A FRAMEWORK FOR THE EVALUATION OF MARINE SPATIAL DATA INFRASTRUCTURES – ACCOMPANIED BY INTERNATIONAL CASE-STUDIES

Christian Seip, Ralf Bill
Professorship for Geodesy and Geoinformatics, Rostock University, Germany
christian.seip@uni-rostock.de

Abstract

Germany is currently developing a marine data infrastructure addressing different topics such as coastal engineering, hydrography and surveying, protection of the marine environment, maritime conservation, regional planning, and coastal research. This undertaking is embedded in a series of regulations and developments at many administrative levels, from which specifications and courses of action are derived. To set up a conceptual framework for the marine data infrastructure of Germany (MDI-DE), scientists at the Chair for Geodesy and Geoinformatics at the Rostock University are building a reference model, evaluating meta-information systems and developing models to support common workflows in marine applications.

Evaluating how other countries built their marine spatial infrastructures is important to learn where obstacles and errors are likely to occur. To be able to look at other initiatives from a neutral point of view, it is necessary to construct a framework for evaluating marine spatial data infrastructures (MSDI). This framework is then used to analyse and evaluate the efforts of Canada, Australia, and Ireland with respect to marine data infrastructures.

Keywords: spatial information science, interoperability, web-based, marine, data infrastructure, evaluation

1 INTRODUCTION – RESEARCH PROJECT MDI-DE

Germany is currently developing a marine data infrastructure (MDI-DE, www.mdi-de.org) with the aim to integrate existing technical developments (such as NOKIS – a marine metadata database in Germany – and the spatial data infrastructure of the German Federal Maritime and Hydrographic Agency [GDI-BSH]) as well as merging information concerning different topics such as coastal engineering, hydrography and surveying, protection of the marine environment, maritime conservation, regional planning, and coastal research. The developments of the MDI-DE are funded by the Federal Ministry of Education and Research [BMBF]; the funded parties and their sub-projects (SPs) within this project are depicted in Figure 1 [1].

Within the MDI-DE project, setting up a marine spatial data infrastructure (MSDI) plays the most important role. Because a German MSDI is built for the first time, evaluating how other countries built their MSDIs would be helpful to learn what and how they built it and where obstacles and errors are likely to occur. To be able to look at other initiatives from a neutral point of view, it is necessary to construct a framework for evaluating MSDIs (Figure 2).

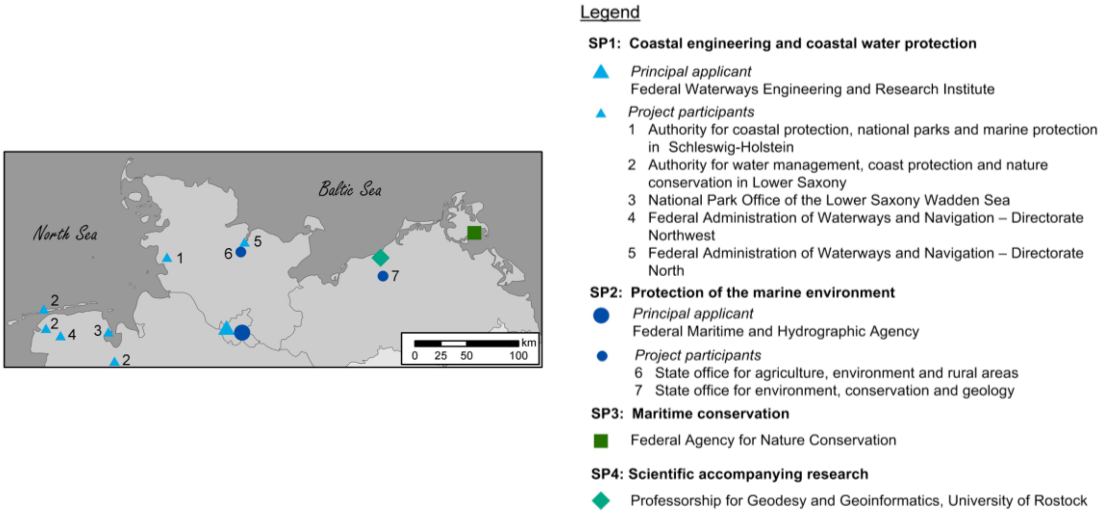

Figure 1: Project participants, sub-projects (SPs) and their locations

As can be seen in Figure 2, this undertaking is embedded in a series of regulations and developments at many administrative levels, from which specifications and courses of action are derived. At the European level, it is the INSPIRE (Infrastructure for Spatial Information in the European Community) initiative as well as the Marine Strategy Framework Directive (MSFD), the Water Framework Directive (WFD), and Natura2000 with their regulation counterparts for Germany and its federal states (Meeresstrategie-Rahmenrichtlinie [MSRL], Wasserrahmenricht-linie [WRRL], Fauna-Flora-Habitat-Richtlinie [FFH-RL], Vogelschutzrichtlinie [VS-RL]). All these directives require inter alia marine data. Sometimes the same data are needed but with metadata in another format, and sometimes they require different data or aggregates of the same data. The MDI-DE will become the central portal for Germany which shall help public employees, for example, to hand out data that complies with the data requirements of the various directives. The MDI-DE is built so that they do not have to look through a manifold of portals and/or have to ask for data anymore. Because other European countries are in the same area of tension as Germany, it is a good idea to see how their MSDI efforts are responding to the requirements of the directives.

