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BOOSTEE-CE

DELIVERABLE T1.1.2

Methodology to harmonize and integrate heterogeneous data

Version 1
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D.T1.1.2: Methodology to harmonize and integrate heterogeneous data

A.T1.1 Development of spatial data infrastructures (SDIs) – geodatabase

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1. Introduction and aim

The deliverable T1.1.2 reports the project methodology developed to harmonize and integrate the heterogeneous data collected in the pilot action (PA) areas of the project (D.T1.1.1) and ensure interoperability. The aim of the document is to present the combination method useful to reduce data heterogeneity, improve its quality and attractiveness and have all data in the same reference system and format for the successive actions of the project (e.g. geospatial database generation, 3D building reconstruction, PV estimation, etc.). The following document presents ideas, solutions and best practices of harmonization processes of spatial data related to energy management, together with the project approach. The key roles in the methodology development is the inclusion of experts, such as spatial planners and geoinformatics people. The document is restricted to project partners (PP), reviewers and JS.

2. Geospatial data and infrastructures

Data source heterogeneity is the main obstacle to develop homogeneous geoinformation systems in different countries. Data availability, accessibility, level of details and licenses varies from country to country (but also from city to city within the same country).
Huge amounts of heterogeneous data sets of different topology are collected nowadays with different data acquisition techniques. In many geo-spatial applications, it is necessary to transfer spatial data between different organizations, with different contents and in different forms for utilization. However, since the spatial databases of different organizations may have been established at different times, are based on different platforms, or have been made to fit different industries or departments, large differences exist between them. The differences are reflected in the following aspects:

- differences in data contents and data sources (vector data, image data, topographic data)
- differences in spatial data model (different spatial database management systems support different spatial data models),
- differences in GIS software.

BOOSTEE-CE project implements a platform Oneplace (WPT2) which includes webGIS solution to let users interactively navigate a map of an urban environment, select a 3D building of interest and retrieve the energy audit and other cadastral/building information. The energy-related data at building level are important e.g. to help define Sustainable Energy Action Plan (SEAP) at urban level and to support the activities of SEAP monitoring. In the framework of this activity development of a GIS database for each city will be done (D.T1.1.3) and will be updated during the whole duration of the project with input and output information from the other WPTs, especially WPT 3 (*Boosting energy efficiency in pilot actions*).

2.1 Energy-related geographical database in the BOOSTEE-CE project

The heart of an energy geographical database is its content. The GIS layers as well as the geo-referenced information produce a powerful tool for monitoring, decision making and communicating for all energy related issues in city planning and operation.

The challenges for a robust and smart design of the 3D Energy Management System (EMS) are:

- the selection of the useful output information that this system should provide (the information that produces an added value to help energy managers and policy makers in daily operations to improve

spatial decision making, rather than a detailed list of information that may be found in many different places),
- the smart exploitation of existing information, such as: cadastral information, energy computation, heat loses and etc. instead of production of new data layers,
- define the level of detail that makes the provided or produced information useful,
- discovery solar energy potentials of public buildings roofs,
- define refurbishment priorities and plan actions what will lead to decreased energy consumption.

In order to target above mentioned challenges the list of different and heterogeneous data about energy and buildings (spatial and non-spatial data) in pilot areas (PA) was created.

Tab. 1 Source of spatial and non-spatial data for particular pilot actions

Pilot action	Dataset	Types of data / info	Owner	Access	
				Public	For PA
PA 1 - Emilia Romagna region (IT)	Cartographic Archive SIT *(Territorial Informative System)*	Orthoimages, Oblique photos	**Local Authority -** Municipality of Bologna	YES	YES
	Technical Map (CTC) Municipality of Bologna	2D geometry of building footprints (vector data), civic numbers, parcels, ownership, historical maps (images)	**Local Authority -** Municipality of Bologna	YES	YES
	Geoportal Emilia-Romagna Region	ESRI Shape file of building footprints	**Regional Authority -** Emilia-Romagna Region - Cartographic Service of the Emilia-Romagna Region, Statistics, Communication and GIS	YES	YES
PA 2 - Judenburg-Lindfeld (AT)	Topographic database	Building footprints (Vector data, dwp or dxf-format Buildings are shown as polygons)	**Local Authority –** Municipality of Judenburg	**NO**	YES
	Digital cadastral map	different layers with data on admininistrative boundaries, satellite images, river networks, geology, cadastral boundaries etc.	**Regional Authority -** Province of Styria	YES	YES
	Energy certificates of buildings	Building geometry and physics heating energy demand transmission heat losses ventilation losses heat gains Energy demand of installations (heating, ventilation, water heating, lighting)	**Local Authority –** Municipality of Judenburg	**NO**	YES
	Solar rooftop cadaster	Size, orientation, angle, irradiation, and potential of solar production for each rooftop: solar area in m2, energy production potential in kWh, colour code for suitability	**Regional Authority -** Province of Styria	YES	YES

