CSCAT: Translation Web Service & Coordinate Systems Catalogue

Proposal of a web service design for dynamic translation and Coordinate Reference System catalogue.

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This paper presents a proposal of designing a web service acting as a Coordinate Reference System (CRS) catalogue. The main task of this catalogue is the interpretation and dynamic translation of the codifications used by the private sector software manufacturers (Ersi, Intergraph, MapInfo, Oracle, IBM, Erdas, etc…) in their proprietary formats of Geographic Information (GI) storage. This proposal allows translating textual, mnemonic and numerical codifications associated with the CRS (datum, ellipsoid, projection, units and parameters) used by software companies to formats and codifications standardized by OGC and ISO (XML and GML). The second aim of the catalogue is to eliminate the uncertainty caused by the different names of a same CRS, thereby warranting their correct identification.

KEYWORDS

Spatial Data Infrastructures, Coordinate Reference System, Datums, Proyections, Ellipsoides, WCTS, Spatial Data Metadata, ISO19115, GML, PROJ4, WKT, Spatial DataBase, PostGIS, Oracle, DB2, SpatialWare, OGC, ISO, EPSG, Interoperability, Web Services, Catalog, Translation Service, Register.

INTRODUCTION

Spatial Data Infrastructures or reference framework (SDI) are an essential requirement to efficiently and effectively using and managing spatial information [1]. These infrastructures are based on the technologies, standards, policies and human resources necessary to manage and promote the use of spatial data [3]. Several actions may be taken in order to foster the use of spatial data; promoting their sharing and facilitating their exchange [4] through a framework of institutional agreements.

These actions, whose aim is promoting shared access to spatial data, are based on the existence of standards, metadata and procedures driving the development of communication networks, allowing the establishment of safe links between databases and users. At the present time technology and standards exist making horizontal integration possible between spatial databases and Geographic Information System (GIS) through interoperability [9]. In order for two systems to interoperably share spatial data, human intervention shall be as small as possible (ISO 2382-1).

The remainder of the paper is organized as follows:

In the first part, differences are shown in the CRS codifications of many spatial data storage formats, caused by the use of non-standardized number, mnemonic or text proprietary codifications, in some cases ambiguous codifications as well.

In the second part, a solution is proposed based on the design of a new catalogue and CRS codification translation service. This service shall further the identification of the proprietary codifications with standardized or widely known codifications such as those of the European Petroleum Surveyor Group (EPSG).

In the third part, implementation of the catalogue and CRS translation service is proposed by means of a relational database taking on and increasing the initial table and relationship schemas defined by EPSG.
Next the outcome of a thorough review of the different CRS proprietary codifications used by the main software manufacturers of the private sector is presented, with the aim of registering in the catalogue such codifications and their equivalents in EPSG.

Finally the conclusions, acknowledgements and references are presented.

LAYING OUT THE PROBLEM:

A conclusion from the analysis of the GI storage formats [8] is the need for CRS homogenization, since every format innately uses a different form to express that information: WKT format text, mnemonics or numbers. After thorough examination, two pseudo-standardized forms have been located to represent that information. The first one in text form, Well Known Text Format [15] and the second one in EPSG numerical codification form.

Text codifications, either WKT or mnemonics, are legible and understandable by human users, allowing to infer that two definitions are equal, equivalent or different. Next a couple of examples are shown.

WKT: DATUM ["Israel", SPHEROID["GRS 1980", 6378137, 298.257222101]
Mnemonics: GCS_European_1950.

Numerical encoding makes human interpretation difficult, though it facilitates its automated use based on programmes. Next some examples are shown.

Erdas:	Projection:	1	Datum: European 1950	Ellipsoid: 5
Intergraph:	Projection:	7	Datum: 4	Ellipsoid: 5

The interoperability of data and services in the context of SDI intends both to be capable of being automatically used with the least human intervention.

Next a few significant samples are presented showing the interoperability problems in the interpretation of CRS for different sources.

CRS representations in WKT format:

DB2 & Esri	**ECW**	**MapInfo & Oracle**	**PostGiS**
GCS_European_1950	European_datum_1950	Longitude /latitude (ED50)	ED50
GCS_North_American_1927	North_American_1927	Longitude /latitude (NAD27)	NAD27
GCS_WGS_1984	WGS_1984	Longitude /latitude (WGS 84)	WGS 84

Table 1: CRS WKT format examples.

