Title:
Title: A3.2 D1 State of the Art in Spatial Data Tools
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Working Group:
References:
A3.1 D1

Short Description:
This document contains the results of the state of the art analysis on spatial data tools and standards. It includes an analysis of existing relevant documents by using predefined templates. It contains also a description of specific rules to apply on existing tools and standards in order to evaluate their suitability for HUMBOLDT. The process for the generation of this document is based on the methodology documented in A3.1 D1.
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010	R. Arnaud	rfc	Chapter 4.1
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1 General information

This document contains deliverable A3.2 D1 (State of the Art in Spatial Data Tools), which is the first in a series of state of the art documents within work package 3 of the HUMBOLDT project. According to HUMBOLDT's description of work this deliverable aims at:

- the determination of strengths and weaknesses of existing frameworks and demonstration applications;
- the description of the functionalities of common-used methods and tools;
- the assessment of the existing standards (including a survey on the adopted standards in regional infrastructures already operating);
- the identification of gaps, where existing standards are not yet supported or interoperability is not yet achieved.

The results of this deliverable will be used for the WP5 *Framework interfaces, models and architecture* (*interface specification)* and for the *Handbook of standards* (A3.6). The handbook of applicable standards, rules, methods and tools to use in HUMBOLDT will serve as an implementation guideline for all implementation activities in HUMBOLDT Work packages and Scenarios.

The market of spatial data tools is evolving quickly, standardisation bodies are permanently working on suitable interface specifications and the overall IT market is also influencing SDI implementations. Therefore, we do not expect this state of the art document to be neither complete nor correct in every respect. In fact, a complete and detailed survey would by far exceed the assigned resources for this task. In addition, the evolving market will change user requirements as well as tool's and standards' features over time, especially considering that the project duration of HUMBOLDT will be 4 years, and we expect HUMBOLDT to provide sustainable solutions to be used even after the project's official end. As a consequence this document will be handled as a living document, meaning that it will be permanently updated during HUMBOLDT project, if regarded necessary. In addition, the document contains an evaluation process and specification, which was developed and used on the current state of the art but can also be used in later phases of the project, when more knowledge on the same or additional tools and standards is available. Since most available descriptions of tools are not complete or do not provide the required level of detail, we clearly distinguished between the neutral description of the tools' features and the evaluation of tools based on previously defined rules. In order to provide hints to the reliability of the evaluation, we also provided an indicator denoting the percentage of rules, which could be applied for each standard or tool due to the available information.

2 Scope

The implementation of a European Spatial Data Infrastructure involves different tools and standards. Considering the main objective of the HUMBOLDT project, the state of the art in spatial data tools and standards has to focus on tools and standards used in the process of data harmonisation. This process includes the harmonisation of the data schemas, the data structures and the harmonisation of the data transfer processes.

According a report on the GIS market in 2004 ([5]) there were 455 different spatial data tools on the German market. The Open Geospatial Consortium lists on its website 369 compliant or implementing products, which are registered to use OGC standards. In order to find a suitable subset of these tools to be evaluated for the HUMBOLDT project context, there is a need of carefully documenting the users' requirements concerning SDI implementation in general and specifically focussing on data harmonisation processes. Since the respective surveys and documents in HUMBOLDT are not yet available, we have to define the scope of this deliverable making some assumptions on the predicted needs of users and providers involved in an SDI development and in data harmonisation processes. Since the deliverable will be handled as a living document, it can/will be refined and attuned to user needs once these will be clearly identified and defined within the framework of the HUMBOLDT project.

For this purpose different categories of needs have been defined (cf. Table 1). For each of these categories "subneeds" can be identified e.g. for data modelling: elaboration of conceptual data models; translation between different data models; etc. Tools and more precisely single software components linked or not with standards are able to satisfy these needs.

Components	Needs
geodata	data modelling (format; semantic / e.g. UML model)
	production of data (e.g. digitalisation)
	model integration/migration
	storage (database)
metadata	discovery (e.g. catalogue)
	metadata (data quality, origin, reference systems, ontology)
service	security (authentication, authorization, access control)
	publication /access (e.g. portal)
	conversion/translation (e.g. FME, CITRA)
	visualisation (web mapping services)
	acquisition (e.g. e-commerce)
	analysis / process (e.g. query)
	participation (e.g. MapTalk)

DATA HARMONISATION

Table 1: Scope of 3.2

In order to reach the objective of data harmonisation, the focus of this deliverable is on tools and standards linked to the needs related to geodata and metadata (cf Table 1, dark grey). Tools and standards linked to some services like security, publication/access or conversion/translation have also to be considered. Tools and standards linked to other services like analysis/process or participation (cf Table 1, white) are not taken into account in this deliverable.

As a result this document mainly focuses on the tools and standards (cf chapter 3) aiming to provide solutions for the following functional categories of tools:

- data modelling (indirectly production, modelling, storage of data, conversion/translation);
- discovery of data (metadata management);
- publication/access (including visualisation of spatial data).

Moreover, descriptions of existing SDI implementations were used to decide which of the large amount of existing spatial data tools (or even general tools) are relevant for SDI development and harmonisation processes.

3 Definitions, glossary

Explanation of terms, expressions used in this document.

Profile: A profile can be defined as a « set of one or more base standards and - where applicable - the identification of chosen clauses, classes, options, and parameters of those base standards that are necessary for accomplishing a particular function » (cf ISO 19104 Terminology)

Specification: « Specifications are technical documents that detail interfaces or encodings. Software developers use these documents to build support for the interfaces or encodings into their products and services ».
Open Geospatial Consortium, http://www.opengeospatial.org/standards

Standard: A standard is defined as « documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose ».
International Standardisation Organisation (ISO), http://www.isotc211.org

Tool: "A software component, sometimes called an application object, which can act as either a service provider or service requester within an application platform."
Open Geospatial Consortium, http://www.opengeospatial.org/

User community: A number of persons applying the same software, tool etc. In contrary to the ***user group*** the *user community* is looser way of cooperation, which provides fewer services and supports. E.g. wikipedia contributors are sometimes regarded as *user community*.

User group: Organisation of persons applying the same software, tool etc. In contrary to the ***user community*** a *user group* is more formalised and organised. *User groups* offer a more extensive service like newsletters, periodic meetings, etc.

4 Results of the Preparatory Work Phase

The A3.2 templates are the final results of the Preparatory Work (PW), where all WP3 partners collected papers and reports and documented them according to the templates. They where specified in deliverable A3.1 D1, containing the methodology for producing all other state of the art documents. Each template refers to one document and contains the description of one or more tools. In some cases also some specific information about standards is given.

To gather the information about all the tools described in the templates an Excel document was elaborated and serves as Annex I to this deliverable (cf the description in chapters 4.1 and 8). Annex I provides a list of all the tools identified in the state of the art analysis and summarises the main characteristics of these tools. Annex I gives a neutral summary of all the information gathered and provides general statistics about all the tools available and described in the templates. Finally, the results contained in Annex I are used for the application of the specific rules (cf. chapter 5).

Deliverable A3.2-D1 provides an overview of SDI-relevant tools and standards, which aims to be as comprehensive as possible. The implementation of an SDI involves heterogeneous IT tools and methods, not only those, which are directly related to spatial data (e.g. security). Therefore, a complete compilation of all possible IT tools would have exceeded the range and resources of this deliverable. Instead, some decisions were made to focus on the relevant tools. Indicating relevance in the HUMBOLDT context tools were considered that support the spatial data harmonisation process with a focus on data modelling, metadata and the visualisation aspects. General tools (e.g. database software) have only been considered if they were explicitly mentioned in a description of one or more SDI implementations. This deliverable does not claim completeness in the description of all possible tools, which could be used to process or manage spatial data.

Likewise, this report does not aim to investigate all GIS (more than 450), OGC-registered programs (about 370), or UML editors (about 40), etc. Again, only those solutions, which have been mentioned in an SDI implementation report, were taken into account.

4.1 Information gathering

An Excel document (Annex I: Annex_I_A3.2_D1.xls on the HUMBOLDT server) is created to gather all the information about the tools described in the templates.

In Annex I a line is used for each tool mentioned in the templates. The line summarise the relevant information and characteristics of the tool (e.g. standards, APIs, programming languages, SDI components, SDI contexts, user groups).

Depending on the functional category, a tool is mentioned in at least one of the following sheets of the document:

- Data modelling and storage of data;
- Discovery and management of data and metadata;

- Publication, access and visualisation.