Pilot action	Dataset	Types of data / info	Owner	Access	
				Public	For PA
		(red =- very good, yellow = good)			
	ALS-data (LiDAR)	Points above sea level	**Regional Authority -** Province of Styria (bought by Municipality)	NO	YES
	Ortho-photos	Orthorectified aerial photograph	**Regional Authority -** Province of Styria	YES	YES
PA 3 – Zlin Region (CZ)	LiDAR data	Points above sea level (point cloud)	**National Authority** (Czech Office for Surveying, Mapping and Cadastre)	NO	YES
	Topographic database	- Underground utilities; - Building footprints – also involve the database (building_sel_cities.dbf) with the info on number of floors	**Regional Authority -** Zlín Region		
	Technical documentation of PA buildings	Data about construction, sanitary and electrical installations, room dimension, used materials etc.	**Regional Authority -** Zlín Region		
	IR data	Thermovision pictures / files	**Regional Authority -** Zlín Region		
	Internal energy database	Data on energy consumption	**Regional Authority -** Zlín Region		
PA 4 – Tolna (HU)	Urban management plan's maps	2D geometry of building footprints - Vector data (dxf files), in which the buildings are shown as polygons	**Local Authority -** Municipality of Tolna	YES	YES
	Construction plans of pilot buildings	Manual reading of building heights from the plans	**Local Authority -** Municipality of Tolna	NO	YES
	Data about the characteristics of the buildings obtained from construction plans of the buildings	Descriptions and figures provided for the pilots: building structure, energy flows of the buildings, and related building engineering systems, HVAC technologies, lighting	**Local Authority -** Department of Construction at Municipality of Tolna; Tolna Facility Management Center.	NO	YES
	Technical documentation of building	Recent refurbishment details (dates, renovated parts of buildings, technologies replaced)	**Local Authority -** Department of Construction at Municipality of Tolna; Tolna Facility Management Center.	NO	YES
	Energy bills	Produced and consumed energy of pilot buildings	**Local Authority -** Department of Construction at Municipality of Tolna; Tolna Facility Management Center.	NO	YES
	Energy certificates	Energy efficiency actions (thermostatic valves, sensors, etc.)	**Local Authority -** Department of	NO	YES

Pilot action	Dataset	Types of data / info	Owner	Access	
				Public	For PA
			Construction at Municipality of Tolna; Tolna Facility Management Center.		
PA 5 – Płońsk (PL)	Topographic database	2D geometry of building footprints + number of floors *(vector data)*	**Regional Authority** (Department of Digitization, Geodesy and Cartography in the Marshal's Office of the Mazowieckie Voivodship)	**NO**	YES
	LiDAR data	Points above sea level (point cloud)	**National Authority** (Head Office of Geodesy and Cartography in Poland)	**NO**	YES
	Energy bills	Yearly consumption and bills for electricity and fuels	**School authority**	**NO**	YES
	Post-completion documentation for the sport hall	Data about construction, sanitary and electrical installations, room dimension, used materials etc. for the new sports hall, which was built in 2016	**School authority** (Municipality of Płońsk owns copies of some documents)	**NO**	YES
	Building inventory	Data about the existing building: maps with room dimensions, building sections and facades, short technical descryption. There are two documents, one including central part of the building and west wing. Second document include east wing and no longer existing old sports hall. (the data is inaccurate and not current, for example: new sports hall is not included; new rooms, like library or toilet are not included)	School authority	**NO**	YES
PA 6 - Koprivnica (HR)	Topographic database	2D geometry of building footprints (*the height of the buildings was taken by the REAN employees on the field*)	**National Authority** (the exact source wish to remain anonymous; use only for the purpose of the project)	**NO**	YES
	Technical documentation of PA buildings	Age of the construction, technical description, building purpose, building gross area etc.	**Local Authority** - City of Koprivnica	**NO**	YES
	Energy certificate	Energy needs for heating and cooling, thermal properties of the building envelope, total primary energy consumption, CO2 emissions	**Local Authority** - City of Koprivnica	**NO**	YES