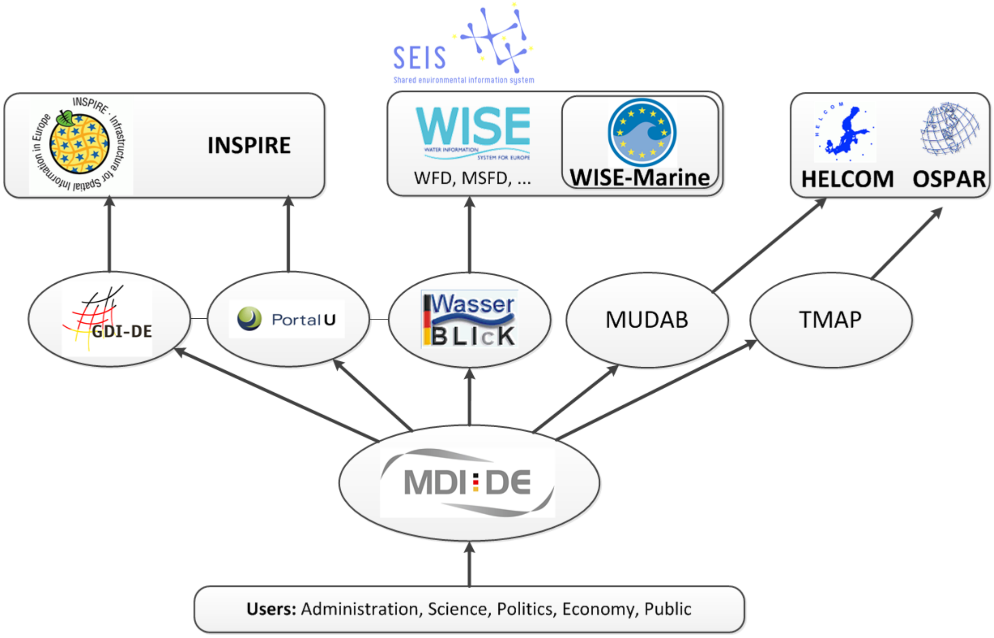

Figure 2: The MDI-DE in the scope of actions from German and European initiatives

To keep track of all the things mentioned and to give the marine data infrastructure (MDI-DE) a conceptual framework, scientists at the Chair for Geodesy and Geoinformatics at the Rostock University are evaluating meta-information systems, developing models to support common workflows in marine applications, developing a thesaurus to support marine keyword lists, and building a reference model evaluating marine SDIs. The reference model for the MDI-DE is the guideline for all developments inside this infrastructure and is based on the Reference Model for Open Distributed Processing (RM-ODP) and other reference models for federal states and Germany as a whole. It is composed of several sub-models (e.g. business model, role model, process model, architecture model, and implementation model) which focus on different aspects of the marine data infrastructure [2].

2 BUILDING THE EVALUATION FRAMEWORK

To build an evaluation framework for MSDIs, existing spatial data infrastructure assessment approaches were used as bases and were expanded to meet the requirements of the marine domain (see section 2.1). Based on researching literature in this field, the components useful for marine SDI evaluation are selected and are then augmented by ones needed especially in the marine context. The resulting indicators are merged in section 2.2 and are then assessed in section 2.4 to verify their usefulness for evaluation. Through the assessment a number of indicators were identified for being considered in the framework for the MSDI evaluation.

2.1 Bases for the framework

The components of an SDI were outlined inter alia in [3]. This publication showed that the two components – people and data – can be linked through the components standards, policies, and access networks (see Figure 3).

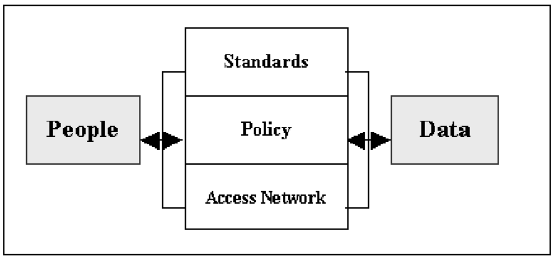

Figure 3: Components of SDI [3].

[4] take these components and define areas that should be inspected when assessing spatial data infrastructures (SDIs): Policy Level – Policy, Management Level – Standards and Access Network, Operational Level – Access Network and Data, Other Influencing Factors – People, Performance Assessment. For the defined areas, the paper then suggests possible indicators to evaluate SDIs (see Table 1). The paper also outlines that "[...] evaluation is about finding answers to questions such as 'are we doing the right thing' and 'are we doing things right'".

Table 1: Possible Indicators for evaluating SDIs [4].

Area	**Possible Indicators**
Policy Level – *Policy*	• existence of a government policy for SDI • handling of intellectual property rights, privacy issues, pricing • objectives for acquisition and use of spatial data
Management Level – *Standards*	• standardisation arrangements for data dissemination and access network • institutional arrangements of agencies involved in providing spatial data • organisational arrangements for coordination of spatial data • definition of core datasets • data modelling • interoperability
Management Level – *Access Network*	• access pricing • delivery mechanism and procedure • access privileges • value-adding arrangements
Operational Level – *Access Network*	• type of network • data volume • response time
Operational Level – *Data*	• data format • data capture method • definition of core datasets • data maintenance • data quality and accuracy
Other Influencing Factors – *People*	• number of organisations and people involved • opportunities for training • market situation for data providers, data integrators, and end-users
Performance Assessment	• degree of satisfying the objectives and strategies • user satisfaction • diffusion and use of spatial data and information • turnover and reliability

[5] are undertaking a similar approach for the assessment of SDIs by proposing three components (data and metadata, web services, and standards) accompanied by several indicators for each of the components. Since indicators could have a technical or organisational meaning, they are further classified by these two factors (see Table 2).

Table 2: Indicators for comparing SDIs on the basis of web services and data management [5].

Component	Indicator	
	Technical	*Organizational*
Data and metadata	• Data capture process • Definition of core datasets • Data format and conceptual model • Data management • Data quality and accuracy • Common modelling language and tools • Harmonization of data and metadata	• Custodianship • Data sharing and partnerships agreements • Business models • Coordinating arrangements
Web services	• Application profile • Clearinghouse and geoportal	• Clearinghouse organization
Standards	• Interoperability	• Organizational arrangements for standardization

Because we want to evaluate and compare MSDIs instead of "regular" SDIs, we may have to adjust the components outlined at the beginning (Figure 3). When having a look at [6], we find out that "the four main components of a successful coastal and ocean information network (COIN), as an important component of an SDI, are:

- online access to data using recognized standards
- metadata catalogues that can be used to search for geospatial info
- a web interface that allows users to search, access and retrieve the best available information from the most reliable sources
- active participation of data providers and data users to ensure that the right data are available to contribute to more effective decision-making."