Where it is not specified to write a text (name of the tool; template numbers; URL; other comments), the cell is filled with:

- 1: the tool corresponds to this aspect (e.g. compliant with a certain standard);
- 0: the tool does not correspond to this aspect;
- cell empty: there is no information about this aspect[1].

For each standard the corresponding national or international standards organisation is mentioned e.g. XML (W3C). The version of the standard is also mentioned if the information was available, e.g. WFS 1.0.0 (OGC).

4.2 Neutral summary, statistics based on PW templates

Annex I provides information about 169 tools. This total result includes sometimes different versions of the same tool (e.g. Flamingo 1.6c and Flamingo 2). Even if the objective was to consider all the tools supporting spatial data harmonisation process with a focus on data modelling, metadata and the visualisation aspects, the results obtained are most probably not complete.

According to the supported functionalities these tools may occur in one or more category of tools (data modelling and storage; data or metadata discovery and management; publication, access and visualisation). Each of these categories corresponds to one Excel sheet of the Annex I. The results show that most of the tools identified concern (cf.Table 2) data publication, access and visualisation (93). However, 50 tools are also identified as useful for data or metadata discovery and management and 26 tools for data modelling and storage.

According to the information available in the templates and to the information needed to apply the specific rules, Annex I provides information about the compliance to one or more standards, a tool's availability (e.g. Open Source, not Open Source), the available Application Programming Interface/s, the programming language/s, its usefulness in a SDI context (SDI component/s; e.g. data modelling), its functionalities (e.g. data management), the SDI context (e.g. European, National), the user groups (e.g. developers), the realisation of a test, its cost, the availability of documentation, the corresponding URL and finally some other comments.

The Table 2 summarises the information obtained for the three categories of tools.

The results show that the tools listed in Annex I mainly concern data management, data harmonisation, data editing and management, catalogue service, portal service, portrayal service and data service on national or regional levels (cf Table 2). They are principally destined to experts and developers.

Approximately 50 standards are identified and one or more tools are compliant with them. Some of these standards can be present in more than one category of tools (e.g. GML and XML). For some standards different versions are available and indicated (e.g. GML, UML, WFS, WMS, GML, SLD, WMC). Unfortunately the version of the standard is not always specified. On the whole, tools providing

[1] If possible, missing information has been completed by using second sources, e.g. the Internet

functionality for data modelling and storage are principally compliant with the GML, the ISO 19103, the ISO 19109 and XML standards. For data or metadata discovery and management the tools are mainly compliant with the ISO19115 and the ISO19139 and for data publication, access and visualisation with OGC standards: WMS, WFS and GML. Concerning the compliance of tools with standards, the results are mainly relevant for two categories of tools (cf Table 2): data modelling and storage (information available for 81% of the tools) and data publication, access and visualisation (information available for 72% of the tools). The majority of the tools of these categories, respectively 77% and 68%, are compliant with one or more standards. The results obtained for the data or metadata discovery and management category, which is worst documented, shows that less than a half (44%) of the tools are developed according to one or more standards.

The results obtained in the Excel document also show that the programming languages used by the tools are mostly object-oriented. Java and C++ are the most used programming languages (cf Table 2). However, information about programming languages is missing for more than half of the tools of each category.

Information about APIs is also missing for more than half of the tools of each category (cf Table 2). The category data or metadata discovery and management presents the highest percentage of not available (n.a.) information (77%).

Even if nowadays open source tools are well spread, the results show a balanced availability of open source and not open source tools. However, not open source tools are in the majority concerning the data or metadata discovery and management category (cf Table 2). As the percentage of not available information is less than 40% for the different categories of tools, these results are considered as reliable.

Results obtained also inform about the cost of the tools (free/commercial) and indicate if the tools have been tested or not and if any documentation is available (cf Table 2). However these results are considered as not very reliable because information is missing for more than 50% of the tools concerning data or metadata discovery and management and data publication, access and visualisation.

Table 2: Summary of the results

<table>
<tr><th></th><th colspan="3">Data modelling and storage of data</th><th>n.a. (%)</th><th colspan="3">Data and metadata discovery and management</th><th>n.a. (%)</th><th colspan="3">Publication, access and visualisation</th><th>n.a. (%)</th></tr>
<tr><td>number of tools</td><td colspan="3">26</td><td></td><td colspan="3">50</td><td></td><td colspan="3">93</td><td></td></tr>
<tr><td>most concerned SDI component</td><td colspan="3">data management, data harmonisation</td><td></td><td colspan="3">data editing and management, catalogue service</td><td></td><td colspan="3">portal service, portrayal service, data service</td><td></td></tr>
<tr><td>compliant with standards / n.a.</td><td>21</td><td colspan="2">5</td><td>19.23</td><td>23</td><td colspan="2">27</td><td>54.35</td><td>67</td><td colspan="2">26</td><td>28.42</td></tr>
<tr><td>most used standards</td><td colspan="4">GML, ISO 19103/ISO 19109, XML</td><td colspan="4">ISO19115, ISO19139</td><td colspan="4">WMS, WFS, GML</td></tr>
<tr><td>most used programming language</td><td colspan="3">Java</td><td>57.69</td><td colspan="3">C++, Java</td><td>65.22</td><td colspan="3">Java, C++</td><td>54.74</td></tr>
<tr><td>most used API</td><td colspan="3">Library, Java, ODBC, JDBC</td><td>57.69</td><td colspan="3">Java</td><td>73.91</td><td colspan="3">Java, php</td><td>60.00</td></tr>
<tr><td>open source / not open source / n.a.</td><td>10</td><td>9</td><td>7</td><td>26,92</td><td>12</td><td>22</td><td>16</td><td>32,00</td><td>34</td><td>36</td><td>23</td><td>24,73</td></tr>
<tr><td>tested / not tested / n.a.</td><td>17</td><td>1</td><td>8</td><td>30,77</td><td>18</td><td>1</td><td>31</td><td>62,00</td><td>26</td><td>1</td><td>66</td><td>70,96</td></tr>
<tr><td>documentation / n.a.</td><td>17</td><td colspan="2">9</td><td>34,62</td><td>13</td><td colspan="2">37</td><td>74,00</td><td>24</td><td colspan="2">69</td><td>74,19</td></tr>
<tr><td>most concerned SDI context</td><td colspan="3">national</td><td>30.77</td><td colspan="3">national, regional</td><td>41.30</td><td colspan="3">national, regional</td><td>53.68</td></tr>
<tr><td>most concerned user groups</td><td colspan="3">experts, developers</td><td></td><td colspan="3">experts, end users, developers</td><td></td><td colspan="3">developers, end users, experts</td><td></td></tr>
</table>

Finally the results obtained are interesting for the state of the art analysis process and are useful for the application of the specific rules. The results are particularly relevant concerning data modelling and storage of data tools because of the amount of available information. However because of missing information the results of the two other categories of tools, and mainly the category data and metadata discovery and management, can be interpreted only with precaution.

4.3 Other relevant aspects, which are not covered by PW templates

The templates in the preparatory work phase (PW) were designed to structure the information collected on tools. Information or experiences on spatial data standards were only indirectly covered or could be described in free text. Nevertheless, some relevant information on standards could be compiled and is documented here.

The standardisation process that concerns geospatial information started in the 1990s. Many worldwide organisations (e.g. ISO, OGC, and W3C) are involved in the process of standardisation, which is aiming to get people to agree on an acceptable technical solution. Standards (cf chapter 3) for geographic information need to be adopted in order to attain the interoperability of geodata and geospatial services. As technology changes, standards are evolving and are regularly revised. The evolution of the standards is essential but can sometimes cause a problem due to the existence of different versions, which are not always compatible.

Although international standards seem to provide higher relevance for an ESDI implementation, some national standards could also appear to be relevant at the European or international scales. Especially, if they are compliant to international standards and offer more practical solutions, including a family of reliable tools for spatial data handling. This is for example the case for INTERLIS in Switzerland. However to be relevant for the implementation's perspective of a European SDI, these standards have to evolve to international standards or be explicitly considered in Implementing Rules. The most important aspect of this evolution is the advent of a European or international consensus concerning these standards. Even if they cannot be considered as the most relevant standards currently, the advantage of these standards should be tested and exposed within HUMBOLDT (cf chapters 5.2.1 and 5.2.2).