Mnemonics and projection numbers:

Projection	Proj4	PCI	FME	Ermapper	Erdas	Dgn	MapInfo	EPSG
OBLIQUE MERCATOR	OMER	OM	HOM10V	obmerc_b	-	12	-	9815
LAMBERT AZ EQU AREA	LAEA	LAEA	AZMEA	lambazea	11	25	29	9820
EQUIDISTANTE CYLIND	EQC	ER	EDCYL	-	35	37	-	9823

Table 2 : Projection coding examples.

From observation of the examples above, it can be stated that it is not easy to identify the CRS, therefore interoperability problems exist.

There are also interoperability problems caused by the different name definitions of the cartographic projections. A single projection, even within the same language may have two different names. For example, Mercator Projection / Orthomorphic Cylindrical Projection or Plate Carré Projection / Equidistant Cylindrical Projection. The problem is made worse by translation to different languages.

PROPOSAL OF AN INTEROPERABLE SOLUTION

After having described the CRS interoperability problems, a solution is proposed based on a catalogue for registration of the proprietary codifications assigned by the software manufacturers to the CRS, confronted with their equivalent codification in EPSG.

The catalogue in its first design approach should store the individual codifications and their equivalents according to EPSG codification. With these initial requirements it should be possible to look up in the catalogue the EPSG equivalent for a codification of Intergraph, Erdas, Mapinfo, etc... and the service should return the corresponding number. This first design proposal is not based on an intelligent system, since it should only enable to add, change or erase codification records and answer consultations.

A web service acting as a catalogue for that purpose may be of interest to solve the problem, since it should allow the applications to clearly get round the difficulties of both interpretation and interoperability. At that point the possibility of the service being able to carry out other operations of a greater scope was considered and a document was defined in the form of use cases with the desirable requirements for the service, the most interesting ones being as follows:

1.- A client holding a CRS stored in a WKT file wishes to codify this same information to incorporate it to a metadata register ISO 19115-19139. The following example shows the response would provide to a request of this type:

WKT Input: DATUM["Israel",SPHEROID["GRS 1980",6378137,298.257222101],

ISO19115 Output: <datum><RS_Identifier><authority><CI_Citation><title>EPSG<title>
</CI_Citation> </authority> <code>7019</code></RS_Identifier></datum>

2.- A client holding the proprietary numerical codifications of the projection, datum, ellipsoid, units, etc... wishes to store this information in the metadata register fields ISO 19115-19139).

3.- A client holding the CRS information, WKT or numerical, assigned by a software manufacturer should carry out a transformation of the coordinate (BoundingBox) from the CRS stored in the geographic coordinate file (latitude/longitude) by using a WCTS service. The following example would show the response would provide to a request of this type:

WKT Input: PROJCS["ED50 / UTM zone 30N",GEOGCS["ED50",DATUM["European_Datum_1950",SPHEROID["International 1924",6378388,297]], PRIMEM["Greenwich",0],UNIT["degree",0.01745329251994328]], PROJECTION["Transverse_Mercator"],PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3],PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000],PARAMETER["false_northing",0],UNI T["metre",1]

XML-WCTS Output: <SourceCRS><CoordinateReferenceSystem><Identifier> <code>23030</code><codeSpace>EPSG</codeSpace></Identifier> </CoordinateReferenceSystem></SourceCRS>

4.- A client holding the CRS information, WKT or numerical, assigned by a software manufacturer should carry out a transformation of the coordinate (BoundingBox) from the CRS stored in the geographic coordinate file (latitude/longitude) by using the public domain PROJ4 software. The following example would show the response would provide to a request of this type:

WKT Input: PROJCS["ED50 / UTM zone 30N",GEOGCS["ED50",DATUM["European_Datum_1950",SPHEROID["International 1924",6378388,297]], PRIMEM["Greenwich",0],UNIT["degree",0.01745329251994328]], PROJECTION["Transverse_Mercator"],PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3],PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000],PARAMETER["false_northing",0],UNI T["metre",1]

Proj4 Output: +proj=utm +zone=30 +ellps=intl +units=m +no_defs

5.- A client holding a CRS associated with a data set codified according to EPSG, needs to store it in WKT format.