These components are similar to the five components, a SDI consist of, which were mentioned at the beginning (Figure 3) just in another form. Comparing them, we can map them to:

- online access to data using recognized standards

  => people, data, standards, and access networks
- metadata catalogues that can be used to search for geospatial info

  => people, data, standards, policies, and access networks
- a web interface that allows users to search, access, and retrieve the best available information from the most reliable sources

  => people, data, standards, policies, and access networks
- active participation of data providers and data users to ensure that the right data are available to contribute to more effective decision-making

  => people, data, policies

From the preceding comparison, it can be seen that the components of SDIs and MSDIs are very similar and comparable to each other. The said comparability enables us to use the indicators (which were meant for SDIs) described in the two beforehand mentioned papers for the evaluation of MSDIs. At this point, a remaining open question is: are any additional indicators required to assess MSDIs?

In order to see if any additional indicators are required, we are looking at the definition of the term MSDI by Russell [7]. MSDIs are "the component of a National SDI that encompasses marine and coastal geographic and business information in its widest sense. An MSDI would typically include information on seabed bathymetry (elevation), geology, infrastructure (e.g. wrecks, offshore installations, pipelines, cables); administrative and legal boundaries, areas of conservation and marine habitats, and oceanography." This means that core data sets still fit as an indicator but that the core data sets are obviously different for an MSDI. Welle-Donker [8] adds to this definition by stating that MSDIs are special SDIs because inter alia "[...] seas and oceans do not stop at national boundaries and the collection of marine data is highly fragmented." Not only seas and oceans ignore national boundaries, but the boundaries itself or their definitions could be problematic because they subject to change over time. This is why an indicator is proposed which checks if the *definitions for shorelines and/or maritime zones* differ in varying MSDIs. Furthermore, [8] states that "the collection of marine data is highly fragmented". This is because there is a manifold of stakeholders in the marine domain. The different stakeholders might use different metadata standards which can be problematic when developing an SDI. This is why *metadata coordination* might be important.

Apart from these additional marine-specific indicators, there still might be indicators missing which might be useful to evaluate MSDIs (as well as SDIs in general, since these will not be marine-specific). In [4] metadata cannot be found at all in the list of possible indicators, although metadata is mentioned in the paper several times. Najar et al. [5] on the other hand, list "Data and metadata" as a component so that some of the indicators listed under this component also apply to metadata and the indicator "harmonization of data and metadata" mentions metadata explicitly. But what is not mentioned in both papers is the *availability of metadata* in general and a *metadata catalogue* in particular (this enables inter alia automatic harvesting). Metadata of course is linked to real data which is usually downloadable. To evaluate if the data might be helpful, ahead of download, view services (Web Map Services [WMS]) are needed. When a user found out that a data set is useful, it would be even easier for him (at least in some cases) if he was able to integrate the data on the fly (through a Web Feature Service [WFS]) without having to download it. For both use cases, an indicator is needed that looks at the *availability of services*. Another aspect also not found in the existing approaches is the *architecture* of a (marine) SDI. This is interesting in order to better understand how other (marine) SDIs got to their infrastructures and how they are built.

2.2 Compiling the framework

Compiling the different approaches described in section 2.1, we end up with several indicators (see Table 3) which will be explained in detail in 2.3. For clarity purposes, all indicators are classified into the technical and organisational factors similar to [5].

Table 3: Possible indicators for the evaluation of marine spatial data infrastructures[1]

Area	Indicator	
	Technical	*Organizational*
A – Data	*Core datasets*	*Degree of involvement of different agencies/institutions*
		Data modelling (Harmonization of data and metadata)
B – Metadata	Availability of Metadata/Metadata catalogue	Coordination
	Data quality and accuracy	
C – Services & Interfaces	Availability of Services	*Access privileges*/Custodianship
	Performance	*Value-adding arrangements*
	Geoportal	
D – Standards	*Interoperability*	
E – Other		*Existence of a government policy for SDI*
		Architecture
		Definition shoreline / Maritime Zones
		Business models

2.3 Description of the indicators

The first **area (A)** covers the organizational and technical indicators regarding data. Because data is the most important thing in a MSDI, this is the first area to look at. The indicator *core datasets* describes which basic reference spatial data is covered by a country's MSDI. The datasets which could be covered are as follows:

[1] sources are *italics* for *[4]* and underlined for [5]

- Bathymetry
- Shoreline and other maritime zones like exclusive economic zone (EEZ)
- Marine Cadastre
- Coastal imagery
- Marine navigation
- Tidal benchmarks
- Benthic/Nature conservation habitats

The indicator *degree of involvement of different agencies/institutions* looks at the degree of involvement of different agencies or institutions by reason that a MSDI has to incorporate various datasets coming from a wide range of agencies/institutions and these will be listed for this indicator and – if possible – compared to the ones that were left out. *Data modelling* or *harmonization of data and metadata* are important (and expensive) steps to provide users with data of quality to be able to understand, interpret, and find. Another factor to be considered here can be data updates, with which it has to be ensured that the same metadata fields are used for equal or similar data sets (e.g. when handling time series data sets which are very common in the marine domain).

For **area B** it is important that data is augmented by metadata to be able to find it and to know which the data is about later on. The indicator *availability of metadata/a metadata catalogue* looks at the availability of metadata and tries to answer the questions "is it searchable?", "how is it held?" and "is it available through a standardized catalogue interface?". Because we are in the marine field, much data will be sensor data, so describing the data quality and accuracy is a big issue. That is why the indicator d*ata quality and accuracy* tells if the metadata is available that handles how the measurements were done and how accurate they are (if the OGC's Observations and Measurements [O&M] standard is used for the metadata, this field is already covered). In general, it would be wise to use internationally approved standards and, if needed, build profiles to meet special requirements. For this purpose the indicator *coordination* is designed because metadata should be homogeneous inside a MSDI or at least appear homogeneous to users. This is needed for example when chemical or physical measurements will be published as they need the same measurement unit and so on to be comparable directly (on a map for example). To achieve this, the metadata fields do not have to be the same but mapping is needed, which requires previously mentioned coordination. There should be a central coordination unit dealing with implementing metadata rules (which standard to use, how to build a profile or mapping and so on).