International standards for geographic information are mainly issued for by two major international standardisation initiatives:

- The ISO/TC 211 (technical committee of the International Standardisation Organisation) specifies methods, tools and services for data management, acquiring, processing, analyzing, accessing, presenting, and transferring such data between different users, systems and locations. In this way the ISO/TC 211 is developing the ISO 19100 series of standards for geographic information in collaboration with the CEN/TC 287 (technical committee of the European Committee for Standardisation) and the OGC.
- The OGC (Open Geospatial Consortium – formerly OpenGIS Consortium) also publishes itself specifications (abstract specifications, implementation specifications and recommendations), which are in some cases considered as implementations (technical details) of ISO standards or as future ISO standards.

At European level CEN/TC 287 is the Technical Committee of CEN concerned with geographic information:

- CEN/TC 287 was started in 1991, but has been "dormant" from 1999 to 2003. Its activities started again in 2004, mainly to adopt the ISO 19100 series of standards.

CEN/TC 287 is working in close co-operation with ISO/TC 211 in order to avoid duplication of work. Presently CEN/TC 287 is mainly working through the "Working Group 5 - Spatial Data Infrastructure" on the following tasks:

- Adopt the ISO 19100 suite of standards as European standard (18 have already been published);
- Identification of standards and their profiles to be used for creating SDI in Europe;
- Guidelines for implementers of SDI in Europe;
- Conformance testing and registers for SDI in Europe.

Since CEN/TC 287 will mainly adopt ISO standards, this deliverable will refer to ISO 19100 series of standards.

International standards are generic and most of the time conceptual. They specify what should be done in particular processes. The explicit way of applying it is usually detailed in corresponding implementation specifications.

The following standards are considered as relevant in the perspective of the implementation of a European SDI. These standards or at least one aspect of them (e.g. use of GML, XML) should be considered in the standards evaluation process and in the handbook of standards. ISO standards include their corresponding profiles (cf. definition).

The relevance of these standards is underlined by the INSPIRE Initiative: «*The INSPIRE profile and guidelines for the implementation shall be based on the ISO 19100 series of standards for geographic information, and where necessary and appropriate, results of other standardisation initiatives can be considered (e.g. Dublin core, OGC)*» [1].

The most relevant existing standards in data modelling and storage are the following ISO standards:

- ISO 19103 Conceptual schema language (e.g. UML profile);
- ISO 19109 Rules for application schema.

To be able to compare the suitability of data from different sources, metadata also complies with standards. Three relevant ISO standards are used for metadata management and discovery:

- ISO 19110 Feature cataloguing methodology;
- ISO 19115 Metadata;
- ISO 19118 Encoding.

Another metadata standard, which does not specifically apply to geospatial information, is also relevant for metadata implementation: ISO 15838 / the Dublin Core Metadata standard for Information discovery (DCMI).

Currently the most relevant standards for publication, access or visualisation services are issued by the two major international organisations:

- ISO 19119 Service architecture;
- ISO 19128 Web Mapping Service / OGC WMS 1.1.1;
- OGC Web Feature Service / draft for ISO 19142;

- OGC Catalogue service.

As the standardisation process is evolving, some new relevant standards regularly appear. The following standards will be accepted in a near future:

- ISO 19136 (GML, XML) for data modelling and storage;
- ISO 19139 (XML, UML; technical specification for 19115) for metadata;
- OGC Web Catalogue Service for publication, access or visualisation of geodata/metadata.

These statements can be made on the basis of the available documents (cf chapter 9). Details on the experiences gathered by through the implementation of the standards can be found in chapter 5.2.1.

5 Evaluation process

This chapter consists of two main parts. In chapter 5.1 a specification of rules is given to support the evaluation of tools and standards for HUMBOLDT. It is intended that these rules will stay more or less stable throughout the duration of HUMBOLDT project, although some of them are not applicable based on the currently available information for some of the tools. Nevertheless, they were designed and documented as useful evaluation help and will be applied as soon as more information will be acquired on the tools or standards. In chapter 5.2 the current results of the evaluation process, the application of rules (where applicable) on tools and standards, are summarised.

5.1 Specification of specific rules for evaluation

The specific rules for the evaluation of tools and standards are based on the general rules, which are described in the *Methodology for standards evaluation* (A3.1D1, Chapter 4.1.2.2 Specific rules). Since the general rules are valid for all WP3 activities they had to be concretised for application in the particular scope of A3.2. The general rules serve as scope and guidelines for creating the specific rules. The A3.2-specific rules cover the general rules and correspond with their purposes.

Since the rules differ in their relevance, they can be weighted in the evaluation process, although this was not applied for this document. Since the decision on the weights assigned to each criterion is crucial, the determination of the weights should be performed in a common decision-making process.

In the following, the specification of the rules contains:

- rules applied to standards (“S rules”)
- rules for evaluating all tools (“T rules”)
- functionality rules for specific tools (“F rules”)

According to the methodology (cf. A3.1D1) all rules have been developed in 3 steps

1. One criterion describes what has to be fulfilled.
2. One or more indicator(s) describe(s) how the criterion should be fulfilled.
3. One or more metrics for every indicator determine how an indicator can be judged and which result is regarded as good or bad. In this evaluation process the metrics are in a range 0 – 1, with the value 1 as top value.

Not each rule is necessarily relevant for each tool (or standard). Scalability, for instance, is not required from a “small” tool fulfilling a limited purpose. Therefore, only a subset of rules is applied depending on the purposes of the tool to be evaluated. To provide comparability the evaluation results are achieved by calculating mathematical means/averages.

Based on these decisions one of the following values will be assigned to each tool or standard:

- Value in the range 0 – 1, with 1 as the best evaluation and 0 as the worst.
- “n.a.” means “not available”: The specific criterion cannot be applied as long as the respective information is not available.

5.1.1 Rules which apply to all standards

Rule S1:

Criterion S1: A standard’s specification must be implemented in at least one software system

In order to guarantee the possibility to implement a standard’s specification, it is verified that the standard's specification has already been implemented successfully. In case of new standards, which have not been implemented yet because of missing time, they could be set “on a watch” in the Handbook of Standards in order to encourage its implementation and testing in the HUMBOLDT project. Vice versa, the category “out-dated” is foreseen in the Handbook for those standards that should not be considered any more. If a standard has been implemented once, we assume that the possibility to implement the standard is given, but just at the minimum level. However, it could be that this implementation was a very isolated and proprietary case. Therefore, the top value of 1 is assigned only if more than one implementation can be stated. A differentiation on how many implementations could be found (2, 3, 4,..) would require more detailed search in order not to overlook an implementation which would lead to wrong results.

Indicator S1:

a) Standard's specification is implemented in more than one system

b) Standard's specification is implemented in one software system

a) No implementation of the standard’s specification is known

Metrics S1:

a) *value_S1 = 1*

b) *value_S1 = 0.8*

c) *value_S1 = 0*

Rule S2:

Criterion S2: Standard must be approved by at least one national or international standards organisation

The approval by a standards organisation (e.g. national standardisation body, CEN, ISO, OGC, OMG, W3C) means that the respective standard has been subject to the approval procedure, which includes suggestions, corrections, and amendments. Considering only approved standards could guarantee that no concepts for standards are top-rated, which have not been intensively considered and reviewed. The determination of approved vs. not approved is unambiguous and easy to verify. Draft standards or OGC discussion papers are not considered approved standards.

Indicator S2: Standard

a) is approved by at least one standards organisation

b) has not been approved by a standards organisation

Metrics S2:

a) *value_S2 = 1*

b) *value_S2 = 0*

Rule S3:

Criterion S3: Standard specification must not lead to different implementations

A standard must be specified in a way that the resulting implementations are compatible to enable interoperability. Ideally, this criterion would be verified by a set of test implementations whose results would be checked on compatibility.

Due to temporal restrictions test implementations could not be executed so far. Therefore, the verification of this criterion is done by analysing reports on incompatibility (S3.1) and reports stating that the specification is not deterministic (S3.2): The implementation according to a given standard specification leads to different implementations which are not compatible. This incompatibility has to be avoided in order not to complicate or even prevent harmonisation processes or interoperability.

In the further run of the project the compatibility of standard specifications can be tested in the HUMBOLDT implementation work (e.g. scenarios).