6.- A client holding a CRS (WKT, mnemonic or numerical) associated with a data set should carry out a transformation of formats to store the information in GML language. The following example would show the response would provide to a request of this type:

WKT Input: GEOGCS["ED50",DATUM["European_Datum_1950", SPHEROID["International 1924", 6378388,297],PRIMEM["Greenwich",0], UNIT["degree",0.01745329251994328]]

GML Output: <GeographicCRS><srsName>ED50</srsName> <srsID> <name codeSpace="EPSG">4230</name><version>6.0</version></srsID> <usesEllipsoidalCS> <EllipsoidalCS gml:id="EPSG7022"> <csName>Internacional 1924</csName><csID> <name codeSpace="EPSG">7022</name> <version>6.0</version></csID> </EllipsoidalCS></usesEllipsoidalCS> <usesGeodeticDatum><GeodeticDatum gml:id="EPSG6230"> <datumName>European 1950</datumName><datumID><name codeSpace="EPSG">6230</name> <version>6.0</version></datumID> </GeodeticDatum></usesGeodeticDatum> </GeographicCRS>

Attaining these aims means to be able to translate the WKT formats of the OGC, PROJ4, GML and XML in a dynamic intelligent manner.

Another design requirement laid down by this Catalogue Service and CRS representation translator is being compatible with the design approach of the Web Services defined by OGC. In order to attain this aim, the catalogue shall implement a set of operations allowing to know the metadata and capabilities of the Web Service (*GetCapabilities*), it shall carry out operations such as insertion, deletion and update of the particular encoding of each manufacturer (*Transaction*: insert, delete, update), as well as consultation and translation of CRS identifiers for different formats (*GetCRS*).

Next the syntax of the operations proposed by the Service is shown. For each one of these operations, the name of the parameters and the types of data accepted in the format Keyword Value Pair (KVP) are shown.

GetCapabilities operation (mandatory):

The operation GetCapabilities should accept the following parameters :

Request / parameter	Mandatory / optional	Description
Request=GetCapabilities	Required	Request name
Version=version	Optional	Request version.
Service=CRSR	Required	Service type.
Format=MIME_type	Optional	Metadata output format Default value text/xml

Table 3: GetCapabilities operation parameters.

The response from the Coordinate Reference System Register (*CRSR*) Service to the operation *GetCapabilities* will be an XML document conformant with a definition schema wherein the following sections shall turn up: 1.- name and title, 2.- service metadata, 3.- capability metadata and finally 4.- metadata of each one of CRS registered formats.

1.- The name and the title identify the service in the abstract, so that the first one may be interpreted by machines and the second one by users.

2.- The Service metadata shall describe the name of the CRSR Service, title, descriptive summary, ways of accessing to or getting conected with the service, keywords identifying it and contact information.

3.- The Capability metadata describe service supported operations, they describe formats accepted for encoding of parameters and URL prefixes of every operations provided by the service.

4.- The metadata associated to registered CRS formats shall identify the name assigned internally in the catalogue for the format (*name, title*), the description of the format (*abstract*) the names of the fields to be consulted (*projection, datum, ellipsoid, units…*).

GetCRS operation (mandatory).

The GetCRS operation is the most important one in the service. It allows users to carry out translation requests between different CRS encoding formats. The service will accept numerical, mnemonic and text encoding and will return encoded responses according to the translation type sought.

The GetCRS operation accepts the following parameters:

Request / parameters	Mandatory/ Optional	Description
Request=GetCRS	Mandatory	Request name.
Version=version	Optional	Service type
Service=CRSR	Required	Service type.
InputFormatId	Mandatory	Original CRS identifier name.
OutputFormatId	Mandatory	Destination CRS identifier name.
SourceCRS	Mandatory if the projection, datum, ellipsoid and units do not appear.	Information package identifying a CRS in the encoding format defined in InputFormatId
SourceProjection	Optional	Projection identifier.
SourceDatum	Optional	Datum identifier.
SourceEllipsoid	Optional	Ellipsoid identifier.
SourceUnits	Optional	Units identifier.

Table 4: GetCRS operation parameters.