Having data and metadata for the data is a good thing so far, but having services to use the data on the fly without having to send files back and forth would increase efficiency considerably. For that purpose **area C** (services and interfaces) deals with the availability of services, their performance and the presence of a geoportal (or clearinghouse). From an organizational standpoint, access privileges and value-adding arrangements are important, too. For interoperability it is important to be able to get marine-related data into any application of your choice and not to depend on a geoportal alone. Thus the indicator *availability of services* lists all the available services categorized in Discovery, View, Download, and Transformation services. What we should not forget here is the availability of a gazetteer. When you want to work with the data provided by services, it is important the services to meet certain criteria regarding response time or *performance* in general. Furthermore, the system has to be able to cope with large data sets and there should be an update cycle with short intervals which is well documented. The MSDI should have a central entry point to access its data, which is the *geoportal* or a *clearinghouse*. For a geoportal, it is important a search functionality and a map viewer to be there. A central portal as a single-entry point is the best way for the users because they do not have to know of and visit other portals. In some way connected discovery services are good as well. Additionally, the indicator *access privileges/custodianship* asks if there was a focus on a role model which dealt with actors or stakeholders of the system while the MSDI was being modelled. Another question is whether there are *arrangements* with the private sector (companies etc.) which *add value* to the infrastructure. For example, the sea cable, a telecommunications company has laid, might affect certain species/populations and to study that you need the data from the company. So it would be great if you would have that data already available through the infrastructure.

All the areas so far should affect standards in some way. How and to what extent is answered by **area D** which asks in its only indicator *interoperability* which standards are used and does their usage lead to better interoperability or not. However, it has to be stated that this is really hard to measure or almost immeasurable. Because it cannot be said which standard is good, or if it is better to use many standards and worse if only a few are used. Another problem can be the existence of different versions of standards because it cannot be said if the latest versions are better than the older ones. Apart from that, this indicator asks if the stakeholders of the infrastructures are involved in standardization processes or organizations.

The last **area (E)** focuses on various aspects important for MSDIs from an organizational viewpoint. It considers the *existence of a government policy for a MSDI* and thus answers the question if the government backs up the developments. However, since the government most probably funds the development of a MSDI, the backing of the government should be implicit. To better understand how other marine initiatives got to their infrastructure and how they are built, the *architecture* and, in particular, the underlying *business models* are examined as well. **Area E** also gazes at the varying *definitions of shorelines and/or maritime zones* in diverse MSDIs from a legal point of view, which is why this is classified as an organizational indicator.

2.4 Assessment of the indicators

After identifying all indicators which sound interesting for MSDI evaluation, an approach is needed to verify if the found indicators really add value to the evaluation process, if the information about the indicators is obtainable and so on. For this purpose, SMART criteria were used to assess the indicators.

2.4.1 Introduction to SMART criteria

According to [9], SMART criteria are usually about the assessment of goals and targets. SMART is a mnemonic which most often stands for **S**pecific, **M**easurable, **A**ttainable, **R**elevant, and **T**imely. The specific meaning of these terms can only be defined by knowing the field they get applied to and defining them for that particular topic. Since SMART can be applied to numerous areas, there are other meanings for some of the letters, inter alia[2]:

- A: achievable, accessible, added value, appropriate, actionable
- R: result-oriented, realistic, reasonable, reliable
- T: tangible

[10] also map SMART criteria to the "5W's+H" rule (What, Why, Who, Where, When, How) making them easier to understand (see Table 4).

Table 4: Mapping between SMART criteria and the "5W's+H" rule [10].

SMART criteria	5 W's+H element
S – Specific	What
M – Measurable	How
A – Add Value & Actionable	Why
R – Realistic	Who, Where
T – Timely	When

The SMART criteria were applied to the marine area, too, mainly in the field of marine protected areas, marine conservation and planning objectives [11] and [12] for example and marine protection targets [9]. SMART criteria were also used for evaluation frameworks, e.g. for injury surveillance systems [13] or in software process improvement frameworks [10]. However, according to our knowledge to date, any SMART criteria were not applied to indicators for the evaluation of (marine) spatial data infrastructures. That is why the following elaborations are assessing the indicators which try to evaluate MSDI's.

[10] are pointing out that SMART not necessarily have to lead to the usage of Boolean values (true and false), but that also an ordinal scale could be used to assess indicators with SMART criteria (see Figure 4) leading to an Indicator Assessment Grid (IAG). If an ordinal scale is used for the assessment of the indicators, an IAG has to be developed after defining the SMART criteria.

[2] Sources: [32], [11], [12], [10] and [13]

SMART	Description	0 *Poor/Absent*	1 *Fair*	2 *Good*	3 *Excellent*
S - Specific	*Indicators must be specific and targeted to the area intended to be measured.*	Not focused on the area intended to be measured	Informally addresses and covers the area intended to be measured.	Addresses and covers the area intended to be measured.	Properly addresses and covers the area intended to be measured.
M – Measurable	*Indicators must permit collection of accurate and complete data*	Incomplete or bad definition	Formal definition of the elements needed for	Definition of the elements needed for cal-	Complete and exhaustive definition of the elements for

Figure 4: The Indicator Assessment Grid [10].

2.4.2 *Defining the SMART criteria for the indicators*

To verify if the indicators found for the evaluation are indeed useful, we have to set up criteria to assess them (see Table 5). The "5 W's and H" rule (see Table 4) is used to define the SMART criteria. Firstly we ask if "*what* is measured" is specific and unambiguous. After that we have to think about *how* or if the indicators are measurable. Then we have to think about *why* we include a certain indicator – we question if the indicator creates added value for the evaluation framework. Because most of the time the information about the MSDIs only stems from bibliographical sources, we have to ask *who* gave the information on a certain indicator and *where* this information was found. In the end, we are asking about the reliability of the indicators and the probability of founding reliable information for the indicator. The question *when* does not make sense as when it comes to the indicators for evaluation, time will be left out.

Table 5: Selected SMART criteria and their meaning

Criterion	Description
Specific	Indicators have to be specific and unambiguous.
Measurable	Indicators have to be measurable, which means that grades can be applied to them at the end of the evaluation.
Added value	Indicators have to create added value for the evaluation framework so that the MSDIs can be compared and evaluated better.
Reliable	Indicators have to be reliable meaning that the information on a certain indicator probably is not restricted.

2.4.3 *Development of the indicator assessment grid*

To assess the indicators, an ordinal scale is used leading to an IAG (see Table 6). The IAG is used because a simple yes/no assessment for the indicators does not seem appropriate due to their complexity.