Indicator S3.1: incompatible implementations

a) are neither reported nor stated in the HUMBOLDT project

b) are reported but could not be verified in the HUMBOLDT evaluation process

c) can be stated and verified in the HUMBOLDT project

Metrics S3.1:

a) *value_S3.1 = 1*

b) *value_S3.1 = 0.5*

c) *value_S3.1 = 0*

Indicator S3.2: a reliable report that specification is non-deterministic

a) does not exist

b) exists and is available

Metrics S3.2:

a) *value_S3.2 = 1*

b) *value_S3.2 = 0*

Result: *value_S3 = 0.5 * value_S3.1 + 0.5 * value_S3.2*

5.1.2 Rules which apply to all tools

A tool's quality depends on several factors including reliability, compatibility, costs and usefulness. The latter can be divided into functionality and usability, which today usually also relates to the technical distinction between application software and user interface. Although all of these aspects are interrelated some general, application-independent rules can be formulated and are defined within this chapter. Chapter 5.1.3 contains the application-dependent rules for spatial data tools that support data harmonisation.

Rule T1:

Criterion T1: Tool must be usable

In user interface design and research the term "usability" denotes all aspects of a user interface, which support the user but are not part of the application functionality of a system. For example, the system may offer the functionality to delete a file. The user interface may provide an alphanumeric command (e.g. "del file.name") for that functionality or a graphical interpretation (e.g. pick file, move it to waste paper basket on the desktop). So, the functionality is the same for both versions of the user interface, but the usability differs. Ideally, usability tests would be conceptualised and executed to evaluate the usability of tools. Due to temporal restrictions the evaluation of the usability has to be confined to existing usability reports and other information sources.

In case of existing usability report(s) for the respective tool, the evaluation of the usability is based on the information extracted out of the report(s).

If no usability report(s) exist(s), the evaluation of the tool has to be based on other factors, which support and improve the usability of the tool:

- user manual (complete information concerning tool)
- user guide, which leads users with a certain level of experiences through a typical set of tasks
- tutorial, a guided tour for beginners
- user groups/community (cf. Definitions)

Remark: Course offers could be considered as well since they aim to improve the users' efficiency and memorability, to reduce the error rate, and to facilitate the learning process for beginners. Since the search for course offers on an international (e.g. European) level considering different types of courses (including e-leaning, etc.) would exceed the range of this deliverable, we have to confine the evaluation to measurable criteria.

Among the many usability criteria that exist we focus on the following ones, which we regard as most important:

- Efficiency: An experienced user has to execute a defined task by using the tool or software system. The time needed to solve the task is measured and indicates how efficient a tool or system is (progress in relation to time needed).
- Easy to memorise: A user who has not applied a system or tool for a while should nevertheless be able to remember the tool's functionality. By repeating a given task after a time period of inactivity with the tool (e.g. two weeks), the needed time for performing the task is measured, compared to earlier results and indicates the memorability of the tool.
- Error rate: This aspect does NOT involve software bugs. It evaluates the tool's ability to lead the user to his/her desired target. A user has to perform a given task. Every action that does not lead to the user's intended target is considered as an error. Errors are documented and counted. A low number of errors indicates high usability.
- Easy to learn: Users, who have never used the tool before, are asked to perform defined tasks. Their needed time is measured. A short time average indicates high usability.
- Acceptance: Measurement of how the users like/accept the tool or system (measured e.g. by interviews or physical indicators, like pulse frequency)

During HUMBOLDT project these usability criteria may be measured for dedicated tools. For the limited time frame of the acquisition of the state of the art, we replace them by easy-to-detect supporting means. The following table shows which usability indicator (column) is effected by which means to improve usability (rows).

	Efficiency	Easy to memorise	Error rate	Easy to learn	Acceptance
User manual	x	x	x		
User guide	x	x	x	x	
Tutorial	x		x	x	
User group	x	x	x		

Based on this table the usability indicators and metrics are determined:

Indicator T1: usability is supported by user manuals, user guides, tutorials, and user groups.

a) all of these 4 means are provided

b) 3 of these 4 means are provided

c) 2 of these 4 means are provided

d) 1 of these 4 means is provided

e) none of these 4 means is provided

Metrics T1:

a) *value_T1 = 1*

b) *value_T1 = 0.75*

c) *value_T1 = 0.5*

d) *value_T1 = 0.25*

e) *value_T1 = 0*

If a formal usability test is executed *value_T1* will receive the final value of the test.

Rule T2:

Criterion T2: tool must be tested

For the evaluation of a tool and for determining its applicability in the HUMBOLDT project, it is essential that the tool has been tested. Ideally, the tool is already being applied (in practice) or the tool has been tested in the HUMBOLDT project. If reliable test reports exist and are available, they are considered as well, but they are less traceable and project-adequate than proved practical experiences or HUMBOLDT-internal tests. Weak reports achieve lower values.

Indicator T2: Tool

a) is already applied (in practice) or has been tested successfully in the scope of HUMBOLDT: it achieved the goal of the test (e.g. service in scenario can be used in service chaining)

b) has been tested successfully by an impartial and reliable institution and test reports are publicly available.

c) tests are reported weakly (non impartial test group, no official and traceable documentation, etc.)

d) tests have not been executed or are not documented

Metrics T2:

a) $0 \leq value\_T2 \leq 1$ *(due to test results)*

b) $0 \leq value\_T2 \leq 0.8$ *(due to test results)*

c) $0 \leq value\_T2 \leq 0.4$ *(due to test results)*

d) $value\_T2 = 0$

Remark: During the application of this rule we distinguished only between $value\_T2 = 1$ (report on test available) or $value\_T2 = 0$ (no tests), due to lack of further information

Rule T3:

Criterion T3: Tool must be easy to integrate or extend

The application of spatial data and services are too wide-ranging to be – usually – fully covered by off-the-shelf solutions. Therefore, tools have to support the system or service programmer in extending the tool by writing and integrating additional components. Open source tools equipped with a usable documentation of the code are regarded as best solution. Non-documented open source code, which needs time to be understood, or documented APIs, which provide access to nevertheless “black boxes”, are considered to be acceptable but not really ideal solutions and are evaluated worse. Any other case does not meet the requirements for the project.

Indicator T3: Tool

a) is open source and a (usable) documentation is provided

b) is open source and no documentation is provided

c) provides an API with documentation

d) neither is open source nor provides an API

Metrics T3:

a) *value_T3 = 1*

b) *value_T3 = 0.8*

c) *value_T3 = 0.8*

d) *value_T3 =0*

Additional Indicators could be (based on ArcGIS API experiences):

- Usability (readability) and completeness of documentation
- Quality of object model (e.g. “missing” methods): for instance the ArcMap object “map” that does not provide a method to redraw the map but needs a link (query interface) to the interface ActiveView to use the ActiveView method “refresh” for redrawing
- Existence of user groups for integrating or extending work, e.g. user groups for coding work,

These criteria could be developed and applied in the further run of the HUMBOLDT project. If so, these criteria would have an influence on the later versions of the Handbook of Standards.

Rule T4:

Criterion T4: Tool must be of no or low cost

Expensive tools constrain the spread of SDIs and could exclude some parties from participating. Therefore, no or marginal costs are preferred. Nevertheless, there must be a differentiation between low cost tools and really expensive tools, which costs some 10.000 of Euros. Therefore, a category of low cost is introduced and suggested to be classified “about or less than 100 Euro”. This value serves as guideline for the evaluation and is oriented according to “usual” software products available on the web (e.g. Eudora mailing program, simple graphics programs).

Indicator T4: Tool is

a) free of charge or is of just marginal costs (e.g. burning of CD, postal services)

b) in a cost range of low (e.g. about or less than 100 Euro) to high (e.g. ten thousands of Euros)

c) of high costs

Metrics T4:

a) *value_T4 = 1*

b) $0.1 \leq value\_F4 \leq 0.9$

c) *value_T4 = 0*

Remark: Due to the lack of information we distinguished only between costs (*value_T4 = 0)* and no costs (*value_T4 = 1)* during the evaluation process.

Rule T5:

Criterion T5: Tool must be scalable

Scalability is required from tools to meet the user requirements and to provide appropriate solutions in different applications. Often, not a full version is needed but some parts (components) only. The metrics of scalability is binary: either a tool is scalable or it is not. If a tool is scalable it is proven that scalability has been considered in the development of the tool. Therefore, the number of “scales” needs not to be distinguished further.

Indicator T5: Scalability is

a) documented in the tool description

b) not documented in the tool description

Metrics T5:

a) *value_T5 = 1*

b) *value_T5 = 0*

Remark: Scalability was not clearly documented at all for any of the tools. Therefore, this rule was not applied to any of the tools.