As values of the ***InputFormatId*** and ***OutputFormatId*** parameters, any of the ones showing up in the metadata name, of the metadata section of the CRS formats, obtained as a response to a consultation type GetCapabilities, may be assigned.

The ***OutputFormatId*** parameter identifies the encoding format of the output CRS. The minimum values the service shall support to respond to the proposed requirements in the use cases are : gml, proj4, xml (iso19115) and EPSG.

The *SourceCRS* parameter will contain compact representations associated to the CRS, such as WKT format, proj4 or EPSG codes. If the information in compact format is not available, the essential data may be provided: projection, datum, ellipsoid and units.

Transaction operation (mandatory):

The transaction operation allows to manage and maintain the CRS catalogue updated in distributed form. The desirable objective is for each software manufacturer, related to the use of Geographic Information (G.I.) to register in the individual or standardized encoding used to store that information in files or in databases. To reach this objective, the service, besides de management of users, shall have at its disposal the operations allowing to insert, modify or delete individual encoding assigned to the CRS. The transaction operation accepts the following parameters :

Request / parameters	Mandatory/Optional	Description
Request=Transaction	Mandatory	Request name.
Version=version	Optional	Request version.
Service=CRSR	Required	Service type.
Type=insert, delete or update	Mandatory	Transaction type
InputFormatId	Mandatory	Original CRS identifier name.
SourceCRS	Mandatory if projection, datum, ellipsoid and units do not appear	Information identifying a CRS in the encoding format defined in InputFormatId.
TargetCRS	Mandatory.	Source EPSG CRS code.
SourceProjection	Optional	Projection identifier.

SourceDatum	Optional	Datum identifier.
SourceEllipsoid	Optional.	Ellipsoid identifier.
SourceUnits	Optional.	Units identifier.
TargetProjection	Mandatory if TargetCRS does not appear	EPSG projection code.
TargetDatum	Mandatory if TargetCRS does not appear	EPSG datum code.
TargetEllipsoid	Mandatory if TargetCRS does not appear	EPSG ellipsoid code.
TargetUnits	Mandatory if TargetCRS does not appear	EPSG unit code.

Table 5: Transaction operation parameters.

The parameters *InputFormatId, SourceCRS, SourceProjection, SourceDatum, SourceEllipsoid* and *SourceUnits* have the same meaning as in the *GetCRS* operation.

The parameter *TargetCRS* represents the compact encoding according to EPSG for the CRS. The remaining parameters, *TargetProjection*, *TargetDatum*, *TargetEllipsoid* and *TargetUnits* allow definition of the encoding of each field, according to EPSG. If a compact code does not exist identifying the source CRS, the parameters *SourceProjection, SourceDatum*, *SourceEllipsoid* and *SourceUnits* should be filled in.

CRS CATALOG & TRANSLATION IMPLEMENTATION APROACH.

In this section an implementation proposal for the previously described Web Service is described by means of the operations *GetCapabilities*, *GetCRS* and Transaction.

In the first place a series of considerations is presented that have motivated the choice of a model of reference data for the implementation proposal. As a step previous to the presentation of the solution proposal, the result of an exploratory study carried out on the documents and standards related to the definition of CRS are presented. That analysis has allowed to select EPSG as a neutral support of encoding for CRS. In the second place, the results of an exploratory analysis carried out on the CRS encoding used by the different sector software manufacturers are presented, and a synthesis of encoding types and the number of codes found is shown. In third place, a series of considerations are presented which are related to the data model used by EPSG in its database, facilitating its utilization as a support for the CRS catalogue. Finally, we propose to add two tables allowing to register WKT and PROJ4 text encoding, in order to improve the efficacy of the service.

Such as has been described in the introduction above, a previous study of overview of the existing standards referring to CRS encoding in the context of OGC and ISO has been carried out. The sources [5], [6], [7], [10], [11], [12], [13] and [14] related to CRS encoding have been reviewed.

The conclusions point to EPSG as the valid, recognized authority for CRS and coordinate transformations. This statement is based on the reading of the last OGC [14] and ISO [7] recommendations wherein CRS identifiers are defined through Universal Resource Name (URN).

The use of URN allows to structure name spaces as directories, so that the parent node whereon it depends may be known at all times. The meaning of the used labels is closely related to their names. For instance, urn:ogc:def:crs:EPSG:6.6:4277 shall be interpreted as a numeric encoding associated by the OGC to the definition of a CRS using the name space of EPSG Version 6.6. This way it is possible to have several name spaces available, with several versions to define a CRS with a value.