Table 6: Indicator Assessment Grid (IAG)

Criterion	Description	Indicator assessment			
		0	1	2	3
Specific	Indicators have to be specific and unambiguous.	Indicator is ambiguous.	Indicator is somewhat specific but could lead to confusion.	Indicator is specific and unambiguous.	Indicator is absolutely specific and unambiguous.
Measurable	Indicators have to be measurable.	Indicator cannot be measured.	Indicator is very hard to grade.	Indicator can be measured.	Indicator can very easily be measured.
Added value	Indicators have to create added value for the evaluation.	Indicator does not create added value at all.	Indicator adds very little value.	Indicator creates added value.	Indicator adds much value.

Criterion	Description	Indicator assessment			
		0	**1**	**2**	**3**
Reliable	Indicators have to be reliable.	The probability of finding reliable information is nearly zero.	The probability of finding reliable information is very low.	It is likely that reliable information could be found.	It is very likely that reliable information could be found.

2.4.4 Applying the SMART criteria to the indicators

The IAG is now used to assess the indicators (see Table 7) by applying values to each criterion which of course are very subjective estimates by the authors. Because of their subjective nature and limited space, the description of why each indicator got applied the specific values will be set aside apart from one example – “availability of services”. This indicator is specific (***S***) as it just lists the offered services (grade 3), but it is very hard to measure (***M***) because there are so many services types and it cannot be defined how many have to be offered to get a ++, or a + and so on (grade 1). However, it does add value (***A***) to the evaluation because services are very important for users nowadays (grade 2) and because of that the available services are mostly well communicated to the users, which means that this indicator should be reliable (***R***, grade 2).

Table 7: Assessment of the indicators

Criterion / **Indicator**	*S*				*M*				*A*				*R*				Ø
Core datasets	0	1	**2**	3	0	**1**	2	3	0	1	2	**3**	0	1	2	**3**	2.25
Degree of involvement of agencies	0	1	2	**3**	0	**1**	2	3	0	1	2	**3**	0	1	2	**3**	2.50
Data modelling (harmonization of data and metadata)	0	**1**	2	3	**0**	1	2	3	0	**1**	2	3	0	**1**	2	3	0.75
Availability of metadata/CSW	0	1	2	**3**	0	**1**	2	3	0	1	2	**3**	0	1	**2**	3	2.25
Data quality and accuracy	0	1	**2**	3	0	**1**	2	3	0	1	**2**	3	0	**1**	2	3	1.50
Coordination	0	1	**2**	3	0	**1**	2	3	0	1	**2**	3	0	1	**2**	3	1.75
Availability of services	0	1	2	**3**	0	**1**	2	3	0	1	**2**	3	0	1	**2**	3	2.00
Performance	0	1	2	**3**	0	1	**2**	3	0	1	**2**	3	0	1	**2**	3	2.25
Geoportal	0	1	2	**3**	0	1	**2**	3	0	1	**2**	3	0	1	**2**	3	2.25
Access privileges/custodianship	0	1	**2**	3	0	**1**	2	3	0	1	**2**	3	0	**1**	2	3	1.50
Value-adding arrangements	0	**1**	2	3	0	**1**	2	3	0	**1**	2	3	0	**1**	2	3	1.00
Interoperability	0	1	**2**	3	0	**1**	2	3	0	1	**2**	3	0	1	**2**	3	1.75
Existence of a government policy for SDI	0	1	**2**	3	0	**1**	2	3	0	1	**2**	3	0	1	2	**3**	2.00
Architecture	0	1	**2**	3	**0**	1	2	3	0	1	**2**	3	0	1	**2**	3	1.50
Definition shoreline/maritime zones	0	1	**2**	3	**0**	1	2	3	0	**1**	2	3	0	**1**	2	3	1.00
Business models	0	1	**2**	3	**0**	1	2	3	0	**1**	2	3	0	**1**	2	3	1.00
Average/Mean value	2.19				0.88				1.94				1.81				1.70

After the application of the IAG, a threshold has to be defined so that it can be decided which indicators are kept and which are not used for the evaluation framework because they fail to add value and/or be specific and/or be measureable and/or be reliable. To compute the threshold T, firstly a mean value Ø of the four criteria was calculated for each indicator. After that the sum of all the mean values was calculated and then divided by the total number of indicators giving the total mean value of all the indicators (see formula).

$$T = N^{-1} \times \sum_{i=1}^{N} \frac{S_i + M_i + A_i + R_i}{C}$$

where

N	total number of indicators	M_i	value of criterion "measurable" for indicator i
i_1	first indicator (A1)	A_i	value of criterion "added value" for indicator i
i_N	last indicator (E4)	R_i	value of criterion "reliable" for indicator i
S_i	value of criterion "specific" for indicator i	C	total number of criteria

The result T = 1.7 (rounded) is the threshold used for the decision which indicators will be left out. Every indicator which has a higher average mean than 1.7 is kept and every one below will be scrapped. But there is one exception from that rule – the indicator *architecture*. Although this indicator is measureable, by no means the architecture of a MSDI is still interesting enough and will be kept just for the sake of including this kind of information in the evaluation.

This approach might seem complex at a first glance but when visualized with a line chart (see Figure 5), underachievers can be easily seen because they clearly are below the average line which indicates the mean value of each criterion. When inspecting the indicator *coordination*, for example, the line chart shows that it aligns pretty closely with the mean value line but is slightly above it all in all. This reflects its assessment mean value of 1.75 which is just a little over T (1.7), which is why this indicator will be included in the final evaluation framework. All the indicators which have a mean value below 1.7 (T) will not be included except for the indicator *architecture* as stated above. The reason for this is that the information about the architecture of a MSDI is very likely to be found (thus the reliability rating of 2). However, this is not true for the other indicators which will be completely left out. On top of that architecture there is the highest mean value of the indicators (amongst two others) scoring right below T, which means that most of the other indicators left out are less specific, add less value and/or do not add as much value for the evaluation. Because architecture is a special case and cannot be measured, no score will be applied to it when using the evaluation framework. The information about the architecture will just be stated as text and/or figures.