5.1.3 Required functionality for specific tools

Specific tools in the context of data harmonisation processes must provide certain functionality to be useful and usable. In order to be not too restrictive for innovation but to ensure interoperability the following rules should specify minimum functional requirements.

5.1.3.1 Data modelling and storage of data

Rule F1:

Criterion F1: Tool is generic

F1 is a specification of the general rule VII in deliverable A3.1 D1. It is intended to avoid tools that are restricted to a specific data model. The ESDI and HUMBOLDT will have to cope with various data models, which will be specific to various information communities and will change over time.

Indicator F1: Tool supports

a) any data model

b) a class of data models for one application domain (e.g. official surveying, transport)

c) one data model (and its derivations) only

Metrics F1:

a) *value_F1 = 1.0*

b) $0.1 \leq$ *value_F1* ≤ 0.6

c) *value_F1 = 0*

Rule F2:

Criterion F2: tool used for generating the data model/schema applies ISO 19103 (Conceptual Schema Language)

For handling various different data models some functional features of the tool will be needed. Among these object orientation and specifically polymorphism will be crucial for the efficient and effective transformation of data models and data sets between local (e.g. Member States) and superordinated authorities (e.g. EC). ISO 19103 ensures these aspects. Since ISO 19103 is currently (January 2007) undergoing a revision process, we consider tools, which are partly compliant (to old or new version of ISO 19103) also as useful.

Indicator F2: Tool is ISO 19103 compliant

Metrics F2:

If yes, completely: *value_F2 = 1*

If yes, partly: $0.1 \leq$ *value_F2* ≤ 0.9

If no: *value_F2 = 0*

Rule F3:

Criterion F3: tool used for data modelling and/or data and model transfer process supports GML/XML (ISO 19136)

It is intended to avoid a tool, which produces an internal representation of the data model or data set, which cannot be used by other tools/programs. The tool should produce data in a way, which can be easily integrated in a transfer or processing procedure.

Currently (January 2007), GML seems to be a suitable solution for the transfer of geodata and their models. Nevertheless, current implementations use different versions and subsets of the OGC standard. Therefore, we will rely on the ISO version of GML, as soon as it is available. Unfortunately, the ISO 19136 document is not yet in the status of an international standard and especially the corresponding encoding rules are not yet finished. So, in a first evaluation step it is intended to check ISO 19136 compliance not formally, but to rely on the tool's description on which (part of) GML version is supported and assign values lower than 1. In addition, we also accept other derivatives of XML similar to GML, since a format conversion causes effort but is always possible.

As soon as ISO 19136 will be available (expected for April 2007), HUMBOLDT will rely on it.

Indicator F3: Tool is ISO 19136 compliant

Metrics F3:

If yes, completely: *value_F3 = 1*

If yes, partly: *0.1 ≤ value_F3 ≤ 0.9*

If no: *value_F3 = 0*

Rule F4:

Criterion F4: tool used for data storage applies ISO 19137 (Core profile of the spatial schema)

The exact representation of geometry is crucial for geodata processing in an SDI. The respective ISO standard (ISO 19107 – Spatial Schema) is not useful for implementation. A useful document will be ISO 19137, which is expected to be available as international standards in March 2007. Since this standard cannot be used in tools yet, we regard implementations, which are close to the standard (or its current version, respectively) still as useful for HUMBOLDT and assign values between 0.1 and 0.9.

Indicator F4: Tool is ISO 19137 compliant

Metrics F4:

If yes, completely: *value_F4 = 1*

If yes, partly: *0.1 ≤ value_F4 ≤ 0.9*

If no: *value_F4 = 0*

5.1.3.2 Discovery and management of data and metadata

Rule F5:

Criterion F5: tool used for discovery and management of metadata applies ISO 19115 (Metadata)

The published metadata international standard ISO 19115 is regarded as crucial for the efficient and effective handling of metadata in HUMBOLDT. Unfortunately, ISO 19115 does not lead to unique implementations, because the schema definition can be (and was) interpreted differently by different programmers. Even its respective encoding rules in ISO 19139 are not consistent to the ISO 19115 schema definition. Nevertheless, the Technical Specification ISO 19139 provides a more reliable (better to implement) definition of the metadata schema than ISO 19115. Therefore, we use ISO 19139 for conformance testing, although it may be changed again in three years (due to ISO regulation for technical specifications).

HUMBOLDT relies in a first phase on the information given by the tool's provider. If the tool is said to be compliant to the core or a valid profile of ISO 19115, using ISO 19139 as encoding, we assign a value of 1 else we assign 0.

Remark: ISO 19115 does not cover imagery and gridded data. The respective extension is not expected before May 2008.

Indicator F5: Tool is ISO 19139 compliant

Metrics F5:

If yes: *value_F5 = 1*

If no: *value_F5 = 0*

Rule F6:

Criterion F6: tool used for catalogue services supports ISO 19110 (Methodology for feature cataloguing), 19115 (Metadata), 19119 (Services), and 19118 rev (Encoding)

A tool used for catalogue services must support the respective ISO standards.

Remark: Currently, ISO 19110 and ISO 19119 are in an amendment process. The amendments are expected to be available, soon. ISO 19118 rev will include ISO 19139 (Metadata - XML schema implementation).

Indicator F6.1: Tool is ISO 19110 compliant

Metrics F6.1:

If yes, completely: *value_F6.1 = 1*

If yes, partly: *0.1 ≤ value_F6.1 ≤ 0.9*

If no: *value_F6.1 = 0*

Indicator F6.2: Tool is ISO 19115 compliant

Metrics F6.2:

If yes, completely: *value_F6.2 = 1*

If yes, partly: *0.1 ≤ value_F6.2 ≤ 0.9*

If no: *value_F6.2 = 0*

Indicator F6.3: Tool is ISO 19119 compliant

Metrics F6.3:

If yes, completely: *value_F6.3 = 1*

If yes, partly: *0.1 ≤ value_F6.3 ≤ 0.9*

If no: *value_F6.3 = 0*

Indicator F6.4: Tool is ISO 19118 compliant

Metrics F6.4:

If yes, completely: *value_F6.4 = 1*

If yes, partly: *0.1 ≤ value_F6.4 ≤ 0.9*

If no: *value_F6.4 = 0*

Result: *value_F6 = ¼ value_F6.1 + ¼ value_F6.2 + ¼ value_F6.3 + ¼ value_F6.4*

Rule F7:

Criterion F7: tool used for data checking operates on freely specified rules

Checking tools are crucial for an automated data processing in an SDI. We distinguish two major functional features:

1. The tool supports the input of a data model and uses the model to automatically produce consistency rules, e.g. to check whether a given data set is compliant to the specified data model.
2. The tool supports the individual specification/input of consistency rules or restrictions and possibly their checking procedures.

Based on the specified rules and restrictions the toll may offer a more or less convenient functionality to handle violations of the rules/restrictions. An explicit indication of the violated rule/restriction and the part of the data set, which is responsible for the violation, is preferred to a simple yes/no answer.

For an ESDI the support of a multilingual environment is crucial. In the case of explicit specification of rules or restrictions in a programming language (or comparable environment) this is aspect is negligible. But, the tool should support (without user's inference) comparing a data set, which was specified in a local language (e.g. French or German) to a data model, which was specified in another language (e.g. English or Spanish).

Indicator and Metrics F7:

In order to provide an overview on the application of rule F7, the following table summarizes the indicators and their respective metrics:

Indicator	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Input of data model	yes	yes	yes	yes	no	no	no	no	no	no
Input of rules/ restrictions	yes	yes	yes	yes	yes	yes	(yes) partly	(yes) partly	no	no
Indication of violations	yes	no	yes	no	yes	no	yes	no	yes	no
Multilingual support	yes	yes	no	no	yes/ no	yes/ no	yes/ no	yes/ no	yes/ no	yes/ no
value_F7	**1.0**	**0.8**	**0.8**	**0.6**	**0.6**	**0.4**	**0.3**	**0.2**	**0.2**	**0.1**

Remark: We would assign the *value_F7 = 0* for a tool, that performs a check but does not even provide the answer yes or no as a result of the check, but we do not expect this case to occur.

Rule F8:

Criterion F8: tool used for conversion operates on any given data/model combination

An ideal support of data conversion would involve two steps:

1. The support of the mapping [2]of the (two) different models, i.e. mapping on the conceptual level.
2. The support of the mapping of the involved data formats, i.e. mapping on the physical level, based on the model mapping.