Pilot action	Dataset	Types of data / info	Owner	Access	
				Public	For PA
PA 7 – Velenje (SI)	LiDAR data	Points above sea level (point cloud), Resolution 5 to 10 points on 1m2 (year 2015)	**National Authority** (ARSO –Agency of Republic of Slovenia for Environmental)	YES	YES
	Digital Ortophoto-DOF25	(aerial survey of surface in 25 cm resolution) Attributes of shp file include ID of objects (SID) and 3 heights of buildings	**National Authority** (The surveying and mapping authotity of Republic of Slovenia)	YES	YES
	Topographic database	2D geometry of building footprints *(vector data)*	**National Authority** (The surveying and mapping authotity of Republic of Slovenia)	YES	YES
	Energy audit certificate for Music school of Velenje	Including information about the building (water, electricity and heat consumption, surface, floors, building materials,…) and with proposition and measures to improve energy efficiency of the building	**Local Authority** - (Municipality of Velenje)	YES	YES
PA 8 - PL/CZ cross-border regions	LiDAR data	Points above sea level (point cloud)	**National Authority** (Czech Office for Surveying, Mapping and Cadastre)	**NO**	YES
	Topographic database	2D geometry of building footprints *(vector data)*	OpenStreetMap	YES	YES
	Technical documentation of PA buildings	- age of construction - type of energy system (electricity and heat consumption) - envelope materials - high of the building - etc.	**Local Authority** (Municipality of Lubawka and Zacler)	**NO**	YES

The information reported in the table above (Table 1), collected to develop the project databases (D.T1.1.3), can be divided into four basic information categories (Fig. 1):

1. **Geographical layers** (spatial data):
   It includes geographical layers that provide the basic spatial information needed for generation 3D buildings models (*2D building footprints (vector) with the information about the high taken directly from attribute table or from LiDAR data (Digital Surface Model – DSM) or Orthoimages*).
2. **Specific layers** (spatial data):
   This comprises additional spatial layers that would facilitate the computation of public buildings energy figures such as: solar rooftop cadaster, IR data
3. **Statistical and survey data sets** (non-spatial data):
   This category comprises non-geographical data sets such as: construction plans, energy audit certificates, energy bills. The information collected inside these data sets is always geo-

referenced (or can be) upon the geographical layers of the first category – figures or information related to every building.

4. **Energy demand** (non-spatial data):
   The ultimate goal of the energy geographical database is to store and present figures for the energy demand and consumption (energy audit certificates, energy bills).

