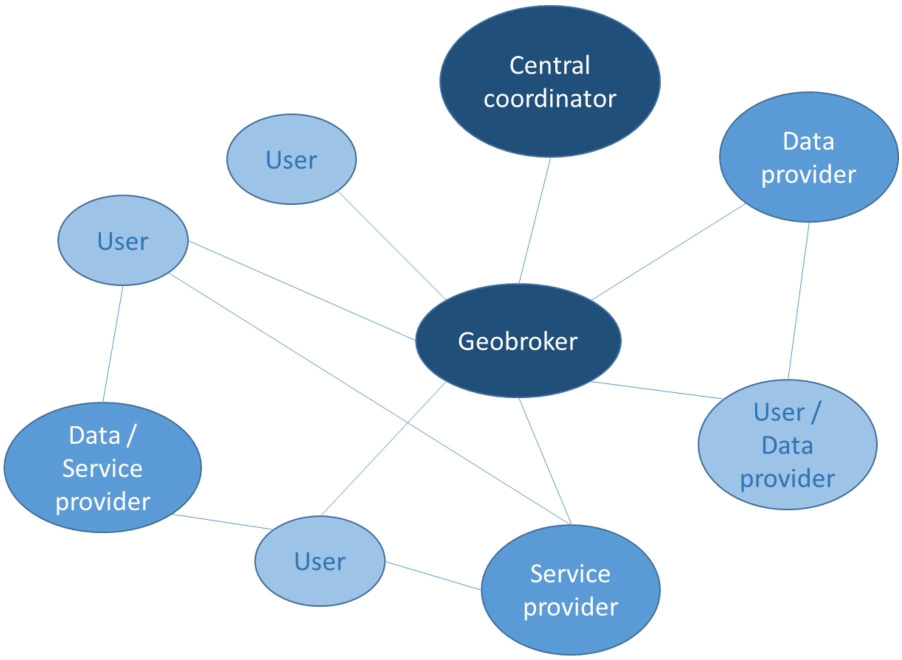

Figure 4: A SDI as a network of organizations (based on Vandenbroucke et al., 2009)

In the context of this study, we do not study all the data providers, but rather the central SDI-node which is coordinated by the CNIG-ES which provides and publishes many of the core geospatial datasets of the National Cartographic System (SCN)[7] used by many user organizations.

[7] The Geographic High Council (CSG) is the management body of the SCN. The SCN is the obligatory framework for action by the General State Administration with regard to mapping for all

Third, the SDI consist of many components, including the data, the services, together with their metadata, the geospatial and other standards that make them interoperable, but also the policy and institutional aspects, the organizational set-up, the aspects related to the people including Human Resource Management (HRM) and capacity building, etc. To describe, or estimate, let alone calculate the benefits of all these elements is a very complex tasks. Therefore, most of these components are not considered in the study.

In the context of the study we consider those components that are of direct importance to the user organization and individual users, i.e. the viewing services, mainly WMS and WMTS OGC web services that are embedded in many user applications, and the data that are mostly downloaded via atom feeds (WFS is hardly used).

In practical terms, the full list of WMS and WMTS, as well as the download figures of key datasets were analysed. This led to a restricted list of the most important (used) web services and a short list of key datasets as listed in Table 4.

Table 4: WMS, WMTS and datasets considered in the analysis

Type of resource	Service Name	Service URL
WMTS	*WMTS Cartografía raster* (Mapping at different scales)	https://www.ign.es/wmts/mapa-raster
	WMTS Mapa base de España (Vector information at different scales)	https://www.ign.es/wmts/ign-base
	WMTS MDT (DTM at different resolutions)	https://www.ign.es/wmts/mdt
	WMTS PNOA MA (Sentinel and orthoimagery PNOA)	https://www.ign.es/wmts/pnoa-ma
	WMTS 1º MTN50 (1st version of the national topographic map at 1 :50.000)	https://www.ign.es/wmts/primera-edicion-mtn
	WMTS Plano de la Villa de Madrid de Pedro Texeira (1656) (Texeira plane)	https://www.ign.es/wmts/plano-texeira
WMS	*WMS Camino de Santiago* (Way of Saint James)	https://www.ign.es/wms-inspire/camino-santiago
	WMS Cartografía raster (Mapping at different scales)	https://www.ign.es/wms-inspire/mapa-raster
	WMS Cuadrículas cartográficas (Geographical Grid Systems)	https://www.ign.es/wms-inspire/cuadriculas
	WMS Fototeca (photograms at different epochs and resolutions)	https://fototeca.cnig.es/wms/fototeca.dll

the Public Administrations that adopt it voluntarily as the model for cooperative action. It was established via Royal Decree 1545/2007

	WMS Información sísmica y volcánica (Seismological and vulcanology information)	https://www.ign.es/wms-inspire/geofisica
	WMS Mapa base (Vector information at different scales)	https://www.ign.es/wms-inspire/ign-base
	WMS Minutas cartográficas (MTN50 drafts (1915-1960))	https://www.ign.es/wms/minutas-cartograficas
	WMS MDT (DTM at different resolutions)	https://www.ign.es/wms-inspire/mdt
	WMS históricas del PNOA (historical orthophotos)	https://www.ign.es/wms/pnoa-historico
	WMS PNOA MA (Sentinel and orthoimagery)	https://www.ign.es/wms-inspire/pnoa-ma
	WMS 1º MTN50 (1st edition of the national topographic map at 1 :50.000)	https://www.ign.es/wms/primera-edicion-mtn
	WMS Redes geodésicas (Geodetic networks)	https://www.ign.es/wms-inspire/redes-geodesicas
	WMS Unidades administrativas (Administrative units)	https://www.ign.es/wms-inspire/unidades-administrativas
Data	National Topograhic Map (raster and vector) and the Topographic Database	
	Orthophotos	
	LIDAR 3D point clouds	

A total of 6 WMTS, of 13 WMS[8] and 3 datasets (download) are considered. They also form the basis for the calculations as will be explained in Section 2.2.

It is important to notice that geographical data and services in Spain are published under a standard licence CC BY 4.0[9].(See SCN[10]).

2.1.3 Comparing with practices in Member States and Google business model

The starting point is the central SDI-Node of Spain as described in Section 2.1.2. In order to estimate the benefits a comparison should be made with other SDIs and similar infrastructures. Therefore, two investigation lines are being explored: 1) practices in a

[8] The original list contained 8 WMTS and 22 WMS. Services for which there were no or incomplete usage figures were not taken into account (some services became obsolete or were new services). The four selected datasets are the ones that are most downloaded.

[9] Creative Commons Attribution license. This license lets others distribute, remix, adapt, and build upon your work, even commercially, as long as they credit you for the original creation. This is the most accommodating of licenses offered. Recommended for maximum dissemination and use of licensed materials. See https://creativecommons.org/licenses/

[10] http://www.scne.es/

selected set of Member States that charge for web services and/or data, and 2) the Google business model that is being applied to the Google maps environment.

2.1.3.1 Comparing with selected Member States

The selection of Member States must be based on a representative sample of European central SDI nodes, i.e. National Mapping Agencies (NMAs) who are charging for web services and datasets[11]. The sample needs to be representative, balanced and non-biased. As far as possible, Northern, Central Europe, Eastern and Mediterranean countries should be represented, with more and less developed SDIs, and any other categories that would make sense for this study. Particular attention was paid to the following points:

- Investigate whether it is necessary and makes sense to assign weights to the fees applied in each country depending on the cost of living;
- Apply the fee mechanisms of the selected Member States (with or without the weighting) to the Spanish figures in order to estimate the benefits or value of the Spanish central SDI-node;
- Identify possible reasons for the resulting figures obtained.

Based on the above mentioned criteria and taking into account that most Member States do not apply charges for the use of WMS/WMTS, and many of them do not charge for data downloads either, a pragmatic approach was followed. Based on a quick screening (desktop research) following list of countries was established.

Table 5: Countries (at least partially) investigated

Country	Characteristics
Slovenia	Charging for services and data
Croatia	Charging for services and data
Netherlands	No charging for services, nor for the data; extensive experience in monitoring and analysing service use
Finland	Charging for services and data
Switzerland	Charging for services and data
Sweden	Charging for services and data
France	Charging for services and data
Belgium (Flanders)	No charging for the services, nor for the data; extensive experience in monitoring and analysing service use

2.1.3.2 Comparing with the Google business model

The benefits of the central SDI-node might also be estimated by linking it to the published fee schema for the usage of Google mapping API's which are functioning in the cloud. Several Google API's are available, of which certainly the Google dynamic mapping API is relevant and comparable with how SDI web services are used in web mapping applications. Google has considered an economic value for each dynamic map served by means of its

[11] The sample might be different or not for services and data.

API[12]. Google dynamic maps are considered interactive objects: the user can freely pan, zoom or switch map layers[13]. So a dynamic map is a complete user session in the viewer. This part of the study needs to investigate what is the equivalence between a user session using a web mapping viewer consuming WMS and WMTS, and a user session using dynamic Google maps. More particularly attention must be paid to following topics:

- Investigate how Google sessions and traditional user sessions in web mapping viewers can be compared;
- Investigate the average equivalent rate of maps (WMS) and tiles (WMTS) in order to be able to compare both types of services. A first rate of 1 map (in a WMS) equals 24 tiles (in a WMTS) had to be checked and verified;
- Investigate how many WMTS tiles are viewed on average by a user during a Google session and/or during a web mapping viewer session;
- Apply the Google fee mechanism on the figures from the central SDI-node in Spain, using different scenarios for user intensity foreseen in the Google business model;
- Draw some conclusions on the results obtained.

2.2 Quantification of benefits

The study aims to try quantification of the benefits of the central Spanish SDI-node. It is clear that there is no direct / straightforward way to do this, but that different pieces of information should be collected and connected, and that some assumptions should be made.

2.2.1 Figures on the use of services, downloads of data

2.2.1.1 Figures on the use of services

The basis for quantifying benefits of the central SDI-node are the figures on the use of WMS and WMTS (number of requests), and the download figures of key geospatial datasets. The IGN-ES collects systematically this type of information. Work with the Member States would ideally deliver similar information in order to compare the figures.

Table 6: Information available regarding the services, central SDI-node ES

Key information	Additional information
Service Name	
Service URL	
Number of Requests / Month	Data Transfer (expressed in GB)[14]
Number of Requests / Year	Data Transfer (expressed in GB)[15]

[12] https://cloud.google.com/maps-platform/pricing/sheet/

[13] https://www.globema.com/short-guide-understanding-google-maps-platform-products-maps/

[14] Not available for all months.

[15] Not available for all months.

The figures should be interpreted taking the following elements into account:

- For the number of requests, no distinction is made between 'successful' and 'non-successful' requests. It means that some of the requests might not have resulted in a response to the client. However, this amount is considered to be very low and thus will have no influence on the results.
- The number of requests includes all kind of operations. For WMS this might include the getCapabilities, getMap, getFeatureInfo operations. For WMTS this might include getCapabilities, getTile, getFeatureInfo operations. For the calculations all requests are taking into account since the majority of the requests are assumed to be of type getMap and getTile. The number of getCapabilities operations is assumed to be very low.
- The total number of requests is taken into account for the calculations, so no distinction is being made between internal and external usage (information that is available for Spain).
- The information about the amount of Data Transferred (the total size of all the pictures, not the data itself) is only indirectly taken into account in the calculations.

Some of the Member States might collect information on the use of the web services in different ways. During the interviews information was asked for on how they collect information, e.g. including the tools used to do so (JMeter, Spatineo …). Some countries might have monthly data as is the case for Spain, others might collect less detailed data and have annual data or monthly averages. The data for Spain are collected and available for several years. In the study we used the data for the period 2016-2020 (included).

2.2.1.2 Figures on downloading of data

For the period of January 2018 – June 2019 CNIG-ES provided data for 83 geospatial dataset: number of files (18.251.378) and total size of files downloaded (1.221.364,33 GB). The datasets include raster and vector data, point data, and cover all possible themes: from topographic maps, over LIDAR points, up to DTM's, orthophoto's, thematic maps such as hydrography, transport network, land cover, urban atlas … Datasets might cover the whole country, or particular regions. The most used datasets are:

Table 7: Most downloaded datasets, central SDI-node ES

Data set	Total files downloaded
LiDAR 1st coverage (2008-2015)	7.146.092
LiDAR 2st coverage (2015-now)	3.173.372
National Topographic Map at 1:25.000 (MTN25 raster)	1.714.520
National Topographic Base at 1:25 000 (BTN25)	824.341
National Plan for Aerial Orthophotography (PNOA) (Most recent PNOA orthophotos)	564.803
National Topographic Map at 1:50.000 (MTN50 raster)	535.861
Digital Terrain Model, DTM05– (MDT05)	491.282

2.2.2 Figures on fees and charging models

Spain itself follows an Open Data policy (CC BY 4.0 license), hence does not charge for web services, nor for the data themselves.

The situation in some of the Member States is different. Therefore, information should be collected on fee mechanisms and fees in place in Member States. Distinction is being made between fees and fee mechanisms for web services, and fees and fee mechanisms for obtaining the datasets themselves (downloads). Not only the fees themselves are relevant, but also how the fee mechanisms works: are the fees per service request, or a fixed amount depending on the type of user, the type of service, the amount of data transferred, etc. In Section 3.1, the situation in some of the Member States is described.

Also the charging mechanism that Google applies is part of the analysis. This is done in detail in Section 3.2.

2.2.3 Use of qualitative information

Besides the quantitative information to be collected, also qualitative information must be collected in order to understand the methods and policies applied, the reasons behind the choices and even some elements of appreciation and evaluation. This qualitative information will also help when interpreting and understanding the results of the calculations.

2.3 Workflow

In this sub-section, the overall work flow for the two parts of the study – comparison with Member States practices and comparison with the Google business model – is first schematically represented and explained. Then the way the information on practices in other Member States was collected is described as well as how the figures were analysed and interpreted.

2.3.1 Description of the workflow(s)

The work to be performed is split in several parts. First there is the analysis of the use of the web services (WMS and WMTS) and the estimation of the benefits. The workflow for this part of the work is shown in Figure 5: Workflow for estimating benefits of WMS & WMTS. Second, the benefits or value of the core datasets must be estimated as well. Figure 6: Workflow for estimating benefits of data (downloads) shows this second part of the work.

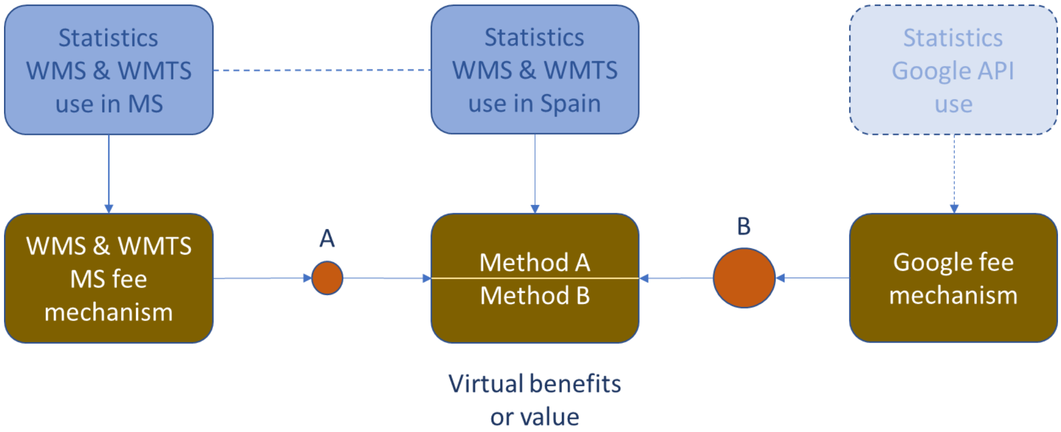

Figure 5: Workflow for estimating benefits of WMS & WMTS

For calculating and analysing the benefits of the web services, two methods are applied. Method A uses the information on the fee mechanisms applied in the Member States to the WMS & WMTS statistics of Spain. This starts from some assumptions and requires some parameters to be applied, but is relatively straightforward since both environments are similar, i.e. they use the same technology (hence the small red circle). Method B tries to link the Google fee mechanism to the Spanish WMS & WMTS use statistics. For this method, several assumptions and parameters need to be taken into account because the Google and SDI environments are not the same (hence the bigger red circle). Method A and Method B are detailed in Section 3.