The remaining indicators after applying the assessment are presented in Table 8 and are the ones used in the next section for the evaluation of international case studies.

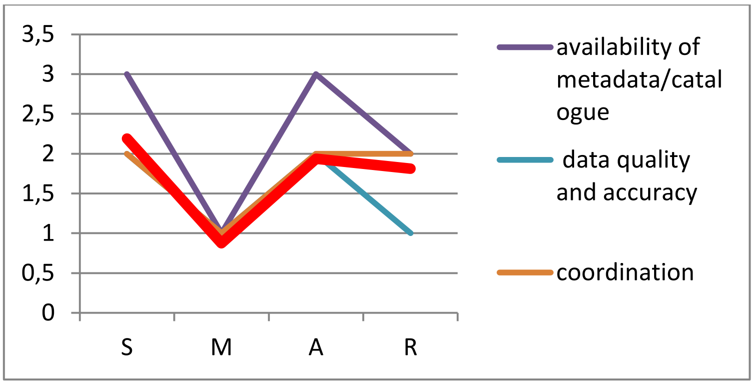

Figure 5: Line chart of indicator assessments for area B

Table 8: Indicators for the evaluation of marine spatial data infrastructures

Area	**Indicator**	
	Technical	*Organizational*
A – Data	1 Core datasets	2 Degree of involvement of different agencies/institutions
B – Metadata	1 Availability of Metadata/Metadata catalogue	2 Coordination
C – Services and Interfaces	1 Availability of Services	
	2 Performance	

Area	Indicator	
	Technical	*Organizational*
	3 Geoportal	
D – Standards	1 Interoperability	
E – Other		1 Existence of a government policy for SDI

3 INTERNATIONAL CASE STUDIES

After building the framework, it is used in this chapter to analyse and evaluate the efforts of selected existing marine SDIs. The efforts of Canada (Marine Geospatial Data Infrastructure [MGDI], COINAtlantic and GeoPortal) and Australia (AODN IMOS Ocean Portal and Australian Marine Spatial Information System [AMSIS]) were selected because they were developed pretty early dating back to at least 2004 [14] and thus should be quite advanced, and information is likely to be found instead of work in progress efforts. Ireland (Marine Irish Digital Atlas [MIDA]) is building its infrastructure for an equally long time and is particularly interesting as it is a European country, which means that it should be affected by the same legislation as Germany.

Since the evaluations are solely based on literature and the portals of the MSDIs, the results of the evaluations are subjective to a certain degree.

3.1 Canada

3.1.1 Introduction

In Canada, the national spatial data infrastructure (NSDI) is called Canadian Geospatial Data Infrastructure (CGDI), but is also known as "GeoConnections", and is divided into twelve nodes. The CGDI "recognizes that governments have a responsibility to make geospatial information available, and to 'play their role' in developing a knowledge economy in response to the needs of citizens, industry, and communities in support of the economic, social and environmental well-being" [15]. The CGDI aims to help users access and integrate said geospatial information by facilitating the infrastructure. Thus the CGDI does not host the spatial data but provides the framework so that various authorities can provide their data through the use of common standards. The CGDI mainly consists of:

- the GeoConnections Discovery Portal (GDP), a national search engine allowing providers to catalogue their data sets and users to search for it;
- GeoGratis, a national repository where suppliers may place data for free distribution;
- GeoBase, a national suite of framework layers that includes place names, a digital elevation model, a layer of satellite imagery, a road network, geodetic (survey reference) points, and a layer of administrative boundaries [16].

The Marine Geospatial Data Infrastructure (MGDI) is one component of the CGDI whose goal is "to satisfy the geographic data needs of water-oriented stakeholders" [17]. The development of the MGDI is led by the Marine Advisory Network node whereupon the Department of Fisheries and Oceans (DFO) and the Canadian Centre for Marine Communications (CCMC) are the key participants of the node (Department of Fisheries and Oceans Canada (2001)). The MGDI assists the economic and social needs of Canada's marine regions and the management of Canada's water resources [17]. As a key partner of both CGDI and MGDI, the Department of Fisheries and Oceans [18] (DFO) is developing the (DFO) GeoPortal, which is a key component of the MGDI and provides services that enable DFO employees to index and publish their data and find, view and download other spatial data. [19] states that "the GeoPortal does not provide a centralized data warehouse, but rather integrates information at the source" by using an open standard-based architecture. This is a good thing and shows that open standards were used.

COINAtlantic is another initiative inside the CGDI which "has implemented a coastal and ocean information network for the western North Atlantic" [6]. The initiative is led by the Atlantic Coastal Zone Information Steering Committee (ACZISC) and aims at the provision of open access to spatial data to support integrated coastal and ocean management (ICOM) by adopting all standards of and complying with the architecture of the CGDI [20].

3.1.2 Evaluation

Table 9: Evaluation of Canadian efforts*

Area	**Indicator**	
	Technical	*Organizational*
A	1 ++ (Core datasets)	2 ++ (Degree of involvement of diff. agencies)
B	1 ++ (Availability of Metadata)	2 ++ (Coordination)
C	1 + (Availability of Services)	
	2 +/- (Performance)	
	3 + (Geoportal)	
D	1 ++ (Interoperability)	
E		1 ++ (Existence of a government policy for SDI)

* ++ very good, + good, +/- not appraisable, - not so good, -- bad

With its many core datasets and the broad variety of involved agencies/institutions, Canada's approaches perform "very good" in **area A** as shown in Table 9. In **area B**, a minor issue is that there is no central catalogue available which is desirable. But apart from that, there are much metadata available in catalogues and thus queryable. Furthermore, everything is well organized with recognition of international trends in standardization. **Area C** is where the most points are lost because there could be more services available and a single central geoportal is lacking. This means that although there are portals for their initiatives, users have to know of all the initiatives and portals and have to visit each of them to search for and get data. Unfortunately, nothing really can be stated for C2 (performance). The rating in **area D** and **E** is overall great due to the facts that the CGDI is endorsing and/or investigating a multitude of *standards* and that the CGDI is the national spatial data infrastructure (NSDI) of Canada, which means that it is implemented by the Canadian government and that the CGDI "[...] recognizes that governments have a responsibility to make geospatial information available [...]" [15]. Thus the government backs up the Canadian MSDI developments.