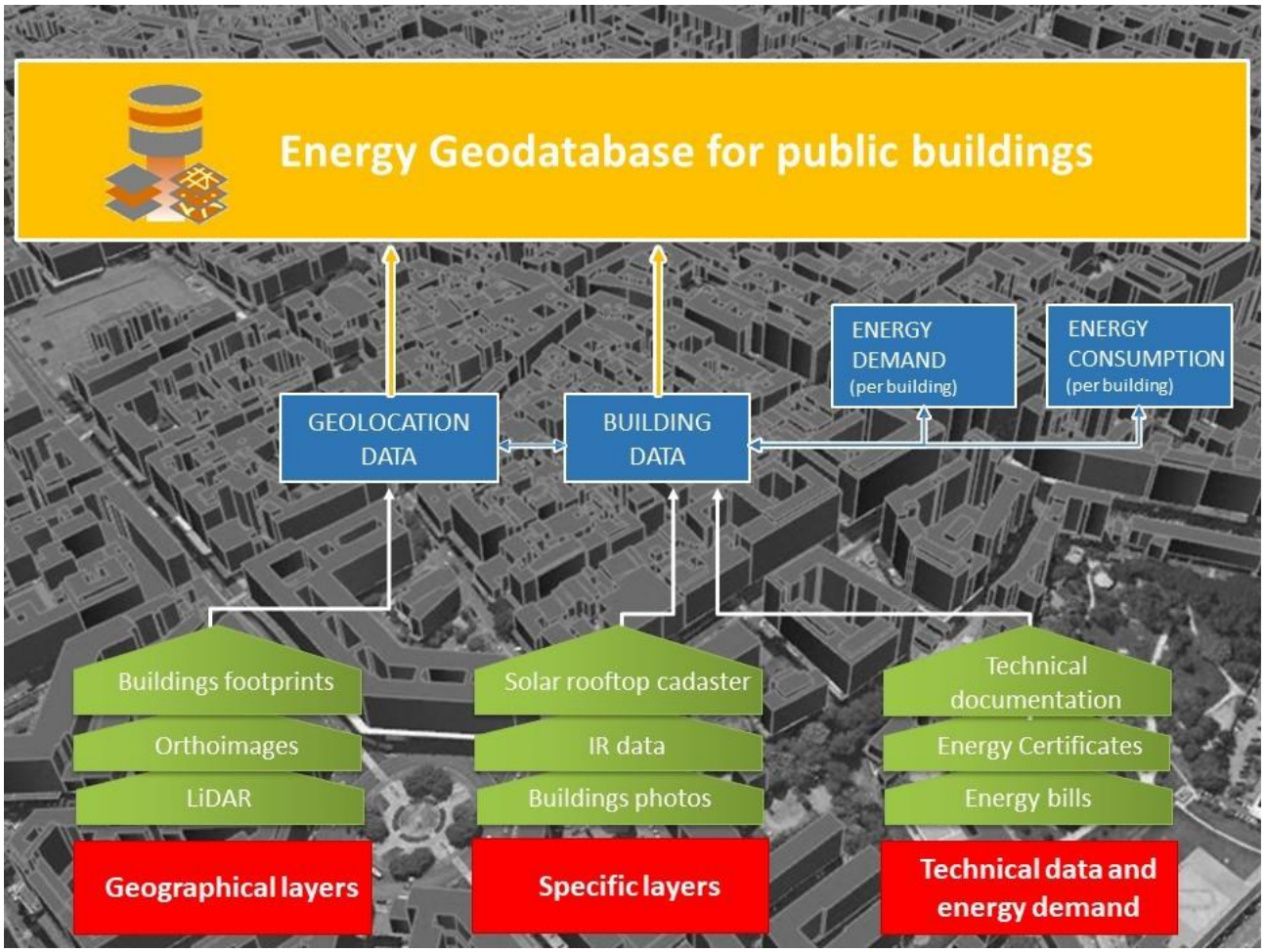

Figure 1. Source of spatial and non-spatial data to develop energy databases.

3. Possible harmonization and integration methods (SOTA)

Data heterogeneity is the main obstacle in interoperability between different platforms and tools and for replicability of solutions in different cities and countries. Existing web services or platforms already implemented need to interoperate through well-known geo-ICT standards (e.g. OGC OWS).
A common framework for monitoring of energy efficiency policies, with harmonized data from building level to district level and ending at national level could improve the interoperability of the different directives/initiatives. Within such a framework, geo-referencing all the relevant building data accurately and consistently will significantly improve data quality and reliability, enable effective scenario modelling to fill gaps in data, and support the overall policy process.

Furthermore, from a potential market perspective, web-based tools providing access to the energy performance of geo-referenced buildings could improve territorial knowledge, and support, for example, the activities of energy service companies and companies involved in construction / renovation of buildings.
On April 5th 2016, the European Joint Research Center presented the interactive and collaborative online European Energy Efficiency Platform[1](E3P). The E3P is conceived to fill the gap opened by scattered data and fragmented knowledge resulting from a rapidly growing energy efficiency market. It is expected to facilitate knowledge exchange in the online community of energy efficiency experts.

3.1 Data harmonization – European framework regulations

The regional and local governance role in reaching the EU targets, the regions and municipalities have to develop and implement climate change mitigation and adaptation strategies by launching initiatives such as the Covenant of Mayors for Climate and Energy initiative. The current level of effort in gathering and disseminating energy data (energy consumption, production and GHG emissions) at national level is not sufficient to support the authorities to define and monitor energy strategies at local level. The local and regional energy planning is imperative to achieve an energy system that increases the security energy supplies reduces dependence on energy imports and creates new opportunities for growth and jobs. The gathering and later on analysis of regional and local energy data will ultimately result in greater environmental and health benefits, particularly through a reduction in air pollution.