It may be concluded that the CRS encoding proposed by EPSG is valid as a neutral substrate and unifying agent for the remaining CRS encoding.

In the following exploratory stage, a great number of geographic information storage formats has been reviewed. This has allowed to assess the number of proprietary or pseudo-standardized encodings catalogued by EPSG in its database. In the following table, the different sources of information, the encoding type and the number of computed CRS definitions are enumerated:

Encodings	**Source**	**Number**
Numeric	EPSG (V6.6) EPSG database	> 13.000
WKT + numeric + proj4	PostGis v1.0 spatial_referece_system table	> 2.650
Mnemonic	Ermapper	165
Wkt	Ermapper	875
Mnemonic + WKT	Esri	2.400
WKT	Oracle 10g	1000
WKT	IBM-DB2 st_spatial_referece_system	2.360
WKT	MapInfo SpatialWare for SQL Server	950
Numeric	Intergraph	190
Numeric	MapInfo	270
Mnemonic	PCI Geomatics	290
Mnemonic	FME	338
Mnemonic	Proj4	193
Mnemonic	Erdas Imagine	254

Table 6: CRS coding count summary.

If to the previous conclusion (presenting EPSG encoding as a unifying agent, stating that the number of CRS encodings and the coordinate transformation contributed are substantially better than the remainder, and stressing the need to materialize the storage of catalogue data in a database, such as is done by EPSG), it may be concluded that the foundation of the catalogue and encoding translation service are the EPSG data model. Another additional advantage this choice contributes is related to the use of other services, such as the coordinate transformation service (WCTS). The *DescribeTransformation* operation needs to use all available information to describe the method used for the transformation or conversion of coordinates.

After having selected the EPSG database as data model and initial contents for the catalogue, we have proceeded to analyse the schemas of its tables. We have confirmed that there are two tables, *Alias* and *Naming System*, that may be used to reach the desired purpose. The table Alias allows the association of synonyms for *datum, ellipsoid, coordinate operation, coordinate operation method, coordinate operation parameter, CRS, units* and *prime meridiam*, the manufacturer to whom they belong being identified by the parameter *naming_system_code*. This way it is possible to add as many numeric or textual synonyms associated to a manufacturer as is necessary.

The schemas of the other previously referenced databases have also been analysed: Oracle, PostGis, SpatialWare, DB2 and Geodatabase (Esri) to find similarities that allow to propose a compact solution for the storage of WKT and Proj4 encodings. The following table displays the data models internally used by the sources mentioned :

Source	Table Schema
Oracle	MDSYS.CS_SRS(CS_NAME, AUTH_NAME, AUTH_SRID, SRID, WKTEXT, CS_BOUNDS)
PostGIS	SPATIAL_REF_SYS(SRID, AUTH_NAME, AUTH_SRID, SRTEXT, PROJ4TEXT)
MapInfo SpatialWare	HG_SPATIALREF(SRID, CS_NAME, AUTH_NAME, AUTH_SRID, SRTEXT)
IBM DB2 SE	ST_SPATIAL_REFERENCE_SYSTEMS(COORDSYS_NAME, SRS_ID, SRS_NAME, DEFINTION, ...)
Esri GeoDataBase	SPATIAL _REFERENCES(SRID, SRTEXT, …..)

Table 7: Spatial database table schemas.

Therefore the next question is to study how to use and/or extend the EPSG data model to facilitate the operations of insertion and consultation with the non-numeric encodings (WKT and proj4). We propose to create two tables allowing to register CRS definitions in WKT and Proj4 respectively. The schemas proposed for the tables are: WKT_DEFINITIONS(AUTH_NAME, AUTH_SRID, WKTEXT) and PROJ4_DEFINITIONS(AUTH_NAME, AUTH_SRID, PROJ4TEXT).

After having selected the support of CRS identifier storage, the storage capability of multiple synonyms of a same CRS has been analysed and it has been defined how WKT and proj4 text encodings will be stored ; we propose to apply the following natural operation guidelines when dealing with consultation and transactional operations :

Use of the table *Naming System* to register manufacturer proprietary formats (Intergraph, Ermapper, etc.). Relate the parameter InputFormatId to the field *Naming_system_name*, to get a value of *naming_system_code*. The input WKT encodings shall have a different handling.