3.1.3 Summary

In summary, it can be stated that a lot has been done in Canada to overcome the tradition of holding data in silos for in-organization/institution-use only. Through the adoption of the Canadian Geospatial Data Infrastructure (CGDI), Canada got to an interoperable MSDI based on widely adopted international standards which offers marine-themed data for (almost) everybody. The only problematic area to be seen is the division into several projects and thus missing a central entry point for marine data so that users do not have to look at several places to get the data they need.

3.2 Australia

3.2.1 Introduction

In Australia, we mainly find two approaches which are aiming to tie in with the Australian Spatial Data Infrastructure (ASDI). One – the Australian Marine Spatial Information System (AMSIS) – focuses primarily on "framework" data (boundaries, cadastre, infrastructure etc.) while the other – the Integrated Marine Observing System (IMOS) Ocean Portal – offers a variety of data mostly from scientific research (e.g., biological and climatic data).

The AMSIS was developed and is maintained by Geoscience Australia (an agency of the government) and – as a web based interactive mapping and decision support tool – offers access to over 80 layers of information in the Australian marine jurisdiction including maritime boundaries, bathymetry, physical and environmental information, legal interests, fisheries and shipping [21].

The Integrated Marine Observing System (IMOS) is a distributed set of equipment and data-information services which, among many other applications, aims at meeting the needs of the research community in Australia. The strategic focus of the IMOS is on the 4-dimensional ocean variability and the impact of major boundary currents on the continental shelf, ecosystems, and biodiversity. The IMOS is organized as a matrix of nodes and facilities where the facilities deliver data streams which are then used by the nodes and other stakeholders. There are facilities inter alia for bluewater, climate observations, coastal currents, water properties, coastal ecosystems, and a biophysical sensor network on the Great Barrier Reef. The data the facilities are producing are made available through the electronic Marine Information Infrastructure (eMII). The eMII is located at the University of Tasmania and handles and organises the storage, accessibility, discoverability, and tools for the visualisation of data. All data are freely available from the IMOS Ocean Portal which allows the discovery and usage of the data from all of the facilities [22, 23].

3.2.2 Evaluation

The Australian approaches perform "very well" when they come to core data sets which were hinted at in the previous section. The AMSIS contains data from agencies and industry sources and the IMOS is a set of nodes. It can be concluded from this that the datasets are coming from a wide range of agencies/institutions and thus giving the indicator A2 a "very good" score, too [22-24].

Although there is no metadata catalogue for the AMSIS, you can find all the layers provided in the AMSIS through the Australian Spatial Data Directory (ASDD). The IMOS uses a modified version of GeoNetwork holding ISO 19115/19139 standard records which provides data discovery, access and download. The ANZLIC (Australia New Zealand Land Information Council) is coordinating the implementation of metadata guidelines and built a metadata profile based on the widely adopted metadata standard ISO 19115 which both the AMSIS and the (IMOS) Ocean Portal use. With these offerings the Australian efforts score is "very good" for the indicators B1 and B2 [22, 23, 25].

Because the AMSIS is using a gazetteer, there has to be at least one service which affects the AMSIS. According to the Oceans Portal project Governance Working Group discussion paper (Oceans Portal Project Governance Working Group (2006)), the projected services include WMS, WFS, gazetteer, and others, of which at least a variety of WMS can be found. All this results in a "very good" score for the indicator C1. On the one hand, nothing could be found regarding the performance of services for the AMSIS, and, on the other hand, there is only one discussion paper [26] which discusses guidelines for availability, reliability, and performance of the IMOS Ocean Portal. This makes the indicator C2 (performance) immeasurable. The AMSIS as well as the IMOS Ocean Portal offer a geoportal with all common functions leading to "very good" for the indicator C3 [24].

Apart from the already mentioned standards, the IMOS' Ocean Portal uses netCDF (Network Common Data Form) [23].Because not more could be brought to light, the indicator D1 is not appraisable and thus cannot be rated.

The AMSIS is strongly connected to the Australian Ocean Governance and related legislation (e.g. Coral Sea Act, The Fisheries Management Act and so on) and is developed and hosted by Geoscience Australia which is an agency of the Australian federal government. The IMOS Ocean Portal is supported by the Australian government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative (http://imos.org.au/aodn.html). In conclusion it can be stated that both initiatives are backed up with funding, development and hosting by the Australian government resulting in a "very good" evaluation for the indicator E1.

Table 10: Evaluation of Australian efforts*

Area	**Indicator**	
	Technical	*Organizational*
A	1 ++ (Core datasets)	2 ++ (Degree of involvement of diff. agencies)
B	1 ++ (Availability of Metadata/CSW)	2 ++ (Coordination)
C	1 ++ (Availability of Services)	
	2 +/- (Performance)	
	3 ++ (Geoportal)	
D	1 +/- (Interoperability)	
E		1 ++ (Existence of a government policy for SDI)

* ++ very good, + good, +/- not appraisable, - not so good, -- bad

3.2.3 Summary

To summarize, we can say that Australia put much effort into their approaches and by providing the framework – the Australian Spatial Data Infrastructure (ASDI) – managed to develop a broad MSDI. Just like the Canadian MSDI, the Australian is missing a single portal. Users have to look at least at two different portals (and, of course, have to be aware of their existence). On the positive side, Australia strongly focuses on free open source software (GeoNetwork etc.) and free and open data usable by anyone without restrictions. Furthermore, they divided their system into several nodes making it better manageable and scalable.

3.3 Ireland

3.3.1 Introduction

The Marine Irish Digital Atlas (MIDA, http://mida.ucc.ie) originally was a three-year project by the Coastal & Marine Resources Centre (CMRC) at the University College Cork which started in September 2002 and is still enduring. The MIDA was not started out to be the marine SDI for Ireland as the name MIDA indicates, but, nevertheless, the MIDA "aims to be a single source for marine and coastal geospatial information in Ireland" [3] from numerous data owners for professional and public use. It provides over 140 data layers (and associated metadata) from more than 35 data sources trying to address the needs of the Irish coastal and marine community, including marine scientists, administrators, educational establishments, the general public and so on [27 -29].