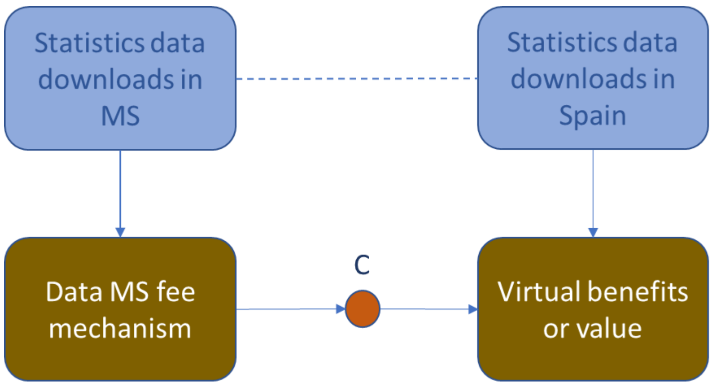

Figure 6: Workflow for estimating benefits of data (downloads)

For calculating and analysing the benefits of the data itself, only a comparison with the fee mechanism in some of the selected Member States is possible. Method C will also require to apply some parameters applying those on the download figures of the Spanish central SDI-node. Method C is explained in Section 3 in more detail as well. Important to notice is that at MS level the applied fee models often address both services and data downloads, so some parts of the discussion of method A and method C are combined.

2.3.2 Collection of the information from other Member States

For the collection of data and information on practices in other Member States, we took into consideration seven different Member States: Slovenia, Croatia, Netherlands, Finland, Switzerland, Sweden and France.

Except for France, where we limited our data collection efforts to desk research, the data collection procedure with the six EU countries consists of five main steps:

1. Explorative interview to better understand practices and experiences in collecting, managing and using use statistics and in calculating and charging fees for accessing data and/or services;
2. Provision of available information on use statistics and on fees charged by the interviewees, through sharing relevant webpages, reports, legal documents, policy documents, studies and statistics;
3. After validation of the available information and the explorative analysis, some interviewees were contacted to clarify particular issues and/or provide additional information;
4. Webinar with all countries/participants to discuss the results of the study *(planned to be held in 2021).*

The interviews and discussions with the country experts were focused on the two central topics of the study: the data/services access and use statistics and the fees for accessing data/services. These interviews can be considered as semi-structured interviews. A set of guiding – open - questions was provided to the interviewees prior to the interview and used as the structure for the interview, but during the interviews also other relevant topics were addressed. An overview of the topic list is presented below.

Box: Interview topic list

1. Questions/discussion on access statistics:

- How is your country collecting statistics on the number of hits/users/downloads (frequency, method)?
- Could you briefly describe the approach for collecting these statistics?
  - *Which level of detail?*
  - *Which statistics?*
  - *Do you analyse the user data? Did you learn particular lessons? If so, which lessons did you learn?*
  -

2. Questions/discussions on access fees:

- Is your country currently asking fees for accessing data and/or services?
  - *If yes, which fees for which data/services/applications/…?*
  - *How is the charging organized: per service request, per access (user session), overall fee for multiple access … ?*
  - *Does the fee-mechanism discriminate based on volumes of data/number of tiles/type of users…?*
  - *Do you analyse revenue streams from this fee-system, analysis of successful services/applications, datasets …?*

The information and data collected through the interviews was used to prepare a country report for each country. Afterwards, additional data and information collected was added to these reports, to get a complete picture of the status in each country.

2.3.3 Analysis and interpretation of the figures

The analysis and interpretation of the figures related to the other Member States is done in three different stages:

- First, an analysis was done at the level of each Member State, with the aim to provide a full understanding of how each of the Member States is dealing with monitoring the use of its data and services and especially with charging fees for accessing and using data and services.

- Second, a comparison was made of the different approaches/figures between the different Member States, to discover similarities and key differences between the different Member States (and also Spain).

- Third, an investigation was made of what it would mean if we would apply particular approaches/figures to Spain, based on the data available on the use of different datasets and services.

The analysis and interpretation of the application of the Google business model is also done in several steps:

- First, the Google mapping products are analysed and the relevant one(s) are selected. The related fee mechanism is analysed as well in this first step and missing information is collected from the Google commercial department.

- Second, some transformation parameters are identified and analysed: 1) the number of tile requests corresponding to one WMS request; 2) the number of tiles that goes in one web mapping user session and 3) the number of Google map loads that go in one user web mapping session. These parameters are no ‘hard’ and ‘fixed’ figures. To work with realistic figures several approaches were followed: i) the experience of IGN-ES was taken into account; ii) the opinion of experts was asked; iii) some simple experiments were carried out and/or iv) some indirect calculations were performed.

- Third, an investigation was carried out to link all the pieces and to estimate the benefits or value of the WMS/WMTS of the Spanish central SDI-node applying the Google charging mechanism.

Section 3 explains in more detail these different steps, while Section 4 provides and interprets the figures resulting from the calculations.

3. Detailed description of findings

This Section provides a detailed description of the findings on the practices in the selected Member States and the functioning of the Google business model.

3.1 Analysis of the practices in the Member States

The analysis of the practices with regard to the collection of information on web services and data downloads, and the data policies and (eventually) also the fee mechanisms is based on the information collected during the 7 interviews. The interview reports are annexed to this report.

3.1.1 General findings on data and service policies

When comparing the different approaches on monitoring the use of services and the download of data some important observations can be made regarding the key differences and similarities between countries. In this sub-section, we briefly summarize these key differences and similarities.

1. All the countries involved in the study have experience in collecting and using statistics on the use of their services. Statistics are collected at the level of the entire infrastructure or platform, for particular datasets and/or services, and in some cases also at the level of individual user organizations. For the collection of these statistics the countries rely on various tools, including open source solutions, commercial solutions such as Spatineo[16] and also data provided via Google Analytics[17].

2. The reasons for collecting and analysing the statistics are similar across countries. In general, the statistics provide information on the status and performance of the infrastructure. They allow to report on the status – of the infrastructure or particular datasets/services – to other stakeholders, such as data owners, but also decision makers. It's also a tool to better communicate with and support of users, and improve the services delivered to these users. Statistics are used to gain insights into needs for new services or improve the performance of existing services.

3. There are important differences in the extent to which these data are further analysed and used, and the extent to which this happens in a planned and systematic manner. Making the data ready for analysis requires some processing, which in some countries is done regularly (e.g. monthly, quarterly, yearly), other countries know that the data are available, and can be extracted and processed (and analysed) in case this is needed.

4. Another difference is the extent to which these data are made available to the public. Some countries systematically make available the statistics (and related reports) via their platform, others rather include a set of key indicators in annual reports of the

[16] https://www.spatineo.com/

[17] https://analytics.google.com/analytics/web/provision/#/provision

organization or the infrastructure. Other countries only use the statistics for internal purposes.

A more detailed discussion of statistics available in some countries is presented in the next sub-section. Since the collected and presented data can refer to different levels, it is important to be cautious in comparing the statistics of different countries. In the next sub-section we include some statistics of different countries, but there are some differences in the scope of these statistics. Some statistics deal with all the services and/or data made available through the central – national – platform, other are limited to the data and services of a single organization.

3.1.2 Data on the use of services and web applications

This section briefly describes the available statistics on the use of geospatial data and web services in the selected European countries. We focus on the countries for which statistics are publicly available or have been shared by the contact persons directly after the interview. These include the Netherlands, Sweden and Switzerland.

3.1.2.1 Netherlands

In the annual reporting on the performance of the PDOK platform, a set of key performance indicators is used to measure and monitor the evolution through time. PDOK ('Publieke Dienstverlening op de Kaart') is the geographical open data platform of the Dutch government. PDOK provides geo web services for many Dutch governmental organizations, for instance Kadaster, CBS, RIVM, Rijkswaterstaat and many more. The portal is hosted and operated by the Kadaster.

The following indicators are included in the statistics made available on the performance of PDOK: number of datasets, number of view and download services, total number of service request (annually), average number of service requests (monthly) and availability of the services.

Table 8: Key figures on datasets, services, requests and availability, Dutch NSDI

	2015	**2016**	**2017**	**2018**	**2019**
Data sets (#)	91	106	126	157	192
View and download services (#)	257	304	344	415	505
Service requests (#)	2,1 billion	4,4 billion	6,3 billion	10,5 billion	14,4 billion
Monthly service requests (average #)	175 million	367 million	525 million	875 million	1,2 billion
Availabilty of the services (average % of the time)	98,50%	99,29%	99,14%	99,49%	99,61%

Since 2015, the Netherlands also prepares and makes available quarterly reports on the access of the PDOK services via the PDOK website[18]. These quarterly reports consist of the access statistics per service and a summarizing report in which also new developments on the platform are discussed. The reports discuss aspects such as the total number of service requests on the platform, the most often used services and the availability of the platform/services.

An extract from the 2019-Q4 statistics sheet, is presented in Figure 4. It should be noticed that the services are structured around the underlying data, with separate statistics for each type of service and also totals per dataset.

The quarterly sheets also contain charts comparing the number of requests per dataset and per data provider. For internal use, some additional - more detailed - statistics are collected and used, in which also TCP/IP-information is used to categorize users and also the use of services by particular users/applications is monitored closely.

Som van aantal	Kolomlabels			
Rijlabels	**2019-10**	**2019-11**	**2019-12**	**Eindtotaal**
AAN	**3 546 619**	**3 485 001**	**3 469 256**	**10 500 876**
atom	3 288	2 802	1 791	7 881
extract	45	34	26	105
ows	9	1	1	11
tms	10 517	11 392	5 188	27 097
wcs	4	1	1	6
wfs	29 605	22 092	22 054	73 751
wms	3 430 009	3 362 862	3 369 697	10 162 568
wmsc	3			3
wmts	73 139	85 817	70 498	229 454
Administratieve Eenheden (INSPIRE geharmoniseerd)	**78 615**	**77 488**	**60 527**	**216 630**
atom		1		1
ows	5			5
wcs	1	1	1	3
wfs	4 181	3 289	7 312	14 782
wms	74 427	74 197	53 214	201 838
wmts	1			1
Adressen	**402 020**	**328 688**	**280 171**	**1 010 879**
atom	25 354	26 355	22 336	74 045
extract	979	731	620	2 330
ows	15	67	22	104
wcs		13		13
wfs	147 082	115 367	96 621	359 070
wms	228 461	185 997	160 412	574 870
wmsc	2			2
wmts	127	158	160	445

Figure 7 Snapshot of the published statistics for services per dataset, Dutch NSDI

3.1.2.2 Sweden

The data and statistics collected in by the Swedish Mapping, Cadastral and Land Registration Authority are similar to the ones available for PDOK in the Netherlands. However, in Sweden, these statistics are not made available publicly and only cover the services of the Swedish Mapping, Cadastral and Land Registration Authority. Another key

[18] See: https://www.pdok.nl/rapportages

difference is that users have to register for accessing most of the data and services, which allows the collection of more detailed statistics at user group level.

In its annual report, the Swedish Mapping, Cadastral and Land Registration Authority uses a 'Supply Index' (*'Leveransindex'* in Swedish) to monitor and show the amount of geospatial data it supplies to society. The index takes into consideration different types of access, such as view services, direct access services, downloads of data (automatic or manual) and real-time location services.

The User statistics sheets (in excel format) contain statistics on requests/hits since 2015, and also provide a series of summarizing charts. The request statistics are categorized into three main groups: view services[19] (or display services), direct access services and downloads. For each specific service or dataset, statistics are made available for different types of users.

Figure 6 shows the evolution of the number of requests since 2016, taking into account the total number of requests per month. An increase can be seen from 166 million requests in January 2016 to 1.061 million requests in October 2020.

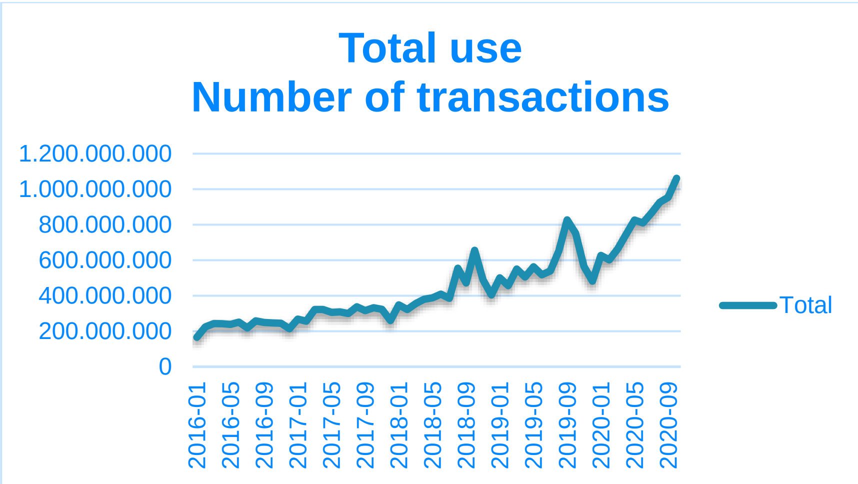

Figure 8 Evolution of the number of requests for services of the Swedish Mapping, Cadastral and Land Registration Authority ('16-'20)

3.1.2.3 Switzerland

Swisstopo[20], the Swiss Federal Office of Topography, communicates on the performance of its SDI by regularly releasing annual statistics on some key performance indicators of the infrastructure. Among these key indicators are the downloads of data via the portal (data.geo.admin.ch) and the requests to the WMTS and WMS. More detailed statistics are available and are used for the preparation of – internal – annual reports on the status and performance of the infrastructure.

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[19] The term view service is used in the context of INSPIRE. These can be e.g. WMS or WMTS.

[20] https://www.swisstopo.admin.ch/

The statistics on the download of spatial data allow to show the evolution in terms of number of downloads and total volume of downloads since 2013. In 2019, there were 43 million downloads, for a total size of 21 TB. Compared to the year before, the download of data increased with 85%. Five years ago, the number of downloads was around 1,1 million, with a total size of 0.6 TB.

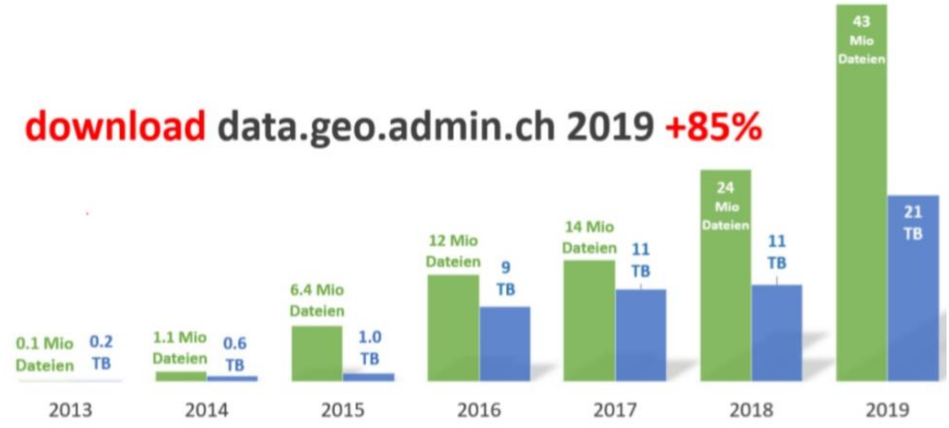

Figure 9: Evolution of the number and volume of downloads, Swiss NSDI ('15-'19)

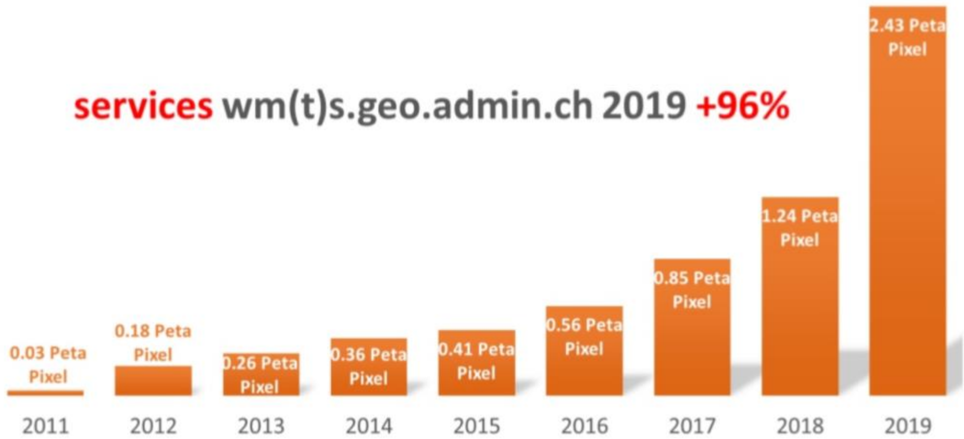

Figure 10: Use of the WMS and WMTS in terms of Peta Pixels, Swiss NSDI ('11-'19)

The use of the WMS and WMTS services is expressed in terms of Peta Pixels. An increase of 96% can be seen for the requests at the services in 2019, compared to 2018: see Figure 10: Use of the WMS and WMTS in terms of Peta Pixels, Swiss NSDI ('11-'19).