3.1.1 The European Union Location Framework (EULF) and the INSPIRE Directive

The European Union Location Framework (EULF) project aims to improve the way 'location information' is used in many different policy areas and in e-government services generally. It does this through a series of recommendations, guidance and actions to promote and deploy best practice. The EULF draws significantly on the legal and technical framework provided by the INSPIRE Directive, which started out supporting European environmental policy. INSPIRE is due to be fully operational by 2020, when Member States have to complete actions to publish interoperable data of interest for energy efficiency.

Table 2. European framework regulations for data harmonization (Source: http://data4action.eu/the-data-access-guidebook-for-sustainable-energy-action-plans-has-been-released).

Sub-National Level	Directive 2012/27/EU: Energy Efficiency[2]
Energy Planning	Directive 2009/28/EC: Renewable Energy[3]
Energy consumption	Directive 2012/27/EU: Energy Efficiency[1]
Data Access	Directive 2010/31/EU: Energy Performance of Buildings[4]
	Directive 2009/72/EC: Internal market in electricity[5]
Data Protection	Directive 95/46/EC: Protection of personal data[6]
	Directive 2002/58/EC: Privacy and Electronic Communications[7]
Environmental Data Access	Directive 2007/2/EC: Infrastructure for Spatial Information in the European Community (INSPIRE)[8]

[1] https://e3p.jrc.ec.europa.eu/
[2] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive
[3] https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive
[4] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
[5] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32009L0072
[6] http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A31995L0046
[7] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al24120
[8] http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32007L0002

In this context, the feasibility study has been initiated within the EULF project, joining efforts from the JRC units H06 (Digital Earth and Reference Data) and F07 (Renewables and Energy Efficiency). It is aimed at verifying how location data can support energy efficiency policies. In particular, its specific goal is to evaluate how the framework set by the INSPIRE Directive for the harmonized collection and exchange of location data can serve the needs of policy instruments addressing energy performance of buildings, energy planning in urban areas, and the national energy efficiency plans of Member States.

3.2 Standards

The standardization is the key role in the process of data harmonization and integration regardless of topic. From a technical point of view, we can define the six basic types of standards for:

- data and metadata formats – e.g. Geography Markup Language (GML);
- data models - e.g. Infrastructure for Spatial Information in Europe/ specifications (INSPIRE);
- communication protocols – various Application Programming Interface (APIs);
- classification systems – hierarchies and nomenclatures including semantics;
- methodologies – e.g. the 5-steps harmonization framework – see Janečka et al. 2013[9] (Fig. 2);
- visualization rules – e.g. various INSPIRE data specifications.

3.3 Previous projects

The following solutions are taken from 4 international projects which rely on spatial and non-spatial data from different sources and different countries to face some energy-related issues:

a) **SUNSHINE**[10] - Smart UrbaNServIces for Higher eNergy Efficiency (Competitiveness and innovation framework programme (CIP));
b) **GeoSmartCity**[11]- Open geo-data for innovative services and user applications towards Smart Cities (Competitiveness and innovation framework programme (CIP));
c) **CitiEnGov**[12] – Cities for Good Energy Governance (Interreg Central Europe);
d) **ACCENT**[13] - Accompany Cities in Energy Strategy (Climate KIC).

These aforementioned projects focus not only on energy data processing, but also on pilot activities related to energy management applications or tools.
City Geography Markup Language (CityGML) Energy ADE[14] and INSPIRE are the two target schemas useful to integrate heterogeneous energy related geodata. CityGML, open standard for exchanging 3D urban data, doesn't contain any energy-related objects or attributes. Urban energy tool developers (CitySim, UMI) have developed their own tailor-made urban information model - Energy ADE for CityGML, with the aim to store relevant energy-related data in a common open city data model to offer data exchange and interoperability possibilities between urban energy stakeholders and tools as well as with other expert fields (acoustics, statics). The Energy ADE Development Group consists of international consortium of urban energy modellers and users from research centers and private companies from 8 countries worldwide.