Nevertheless, there exist tools that still may be of use for HUMBOLDT, although they support only the first or only the second step. Therefore, two indicators F8.1 and F8.2 are introduced for this rule.

Indicator F8.1: tool supports model mapping/conversion

Metrics F8.1:

a) tool provides a language or GUI to specify a model (schema) mapping of two arbitrary given models; as a result the tool delivers a conversion code: *value_F8.1 = 1.0*

b) tool provides a language or GUI to specify the mapping of an arbitrary model to a predefined (tool intrinsic) model:
value_F8.1 = 0.5

c) tool supports only the mapping of two predefined models:
value_F8.1 = 0.2

d) tools does not support model mapping/conversion
value_F8.1= 0

Indicator F8.2: tool supports format mapping/conversion

Metrics F8.2:

a) tool uses the result from the model mapping process to specify a format mapping of the respective two data formats; as a result the tool delivers a converter: *value_F8.2 = 1.0*

b) tool provides a language or GUI to specify a format mapping of two arbitrary given formats, without previous model mapping; as a result the tool delivers a converter: *value_F8.2 = 0.5*

c) tool provides a (set of) one-to-one converter(s) for a limited number of predefined formats: *value_F8.2 = 0.2*

d) else: *value_F8.2 = 0*

Result*: value_F8 = ½ * value_F8.1 + ½ * value_F8.2*

[2] In this context we use "mapping" in the mathematical or computational meaning, <u>not</u> in the cartographic sense.

5.1.3.3 Publication, access and visualisation

Rule F9:

Criterion F9: if a client/server architecture is used, the tool used for data publication, access, or visualisation applies one or more of the OGC specifications for Web Mapping Services (WMS), Web Feature Services (WFS), or Web Coverage Services (WCS)

Publication, access and visualisation of geodata are not in the focus of HUMBOLDT but are necessary to implement useful case studies (e.g. the HUMBODT Scenarios). In order to support interoperability some interface standards have to be applied. Currently, in the geoinformation community only interface standards for client/server architectures are available. Therefore, tools, which are used in such architectures, have to apply the respective OGC standards. Publication, access or visualisation tools/services, which rely on other architectures are not covered by rule F9 and are not judged at all.

OGC's WFS specification as input for ISO 19142 has currently not even the state of a working draft and will most probably be changed substantially. Therefore, this rule will currently be used based on the OGC implementation specification and with a low weighting, only. OGC's WCS cannot be regarded as usable at this point in time, because it still contains inconsistencies and errors. Therefore, the Indicator F9.3 and Metrics will not be applied to a tool, currently.

Indicator F9.1: Tool is OGC WMS (ISO 19128) compliant

Metrics F9.1:

If yes, completely: *value_F9.1 = 1*

If yes, partly: *0.1 ≤ value_F9.1 ≤ 0.9*

If no: *value_F9.1 = 0*

Indicator F9.2: Tool is OGC WFS (later ISO 19142) compliant

Metrics F9.2:

If yes, completely: *value_F9.2 = 1*

If yes, partly: *0.1 ≤ value_F9.2 ≤ 0.9*

If no: *value_F9.2 = 0*

(Indicator F9.3: Tool is OGC WCS compliant

Metrics F9.3:

If yes, completely: *value_F9.3 = 1*

If yes, partly: *0.1 ≤ value_F9.3 ≤ 0.9*

If no: *value_F9.3 = 0)*

Result:

a) If tool is for visualisation only: *value_F9 = value_F9.1*

b) If tool is used for visualisation and geodata access or storage:
*value_F9 = 0.75 * value_F9.1 + 0.25 * value_F9.2*

c) If tool is used for geodata access or storage:
value_F9 = value_F9.2

5.2 Application of rules

The information available for the majority of spatial data tools and standards was not as detailed as would have been useful for the application of the rules. Nevertheless, the defined rules were applied where possible in order to check their suitability as well as the quality of the available information.

The following summary includes a list of those standards and tools in the different categories, where most information was available. Nevertheless, it is possible that not mentioned standards and tools are equal or better.

The rules, which were developed for this document will be applied again, when more information will be available, e.g. by testing different tools and standards in the HUMBOLDT scenarios and implementation phases.

5.2.1 Standards

The investigated documents contained information about 53 different standards used in SDI implementations. For 25 of the standards enough information was available to apply all three rules for standards. The following table (cf Table 3) shows these 25 standards and their evaluation results. A list of which tools support which standards is available in the Excel document “Annex_I_A3.2_D1.xls” and the full list of all 53 standards and their evaluation results is available in the Excel document “Annex_II_A3.2_D1.xls” on the HUMBOLDT server. A value close to or equal to “0” indicates a bad result, a value of “1” indicates the best possible result. The standards with the best results are highlighted in grey colour in the table. S1 received the value “1” for all listed standards and indicates, that the standards were implemented and tested in more than one tool. Rule S2 indicates whether the standard is approved by a national or international standardisation body. Therefore some defacto standards or standards’ derivates received a “0” value. Values for rule S3 indicate whether the standard’s implementations caused documented problems concerning incompatibilities within a specific version or between different versions of a standard. The different rules were weighted equally to derive the mean. This leads to the effect, that a standard, which leads to deterministic implementations but is not approved by a standardisation body is rated lower than an approved standard, which causes problems in its implementation. We currently ignore this effect, since we also lack information on how some standards are compatible or contradicting each other. We found some evidence in the documents that this may be the case (e.g. ISO 19107 and ISO 19115) but were not able to judge on all possible or necessary combinations of standards, currently.

Table 3: Evaluation of Standards

Name of Standard	*Value for Rule*			**Mean Value**
	S1	*S2*	*S3*	
CS-W 2.0 (Catalogue Service Web / OGC)	1	1	0.25	0.75
Defacto standard DXF / DWG (AutoCAD)	1	0	0.25	0.42
defacto standard SHAPE (ESRI)	1	0	1	0.67
GML 2.0 (OGC)	1	1	0.25	0.75
GML 2.1.2 (OGC)	1	1	0.25	0.75
GML 2.1.2 (OGC)	1	1	0.25	0.75
GML 3.0 (OGC)	1	1	0.25	0.75
GML 3.1.1 (OGC)	1	1	0.25	0.75
HTML	1	1	1	1
INTERLIS 1/2 (SNV)	1	1	1	1
INTERLIS-UML2	1	0	1	0.67
ISO 15836-Dublin Core (or its profiles)	1	1	1	1
ISO 19103/19109 profile	1	1	0.25	0.75
ISO19107 "Geographic information – Spatial schema" (ISO, 2001)	1	1	0.25	0.75
ISO 19115 (or its profiles)	1	1	0.25	0.75
ISO 19119 (or its profiles)	1	1	0.25	0.75
ISO 19139 (or its profiles)	1	1	0.25	0.75
Simple Features for SQL	1	1	1	1
SQL (ANSI / ISO)	1	1	1	1
WCS (Web Coverage Service / OGC)	1	1	0.25	0.75
WFS 1.0 (OGC)	1	1	0.25	0.75
WMS 1.0.0 (OGC)	1	1	0.25	0.75
WMS 1.1.0 (OGC)	1	1	0.25	0.75
WMS 1.1.1 (OGC)	1	1	0.25	0.75

Among the 53 reported standards are also some, which do not strictly belong to the geo-related group of standards. For example, UML, XML, SQL, etc. are also mentioned and evaluated. We mention them if they are described as relevant for an existing SDI implementation.

In some cases the most recent version of the respective standard does not occur in Table 3. This is due to the fact, that we only listed and evaluated standards, which are reported to be currently in use in an SDI or harmonisation project.