An interesting practice implemented by Swisstopo is its reporting on the performance of the infrastructure through an online dashboard, in which up-to-date information is provided on a set of key performance indicators[21]. Among these indicators are the number of users (daily, monthly, yearly), the number of requests for different services, the number of datasets and also the response time and uptime of the services (see Figure 11: Snapshot of the dashboard with Key Performance Indicators (KPI), Swiss NSDI).

[21] See https://cms.geo.admin.ch/stats/dashboardV002.html

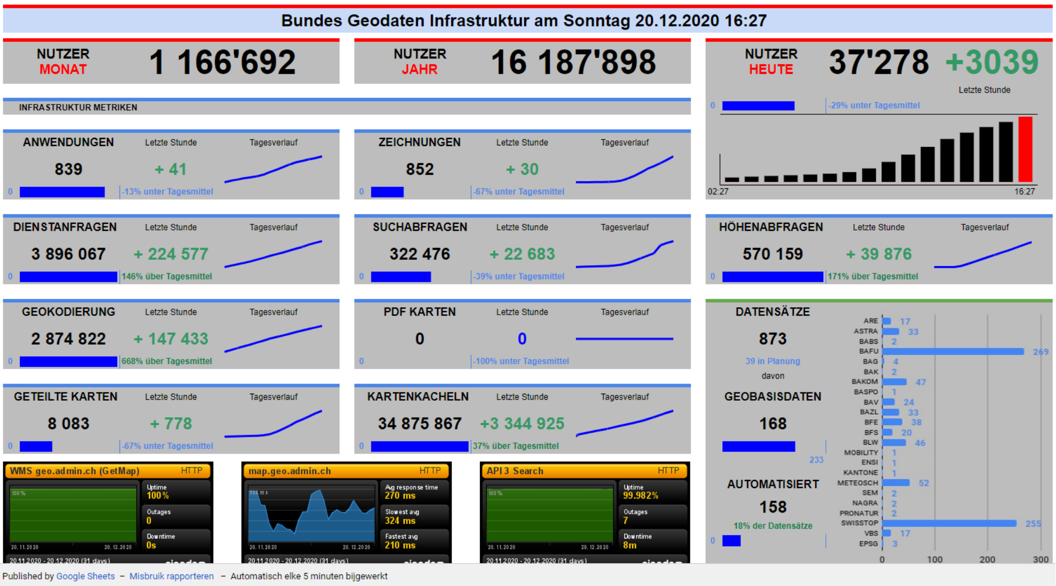

Figure 11: Snapshot of the dashboard with Key Performance Indicators (KPI), Swiss NSDI

3.1.3 General findings on charging for the access to data and services

The second aspects studied are the approaches for charging for geospatial data and services in the different countries. The information collected for each of the countries in the study shows some important differences and similarities between the different countries.

An important finding is that the majority of the organizations involved in the study, which all can be considered as mapping agencies, still charge for the use of services and the download of data. In this way, they are different from the CNIG-ES and IGN-ES in Spain, which makes it data and services available free of charge. From the seven other countries involved in the study, this is also only the case in the Netherlands, which also adopted an open data policy for all its data and services. Also in Slovenia an open data policy is in place for most of its data and services. Only for some high-quality services and viewers, users need to register and pay a – very small – registration fee.

Charging policies are evolving. Important to notice is that the Netherlands are considering to start charging for the use of its services from 2021 onwards. Fees will be put in place, mostly for the very large users of services. In Switzerland the shift towards a full open data policy will be made in 2021. This means that currently fees are still in place for accessing data and services, but this will change soon.

Fees for obtaining the data (download) in most countries are determined for each data set separately, although most mapping agencies use a set of standard fees. For access to WMS and WMTS, countries usually make no distinction between different services. Standard fees are determined, which in several countries are dependent on the number of requests. The fee per request often is lower in case of a higher number of requests. Only in Sweden, there are different prices in place for different types of services.

3.1.4 Country approaches on charging for data and services

In this section we provide a brief overview of the approaches on charging for obtaining the data and using the services in the different Member States.

3.1.4.1 Netherlands

All geospatial data and services on PDOK, the central portal of country-wide geo-information in the Netherlands, are openly available. No fees are asked for accessing and using these data, but plans exist to charge fees for accessing services in 2021, especially for very big users of these services.

3.1.4.2 Slovenia

In general, geospatial data and services are freely accessible and available. However, certain services, for which the Surveying and Mapping Authority guarantees the availability and provides user support, are only accessible for registered users. The costs of registration are defined in the *"Rules on the conditions and method of computer access to data from records and geodetic databases"* (Official Gazette of the RS, No. 25/2008 and 10/2011), which state that the user pays a tariff of 75 euros and value added tax for registration. For state administration bodies and judicial bodies, registration is free of charge.

Revenues collected in this way are very limited. Since 2010, approximately 52.000 EUR has been collected, on average around 4.250 EUR is collected yearly.

3.1.4.3 Croatia

A legal framework (Regulation) is in place determining the access to the data and services from the State Geodetic Administration (DGU). For downloading data and accessing WMS, a – yearly – agreement is needed with DGU. Although some public WMS can be accessed free of charge, better performing WMS are delivered through Service Level Agreements (SLA) with individual organizations. User organisations pay an annual fee, and DGU ensures the performance of the services. Fees are determined in the *"Ordinance on determining the amount of actual costs of using data from state survey documentation and real estate cadastre"* (OG 59/2018 (July 4, 2018)). Annex I of this Ordinance contains the fees for directly obtaining (downloading) and using data, Annex II contains the fees for accessing data through network services.

Annex I – on the fees for downloading and using data - is structured around different types of data, and covers both digital and analogue data. Among the types of data covered in the Ordinance are data on geodetic points, aerophotogrammetric data and images, orthophotos, the Croatian Basic Map, detailed topographic data and maps, the digital relief model, administrative borders and cadastral maps. Table 9 provides an overview of the fees applicable to some key datasets:

Table 9: Fees for datasets in Croatia

Data	Data format	Fee
Orthophoto map - colour	TIFF + TFW + DWG	19.90 EUR per sheet
Croatian Basic Map (1:5000)	TIFF + TFW	13.27 EUR per sheet (100.00 kn)
Topographic Map (1:25000)	TIFF + TFW	13.27 EUR per sheet (100.00 kn)
Topographic Map (1:100000)	TIFF + TFW	9.95 EUR per sheet (75.00 kn)

Digital height model (DMV) with resolution of 25 x 25m	Digital ASCII	6.63 + 0.027 EUR per Ha (50.00 + 0.20 kn /Ha)

Annex II entails the fees for accessing different types of **network services**[22], including also Web Map Services (WMS) and Web Map Tile Service (WMTS). Fees for accessing and using these services for a period of 1 year are:

- 6,000.00 kn (796.83 EUR) for WMS
- 4,000.00 kn (531.22 EUR) for WMTS

Important to notice is that these fees should be considered as standard fees, but specific coefficients are used to calculate the actual fee for the use for particular purposes:

- For the use for scientific and/or educational purposes, fees should be multiplied by factor 0.1, and in case data are published as part of the scientific research by factor 0.3;
- For public disclosure of the – original – data, fees should be multiplied by factor 1.3;
- For the production of derived products, different coefficients are in place, which are different for analogue and digital products and depend on the number of copies / licenses. Fees should be multiplied by – at least – factor 1.3. For the production of digitally derived products the fees will be multiplied by factor 5, in case of more than 50.000 – sold - products or licenses;
- For the use of orthophotos, the Croatian Base Map and topographic data, coefficients are used to calculate the total fee, with lower fees per unit in case multiple products are bought.

In total approximately 330.000 EUR is collected yearly through revenues from selling data licenses and for providing access to services.

3.1.4.4 Sweden

In Sweden, there is a specific document to inform interested customers about the charges and delivery terms of the Land Survey. The document is divided into different sections depending on the means of delivery and the type of information. The fees set out in that document are laid down in the Lantmäteriet's regulations on charges for basic geographic information. There's a separate section on accessing data via view services, while prices for downloading data are structured and presented per dataset.

For the standard fees for data, a distinction is made between two models, i.e. an annual fee model and a one-off fee model. In the annual fee model, the license fee is paid annually and in advance. The annual fee grants the right to use the service and receive updates, against a delivery fee. In the one-off fee model the license fee is paid at a single point and confers an unlimited right of use for a specific period. Overall, fees under the one-off fee model are around 4-5 times higher than fees under the annual fee model. For the purpose of this study, we focus on the fees under the annual fee model. The applicable fees for some relevant key datasets are presented in Table 10.

Table 10: Fees for some of the core datasets, Swedish NSDI

Data	Fee	Maximum fee

[22] The term network services is used in INSPIRE and covers among others view service, download and discovery services. In practices these are WMS/WMT, WFS (or Atom Feed) and CSW.

Ortho-images	1.39 EUR per km² (14 SEK per km²)	141 665 EUR (1 430 000 SEK)
Laser data NH	0.2 EUR per km² (2.00 SEK per km²)	38 638 EUR (390 000 SEK)
Map 1: 10 000 with cadastral breakdown	0.09 EUR per km² (0.90 SEK)	12 403 EUR (125 204 SEK)
Map 1: 10 000 with road names	0.043 EUR per km² (0.43 SEK per km²)	7 453 EUR (75 242 SEK)

Also for the access to WMS and WMTS services, two models are in place. Users can pay a fixed annual fee (per service) or fees per request. Table 11 shows the fixed annual fee for each of the WMS and WMTS services that already are operational.

Table 11: Fees for the use of WMS and WMT, Swedish NSDI

Data	Type	Fixed annual fee
ELF Base Map	WMS	12 383.36 EUR (SEK 125 000)
Real estate information service	WMS	11 577.45 EUR (SEK 116 865)
Historical orthophoto	WMS	0 EUR (SEK 0)
Hydrography Inspire	WMS	1 447.07 EUR (SEK 14 607)
Digital terrain model	WMS	5 250.54 EUR (SEK 53 000)
Orthophoto	WMS	155 534.99 (SEK 1 570 000)
Topographic raster map (aggregated)	WMS	8 222.55 (SEK 83 000)
Topographic raster map (layers)	WMS	12 383.36 EUR (SEK 125 000)
Buildings	WMTS	4 953.34 EUR (SEK 50 000)
Topographic data (1:10000)	WMTS	24 766.72 EUR (SEK 250 000)

For the fees per request, the services are categorized into three fee levels. Overall, services under level 1 have the highest fee, services under level 3 the lowest. For all services the fees are lower in case of a higher number of requests. Table 12 presents the three fee levels, the services under each of the levels and the lowest and highest fee for each level.

Table 12: Fee levels depending on intensity of use, Swedish NSDI

Fee level	Fees	Services
Fee level 1	Between 0.63 and 0.014 EUR per transaction (SEK 6,42 — SEK 0,143 per transaction) (for 500 - 1 000 000 transactions with image size 500 x 500 pixels).	Ortho-photo view, Ortho-photos annual, Ortho-photo IR yearly
Fee level 2	Between 0.14 and 0.0032 EUR per transaction (SEK 1,43 — SEK 0,032 per transaction) (for 500 - 1 000 000 transactions with image size 500 x 500 pixels).	ELF base map, Real estate breakdown, Topographic web map, Topographic web map Display, layered, Topographic web map, cache, Building, Real estate breakdown, Marking-regulating provision, ,Rights Visit,
Fee level 3	Between 0.032 and 0.00072 EUR per transaction (SEK 0,33 — SEK 0,0073 per transaction) (for 500 - 1 000 000 transactions with image size 500 x 500 pixels).	Digital terrain model, Plans, provisions and rights, Hydrography Inspire

Also in Sweden, the proposed fees are the standard fees, and coefficients are used to calculate the exact fees depending on a series of factors:

- For public use of data, the number of users is taken into account. In case the number of users within an organization is below 20, the fees will be reduced.
- For non-commercial use of the data, the applicable fee is the license fee x factor 0,1.
- For research, education and cultural use, no license fee is asked for a large group of data and services. In some cases, delivery or processing fees still might be applied.
- For state authorities which are not enterprises, no fees are charged.

Approximately 23.62M EUR is collected yearly through revenues from data and services.

3.1.4.5 Switzerland

Also in Switzerland, different approaches are in place for calculating and charging fees for access to data and services.

Fees applicable to the (download of) data are determined in the Ordinance of 20 November 2009 on the emoluments of the Federal Office of Topography. This Ordinance contains the unit prices of the basic fee and several discount coefficients. Table 13 shows the unit price for various types of data.

Table 13: Fees for different types of data, Swiss NSDI

Type of data	Unit	Price (EUR)
Aerial photos	Megapixel	0.14
Satellite images	Megapixel	0.14
Orthophotos	Megapixel	0.14
Topographic model of the landscape (Scaling > 1: 100,000)	Surface in km²	0.42
Topographic model of the landscape (Scaling ≤1: 100,000)	Surface in km²	0.0023

Type of data	Unit	Price (EUR)
Digital cartographic model 10	Surface in km²	0.42
Digital cartographic model 25	Surface in km²	0.42
Digital cartographic model 50	Surface in km²	0.10
Digital cartographic model 100	Surface in km²	0.026
National map at 1: 10,000	Megapixel	0.046
National map at 1: 25,000	Megapixel	0.23
National map at 1: 50,000	Megapixel	0.23
National map at 1: 100,000	Megapixel	0.23
National map at 1: 200,000	Megapixel	0.12
National map at 1: 300,000	Megapixel	0.12

With regard to the discount coefficient in place, a distinction is made between public and commercial use. For public use, three relevant aspects are taken into consideration: the functionality, usability and level of processing. Factor 1 (no reduction) applies in case all functionalities are used, the data can be fully used and without restrictions when no or very little processing of the data is done. In case of limited functionality, reduced usability and an high level of processing, discount coefficients (with factor 0.50, 0.25 or 0.1) apply. For commercial use, an additional factor is taken into consideration, namely the importance of geodata in the final product. Discount coefficients apply in case of an average or low importance. Important to mention also is that no fees are charged for using the data for scientific or research purposes.

For access to services, a more simplified approach is in place, with different fee models for WMS and WMTS, and within each model different fee levels depending on the number of requests. Table 14 below summarizes the fee models for access to view services.

Table 14: Fees for using WMS and WMTS, Swiss NSDI

	WMS	WMTS
Level 0	Free access up to 5 000 megapixels a year	Free access up to 25 000 megapixels a year
Level 1	558 EUR (CHF 603.10) for 20.000 megapixels = 0.027 EUR per megapixel	2218 EUR (CHF 2'398.10) for 100.000 megapixels = 0.022 EUR per megapixel
Level 2	2218 EUR (CHF 2398.10) for 100.000 megapixels = 0.022 EUR per megapixel	7532 EUR (CHF 8'142.10) for 500.000 megapixels = 0.015 EUR per megapixel
Level 3	7532 EUR (CHF 8142.10) for 500.000 megapixels = 0.015 EUR per megapixel	11.683 EUR (CHF 12'629.60) for 1.000.000 megapixels = 0.012 EUR per megapixel

In Switzerland, revenues for selling data and access to services are estimated around 4.63M EUR yearly, with the biggest part (approximately 80%) coming from selling the data.

3.1.4.6 Finland

For the download of data, Finland has put in place an harmonized fee policy, with standardized fees for most of its dataset. For all datasets, this fee consists of two parts:

- For the first map sheet, a standard fee of 89.27 EUR has to be paid
- For each of the following sheets, the fee is 15.73 EUR per sheet

This policy is in place for many datasets, including elevation zones, laser scanning data, orthophotos, terrain maps and data, and elevation models. There are differences in the fees for these datasets in case data are needed for all over Finland. Table 15 shows the differences between the data in case of data for the entire Finnish territory.