Use of the table *Alias* to store in the field *Alias* the synonyms, either mnemonic or numeric, associated by EPSG to an assigned encoding. In order to keep the information classified, the type of identified element is differentiated in the field *object_table_name*: CRS, datum, ellipsoid, etc…

Use of the WKT_definitions table to locate the encodings of the same name. If the search has not been successful, we propose to analyse the WKT definition, also to separate PROJ, DATUM, ELLIP, UNITS and to try to carry out the individualized and independent search in the Alias table, indicating the corresponding table in each case as *object_table_name*.

Use of the *PROJ4_definitions* table to locate the complete encoding of a CRS according to proj4. If the result is not successful, we propose to determine projection, datum, ellipsoid and projection parameters from the CRS compact identifier, to be able to carry out the searches of alias type proj4 with the individual identifiers. This way, a definition according to this encoding may be composed.

Before simple transactional insertion (datum, projection, ellipsoid, units) we propose to act exclusively on the tables *Naming System* and *Alias*. When dealing with WKT type encodings, we propose to include a new register in the table *WKT_definitions*, and in addition we propose to determine the names associated to the projection, datum, ellipsoid and units, so as to create new alias' in the table Alias. This way we teach the system to analyse future definitions not registered in the same format.

The output formats ISO19115 (XML), GML, EPSG, shall use as compact as possible a CRS encoding assigned by EPSG.

REVIEW OF ENCODINGS USED BY THE MANUFACTURERS

In this section we describe the sudies made to relate the different numeric and mnemonic encodings used by a number of manufacturers with the EPSG codes. The final objective of this study is to increase the expectations for success, as well as acceptance and utilization on the part of the users. In order to achieve this goal, we propose massive loading of proprietary encodings in the register, after this has been implemented.

The starting point of this study is [8]. In this document, the existence of multiple formats to encode CRS information was noted. The realization of a harmonization process was proposed. This study may be carried out as a customized solution or it may be integrated into a Web Wervice with a more generic purpose. The result of this harmonization study has allowed to initially have the EPSG encodings for the following file formats: Intergraph, MapInfo, MicroDEM, USGS DEM, Ermapper, EOSAT, Erdas, NTIF and PCI-Geomatica. For this study, the already mentioned sources have been analysed: PostGIS, Oracle, DB2, SpatialWare, FME, Wkt (Esri) and Proj4.

The following table summarily displays the formats and number of reviewed encodings for each software manufacturer.

Manufacturers	**CRS**	**Projection**	**Datum**	**Ellipsoid**
Intergraph		Numeric (47)	Numeric (97)	Numeric (46)
Ermapper	WKT (875)	Mnemonic (37)	Mnemonic (128)	Mnemonic (128)
MapInfo		Numeric (44)	Numeric (165)	Numeric (165)
Erdas		Numeric (58)	Mnemonic (150)	Numeric (46)
FME		Mnemonic (59)	Mnemonic (200)	Mnemonic (79)
Esri	WKT (1995)			
PCI- Geomatica		Mnemonic (31)	Mnemonic (227)	Numeric (32)
Proj4		Mnemonic (121)	Mnemonic (9)	Mnemonic (42)
Oracle	WKT (1000)			
PostGis	WKT (2650)			
DB2	WKT (2360)			
SpatialWare	WKT (950)			

Table 8 : Software manufacturer formats and counts encodings.

CONCLUSIONS:

The main conclusions of this document are:

Important semantic interoperability problems have been detected in the encodings used by software manufacturers for the CRS.

We have reasoned out the choice of numeric encoding and the data storage model used by EPSG for the Coordinate Reference Systems and Coordinate Transformations.

We have defined an abstract proposal for a Web Service acting as a Catalogue and CRS encoding translator, based on user cases and the definition of the service interfaces.

We have defined an implementation proposal of such a service based on the EPSG database.

An extensive analysis of the individual encodings of each manufacturer and their EPSG equivalent has been carried out.

As future work, we propose the implementation of the translation service and catalogue, the loading of data and its validation through the design and carrying out of a test bed.

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