[9] Janečka K, Čerba O, Jedlička K, Ježek J (2013) Towards Interoperability Of Spatial Planning Data: 5-Steps Harmonization Framework. In: Proceedings of 13th SGEM GeoConference on Informatics, Geoinformatics And Remote Sensing, ISBN 978-954-91818-9-0 / ISSN 1314-2704, June 16-22, 2013, Vol. 1, 1005 – 1016 pp. DOI:10.5593/SGEM2013/BB2.V1/S11.051.
[10] http://www.sunshineproject.eu/
[11] http://www.geosmartcity.eu/
[12] http://www.interreg-central.eu/Content.Node/CitiEnGov.html
[13] https://www.accentproject.com/
[14] https://geospatialworldforum.org/speaker/SpeakersImages/Romain%20Nouvel.pdf

Within the **SUNSHINE** project the initial conditions were: detailed building energy need estimations were available from Energy Performance Certificates, but only for a limited subset of the buildings stock. Errors have been found in EP values data, as well as cadastral references (5%). The solution is to provide an automatic estimation capable of being computed at wide scale and that just needs basic buildings' data as input (footprint, areas, volumes, uses, num. building units, Municipal register of buildings, Cadastre; construction period, height, ISTAT census, Regional topographic database, onsite observation and measurements; Energy Performance (EP), heat transfer, other properties derivation from typological databases) – creation of energy map.

GeoSmartCity implements a platform to share and publish geographical open data coming from different sources, such as Public Administrations, Multi-utilities, Companies and Crowd-sourcing. The platform includes specialized web services to integrate public geographical data with other geo-refenced data (public or private) useful for the smart management of urban infrastructures and public services in the context of the Smart City initiative and the Digital Agenda for Europe. To facilitate GeoSmartCity project pilots to harmonize their own data, a double-step approach has been proposed:

1. 1st transformation into an extended pseudo-INSPIRE SQL database (for "Buildings" data theme), structured for creating target databases on pilots' premises
2. 2nd transformation from the pseudo-INSPIRE SQL DB into GSC (INSPIRE extended) GML compliant datasets

SQL structures are based on extended INSPIRE data model. This approach also facilitates pilots to replicate the entire workflow in the future (beyond GeoSmartCity project).

The Interreg project **CitiEnGov** contributed to the energy efficiency field with the realization of the CitiEnGov toolkit, best practices catalogue, training schema and pilot actions for improving energy performances. In particular, the toolkit, based on webservices and 2D geospatial data, should improve public authorities' capacities to define and implement low carbon energy planning and strategies. BOOSTEE-CE and CitiEnGov signed a letter of intent to jointly organize energy-related events as well as exchange data and best practices.

The **ACCENT** project's main objective is to run an on-line platform for constructing and evaluating energysaving strategies in cities. An ACCENT Tool was developed with the aim to gather all statistical and other information about a city that can be shown through a georeferenced information system (GIS), such as population density, energy systems in buildings, year of building construction, building ownership and uses, power grid layouts, and the percentage of homes suffering energy poverty. The platform also makes use of tools developed under other European projects, such as TÁBULA and EPISCOPE, which arrived at a classification of buildings types and design features for estimating buildings' thermal performance. Collected information and these tools, plus a calculation engine specifically developed for this purpose, yield an estimate of buildings' energy performance and energy consumption at different scales (by building, quarter, district and city) and can break energy data down by use (heating, cooling, lighting, domestic hot water, etc).

4. Transnational methodology for harmonization and integration

Data integration involves combining data residing in different sources (e.g. different reference systems of file formats) and providing users with a unified view of them. Issues with combining heterogeneous data sources often referred to as information silos, under a single query interface have existed for some time.

INSPIRE is based on the infrastructures for spatial information established and operated by the EU Member States. The Directive addresses 34 spatial data themes needed for environmental applications with key components specified through technical implementing rules[15]. The principles considered to help define the data interoperability process:

- that spatial data are stored, made available and maintained at the most appropriate level,
- that it is possible to combine spatial data from different sources across the Community in a consistent way and share them between several users and applications,
- that it is possible for spatial data collected at one level of public authority to be shared between other public authorities[15].

The components relevant for data interoperability are[16]**:**

a) INSPIRE principles
b) Terminology
c) Reference model
d) Rules for application schemas and future catalogues
e) Spatial and temporal aspects
f) Multi-lingual text
g) Coordinate referencing and units model
h) Object referencing modelling
i) Identifier management
j) Data transformation
k) Registers and registries
l) Metadata
m) Maintenance
n) Quality
o) Data transfer
p) Consistency between data
q) Multiple representations
r) Data capturing
s) Conformance.