Table 15: Fees for datasets, Finnish NSDI

Data	Fee
Elevation zone raster throughout Finland (pixel 32 m)	315.00 EUR
Laser scanning data for the entire production area	236.29 EUR
Orthophoto throughout Finland	3150,00 EUR
Terrain map 1: 100,000 and 1: 250,000 - the whole of Finland	315.00 EUR
Terrain map raster 1: 100,000	167.98 EUR
Terrain database all material throughout Finland	525.00 EUR
Background map raster all over Finland 1: 5,000	1575.00 EUR
Background map raster all over Finland 1:10 000	525.00 EUR
Background map raster all over Finland 1:80 000	210.00 EUR
Height model 2m all over Finland	1575.00 EUR
Elevation model 10m all over Finland	787.50 EUR

Table 16: Fees for WMS and WMTS, Finnish NSDI

WMS			WMTS	
Requests per year	**Fee**		**Requests per year**	**Fee**
75,000	€ 200.00		300,000	€ 200.00
100,000	€ 231.00		500,000	€ 240.00
200,000	€ 319.00		750,000	€ 290.00
500,000	€ 506.00		1,000,000	€ 340.00
1,000,000	€ 726.00		2,000,000	€ 480.00
2,000,000	€ 1,023.00		5,000,000	€ 750.00
5,000,000	€ 1,606.00		10,000,000	€ 1,060.00
10,000,000	€ 2,277.00		20,000,000	€ 1,500.00
20,000,000	€ 3,212.00		50,000,000	€ 2,370.00
			100,000,000	€ 3,350.00
			150,000,000	€ 4,100.00
			200,000,000	€ 4,730.00
			250,000,000	€ 5,290.00
			300,000,000	€ 5,800.00

WMS			WMTS	
			500,000,000	€ 7,480.00
			1,000,000,000	€ 10,580.00

For the access to WMS and WMTS, fees are based on the number of requests, i.e. requests with a single size of 500x500 pixels for WMS and 256x256 pixels for WMTS. The minimum fee per service is 200 EUR/year, for WMS there is a maximum of 20M EUR per service per year. If the annual application volume is higher than 20M, users must use the WMTS.

3.1.4.7 France

For the access to web services, including WMS and WMTS, a distinction is made between three types of users:

- **Private user:** for private use in webpages or internal applications
- **Professional user:** in case of accessing services via an application whose functionalities are limited compared to those offered by a geographic information system (GIS).
- **Expert user**: use of services via a geographic information system.

In case of a WMS, a transaction refers to 1 image. In case of a WMTS, 1 transaction is equivalent to 16 tiles.

For **private users**, the first 2 000 000 requests are free of charge. Above 2 000 000 requests, the following fees apply:

- 5500 EUR for 10M transactions
- 10 000 EUR for 20M transactions
- 22 500 EUR for 50M transactions
- 45 000 EUR for 100M transactions
- 80 000 EUR for 200M transactions

For private use of the services, the fees vary between 0,0004 EUR and 0,00055 EUR per transaction.

For **professional users** – i.e. not using a GIS – 10.000 transactions per year are free of charge. Above 10.000 transactions, the following fees apply:

- 100 000 transactions: 2 600 €
- 200 000 transactions: 3 700 €
- 500 000 transactions: 5 800 €
- 1 000 000 transactions: 8 200 €
- 2 000 000 transactions: 11 600 €
- 5 000 000 transactions: 18 400 €
- 10 000 000 transactions: 26 000 €
- 20 000 000 transactions: 36 800 €
- 50 000 000 transactions: 58 200 €

For these professional users, the fees are between 0,026 EUR and 0,0011 EUR per transaction.

Also **expert users** can make use of 10.000 transactions per year for free. Above this threshold of 10.000 transactions, the following fees are applicable:

- 20 000 transactions: 1 500 €
- 50 000 transactions: 3500 €
- 100 000 transactions: 6 000 €

- 200 000 transactions: 10 000 €
- 500 000 transactions: 20 000 €
- 1 000 000 transactions: 35 000 €
- 2 000 000 transactions: 60 000 €
- 5 000 000 transactions: 115 000 €
- 10 000 000 transactions: 160 000 €
- 20 000 000 transactions: 225 000 €

For these expert users, the fees per transaction are between 0.075 EUR and 0.011EUR.

3.1.5 Conclusion

To better understand the current level of use of the central node of the Spanish SDI, a comparison can be made with the access and use statistics of different countries. The table below shows the number of requests of the different WMS and WMTS of the central SDI-nodes of Spain (CNIG-ES), the Netherlands (PDOK) and Sweden (Swedish Mapping, Cadastral and Land Registration Authority). It can be noticed that the total number of WMS and WMTS requests is the highest in Spain, with especially a very high number of WMTS requests. However, it should be noticed that the scope of the collected statistics is slightly different, and caution is needed in interpreting these numbers.

Table 17: Figures on number of requests of WMS/WMTS in ES, NL and SE ('18-'19)

	2018	2019
Spain		
WMS	816 409 171	905 719 332
WMTS	8 038 086 513	14 033 236 624
WMS + WMTS	**8 854 495 684**	**14 938 955 956**
Netherlands		
WMS	N/A	3 498 542 097
WMTS	N/A	6 053 873 909
WMS + WMTS	**N/A**	**9 552 416 006**
Sweden		
WMS	1 981 894 830	2 704 274 341
WMTS	2 780 465 012	3 593 371 308
WMS + WMTS	**4 762 359 842**	**6 297 645 649**

The table below summarizes the fees in place for the access and use of data, WMS services and WMTS services in the different countries. The fees presented in the table are the standard fees, and do not take into consideration the fact that fees can be different for particular user groups and/or types of use.

Table 18: Fees in place for using data and services in several European countries

Country	Data	WMS	WMTS
Netherlands	No fee	No fee	No fee
Slovenia	No fee	Fee for registration (once): 75 EUR + VAT	Fee for registration (once): 75 EUR + VAT
Croatia	Different fees per dataset, between 9.95 EUR and 19.90 EUR per sheet	Yearly fee of 6,000.00 kn = 794.10 EUR	Yearly fee of 4,000.00 kn = 529.40 EUR
Sweden	Different fees per dataset, 0.043 and 1.43 EUR per km²	Between 0.0073 and 0.64 EUR per request	Between 0.003 and 0.14 EUR per request
Finland	Standard fees: 89.27 EUR for the first map sheet, 15.73 for the following sheets	Two models: fixed annual fee (per service) or fee per request (with three levels of products, and decreasing fees for higher number of requests).	Two models: fixed annual fee (per service) or fee per request (with three levels of products, and decreasing fees for higher number of requests).
Switzerland	Different fees per dataset, with unit prices per megapixel	Free access up to 5,000 megapixels a year Between 0.027 EUR and 0.015 EUR per megapixel	Free access up to 25 000 megapixels a year Between 0.022 EUR and 0.012 EUR per megapixel
France	N/A	For expert users, the fees per transaction are between 0.075 EUR and 0.011EUR (1 transaction = 1 image)	For expert users, the fees per transaction are between 0.075 EUR and 0.011EUR (1 transaction = 1 tile)

For a complete – and correct – picture of how countries are dealing with charging fees for access to their data and services, it is however important to take into consideration the different additional parameters that – based on the standard fees presented above – determine the actual fees that need to be paid by the users. Three main parameters can be identified:

1. Types of users and/or types of use with associated coefficients
2. Intensity of use (or use levels) with associated fees
3. Types of data with associated fees

With regard to the different **types of users and type of use**, often a distinction is made between at least three types of user(s): public authorities, research and education institutions and commercial users. In some cases also the – online – publication of the data is considered as a specific type of use, different from the production of derived products. Examples of applying these parameters to determine the fees can be found in:

- ***Croatia:*** For the use for scientific and/or educational purposes, fees should be multiplied by factor 0.1, and in case data are published as part of the scientific research by factor 0.3. For public disclosure of the – original – data, fees should be multiplied by factor 1.3
- **Sweden:** For non-commercial use of the data, the applicable fee is the standard fee x factor 0,1. For research, education and cultural use, no license fee is asked for a large group of data and services. In some cases, delivery or processing fees still might be asked. For state authorities which are not enterprises, no fees are charged
- **Slovenia:** Certain services and viewers are only accessible for registered users, and there's a small fee is charged for this registration. However, For state administration bodies and judicial bodies, registration is free of charge.

With regard to **different use levels,** it is a common practice to charge lower fees per request or per download for higher number of requests/downloads. In some countries (Switzerland, France), a first set of requests is available for free. Other countries have put in place a minimum and/or maximum fee. Some examples of the use of different use levels:

- **Switzerland**: Four fee levels are in place for the access to WMS and WMTS, with the lowest level providing access for free. The fee per transaction is lower in case of a higher number of transactions.
- **France:** the number of levels (and also the fees) are different for different user groups (e.g. private users versus professional users), but for each group a first set of transactions is free of charge. Again, a higher number of transactions result in a lower fee per transaction.
- **Sweden:** For all services the fees are lower in case of a higher number of requests.

The identification of **different types of data or services** with associated fees especially applies to the access to data. Only in Finland, the type of data is a relevant factor in determining the fees for accessing these data through services. Other countries have determined a specific fee for each dataset. Some examples:

- **Finland:** Three fee levels are used, and each view service is categorized into one of these levels. View services for orthophotos are in level 1, the level with the highest fees. View services for hydrography data and the digital terrain model are in fee level 3, for which the lowest fees are applicable. Among the view services in fee level 2 are services for viewing topographic data (WMS and WMTS).
- **Sweden:** Different fees per dataset, with fees between 0.043 and 1.43 EUR per km^2
- **Croatia:** Different fees per dataset, between 9.95 EUR and 19.90 EUR per sheet

These three key parameters are applied in several of the countries included in our analysis. In additional to these main parameters, other countries take into consideration other parameters in determining the fees for accessing data and services:

1. In **France,** the use of services through – more advanced – GIS systems results into higher fees.
2. In **Switzerland**, aspects such as the functionality, usability and level of processing determine the fees for data.

In Sweden, a distinction is made between an annual fee model and a one-off fee model. In the annual fee model, the license fee is paid annually and in advance. In the one-off fee model the license fee is paid at a single point and confers an unlimited right of use for a specific period.

3.2 Analysis of how the Google model works

In this section we describe the Google Business Model and how it is applied to the specific Google Mapping product(s). The different products are presented, as well as the fee model for each of them.

3.2.1 Google's business model

In the most recently reported fiscal year, 2019, Google's revenue amounted to 160.74 billion US$ (Johnson, 2021). Google's revenue is largely made up by advertising revenue, which amounted to 134.81 billion US$ in 2019 and which is mostly generated via its search engine and its AdSense program, which places ads on millions of websites (Parr, 2010). This model is based on particular technologies, i.e. computer algorithms to determine search positioning (Google, 2010):

- PageRank – This is the technology that determines the importance of each page. It considers 500 million variables and 2 billion terms to determine how a page will rank in the search engine.
- Hypertext-Matching Analysis – This is the technology that analyses page content and ensures the results returned are relevant to the query entered into the search engine.

Google (and its parent company Alphabet) offers not only a search engine, but many products and services, among others: Google Cloud, Gmail, Google Books, YouTube, and Google Maps. Although Google doesn't charge fees to the end-user searching their websites, the company has generated billions of dollars through fees, advertising revenue, and ad-sharing programs as explained above. Google's AdWords program allows businesses to place ads on Google's websites, including its search engine, Google maps, video, and email platforms. In turn, Google charges those companies to advertise while the companies get the benefit of brand exposure (Google, 2020).

It might be surprising that Google earns money through the use of maps. However, a simple example can illustrate how it works. When an end-user is searching for information on a city he/she wants to visit on google.com, e.g. Madrid this would result, among other things, in a detailed map of the city via Google Maps. The Maps program allows users to zoom in and out and move the map to search neighbouring areas. Along the side of the search results screen are a number of small advertisements for Madrid-based businesses, hotels, restaurants, and links to other sites. This type of paid advertising is the primary way in which Google earns most of its revenue.

Part of Google's revenue is coming from its core products, including Google Maps[23], but it is unclear how much this is exactly for the Maps related products. Google also generates income from its free Maps program through another, more subtle, form of advertising (Investopedia, 2020). Google Maps include a lot of information, also about businesses (hotels, restaurants, shopping malls …). For example, Google allows businesses to use their company logos instead of the generic icons for a fee. For example, Hilton can pay a fee to have its signature H-logo embedded in each map, instead of having the usual bed

[23] Google properties or websites generated over 70% of the company's $40.3 billion in revenue, in the third quarter of 2019.

icon used for hotels. Finally, Google also generates revenue through its Google Maps Platform itself. The platform is meant for developers that want to integrate Google Maps in websites by using one or more of the Google Maps API's. Applications developed might be basic - 'simple' mapping of features - to more complex implementations such as tracking the whereabouts of trucks in a fleet, or the closest Uber taxi.

3.2.2 The way the use of Google Maps API's work

Google has many products for providing maps and related information on the web. The dedicated Google Maps Platform[24] helps the potential costumer to choose the right product and API to implement it, to make business choices and set-up an account.

The Google products are grouped in three types: maps, routes and places. Products might be for apps on a mobile or for computers in the office. The maps product is split into Maps and Street View. The first allows displaying maps as images (using Maps Static API) or interactive/dynamic maps (using the Maps JavaScript API). The latter allows to embed Street View Imagery and high resolution satellite imagery (both static and dynamic Street Views are possible). The routes product features Directions, Distance Matrices and Roads. Finally the Places product features are: current place, place details, find place, geocoding, geolocation and more.

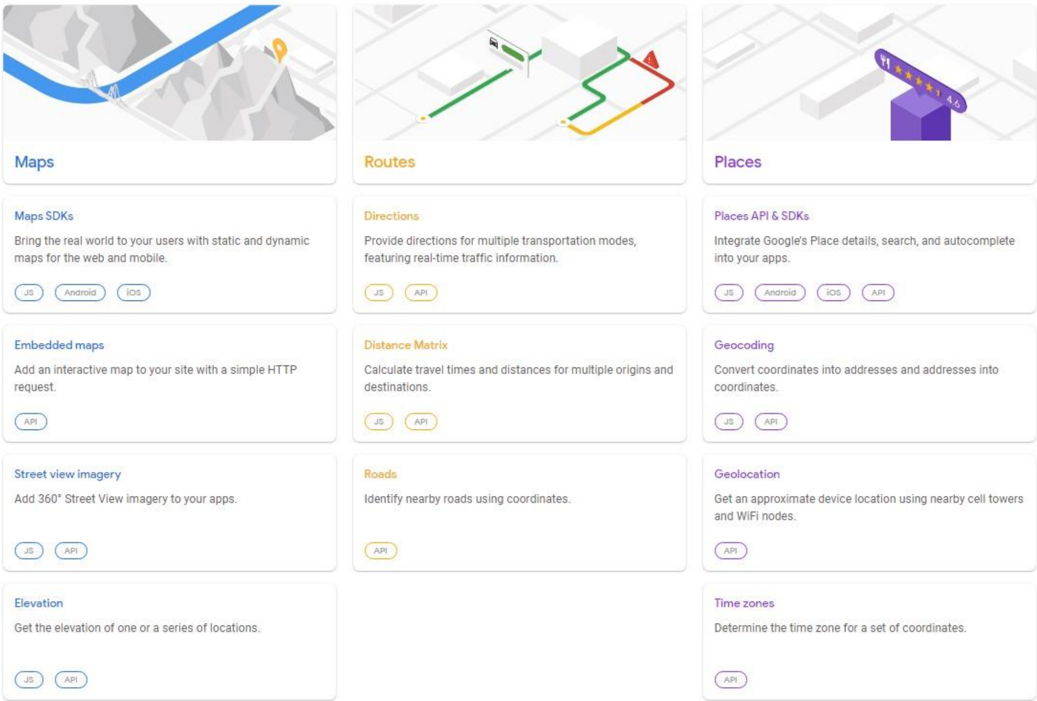

Figure 12: Overview of Google Maps Platform products

In the context of this study, focus is on mapping, not so on routing and places. These two products are more comparable to GIS functionalities such as 'finding the fastest route to a

[24] https://cloud.google.com/maps-platform

destination' or 'geocoding'. So focus is on the map products. But even within the map products offered, there are several features. Google Maps makes distinction between Maps and Street View. The latter is also not relevant in the context of our study. Very few SDI's include Street View functionality and they are certainly not comparable with 'traditional' viewing services such as WMS and WMTS.

Basically, four type of API's might be of interest for the study; Dynamic Map, Static Map, Embed Map and Embed Advanced Map.