There was only a small set of geo-related standards, for which we did not find any reported problems on version or implementation incompatibilities. Among these, INTERLIS (in its version 1 and 2) was the standard, which was used for the longest time period (more than 15 years) in data transfer, data harmonisation and SDI implementation. INTERLIS is a Swiss standard, providing a lexical conceptual schema language, including a well-defined meta model and geometric primitives, and a transfer format (specified through encoding rules). INTERLIS was specifically designed to support spatial data modelling, schema conversion and data transfer. INTERLIS 1 was developed in the 1980ies and was based on a relational concept, whereas INTERLIS 2 was designed in the years 2000 – 2003 to be fully compatible to ISO 19100 standards series and to strictly support the OMG definition of the model-driven approach (MDA). The compiler is currently supporting an object-oriented paradigm, so that INTERLIS schemas can be transformed to or derived from UML schemas. As a result INTERLIS seems to be interesting enough to be further evaluated for HUMBOLDT. In HUMBOLDT INTERLIS may serve as a useful standard for the specification of well-defined conceptual data models (or *application schemas* in the nomenclature of ISO/TC211). It seems to be a useful implementation of ISO standards. There are some restrictions (e.g. there are much less geometric primitives supported by INTERLIS than specified in ISO 19107), but instead the interoperability and compatibility of implementations is ensured. In addition, some concepts (e.g. multilingualism) are offered, which are not sufficiently covered by ISO 19100. Even if the tests in HUMBOLDT will be positive concerning the usefulness of INTERLIS, UML will also be used for data modelling, since it is mandatory for all ISO 19100 application schemas and it is an adequate graphical (i.e. easy-to-understand) representation of data models, whereas INTERLIS provides the lexical representation.

Nevertheless, INTERLIS and UML do not cover all interface specifications, which are needed in an SDI implementation or between all components in a data harmonisation process. Especially, for service interfaces we did not find any suitable alternatives to OGC standards. For HUMBOLDT we will have to carefully specify, which versions of the OGC standards we use and whether to allow or prohibit the so-called “vendor specific” parameters. Concerning ISO 19100 series, we will test and use mainly those specifications, which are not covered by OGC standards or by other, more detailed and tested specifications. This is mainly due to the fact, that ISO standards are in most cases not tested before the release of a standard, whereas OGC implementation specifications have to be implemented before the specification is accepted. This effect results in many problems due to non-deterministic specifications in some of the ISO standards, e.g. in ISO 19115.

Other aspects, which are not specific to SDI implementations, e.g. service orchestration, security aspects, etc. are not specifically mentioned in the available documents describing SDI implementations. Nevertheless, we expect that there will be the need to provide more (non-geo) interface standards for the HUMBOLDT implementation phases. Since these standards will also be dependent on the chosen architecture for HUMBOLDT, it is currently not possible to choose or specify them explicitly.

Another category of standards is also relevant for HUMBOLDT scenarios but could not be evaluated in this work package. Standardised, i.e. common and well-defined application schemas (data models) are also needed for interoperable SDI implementations and harmonisation processes. This work will be carried out in work package 7.

5.2.2 Tools, which can be used for data modelling and storage of data

The following table contains all tools, for which at least 60% of the rules could be applied. A list of all evaluated tools, a classification of their features and the respective URLs are available in the Excel document “Annex_I_A3.2_D1.xls”, and the full list of all 26 tools in this category and their evaluation results are available in the Excel document “Annex_II_A3.2_D1.xls” on the HUMBOLDT server. A value close to or equal to “0” indicates a bad result, a value of “1” indicates the best possible result. The tools with the best results are highlighted in grey colour.

Table 4: Evaluation of tools for data modelling and storage of data

Name of Tool	*Percentage of Rules, which could **not** be applied*	**Mean Value**
ArcSDE	36	0.63
Autodesk Map 3D 2005	36	0.67
GeoXACML	24	0.46
INTERLIS 2 Checker	33	1
INTERLIS 2 tools	24	0.83
INTERLIS 2 FME module	36	0.88
INTERLIS Compiler	24	0.89
INTERLIS Studio	24	0.68
Microsoft Access	24	0.54
Microsoft SQL Server	24	0.54
NetCDF	24	0.61
ORACLE Database	24	0.54
PostgreSQL	24	0.71
UGAS (ShapeChange)	24	0.89
UML/INTERLIS-Editor (UML Editor)	24	0.93

Similar to the list of standards, the list of tools also contains tools, which are not strictly related or limited to geo-spatial applications, e.g. data base management systems. They are listed, when they were mentioned in reports as fundamental tools to support the SDI implementation or the data harmonisation process. Regarding the process of data modelling this effect can be explained as follows. The harmonisation of spatial data can happen on different levels:

1. Harmonising at physical level,
   which essentially means format conversion. This is the main reason, why GIS products (e.g. ArcGIS or GeoMedia) are mentioned in many documents. They were used for format conversion in this context.
2. Harmonising at logical level,
   which essentially means harmonising data structures on the data base level. This is the reason for the list of data base management systems occurring in the list of tools (e.g. ArcSDE, Oracle, PostgreSQL).
3. Harmonising at conceptual level,
   which means mapping of conceptual data models. Typical representatives of this category are all tools to process INTERLIS models and the tool called UGAS.
4. Harmonising the access on the data,
   which means managing the access control. GeoXACML.services is the tool in this category.

Since all of these levels are relevant, solutions for the different levels will have to be provided in HUMBOLDT. The model driven approach in principle supports the mapping at conceptual level and provides the mapping at lower levels (logical and physical level) automatically. Therefore, HUMBOLDT will start by focussing on the tools at conceptual level. Moreover, most of the INTERLIS tools, UGAS and GeoXACML are available as open source JAVA packages.

5.2.3 Tools, which can be used for data and metadata discovery and management

The following table contains all tools, for which at least 40% of the rules could be applied. A list of all evaluated tools, a classification of their features and the respective URLs are available in the Excel document “Annex_I_A3.2_D1.xls”, and the full list of all 50 tools in this category and their evaluation results are available in the Excel document “Annex_II_A3.2_D1.xls” on the HUMBOLDT server. A value close to or equal to “0” indicates a bad result, a value of “1” indicates the best possible result. The tools with the best results are highlighted in grey colour.

Table 5: Evaluation of tools for data and metadata discovery and management

Name of Tool	*Percentage of Rules, which could **not** be applied*	**Mean Value**
ArcCadastre	58	0.5
ArcGIS (ESRI)	58	0.7
Bentley Micro Station	57	0.5
CatMDEdit	55	0.85
GeoCatalog (sdi.suite con terra)	38	0.68
GeoMedia (Intergraph)	44	0.8
GeoNetwork	55	1
GeoXACML	36	0.33
I/RAS C (Intergraph)	57	0.5
iliX	56	0.27
INTERLIS 2 Checker	53	1
INTERLIS 2 FME module	56	0.62
INTERLIS 2 tools	25	0.86
INTERLIS Studio	25	0.86
MapInfo Professional	58	0.5
Micka / Micka Metadata and catalogue system	60	0.76
RedSpider Catalog 2 (Ionic software)	52	0.45
STAR GIS	58	0.7

This category contains two major types of tools:

1. general data management (e.g. tools for INTERLIS) or GIS (e.g. GeoMedia, ArcGIS, STAR GIS) tools, which are also used for metadata management
2. specific implementations for metadata generation, search and/or publication (e.g. CatMDEdit, GeoNetwork, Micka).

Although in this category not very much detailed information is available on the tools, HUMBOLDT will try to avoid producing new solutions. Instead, existing solutions (many of which are open source) will be used and extended. First candidates for further evaluation in this context are certainly CatMDEdit, GeoNetwork, and Micka.

5.2.4 Tools, which can be used for publication, access and visualisation

The following table contains all tools, for which at least 60% of the rules could be applied. A list of all evaluated tools, a classification of their features and the respective URLs are available in the Excel document “Annex_I_A3.2_D1.xls”, and the full list of all 93 tools in this category and their evaluation results are available in the Excel document “Annex_II_A3.2_D1.xls” on the HUMBOLDT server. A value close to or equal to “0” indicates a bad result, a value of “1” indicates the best possible result. The tools with the best results are highlighted in grey colour.

Table 6: Evaluation of tools for publication, access and visualisation

Name of Tool	*Percentage of Rules, which could **not** be applied*	**Mean Value**
ArcGIS (ESRI)	20	0.76
ArcIMS (ESRI)	20	0.76
Autodesk AutoCAD	20	0.76
Autodesk MapGuide	28	0.96
Deegree OGC-based services - Degree (latlon)	20	0.85
Ferret	20	0.75
GeoMedia (Intergraph)	20	0.76
GeoMedia WebMap	20	0.76
GeoXACML application (authorisation solution for Web Services)	20	0.65
LAS (Live Access Server)	20	0.9
MapInfo Professional	36	0.75
Mapmaker	28	0.9
PyWPS	36	0.81
STAR GIS	36	0.7
UMN Mapserver	20	1
UMN Mapserver (Cascading WMS case)	28	1
WIRELESS INFO - CREATING MODEL	41	0.7

In this category most of the used tools are common commercial or open source Web GIS solutions. Functionality and features of the evaluated tools are rather similar. The lower values of the commercial tools (e.g. ArcGIS, GeoMedia, STAR GIS) in comparison with open source tools (e.g. DEGREE, LAS, UMN) can be explained by the lower ratings in the rules concerning costs and extensibility of the tool.