3.3.2 Evaluation

Through the involvement of some key data owners (such as the Marine Institute and the Department of Communications, Energy and Natural Resources) many core data sets can be found in the MIDA resulting in "very good" for the indicator A1 [29]. There are 35 organizations providing data for the MIDA, over half of them of which are government organizations, more than a quarter educational institutions and so on meaning that data comes from a variety of data owners, which results in "very good" for A2 [30]. Because Ireland as a European country is caught in the same tension of EU directives as Germany, it is additionally checked how Ireland complies with these directives. This is not qualified as an indicator because it is very hard to measure and it is not general enough to include it in the evaluation framework. Some organisations which contribute to the MIDA have to publicise data for the EU's Water Framework Directive. The Environmental Protection Agency (EPA) is one of them, and contributes a few layers to the MIDA: lakes and rivers, bathing water quality at beaches, coastal and transitional waters, and river basin districts [29]. Since ISO 19115 is the core of the metadata standard for INSPIRE, the MIDA to some extent ties in the INSPIRE initiative, too.

The MIDA provides metadata for all its data sets in accordance with ISO 19115 but not through a catalogue, however, outside the MIDA there is the Marine Data Online (MDO) which is a GeoNetwork-based data catalogue offering an INSPIRE compliant data discovery service (http://catalog.marine.ie). Furthermore, there is the Irish Spatial Data Exchange (ISDE, http://www.isde.ie) which offers a CSW 2.0.2 and is also able to search the catalogue of the Marine Institute resulting in a "very good" grade for the indicator B1. The Irish government initiated the Irish Spatial Data Infrastructure (ISDI) which developed an ISO 19115 metadata profile adopted by all parties in the ISDI community (including the marine community), which means that the organisation of metadata seems very well coordinated ("very good" for the indicator B2).

Due to the fact that the MIDA is using MapServer, it offers its data with OGC services like WMS, WFS, and WCS resulting in "very good" for the indicator C1. The MIDA's portal (or "atlas" as they call it) is a fully functional GIS web but its outdated look and feel leads to deduction and leaving "good" for the indicator C3. Unfortunately for the indicator C2 (performance) not much information could be found making this immeasurable.

Regarding metadata, the usage of the ISO 19115 profile has already been discussed in detail in the indicator B2 (coordination) and the support of OGC web services standards has been pointed out in the indicator C1 (availability of services). That is why accessing data and thus interoperability is not an issue in Ireland's marine community anymore ("very good" for the indicator D1).

The topic involvement of the government was touched in B2 (coordination) where it was pointed out that the ISDI (initiated by the Irish government) initiated the development of the MIDA. Furthermore, [31] pointed out that there was the "recognition that an ISDI should seek to fully incorporate marine and coastal data from the very beginning [...]" which results in "very good" for the indicator E1.

Table 11: Evaluation of the Irish efforts*

Area	Indicator	
	Technical	*Organizational*
A	1 ++ (Core datasets)	2 ++ (Degree of involvement of diff. agencies)
B	1 ++ (Availability of Metadata/CSW)	2 ++ (Coordination)
C	1 ++ (Availability of Services)	
	2 +/- (Performance)	
	3 + (Geoportal)	
D	1 ++ (Interoperability)	
E		1 ++ (Existence of a government policy for SDI)

* ++ very good, + good, +/- not appraisable, - not so good, -- bad

3.3.3 Summary

In conclusion, the Irish began early and did "very well" in implementing a marine SDI. Through its embedment in the Irish Spatial Data Infrastructure (ISDI) with the incorporation of marine and coastal data from the very beginning, the government supported the MIDA. Furthermore, governmental agencies like the Marine Institute and the Department of Communications, Energy and Natural Resources provided many core data sets. Through the use of the ISO 19115 standard which is the profile also developed by the Department of Environment, Heritage and Local Government, aspects of data quality and accuracy have got implemented. Through the development by the Department of Environment, Heritage and Local Government and the initiation of the ISDI, metadata was coordinated from a central point from a government level. The MIDA emphasizes the use of free open source software and offers its services through MapServer and – unfortunately through another portal – its metadata through GeoNetwork. On the negative side, it has to be stated that although a fully-functional portal is available for the MIDA, the look and feel of it could be improved (e.g. there is always a new window for adding/removing layers).

4 LESSONS LEARNED AND FUTURE PROSPECTS

This paper illustrated the development of an evaluation framework especially made to cover the needs of marine SDIs. The evaluation framework is composed of a set of indicators which were assessed on their own to see if they really contribute to the evaluation. The indicators selected were then used to evaluate some international MSDIs.

Because all countries inspected had a manifold of involved agencies/institutions which contribute to their MSDI, this is really important to consider. Most of the MSDIs (Canadian and Australian) are part of the national spatial data infrastructure (NSDI) which is why the German MDI-DE activities should become a part of the GDI-DE (German NSDI) in the future. Australia and Ireland are using at least partly free open source software (FOSS, e.g. GeoNetwork in Australia, MapServer in Ireland) which suggests that using FOSS is possible for the development of a MSDI. What can be learned from Australia, in particular, is that it is a good idea to develop the MSDI as a set of nodes because of the amount of agencies and institutions involved. Furthermore, they are using SensorML for sensor data. Accuracy and the description of data quality are important for sensor data which is why SensorML seems to be a good choice for this kind of data. Australia is also offering a marine gazetteer which is a useful addition to a MSDI and should be developed for Germany, too.

The biggest obstacle seems to be the division into several projects which all inspected countries share. All are missing a central entry point for marine data, which means that data maybe are stored multiple times; a user has to know of the existence of all the portals and has to look at multiple portals to find the required data. Regarding EU directives, it would have been great to learn from Ireland as the only European country inspected. Although the MIDA publicises data for the EU Water Framework Directive and has to comply with INSPIRE requirements in the future, no really useful information could be found about this topic. This is the reason why Germany cannot learn from them in this field.

In the future, it would be good to evaluate more countries especially in the EU to see how they cope with the requirements of INSPIRE and other marine related directives like MSFD and WFD.

Furthermore, it has to be stated that the evaluations just reflect an outside look at the infrastructures and thus may lack accuracy in some points. To eliminate this problem, web forms could be developed which experts use to describe and assess their own country's infrastructure.

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