- **Dynamic Map** which is an interactive object. The user can freely pan, zoom or switch map layers. A web page or application displays a map using the JavaScript API.

- **Static Map** which is just an image added to the webpage with simple HTML. It is not interactive, which means no panning, zooming or changing map layers. The product to use is Map Static API.

- **Embed Advanced Map** lets you place an interactive frame with the map on your site with simple HTML (by adding URL). Except for marking the place with the pin you can also show on it the street view, routes or insert a search field. The products use the Maps Embed API.

- **Embed Map** lets you place an interactive map frame on your site with simple HTML (by adding URL). You can put a single marker on it.

Table 19: Comparison WMS/WMT and Google Maps API's gives a better insight with which Google Map API WMS/WMTS can compare. It becomes clear that WMS/WMTS is closest to the Dynamic Maps of Google although it is hard to link their functionality one-on-one. The common functionalities are: map visualization, panning/zooming, setting map parameters (e.g. extent), using map styles, displaying information about a location /feature. However, it should be noted that Dynamic Maps can do much more, such as drawing shapes on the map and integrating street views or geocoding, functions/operations not part of a WMS/WMTS.

Table 19: Comparison WMS/WMT and Google Maps API's

Function	WMS / WMTS	Dynamic	Static	Embed	Embed Advanced
Visualize map	👍	👍	👍	👍	👍
Pan/zoom	👍	👍	👎	👍	👍
Setting map parameters	👍	👍	👍	👍	👍
Using styled maps	👍	👍	👍	👎	👎
Display information about location	👍	👍	👎	👍	👍
Adding layers	☞	👍	👎	👎	👎
Drawing shapes on map	👎	👍	👍	👎	👎

👍: supported - 👎: not supported - ☞: indirectly

For the purpose of this study it is proposed to compare WMS/WMTS with the Dynamic Maps. The Static Maps do not allow panning and zooming, a key feature of WMS/WMTS, while Embed and Embed Advanced do not allow styling.

One of the observations made on the use of Dynamic Maps is that they might require better bandwidth and implementation requires good JavaScripting skills.

3.2.3 The Google fee charging mechanism

Google has put in place a fee charging mechanism for its products which is known as a pay-as-you-go pricing model. It should be noticed that the 'simpler' products are free of charge as can be seen in Figure 13: Applicable rates for different Google Map products. Maps on mobile devices are for free, also embedded maps. Static Maps have the lowest fees, while Street Views are the most expensive ones. The latter are not considered in our study though.

SKU	$200 monthly credit Equivalent free usage	Monthly volume range (Price per thousand)		
		0—100,000	100,001-500,000	500,001+
Mobile Native Static Maps	Unlimited loads	$0.00	$0.00	
Mobile Native Dynamic Maps	Unlimited loads	$0.00	$0.00	
Embed	Unlimited loads	$0.00	$0.00	
Static Maps	Up to 100,000 loads	$2.00	$1.60	CONTACT SALES
Dynamic Maps	Up to 28,000 loads	$7.00	$5.60	for volume discounts.
Local Context Map beta	Requires enabling Dynamic Maps	$0.00 during beta	$0.00 during beta	
Static Street View	Up to 28,000 panos	$7.00	$5.60	
Dynamic Street View	Up to 14,000 panos	$14.00	$11.20	

Figure 13: Applicable rates for different Google Map products[25]

Another important observation to be made is that the prices are variable depending on the volume: less than 100.000 map loads per month, between 100.000 and 500.000 map loads and above 500.000 map loads per month. The notion of map loads needs some explanation here. A single map load is charged when any of the following occur: 1) a web page or application displays a map using the Maps JavaScript API or 2) an application requests a single map image from the Maps Static API. After a web page or application loads a map, or a static map image, or a Street View panorama, any user interaction with it, such as panning, zooming, or switching map layers, does not generate additional map loads or affect usage limits. So the map load is like an initial start of a web mapping application in which a starting map is uploaded, and after that the user is performing all kind of actions and interactions: e.g. adding a layer, querying spatial objects, panning/zooming.

In practical terms a user (developer in this case) has to register first on Google Maps Billing Platform and choose the product(s). The billing mechanism works as follows:

[25] SKU = means Stock Keeping Unit, a unique identifier for each distinct service that Customer can purchase under an Agreement.

- Usage is tracked for each Product Stock Keeping Unit (SKU).
- A SKU is the combination of the Product API + the service or function called (for example, Places API - Place Details).
- A product may have multiple SKUs billed at different rates (for example, Places API - Place Details; Places API - Autocomplete - Per Request).
- As explained above, SKU pricing is tiered, based on volume of use, with three tiers: 0–100,000; 100,001–500,000; 500,001+.
- Cost is calculated by SKU Usage x Price per each use.
- For each billing account, for qualifying Google Maps Platform SKUs, a 200 US$ Google Maps Platform credit is available each month, and automatically applied to the qualifying SKUs.

Which use pattern would lead to which invoice? This can better be illustrated with a few examples. Assuming that a user of the Dynamic Maps API[26] has exactly 80.000 map loads in a month. This would result in:

*((Number of map loads / 1.000) * 7,00 US$) – 200 US$) = 360 US$*

A bigger user that reaches e.g. 450.000 map loads would pay

*((Number of map loads / 1000) * 5,60 US$) – 200 US$) = 2.320 US$*

The 200 US$ is a credit that any registered user will obtain. Very big users, above 500.000 map loads per month will have to contact the sales department for negotiating volume discounts. This is on a case-by-case basis. Also, other credits might be applicable, this is e.g. the case for non-profit, crisis response, and news media organizations. Finally it should be noted that the pricing includes technical support and that users can monitor usage and set usage limits (on a daily basis).

[26] A web page or application that displays a map using the Maps JavaScript API. A map is created with the google.maps.Map() class.

4. Results from the analysis

In this section the different parts in the approach are brought together: Method A and Method B with the figures on the use of WMS and WMTS, and Method C with the figures on the download of the data. We explain how the calculations were performed, discuss and interpret the results and provide comments on potential improvements to the model applied.

4.1 How calculations were performed

This sub-section provides details about how the calculations were performed; the key parameters in the equation, the different scenarios applied.

4.1.1 Key parameters in the quantitative model

4.1.1.1 Method A & C – Applying fees of Member States to the Spanish SDI

In Section 3 of this report, we described the different parameters used by mapping agencies in Europe to determine the fees for accessing their data and services. We noticed that more simple models are in place for what concerns the access to services in both Slovenia and Croatia, with one-time (Slovenia) and annual registration fees, that allow access to all services. This registration fee does not apply to all user groups, and especially public authorities are exempted from this fee. This approach of different fees for different user groups also is in place in more complex fee models, and can be considered as one of the key parameters in these models.

Looking at the more advanced/complex fee models included in our study – France, Sweden, Finland and Switzerland – the following three key parameters can be identified: the types of users and/or types of use, the intensity of use (or use levels) and the types of services/data with associated fees.

In our quantitative model for applying the charging models of other countries, we deal with these parameters in the following way:

1. *Type of users:* we work with different scenarios, which refer to a different number (or percentage) of users that need to pay a fee (this approach will be further explained in the next section);
2. *Intensity of use:* we will work with a fee per request, based on the applicable fees for different use levels;
3. *Types of services/data:* we will perform separate calculations for WMS, WMTS and a selection of datasets.

The current statistics available on Spain include data on the number of requests (WMS & WMTS) and the number of downloads (of data). This means that for estimating the potential revenues for the central SDI-node of Spain we need to determine the fee for 1 single request or download. In this way, we are able to estimate possible revenues based on available statistics on number of requests/downloads, without detailed information on the total number of users or on the intensity of use of different users. For the calculation of this fee per request/download, we will take into consideration the fees currently in place in the different Member States.

1. Member States fees for WMS and WMTS

For the access to WMS and WMTS, we will use the fees of three countries in which fees are determined at the level of single requests: Finland, France and Sweden. For each of these countries, we will include two fees in our calculations:

- The lowest possible fee (‘minimum fee), which is the fee in place in case of a high number of requests (per user organization);
- The average fee, which is the average of the lowest possible fee and the highest possible fee per country.

Table 20 below demonstrates this approach for the access to WMS.

Table 20: Fees in place in Member States for WMS

Country	Fees in place	Minimum fee	Average fee
Finland	9 different fees, between 0,00016 and 0,0026 EUR per request	0,00016 per request	0,00138 EUR per request
France[27]	9 different fees, between 0,0011 and 0,026 EUR per request	0,0011 per request	0,01355 EUR per request
Sweden[28]	Several fees, between 0.14 and 0.0032 EUR per transaction	0.0032 per request	0,07 EUR per request

In a similar way, an average fee can be calculated for a WMTS request, as illustrated in table 21.

Table 21: Fees in place in Member States for WMTS

Country	Fees in place	Minimum fee	Average fee
Finland	16 different fees, between 0,00001 and 0,00066 EUR per request	0,00001 per request	0.00033 EUR per request

[27] For France, we take into consideration fees for professional users

[28] For Sweden, we take into consideration the fees at the second fee level

Country	Fees in place	Minimum fee	Average fee
France[29]	9 different fees, between 0,0011 and 0,026 EUR per request (which consists of 16 tiles)	0,00006 per request	0,00084 EUR per request
Sweden[30]	Several fees, Between 0.003 and 0.14 EUR per request	0,0032 per request	0,071 EUR per request

2. Member States fees for downloading data

For the fees per download, we focus on particular datasets and take into consideration identical or very similar datasets in other countries. Our selection includes the following three datasets: Orthophotos, Topographic Map (1:25.000) and LiDAR data. For each of these datasets, two fees were taken into consideration, i.e. fees of two different types of countries.

Table 22: Fees in place in Member States for data

	Finland	Croatia / Sweden
Orthophoto	15,73 EUR per sheet *(Finland)*	19,90 EUR per sheet *(Croatia)*
Topographic Map (1:25000)	15,73 EUR per sheet *(Finland)*	13,27 EUR per sheet *(Croatia)*
LIDAR data	15,73 EUR per sheet *(Finland)*	3,96 EUR per sheet (or 0,99 EUR per km² , Sweden)

3. Corrections for the different types of users

As explained in the previous chapter of this report, it is a common practices in many Member States to only charge fees to particular users groups, or to ask lower fees for a particular use and user organizations. This means that not all requests or downloads should be considered as requests/downloads for which a fee has to be paid. To deal with this parameter, we will integrate the following three options in our calculations:

- A fee is in place for all requests and downloads, which means 100% of the total estimated value is applicable

[29] For France, we take into consideration fees for professional users. Since in France 1 WMTS request = 16 tiles, we divided the fees by factor 16.

[30] For Sweden, we take into consideration the fees at the second fee level

- A fee is in place for half of the requests and downloads, which means 50% of the total estimated value is applicable
- A fee is in place for just 10% of all the requests and downloads, which means 10% of the total estimated value is applicable

4.1.1.2 Method B – Applying the Google business model to the Spanish SDI

Figure 14: Method B – Bringing the pieces together to compare Google and the Spanish SDI-node provides the overview on how the Google business model can be linked and applied to the central Spanish SDI-node. Since these are similar but yet different technological environments there are three key parameters to be considered and one assumption is made.

1. The figures on requests from WMTS and WMS are the starting point, but the WMS are weighted based on the parameter(s) **"Number of tiles / WMS request"**. The parameter is set as a range between 14 and 36. Using several values can lead to different scenarios (see section 4.2). Alternatively an average could be applied as well. This results in a total number of tiles for a particular year for the central SDI-node of Spain.
2. The second parameter that is needed, is the **number of tiles** that are used in a particular **user session** (since the user web mapping session is what will be compared with a map load in the Google model). Further in this section we describe how we defined this parameter. Also here, there is not one fixed value, but several methods of estimating this parameter were applied and led to a range of values that in their turn lead to different scenarios in the calculation.
3. The third parameter is the **price level** for Google map loads. There are two elements that lead to variation in the prices: 1) the intensity of use (3 levels of which the third level can be variable) and 2) the price changes over time and the changes due to the US$ / € exchange rate at different times.

The assumption is that a Google map load on which the Google fee system is based equals to a user session in a SDI web mapping application.

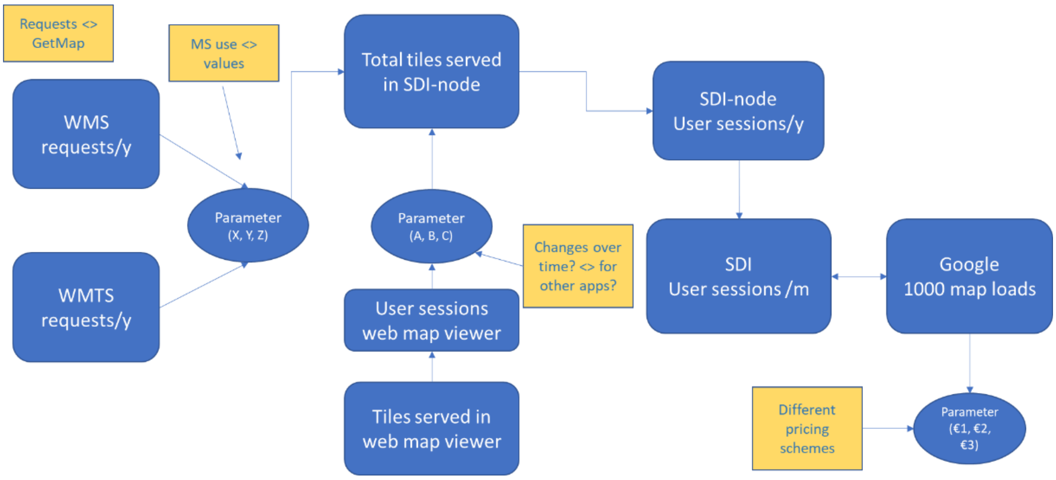

Figure 14: Method B – Bringing the pieces together to compare Google and the Spanish SDI-node

The pieces are then tight together as follows: 1) the total number of tiles per year for the SDI-node is calculated taking into account the weighting parameter for the **number of tiles per WMS**; 2) the number of user sessions is calculated for a year, respectively a month using the parameter **number of tiles per user session** and 3) the parameter **fee per 1000 user sessions per months** is used to calculated the monthly value of the SDI-node and then calculated for a whole year.

We now explain the assumption and the three steps in more detail.

1. The challenge of comparing WMS and WMTS

The key figures of the central Spanish SDI-node consist mainly of the core WMS and core WMTS when it comes to the visualization capabilities towards the users. It is important to understand the difference(s) between the two types of web services in order to correctly interpret the figures. In the data from Spain it is clear that the number of requests from the (fewer) WMTS is much higher than the number of requests from the WMS. This is logic since a WMS request results in exactly one map in the form of a picture, while a WMTS will generate multiple requests for covering the same area with a number of tiles. Table 23: Number of requests for WMS and WMTS in the central SDI-node of ES ('16-'20) provides an overview of the number of requests for the 6 WMTS and the 13 WMS of the central Spanish SDI-node. It also provides insight in ratio of the number of requests for the WMTS against the number of requests of the WMS. As can be seen from the table the ratio is raising from less than 4 to more than 16.

Table 23: Number of requests for WMS and WMTS in the central SDI-node of ES ('16-'20)

# of requests (per year)	2016	2017	2018	2019	2020
WMTS	3.591.318.000	4.324.051.938	8.031.710.102	14.027.335.376	17.898.719.075
WMS	959.754.108	920.644.250	779.033.600	901.520.866	1.086.603.543
WMTS/WMS	3,74	4,70	10,31	15,56	16,47

With these figures, it is not yet answered how many tiles go in one map, which is one of the specific objectives of the study and an important parameter in the further calculations. Therefore, we applied several methods to find an answer to this question: 1) through the desk study and the interviews we obtained figures which reflect the opinion of some SDI experts; 2) we executed some experiments to estimate the number of tiles going in one map and 3) we used information collected by the Spanish SDI to calculate it through an indirect way. Each of the methods is explained in more detail.

Opinions of experts and literature
In the course of previous work within the Spanish SDI it was estimated that 1 map request (WMS) corresponds to 24 tiles (WMTS) (Rodríguez Pascual et al., 2019). The French SDI refers to a number of 16 tiles for a WMS. During the interview, the Dutch SDI experts stressed that this number depends on the way the service(s) is (are) set-up and is therefore variable. The tiling is done beforehand: different tiling schemes might be applied to different WMTS. Also the resolution might have an impact, as well as the way the WMTS are called for from within the different applications. Therefore it was estimated that this figure can vary between 14 and 50 tiles per WMS. This was confirmed by an expert from the Flemish SDI who stated that the number can, in some cases, be quite high and even vary during a user session depending on how the user is panning and zooming. No scientific literature was found so far.