For HUMBOLDT, tools in this category are of lower importance, because they do not directly support harmonisation process. Nevertheless, these tools are needed for implementations in the HUMBOLDT scenarios. As a result HUMBOLDT will guarantee the interoperability with these tools mainly through the usage of respective standards without limitation on the usage of specific tools. Nevertheless, the GeoMedia tools would be adequate candidates for testing, since they are freely available (although they are commercial products) in the HUMBOLDT project. In addition, some open source tools, e.g. LAS, UMN, should be tested also. Especially if a more flexible adaptation of the tool is necessary.

6 Summary of aspects that will be input to the Handbook of standards

Based on the evaluation of tools and standards for this deliverable it is not useful and was not expected to specify any tool or standard as strictly mandatory for implementation in HUMBOLDT. Nevertheless, the process of documenting and evaluating the state of the art led to a list of candidates to be tested and discussed in HUMBOLDT.

6.1 Standards

Since many problems concerning incompatibilities between (the same) standards' versions were reported, we conclude, that it will be inevitable to clearly specify a valid standard's version in the HUMBOLDT Handbook of Standards (A3.6 D1). Moreover, due to the reported incompatibilities between different standards, none of the standards will be classified as mandatory for the first version of the Handbook of Standards.

Based on the evaluation (cf chapter 5.2.1) the following standards will be taken into account for the Handbook:

Table 7: List of candidate standards for HUMBOLDT

Standard	Approved by	Name/Purpose	Proposed Usage in HUMBOLDT
CS-W 2.0	OGC	Catalogue Service for Web	Creation and usage of HUMBOLDT Catalogue Service to register and find data and services
GML	OGC	Data Description Language	Target format of data modelling processes, storage and transfer of geo data
INTERLIS 2	Swiss Association of Standardization (SNV)	Swiss standard for data modelling and exchange	Various usages for data modelling, checking and transforming (referring to INTERLIS tools)
ISO 15836	ISO	Dublin Core for Metadata	Standard for metadata acquisition and maintenance
ISO 19103	ISO	Standard on Conceptual Schema Language	Rules and guidelines for using Conceptual Schema Languages (e.g. UML, INTERLIS), for instance in data modelling process
ISO 19109	ISO	Rules for Application Schema	Creation of common data models in diverse applications

ISO 19125	ISO	Definition of Simple Features access: architecture (part1) and SQL option (part 2)	Geo data management, integration and retrieval
ISO 19139	ISO	XML schema for metadata implementation	Creation of metadata
UML	OMG	Unified Modelling Language	Data modelling process
WMS	OGC	Standard for Web Map Services	Publication of raster Images (Maps) on the web
WFS	OGC	Standard for Web Feature Services	Providing of spatial data on level of geographic features (vector data)
WCS	OGC	Standard for Web Coverage Services	Web-based access to large raster data sets

6.2 Tools

The evaluation of spatial data tools (cf chapters 5.2.2, 5.2.3, and 5.2.4) led to the following list of tools, which should be tested and evaluated in more detail within HUMBOLDT.

Table 8: List of first candidate tools for testing in HUMBOLDT

Name of Tool	**Proposed Usage in HUMBOLDT**
GeoXACML.services	Data access control
INTERLIS compiler	Generation of conceptual data models, generation of transfer formats (e.g. GML)
INTERLIS checker	Consistency checking of data model and data; topologic consistency checks
UML/INTERLIS Editor	Generation of UML based application schemas (data models) and conversion to INTERLIS
INTERLIS FME module and FME, or INTERLIS tools, or INTERLIS studio	Reading INTERLIS files and subsequent schema mapping (followed by automatically generated data structure or format mapping)
UGAS	Mapping UML application schemas to GML
CatMDEdit	ISO19115, 19139 conformant metadata specification and editing

GeoNetwork	Metadata/Catalogue information system
Micka / Micka Metadata and catalogue system	Metadata/Catalogue information system
GeoMedia Tools	Commercial component-based GIS software package; for analysis and visualization of spatial data
LAS (Live Access Server)	Modular web server for geo-referenced data (freeware)
UMN Mapserver	Open source map server

We expect, that this list will be modified and extended when more details concerning data harmonisation processes and the definite HUMBOLDT architecture will be known.

7 Open issues

In general, the basic material, on which this deliverable is based, contains two major drawbacks:

1. The amount of spatial data tools on the market is overwhelming,
2. The level of detail in the product descriptions is far too low from being adequate for a reliable evaluation.

These problems were handled by relying mainly on descriptions and documented experiences in existing SDI implementations, focussing on data harmonisation processes. Therefore, and since a thorough analysis of user requirements is not yet available, we cannot be sure to be complete and currently do not dare to give a final judgement on the evaluated tools and standards.

In addition, this document focuses on tools and standards, only. It would be also interesting to consider existing solutions (i.e. process chains) based on these tools whether they can be reused in the HUMBOLDT context. We expect to receive a clearer view on this aspect in deliverable A3.5 D1 (State of the art in data harmonisation and management).

Although, we were able to identify first candidates for tools and standards to be tested in HUMBOLDT, there are some documented deficiencies, which may lead to the development of new and better solutions in HUMBOLDT. The following list contains the most important aspects:

- Currently, there is no consistent and complete set of interface standard specifications for all relevant aspects in an SDI implementation. Some standards contradict each other or are incompatible between their own versions. The result is that existing SDI implementations are interoperable within their own scope but not with each other.
- We found only one family/set of tools, which seems to support a complete harmonisation process (i.e. tools for INTERLIS processing). Not all of these tools are open source or at least freeware solutions. For most of the tools no documentation in English is available. The tools do not interact well with each other. There is no framework supporting the process control or workflow management in the harmonisation process. Users need a basic GIS and Computer Science education and have to be trained specifically for using each of the tools.
- Most of the evaluated tools are not interoperable with each other, although in many cases they support the same interface standards.
- We did not find reports on tools, which support a complete harmonisation process or even its management. Instead we found only tools to support small, isolated steps in the process.
- The usability of many of the tools was described as extremely bad (only suitable for experts with additional training), but detailed lists of user requirements and/or formal usability tests were not available.

8 Conclusion

The major aim of this deliverable is to provide an overview on relevant, existing tools and standards for SDI implementation, focussing on the data harmonisation processes. In addition, the document should provide a stable methodology to evaluate tools and standards for judging available best practices. This should be done by taking into account, that during the duration of HUMBOLDT project more knowledge on more tools and standards will be gained. In addition, this document should be one of the basic sources of background knowledge to produce useful content for the HUMBOLDT Handbook of Standards.

As a result this deliverable consists of four major parts:

1. The definition of the scope (cf chapter 2) of the document, including some assumptions on user requirements in order to restrain the amount of tools to evaluate.
2. The documentation of the existing tools and standards and their respective features (cf chapter 4).
3. The description of the evaluation process, including the specification of evaluation rules and the results of the evaluation process (cf chapter 5).
4. The conclusions for the HUMBOLDT Handbook of Standards (cf chapter 6), which will be documented in task A3.6 of work package 3.

In chapter 7 of this document all aspects are documented, which occurred as open issues or problems in the usage of the existing tools and standards for SDI implementations.

Since the complete list of all tools and standards, their features and evaluation details would disturb the readability and intelligibility of this document, these details can be found in the two Annexes.

Annex I (Filename: Annex_I_A3.2_D1.xls) contains the full list of tools for all three categories and information for each tool according to the following categories: supported standards, availability (licences), API, used programming languages, supported SDI components, functionality of the tool, SDI context for which the tool was created, typical user groups for the tool, tests, available documentation, URL for more information on the tool, comments.

Annex II (filename: Annex_II_A3.2_D1.xls) contains the complete list of evaluation results for all standards and tools according to the definition of rules given in chapter 5 in this document.

9 References

This list contains all reference documents, which were used during the generation process of this deliverable. If a URL is required to check further information on a tool, we recommend to use the URL list provided in the excel sheet (Annex_I_A3.2_D1.xls) on the HUMBOLDT server.

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