Simple experiments
In order to have a better view on this relationship WMTS/WMS, it was decided to set-up a simple experiment by using the Flemish geo-portal geopunt.be and by simulating a 'real' user session during which WMTS are used. Since there was not a lot of time to develop more complex and automated experiments it was decided to focus on the most used WMTS of Flanders, the WMTS GRB (Large Scale Reference Database). It is a 'complex' WMTS including 33 layers and used by many applications such as the geopunt.be map viewer. The tiling system is complex with different levels: from 256x256, 512x512, 1024x1024 and even 2048x2048.

The experiments were quite simple. Using the web map viewer with the WMTS GRB as a background and simulating 'real' sessions searching for information about a few municipalities and panning, zooming allowed – especially when zooming out – to see the tiling system building up the mosaic of tiles forming each time the map filling the screen. Counting was done manually by observing the screen. Depending on the different zooming levels, different results were obtained: between 24 and 36. Unfortunately it is difficult to 'capture' a static image of the mosaic when it is building up[31]. The experiment confirmed however that the figure is variable depending on how the user is using the application and the way the WMTS is set-up.

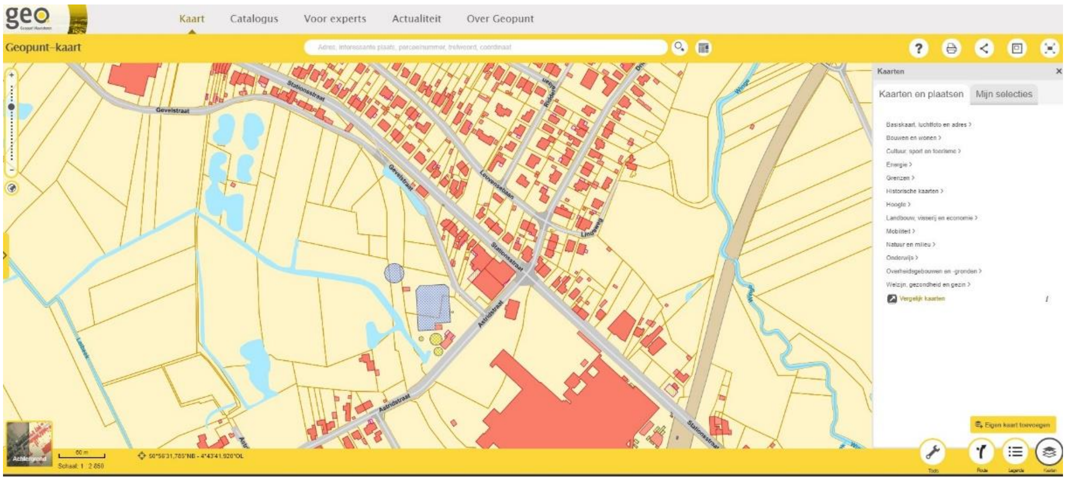

Figure 15: Use of the WMTS GRB in the geopunt web mapping application

Calculations
Another way of estimating the number of tiles per map is to use the figures related to the number of requests and the amount of data transfer in response to the requests (in GB)[32].

First, the average size of a tile for the WMTS is calculated:

Average size of a tile (KB) = Amount of data transferred (GB) / Number of requests

In the second step the number of tiles for each WMS request is calculated:

Number of Tiles = Amount of data transferred (GB) / Average size of a tile (KB)

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[31] In this case a less performant Internet connection would allow to better observe/count the tiles.

[32] Please note that there is not download of the data itself, just pictures are transferred here.

With 1 GB = 1.048.576 KB in the first two steps.

Finally, in the last step the average number of tiles per WMS request is calculated:

Average # tiles = Number of Tiles / Number of WMS requests

This is applied / tested for one dataset PNOA[33] for which a WMTS and WMS exist. The result is shown in Table 24: Number of tiles per WMS request for WMS PNOA.

Table 24: Number of tiles per WMS request for WMS PNOA

	Requests WMTS	Data transfer (GB)	Tile size (KB)	Tiles WMS	Tiles/WMS request
2019	5.006.315.444	73.823,47	15,46	5.989.098.455	21,50
2020	5.663.703.936	90.436,08	16,74	8.298.066.084	25,01

The figure of 21,50 to 25,01 seems to correspond to the figures from the experts and the experiments (order of magnitude). Nevertheless, since the different methods reveal differences, it is proposed to work with different scenarios or a range for the parameter: from 14 to 36.

2. Estimating the number of tiles in a user session

The major challenge in the whole exercise is to have an idea about the number of tiles that go in one user session of a web mapping viewer. There are some figures about the usage of key web mapping viewers.

Table 25: Examples of web map viewers of the Spanish SDI and their number of view pages

Name	URL	2019	2020
SIGNA viewer	http://signa.ign.es/signa/	95.992	140.650
Web Download Center	http://centrodedescargas.cnig.es/CentroDescargas/	1.041.705	1.353.587
IBERPIX 2	http://www.ign.es/iberpix2/visor/	1.155.894	1.258.578
IDEE	http://www.idee.es/visualizador/	97.836	106.547

These web mapping viewers all use one or more of the WMTS and WMS. However, the difficulty is to know precisely which ones and in which sessions. Not necessarily all data layers are activated, and it is even more difficult to know the exact number of requests in terms of WMTS tiles and WMS requests. Therefore, we looked into different methods, similar to the methods we have applied for estimating the number of tiles in one WMS map: 1) estimates on the basis of expert opinions; 2) estimates based on simple experiments and 3) calculations using web service monitoring tools and data coming from Google analytics.

[33] https://pnoa.ign.es/

Before explaining the results from the three methods it is important to repeat what is meant with a user session in a web mapping viewer. A user (TCP/IP address as a proxy) might access a portal or any other web application several times. A user session in this context is defined as the start of using the interface of the web application at a certain point in time to use the functions provided (e.g. visualize layers, querying spatial objects, panning and zooming …) and to quit the application at a certain point in time.

Experts opinions

During the interviews conducted with experts from the selected Member States some information could be collected on the number of tiles that are requested in a typical web mapping user session. The figures mentioned are, again, no 'hard' figures, nor unique figures. User sessions can be short or long, but based on their experience they came up with a figure. In the Netherlands and Belgium the number of 500 tiles per session was mentioned. In work done by CNIG-ES, some estimates were done based on a series of assumption that come up with the figure of 326 tiles per session (Rodríguez Pascual et al., 2019).

Simple experiments

Similar to the experiments for better estimating the number of tiles in one view, the number of tiles can be 'counted' in a real user session. To perform the experiments, it was decided to use one viewer and to generate two realistic scenarios. The viewer was again geopunt.be. The scenarios were as follows:

<u>Scenario 1</u> – Estimating the flood risk for a particular house in a Municipality in Flanders (Rotselaar). Following steps were taken.

1. Open Geopunt.be and activate the WMTS GRB as one of the background options (WMS and WMTS GRB);
2. Pan the map of Flanders to get the region of Leuven more or less in the centre of the map extent;
3. Zooming and panning 2 times to have the municipality in the middle of the map leading to a map showing roads, hydrography, build-up area;
4. Zooming and panning further to the street of interest which happened in 3 times until the streets are shown as areas, parcels are added, house numbers as well as buildings;

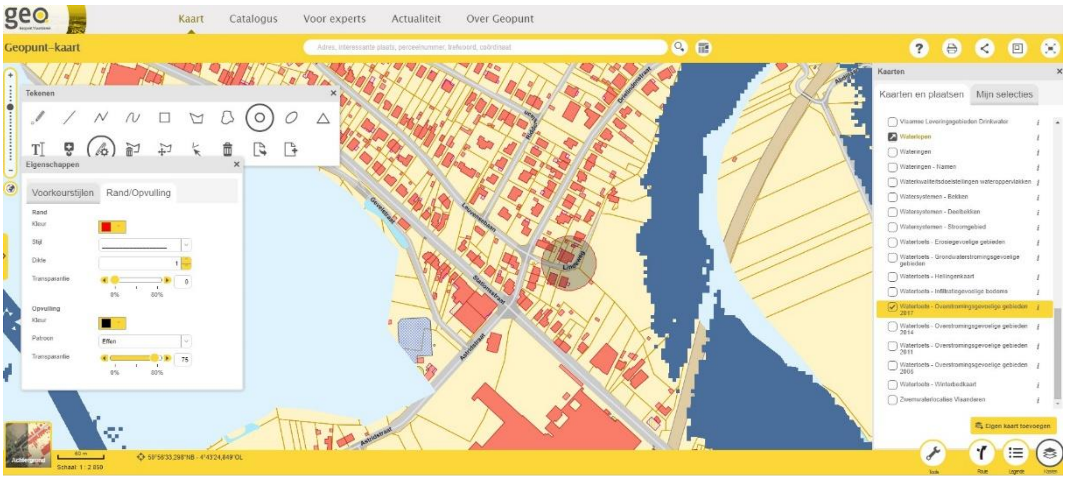

Figure 16: Screenshot of the web mapping viewer of geopunt.be in scenario 1 (flood risk)

5. Identifying the exact address, indicating it on the map with the drawing tools (no WMS/WMS requests);

6. Asking for information on the cadastral parcel, statistics on the municipality;
7. Looking for layers related to water (found under nature and environment), and more particularly for the layer(s) on flood risks – among the 52 layers available). This step does not generate WMS, nor WMTS;
8. Selecting the flood risk areas (2017) which is activating the WMS related to Flood Risk dataset. The user can see the house is not in a flood prone area, but very near.
9. Start zooming out to see the neighbourhood, in several steps, also panning and zooming on particular areas, close to the house and with particular interest in the Natura 2000 site 'De Gevel'. Also identifying the risk for a neighbouring street to be flooded (high risk area).

The steps were repeated 3 times but with small differences in the way the panning and zooming was done, etc. Scenario 1 led to an estimated 420 tiles (on average) visualized in the different steps.

<u>Scenario 2</u> was set-up in a similar way. The scenario was to try finding different locations close to Brussels with minimal noise impact from the airport of Zaventem (BRU). The experiment was very similar but resulted in a slighter higher number of tiles (estimated), 450 for the session since there were more steps since several locations were 'investigated'. Nevertheless it is a quite similar result. It is clear that it the way the application is used influences the number of tiles visualized: expert versus novice user; the complexity of the case; the area of investigation. In the discussion on the results we come back on this.

Calculations

A more precise calculation is possible, but requires additional information that was not (yet) available at the time of writing this report. Following figures would allow calculating the number of tiles in a user session 'precisely':

# of tiles in a user session =

# of requests for WMTS 'A' from application 'X' / # TCP/IP visits to application 'X'

With the requests and the visits being calculated over the same period (month, year).

In Finland and Flanders, the SDI-node is using Spatineo monitoring tools which deliver the information on the number of requests for any services from applications X, but also Y, Z, … Figure 17: Example of Spatineo report with information on top origins of service requests shows this for a Finnish SDI-node.

The other part of the equation requires detailed statistics from Google, i.e. the number of TCP/IP addresses that visited the web viewer. These statistics are usually collected by ICT departments and require some post-processing. We have asked this information to the Flemish and the Finnish central SDI-node, but did not obtain it yet at the time of writing this report.

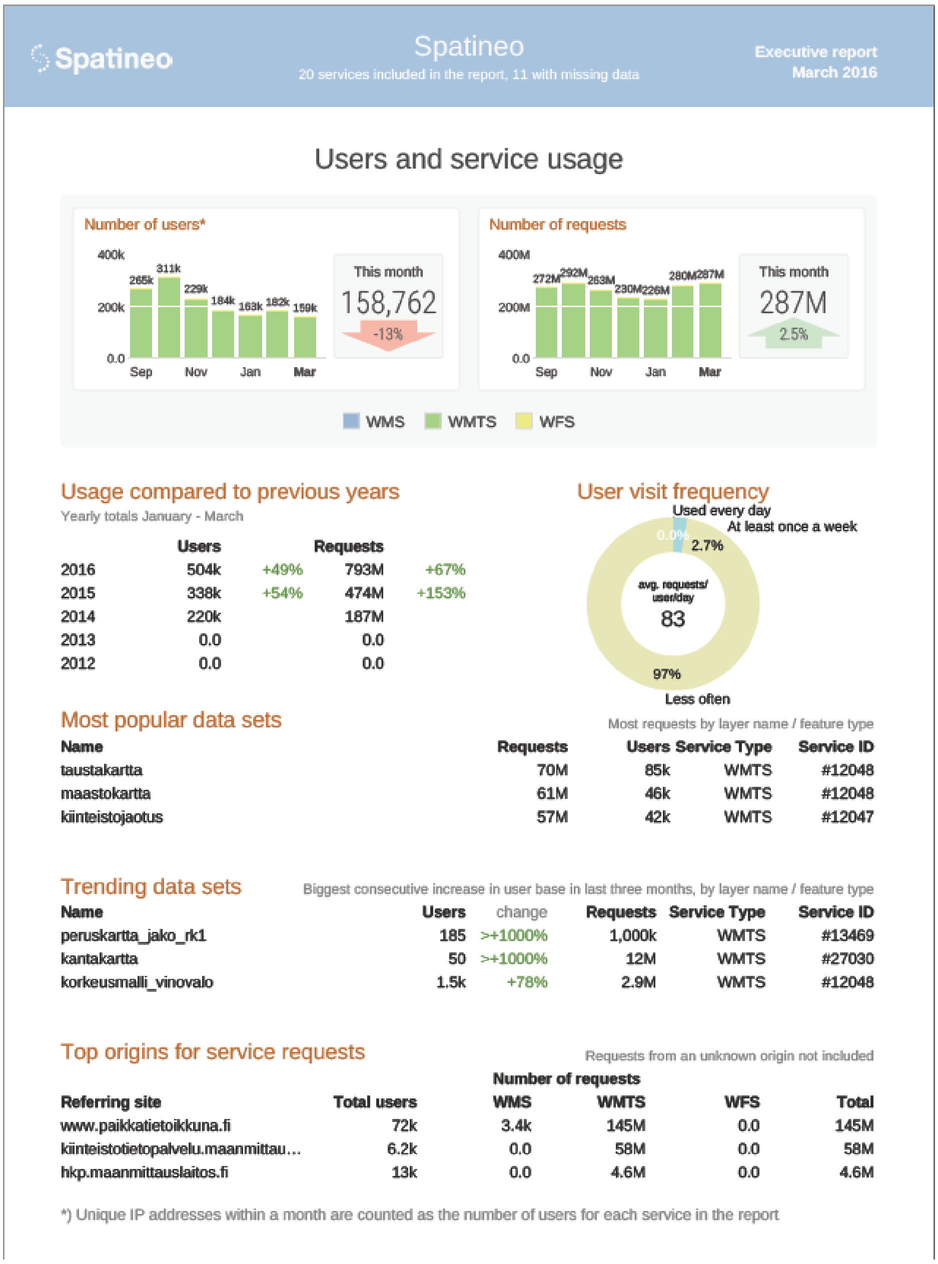

Figure 17: Example of Spatineo report with information on top origins of service requests

3. Application of Google pricing scheme

The pricing schema of Google is relatively simple, and quite stable (it is not changing a lot over time). The price is depending on the intensity of use, with three categories.

Table 26: Three charging tiers of Google (price/1000)

Monthly volume range (map loads = user session) (Price per 1000 map loads)		
0 – 100.000	100.001 – 500.000	> 500.000
$7.00	$5.60	Discounts to be negotiated

On top, every registered user receives a credit of 200 US$ / month. For the sake of simplicity we decided to work with the lower category only. The number of user sessions for the central SDI-node in Spain is around 14.500 per month in 2020, so we apply the higher fee, but take into account the credit for initial use. The latter is a fixed credit and amounts to 2.400 US$ on an annual basis or 1.996 €. A last element to take into account is the US$ - € rate which is fluctuating over time. In the calculations average exchange rates are used to take these dynamics into account.

4.1.2 Working with different scenario's

4.1.2.1 Method A & C – Different scenarios

For estimating the impact of the central node of the Spanish SDI, in terms of possible revenues, we apply a simplified model, that integrates the different approaches in place in other countries.

We identify three main scenarios that will be taken into account:

- With different fees related to the fees determined in three countries (Finland, France and Sweden)
- With different levels of fee, where we take into consideration the lowest possible fee and the average of the lowest and highest possible fee
- With different percentages of requests for which a charge is requested (100%, 50%, 10%).

The scenarios for the comparison of WMS/WMTS with other MS are summarized in Table 27.

Table 27: Scenarios for the comparison of WMS/WMTS with other MS

<table>
<tr><th colspan="6">Country</th></tr>
<tr><td colspan="2">Finland</td><td colspan="2">France</td><td colspan="2">Sweden</td></tr>
<tr><th colspan="6">Fee</th></tr>
<tr><td colspan="3">Minimum fee</td><td colspan="3">Average fee</td></tr>
<tr><th colspan="6">Percentage of requests actually being charged for</th></tr>
<tr><td colspan="2">100%</td><td colspan="2">50%</td><td colspan="2">10%</td></tr>
</table>

Also for the analysis on data downloads, we identify several scenario's.

- With different fees related to the fees determined in two countries (Finland and a second country)
- With three different datasets: orthophotos, the topographic map and LIDAR data
- With different percentages of downloads for which a charge is requested (100%, 50%, 10%).

Table 28: Scenarios for the comparison of data downloads with other MS

<table>
<tr><th colspan="2">Country</th></tr>
<tr><td>Finland</td><td>Croatia / Sweden</td></tr>
<tr><th colspan="2">Datasets</th></tr>
</table>

Orthophotos	Topographic Map (1:25000)	LIDAR data
Percentage of requests actually being charged for		
100%	50%	10%

4.1.2.2 Method B – Different scenarios

For the application of the Google business model there are three scenarios taken into account: 1) with different values for the estimated number of tiles for each WMS map; 2) with different values for the estimated number of tiles in a user session and 3) for one pricing scheme but variable exchange rates applied (so different for each year). The scenarios are summarized in Table 29: Scenarios for the comparison with the Google Business Model.

Table 29: Scenarios for the comparison with the Google Business Model

<table>
<tr><th colspan="60"># of tiles / WMS map</th></tr>
<tr><td colspan="15">16</td><td colspan="15">24</td><td colspan="15">32</td><td colspan="15">36</td></tr>
<tr><th colspan="60"># of tiles / user session</th></tr>
<tr><td colspan="20">326</td><td colspan="20">450</td><td colspan="20">500</td></tr>
<tr><th colspan="60">Fee per 1000 user sessions (In €)</th></tr>
<tr><td colspan="60">7 US$</td></tr>
<tr><td colspan="12">5,85€</td><td colspan="12">6,25€</td><td colspan="12">5,93€</td><td colspan="12">6,21€</td><td colspan="12">6,33€</td></tr>
<tr><td colspan="12">2020</td><td colspan="12">2019</td><td colspan="12">2018</td><td colspan="12">2017</td><td colspan="12">2016</td></tr>
<tr><td colspan="60">Fixed credit of 1.996€</td></tr>
</table>

4.2 Discussing and interpreting results

This sub-section discusses the results of the calculations obtained, and interprets them, for the benefits/value based on fee mechanisms in the Member States first, and the benefits/value based on the Google business model next.

4.2.1 Benefits other Member States as compared to Spanish SDI-node

The application of Method A and C, with the different parameters in the different scenarios does not lead to one single figure representing the benefits or value of the Spanish SDI node but rather a series of figures. In this section we will present a selection of these figures, with information on how they have been calculated and should be interpreted.

We first discuss the results of the calculations of applying the fees of other member states for access to WMS. The presented results all deal with scenarios in which only 10% of the requests require a fee to be paid. We show the results of three different possible scenarios in Table 30: Results of the calculations: WMS fees of other MS applied to Spanish SDI-node.

Table 30: Results of the calculations: WMS fees of other MS applied to Spanish SDI-node

	# of requests (per year)	Finland - minimum fee 10% of requests at 0,00001 EUR per request	France - minimum fee 10% of requests at 0,0011 per request	Sweden - average fee 10% of requests at 0,07 EUR per request
2016	959.754.108	15.356 EUR	105.572 EUR	6.814.254 EUR
2017	920.644.250	14.730 EUR	101.270 EUR	6.536.574 EUR
2018	779.033.600	12.464 EUR	85.693 EUR	5.531.139 EUR
2019	901.520.866	14.424 EUR	99.167 EUR	6.400.798 EUR
2020	1.086.603.543	17.385 EUR	119.526 EUR	7.714.885 EUR

In each of these scenarios, a fee per request is used to calculate the value of the SDI-node from 2016 to 2020, based on the number of requests per year. It can be seen from this number that the total estimated value is very diverging, as also the fees per request are very different. This illustrates the difficulties of estimating the fee per request, as very diverse approaches (and fees) are in place in the different countries. But even within single countries fees can be very different, depending on the intensity of use of an organization.

For taking into consideration the differences in the costs of living between countries, a 'correction factor' can be applied, based on the Price level index (PLI) of the different countries. Looking at the results presented in table 28, it is important to notice that the Spain has a lower PLI (96,3) than these three other countries (125,6 for Finland; 123,0 for Sweden and 113,4 for France). As a result, the corrected or adjusted total benefits/value will be lower than the values presented in table 28. In the detailed calculations, these corrected estimations are included.

This approach – without and with corrections - can also be used for calculating the value of the WMTS requests. Table 31: Results of the calculations: WMTS fees of other MS to Spanish SDI-node shows the results of the calculations without correction. Since here the number of requests per year strongly changes (increases) over years, the differences between the estimated values per year are even more significant.

Table 31: Results of the calculations: WMTS fees of other MS to Spanish SDI-node

	# of requests (per year)	Finland - minimum fee 10% of requests at	France - average fee 10% of requests at 0,00084 EUR	Sweden - minimum fee 10% of requests at 0,0032 EUR per request

		0,00001 EUR per request	per request per request	
2016	3.591.318.000	3.591 EUR	301.671 EUR	1.149.222 EUR
2017	4.324.051.938	4.324 EUR	363.220 EUR	1.383.697 EUR
2018	8.031.710.102	8.032 EUR	674.664 EUR	2.570.147 EUR
2019	14.027.335.376	14.027 EUR	1.178.296 EUR	4.488.747 EUR
2020	17.898.719.075	17.899 EUR	1.503.492 EUR	5.727.590 EUR

A slightly different approach is used for calculating the value related to the downloads of data based on the fees in place in other Member States. As explained in the previous section of this report, here we 1) look at specific datasets and 2) work with one fee per country (per dataset). We again start from the assumption that only 10% of the downloads are downloads for which a fee needs to be paid. The results of two applied scenarios are presented in Table 32: Results of the calculations: Data download fees of other MS to Spanish SDI-node. Scenario 1 ('Country 1) is based on the fees applied by the National Land Survey in Finland, scenario 2 ('Country 2) is based on the fees applied by the State Geodetic Administration in Croatia for both orthophotos and the National Topographic Map and the fees applied by the Swedish Mapping, Cadastral and Land Registration Authority for the LIDAR data.

Again, these results can be corrected by applying a 'correction factor' based on the Price level index (PLI) of the different countries. Important to notice here is that the corrected results for country 2 for both orthophotos and the National Topographic Map will be higher. In both cases fees in place in Croatia are used, and Croatia has a lower PLI than Spain (71,2).

Table 32: Results of the calculations: Data download fees of other MS to Spanish SDI-node

Data set	**Total files downloaded**	**Country 1** *(10% of downloads)*		**Country 2** *(10% of downloads)*	
		Fee per download	Total value	Fee per download	Total value
LIDAR 2st coverage (2015-now)	3.173.372	15,73 EUR	**4.991.714 EUR**	3,96 EUR	**1.256.655 EUR**
National Topographic Map at 1:25.000 (MTN25 raster)	1.714.520	15,73 EUR	**2.696.939 EUR**	13,27 EUR	**2.275.168 EUR**

National Plan for Aerial Orthophotography (PNOA)	564.803	15,73 EUR	**888.435 EUR**	19,90 EUR	**1.123.958 EUR**

The resulting figures allow us to share some first observations with regard to the approach and the results themselves:

- Overall, the proposed approach seems to be straightforward and doesn't look very complex. Estimations of the fee per request/download are used to calculate the total value, based on the total number of requests/downloads. The key challenge however is in the estimation of this fee per request (for WMS and WMTS), since both within countries as between countries the adopted fees are very divergent, which makes the estimation – or selection – of the most applicable fee very difficult.
- In the previous chapter and sections of this report, we provided an in-depth discussion of the different approaches in place for calculating fees for downloading data and accessing WMS/WMTS. We were able to identify the main similarities between the models in place in different countries. An important difference however is in the fees that are applied, which seem to be much higher in some countries compared to other countries. Independent from the complexity of the fee models, it is the level of these fees that strongly determines the estimated value.
- By using different scenarios for calculating the total value, we demonstrate the importance of further investigations on the fees per request/download. We are aware that we have included some scenarios that are less realistic, and could be excluded when looking for the most applicable fees (and related value). However, we think it is useful to add them to the calculations, to further clarify the approach adopted.
- Among these scenarios to be excluded, are those scenarios in which all user organizations pay the lowest possible fee, which in reality would mean that all user organizations are very large users of the WMS/WMTS. Also the scenarios in which fees need to be paid for all requests are less realistic, since most countries have a policy in place in which certain user groups do not need to pay fees for accessing WMS/WMTS.
- An important element in the validation of the parameters and calculations will be the feedback from the Member State representatives. These representatives are in the best position to provide feedback and input on the applicable fees per request/download in their own country. In preparing the scenarios and calculations, we mainly look at the fees and fee models formally in place. In a next stage, we aim to investigate which of the fees we have identified – and taken into consideration in their country are the most relevant (i.e. looking at the intensity of use of different user organizations in their country). This validation will allow us to further fine-tune our calculations, without changes to the overall approach of our calculations.
- After the validation of the fees per country, also differences between countries should be further investigated and validated. Again, the feedback from Member States representatives will be of great value. The use of a correcting factor to take into consideration differences in the costs of living between countries can be recommended.

4.2.2 Benefits Spanish SDI-node based on Google model

The application of Method B, using the different parameters in the different scenarios does not lead to one figure representing the benefits or value of the Spanish SDI node but rather a series of figures or a range.

All figures have been brought together in an XLS template with calculations represented in two ways:

1. All the key WMTS and WMS are listed in the spreadsheet as rows with their name, URL and the measured number of requests, and with all the calculations according to the different scenarios. Such a sheet should be established for each year;
2. A summary table providing an overview per year in which the value of the parameters can be changed providing immediately the corresponding figures.

The first representation allows to see results at the level of individual services as well as the overall results. The latter allow to see the lowest estimates and the highest estimates. The values could also be averaged, but it is felt that this would not provide good insights. Averaging could be done at the level of the parameters, or at the level of the end results.

Table 33: Results of the calculations: Spanish SDI-node – Google model

	Lowest # tiles/WMS (16) Highest # tiles / user session (500)	Highest # tiles/WMS (36) Lowest # tiles / user session (326)
	Minimum	**Maximum**
User sessions / year	56.903.338	142.583.088
User sessions / month	4.741.945	11.881.924
Value SDI-node / month	29.635€	74.262€
Value SDI-node / year	**355.646€**	**891.144€**

Table 33: Results of the calculations: Spanish SDI-node – Google model the minimum benefit, on annual basis, is 355.646€, while the maximum benefit amounts to 891.144€. The lowest level is reached when we assume the lowest number of tiles per WMS map (16) and the highest number of tiles per user session (500), while this is opposite for the highest level, i.e. highest number of tiles / WMS map (36) and the lowest number of tiles per user session (326).

When taking into account figures for different years, one can also monitor the evolution of the benefits/value. Figure 18: Evolution of the benefits of the SDI-node based on 24 tiles/WMS and 450 tiles/session gives the figures for the period between 2016 and 2020.

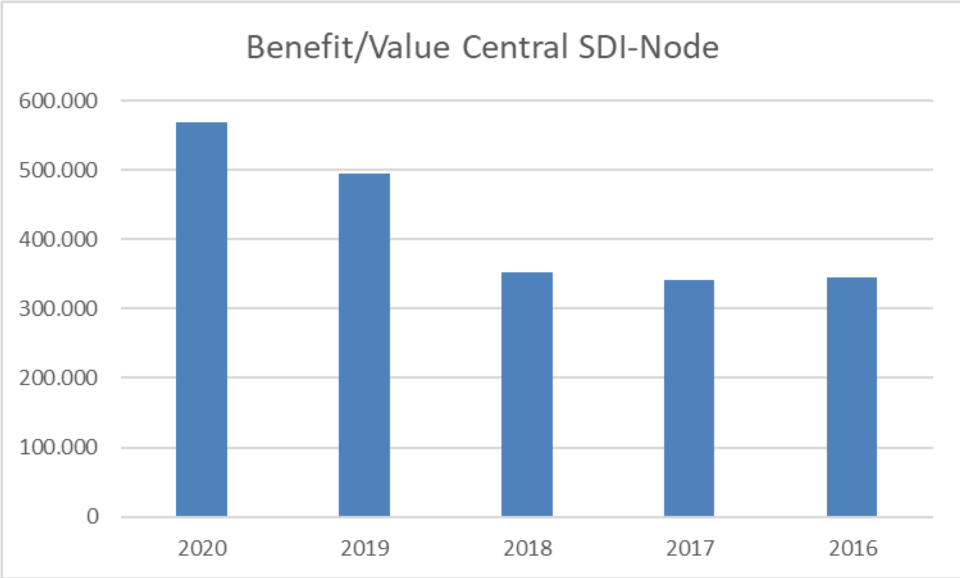

Figure 18: Evolution of the benefits of the SDI-node based on 24 tiles/WMS and 450 tiles/session

It can be observed that between 2016 and 2018 the benefits or value remained quite stable, while it raised a lot in 2019 and 2020 especially because the rising number of requests for both WMTS and to a lesser extent WMS (from 3,5 to 17,9 billion for WMTS, and from 959 to 1.086 million for WMS respectively).

The resulting figures allow us to draw some first observations with regard to the approach and the results themselves:

- The factor that has the biggest impact on the benefits or value is the number of service requests. When these numbers are rising, then the benefits are rising as well. This makes sense since rising numbers of requests express the services are used more and more through popular, and sometimes new web mapping applications.
- Linked to this, it is also clear that the richer the central-node is, i.e. the more WMTS and WMS there are, the more requests this will generate, and thus also more value. However, it should be noted that this depends on whether the services are 'used', this means are embedded in (new) applications.
- If the approach and methodology would be applied on the full Spanish SDI, taking into account key web services from other federal nodes and also the regional SDI-nodes, the value would be entirely different of course. Also when the approach and methodology would be applied on other SDI's, in other countries, there might be very different results.
- From the more detailed figures, it becomes also obvious that some services generate more value than others. In fact four services are popping-out: WMTS Mapping at different scales (*Cartografía raster*) (83.932€), WMTS Vector information at different scales (*Mapa base de España*) (88.120€), WMTS Sentinel and orthoimagery PNOA (*PNOA MA*) (95.980€) and WMS Sentinel and orthoimagery PNOA (*PNOA MA*) (between 55.724 and 192.298€ depending on the parameters/scenario used/applied).
- It is also interesting to compare the results on the benefits with the estimated costs of the Spanish SDI. When taking into account an average annual benefit of 582.697€ (based on the different scenarios), and compare that to the estimated implementation costs of 152.880€ and a depreciation/maintenance cost of around 100.000€/year (Rodriguez et al., 2019), this mean that the annual Return on Investment (RoI) is between 1/6 and 1/4 (the latter for the years after the implementation)

- Two parameters are influencing the results mostly: the number of tiles per WMS map and the number of tiles per user session. The parameter that has the biggest impact on the results is certainly the number of tiles per WMS map. The advantage of the approach is that managers from the Spanish SDI can alter these parameters when new research or experiments might lead to new values to be used.
- However, the approach allows now flexibility, by working with ranges the value of the influencing parameters are not fixed, once and for all; they can be applied according to own or new insights.

4.3 Possible improvements to the model

In this sub-section some critical reflections and issues encountered are highlighted, while some possible future steps and improvements to the approach/methodology are identified as well.

4.3.1 Issues encountered, critical reflections

4.3.1.1 Applying Member State fee model to the Spanish SDI-node (Method A and C)

Our comparison of the fee models applied in other countries and the application of these models to the Spanish SDI-node allows us to identify some issues and challenges related to this approach and its relevance and applicability for estimating the value of the Spanish SDI-node. Although some of these issues already have been raised and briefly discussed before, we provide a more complete overview here. Many of these issues are related to the key parameters we've identified as part of our approach.

- A first parameter is the intensity of use, which strongly determines the fees that actually need to be paid by different user organizations. In case of a higher total amount of requests, the fee per request will be lower. The current approach looks at the lowest possible fee and the highest possible fee. While the lowest possible fee is used directly in our calculations, we also make use of the average of the lowest possible fee and the highest possible fee, to better reflect the presence of organizations with different levels of use intensity (i.e. very large users versus smaller users). Such an average could also be calculated by looking at all possible fees (and not only the lowest and the highest possible fee), while another alternative approach could be to use the median fee (per country).

- Related to this, we did not take into consideration the importance or relevance of these different fee levels, but worked with the fees as identified in the formal fee models. In case more information would be available on which fees actually are paid by in a particular country (e.g. the percentages of users organizations that need to pay a fee) or on the distribution of user organizations across different levels of intensity (e.g. how much very big users, how much very small users) we could further refine the approach. Also a general estimation of the average fee per country – by the MS representative – could be helpful.

- An alternative approach could be to work with statistics on or estimations of the intensity of use of user organizations in Spain. However, based on the information and statistics currently available, it seems to be difficult to prepare such estimations.

- Another relevant parameter identified in the study was the distribution of user organizations across type of users, since many countries have adopted a fee model in which specific user groups – government, research, education – need to pay no or a lower fee. In the current approach we deal with this parameter by working with different scenarios expressing different percentages of requests actually being charged for (100% - 50% - 10%). Also here further refinements are possible.

- Also these refinements could be based on more insight in the distribution of user groups across these types of users in the other Member States. Some of the experts involved in the study already shared some insights on the number/percentage of user organizations that need to pay a fee for accessing services and/or downloading data. Based on the experiences in some countries, the estimation that a fee is charged for 10% of the downloads/requests seems to be most realistic, but needs to be further validated.

- An alternative approach here could be – again – to work with statistics or estimations on the distribution of user organizations across type of users in Spain. Although some information is available on this, it seems difficult to provide a reliable estimation.

- For the calculations of the value from downloads of data, we focused on a selection of three datasets. For an estimation of the overall value related to the downloads of data, it is important to take into consideration all datasets. An important challenge here – even with a small selection of datasets - is the identification of identical or similar datasets in other countries, as there always will be small differences between similar datasets in different countries (which also might influence the fee or value of the dataset).

- The current calculations are based on comparisons with a small selection of other countries. The number of countries but especially the selection of countries will have an impact on these estimations. Adding more countries and/or countries with significantly lower or higher fees will affect the results of the calculations.

- Some countries foresee a first set of requests (WMS, WMTS) that is available for free. In our current approach, we do not take this into consideration.

4.3.1.2 Applying the Google Business Model to the Spanish SDI-node (Method B)

When trying to link and applying the Google Business Model to the Spanish central SDI-node several assumptions were being made and parameters were given a value based on a mixture of experts' opinions, simple experiments and calculations. On all of these, issues could be identified that potentially influences the end results. They are listed here and briefly discussed (in sub-section 4.3.2 we will provide some ideas on potential improvements to the approach and model applied.

- The fact of using figures on number of requests of WMTS and WMS is logic: the more the services are used, the higher the value or benefits are. Also, calculating the benefits or value of just one node of the SDI based on key services seems acceptable. It can be seen from the figures that the number of services taken into account could be further limited since from the 20 services analysed, only 4 really matter (have a big impact on the end result). Analysing fewer services would make the exercise also simpler.

- On the other hand, the approach tries to make figures on WMTS and WMS comparable, which is also acceptable. It should be noted however, that in the current approach we ‘upgrade’ or put a higher ‘weight’ on the WMS. One could also argue that you need to ‘downgrade’ or put a lower ‘weight’ on the WMTS. The results would be considerable different. There are also arguments to just use the request figures ‘as-is’, without recalculating.

- The latter is related to how WMS and WMTS are valued by experts and users. Indeed, there are big differences between different type of services. Many ‘simple’ WMS just visualize a particular dataset or layer (e.g. administrative boundaries, flood risk areas), while most of the WMTS are integrated or complex services in which many layers are brought together, often used as a kind of base or background map used by various users in different applications. So it is defendable to give these services ‘more weight’.

- The estimations for the number of tiles in a WMS map remains relevant but might need some more testing. Although several methods were used to come up with different values for this parameter, this could be further improved and checked. For example, in the calculations making use of number of requests and the amount of data transfer figures it was found that for some services/datasets this does not work very well. In case of PNOA it provides comparable results with the value collected from the expert opinions and of the experiments, but for Cartographic Raster and Base Map this gave much lower values. Currently it is not known why.

- Also for the number of tiles in a user session, the values remain good estimates. However, as is the case for the parameter ‘tiles per WMS map’ this value will largely depend on the user, the way the WMTS is set-up, etc. These values should be confirmed with calculated ones. However this can only be done when the SDI has a powerful tool for monitoring the number of requests coming from the key applications that use them (e.g. Spatineo). Moreover, key figures can come from Google analytics that can provide information on the number of visits (based on TCP/IP addresses) to the applications that use the services.

- Related to this, even if these figures are available, they should be interpreted with care and are also rather a proxy than an exact figure. First, depending how Google Analytics is used, figures might refer to the calls to the full geo-portal and not alone to the web mapping viewer that is part of it. Second, a TCP/IP address might hide many users, e.g. one TCP/IP address for a building of a Public Agency. So using figures from Google Analytics might require some post-processing.

- Another element in the equation is the current assumption that a user session in a web mapping viewer corresponds (1-on-1) with a Google map load. It can be considered as a good proxy, but still we need to understand that a Google dynamic map is in reality a bit more complex than what is being done with a WMS and WMTS in the context of an SDI. Dynamic maps have many built-in functionalities that are not part of the web services but should be embedded in the application (e.g. adding a layer). From that perspective, a dynamic map of Google is more valuable than web services.

4.3.2 What could be improved in the approach

Several steps could be taken to further improve the approach and methodology for estimating the benefits / value of the Spanish central SDI-node (or any other SDI-node for that matter). Most of the ideas relate to the improvement of methods for estimating the possible values of the different parameters.

1. More extended experiments – This can entail several aspects. First, a Google account could be set-up in order to experiment with the dynamic maps API (and eventually the other API's) to analyse how the billing system is working in practice and how it reacts on real use (number of map loads). Second it would be good to have a simple case using google maps and WMS/WMTS together to verify how they compare. Third, to organize more user sessions making use of several applications in which the user makes use of WMS and WMTS. Try to link TCP/IP addresses and the number of requests they generate (controlled experiments). In this type of experiments students could be involved (to have more data).

2. Calculate the key parameter values with more data from more SDI-nodes including data from other Member States to verify whether similar results are obtained. Ask SDI-nodes that use Spatineo to deliver detailed figures on the use of WMS and WMTS and the applications from which they are called. Also ask the SDI coordinators to collect information from their ICT department with regard to Google Analytics and geospatial applications (web mapping) over a period of time, e.g. the last two years.

3. Organize a survey to collect more opinions from experts on the key parameters used in this study. The survey could be extended to cover also other aspects related to the economic value of their SDI.

5. Overall conclusions and recommendations of the study

5.1 Conclusions

This study aimed at finding a methodology for estimating/calculating the benefits/value of the key components (data and web services) of the central Spanish SDI-node in monitory terms. The central SDI-node was defined in terms of 4 key datasets, 6 WMTS and 13 WMS provided by CNIG-ES and NGI-ES. The approach defined three pathways. Method A analysed the Spanish figures on WMS/WMTS use with the charging mechanisms in place in some Member States. Method B analysed the same figures with the charging mechanism applied by Google also resulting in figures for the benefits/value of the central node. Finally, Method C applied the charging fees for the data to the download figures for the 4 key datasets of the central SDI-node.

Information was collected on the Spanish SDI: monthly and annual WMS/WMTS number of requests and number of files and size of data downloads. Similar data were collected from 7 European countries: Croatia, Finland, France, Netherlands, Slovenia, Sweden and Swiss. For Method B, fees were publicly available on the Google Map platform. For linking the different pieces of the information together, several assumptions and parameters had to be defined and taken into account. For the comparison with the Member States these were parameters such as the fee mechanisms itself, type of user organisation, intensity of use. For the comparison with the Google charging-model: the number of tiles for a WMS, the number of tiles for a user session, the intensity of use (variable fees of Google).

For all the methods scenarios were identified with different assumptions and values for the parameters. This led to benefits/values that were not fixed but led rather to ranges or averages. Comparing to the Member States fee models the benefits on an annual basis for the Spanish WMS/WMTS are estimated at between 35.000€ and 13.3 million € for 2020 depending on the model applied by the Member States, so a very variable result. For the Swedish model (the highest fees) this results in the quite impressive value. Applying the Google-model to the same Spanish WMS/WMTS results in a value between 355.000 and 891.000€ for 2020 which is more modest, but still considerable. For estimating the value of the data itself, especially the LiDAR data seem to be valuable with a value between 5,0 and 6,3 million €.

The results are not exact calculations but should provide an idea of the order of magnitude. It is clear from the study that there is room for improvement by further investigating the fee-models, fine-tuning the parameters and assumptions and maybe also extending the calculations for other SDI’s (see also Section 5.2).

5.2 Recommendations

What follows are the most important recommendations emanating from the study: they relate to the data/information collection, the methodology and possible improvements, as well as how the resulting information can be used.

1. Extending the analysis from one SDI-node to other SDI-nodes

In this study, only the central SDI-node was taken into account. It would be interesting and reveal new insights to extend the analysis to other national SDI-nodes and also to regional SDI's (and their respective nodes). This would provide not only insights in the overall value of the Spanish SDI, but also reveal similarities and differences between SDI-nodes, and how and to which degree they contribute to the value/benefit equation. Whenever usage and download data are available, this can be done relatively easily. Similarly, the exercise can also be done for other countries which would allow to compare European NSDI's from the perspective of their economic value. In turn, this might allow to start better understand why different SDI's are more used than others, what are key services and datasets to invest into, etc..

2. Analysing apps and applications

Although web services (WMS/WMTS) are used by many users that are not identifiable unless one would make an analysis at the level of single TCP/IP addresses, it is clear that the 'big users' are the key web mapping applications. Even if it is not possible to know more about the individual end-users of those applications (can be citizens, staff from public authorities, researchers …), it says something about how the value is generated, i.e. by using the data & services through the functionalities of these applications. In some cases the applications are general web mapping viewers, in other cases they support dedicated work processes of public authorities. From this study it seems that the generic application generate most use, but it would be worthwhile to investigate this in more detail. This would require information on visits to those applications (Google analytics) and also information on which web services are called by which application, and how often. In some countries this information is already available, but needs still to be analysed in detail.

3. Better insights in the Google mechanism and business model

The Google eco-system of API's and their business and charging mechanism is clear and well-documented. However, it would provide even better insights when the Google API's would be tested and used in a real setting. This would require to set-up a more advanced testing / experimenting environment, and/or the collection of more precise information from clients of Google that have Google maps accounts. The first idea is feasible but needs the set-up of an own account the implementation of one or more API's in a application similar to the web mapping applications of SDI geo-portals. The latter would require the set-up of survey or the collaboration of Google. Information that might help analysing would be: what the applications are doing, which API's are used, the monthly billing information, etc. This is thought to be feasible but would need considerable efforts and time, almost a project on its own.

4. Data on the use of web services

The key information to be able to estimate / calculate the benefits / value of a SDI-node in monetary terms is related to the use figures of the web services that are mostly used by users (and applications). Therefore, it is important that Member States collect and document this information in a similar way. As far as can be seen from the countries analysed in this study, this is already the case to large extent. However, it would be good to have some guidance for the Member States through the MIG/MIG-T. This would guarantee a harmonized approach for collecting this type of information, and ultimately, comparability of the estimated/calculated benefits/value. It is recommended that the collection of SDI usage information would not limit to the web services, but also relate to the main ‘users’, i.e. the applications that use the services, and the user visits (usually obtained via Google analytics, based on TCP/IP figures).

5. Data on charging mechanisms and fees

It would be interesting to know from Member States that charge for services and/or data what revenue this generates for each of the categories: data, different types of web services, etc., but also the costs specifically related to set-up and maintain the charging mechanism. It seems that for some countries the revenue stream is quite modest, while in other countries this is a considerable sum. It would be good to have an analysis on the factors influencing the figures such as the type of user organisations, the number of user organisations and contracts, etc. Evolution over time is also relevant information to better understand revenue figures. Moreover, some countries use fee-mechanisms to define contributions for maintaining the data and services, so not charging the usage, but rather use usage figures to define the financial contribution to the SDI.

6. Extended experiments

For having the parameters such as the number of tiles per WMS, and the number of tiles per user session, some simple experiments were conducted. More advanced experiments are necessary to better understand the dynamics of the tiling system behind the different WMTS used. A WMTS can have many levels, different resolutions and ultimately a number of tiles pre-fixed. This information is best known, to better understand the ‘behaviour’ of the WMTS which also helps understanding the figures. The experiments conducted in this study were limited to a visual check, but there might be other ways of collecting this information based on the more detailed information on how the WMTS has been established. The problem of the visual checks is that it works better when the internet connection is slower.

References

Absolom, N., Cahill, S., Howdle, D., Lowton, K., Scott, C. and Tuohey, N. (2010). Google and the Fundamentals of Internet Business: Google Business Model. Last visit, February 2021. https://sites.google.com/site/net205apples/google-business-model

Barbero, M., Lopez Potes, M., Vancauwenberghe, G. and Vandenbroucke, D. (2019). The role of Spatial Data Infrastructures in the Digital Government Transformation of Public Administrations , Publications Office of the European Union, Luxembourg, ISBN 978-92-76-09679-5 (online), doi:10.2760/324167 (online), JRC117724.

Digital Globe (2013). Web Map Tile Service Developer Guide: Cloud Services.

European Commission (2007). *Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 Establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)*. Available from Internet: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=OJ:L:2007:108:TOC

Globema (2018). A Short Guide to Understanding Google Maps Platform Products – Maps. Last visit, February 2021. https://www.globema.com/short-guide-understanding-google-maps-platform-products-maps/

Investopedia (2019). How Does Google Maps Make Money? Last visit, February 2021. https://www.investopedia.com/articles/investing/061115/how-does-google-maps-makes-money.asp

Johnson, J. (2021). Google: global annual revenue 2002-2020. Last visit, February 2021. https://www.statista.com/statistics/266206/googles-annual-global-revenue/

Josuttis, N.M. (2007). SOA in Practice: The Art of Distributed System Design. O'Reilly Media, Sebastopol, CA, USA. ISBN-10: 0-596-52955-4 and ISBN-13: 978-0-596-52955-0.

Kruse, J.B., Crompvoets, J. and Pearlman, F. (2018). GEOValue - The Socioeconomic Value of Geospatial Information. CRC Press, Taylor & Francis, Boca Raton, New York.

Open Geospatial Consortium (2006). OpenGIS® Web Map Server Implementation Specification, Version 1.3.0 (OGC 06-042). Edited by de la Beaujardiere, J.

Open Geospatial Consortium (2010). OpenGIS® Web Map Tile Service Implementation Standard, Version 1.0.0 (OGC 07-057r7). Edited by : Masó, J., Pomakis, K. and Julià, N.

Parr, R. (2009). The Google Revenue Equation, and Why Google's Building Chrome OS. Retrieved July 6, 2010 from http://mashable.com/2009/07/11/google-equation/

Rodríguez Pascual, A.F., López Romero, E. and Abad Power, P. (2019). Estimación de costes-beneficios de un nodo IDE (Cost-Benefits estimation in a SDI node). In REVISTA MAPPING, Vol. 29, 199, 40-44enero-febrero 2020ISSN: 1131-9100.

Rosencrance, L., Gerwig, K. and Novotny, A. (2021). Definition TCP/IP (Transmission Control Protocol/Internet Protocol). TechTarget, Search Networking. https://searchnetworking.techtarget.com/definition/TCP-IP

Vandenbroucke, D., Crompvoets, J., Vancauwenberghe, G., Dessers, E., Van Orshoven, J. (2009). A Network Perspective on Spatial Data Infrastructures: Application to the Sub-national SDI of Flanders (Belgium). Transactions in GIS, 13 (1), 105-122. doi: 10.1111/j.1467-9671.2009.01166.x

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