Each component may contribute in a different way to the interoperability of spatial data. In practice not all data interoperability components must be taken into account during the process of data harmonization. Following these inputs, the project methodology firstly applies a check to the data to evaluate their quality, consistence, location, attributes, etc. Once the check is performed, the harmonization can start.

4.1 Harmonization and integration framework

The proposed methodology by Janečka et al. 2013 (Figure 2) for the process of data harmonization is also applicable on energy data and could be used mainly by data providers and stakeholders. Following this approach, the BOOSTEE-CE project methodology includes 5 steps:

1. **Understanding the theory of spatial data harmonization** – define the most suitable and appropriate technique to be used for converting data between different data structures, while losing as little information as possible.
2. **Source data understanding** – consider and understand the source data schemes up to the level of attributes.

[15] http://inspire.jrc.ec.europa.eu/
[16] http://inspire.ec.europa.eu/documents/Data_Specifications/D2.5_v3.2.pdf

3. **Target data understanding** – deep understanding of target data schemes up to the level of attributes.
4. **Definition of harmonization and integration steps** – analysis of source and target data differences in order to develop geometry and attribute matching scheme which describes the conversion of source data into target data scheme, layer by layer, table by table, attribute by attribute.
5. **Practical realization** - implementation of the above-defined harmonization steps in a selected tool / software. Three types of software are commonly used: Geographic Information Systems, Spatial databases or ETL (Extract Transform and Load).

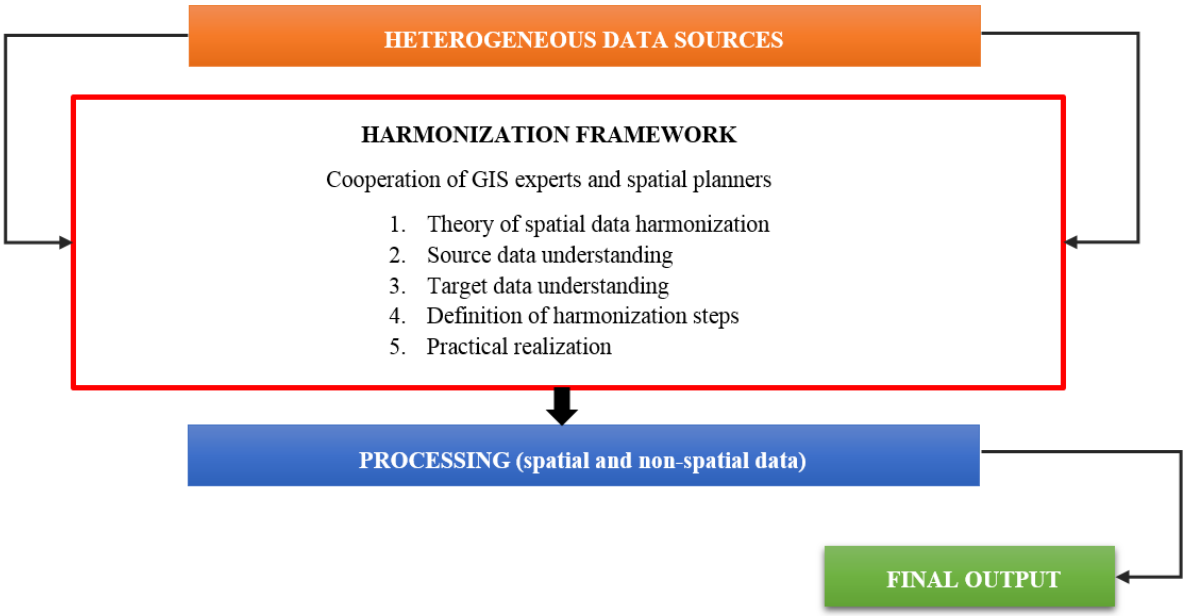

Figure 2: The proposed 5-step harmonization and integration framework for harmonization of spatial planning data (adapted from Janečka et al. 2013).

4.2 Harmonization and integration inside a geodatabase

For a successful data harmonization, the specific operations above described can be done directly inside a relational database management system with a spatial extension (e.g. PostGIS, Oracle Spatial, etc.). Within geodatabase, different operations are performed to support the transformation of attributes as well as geometries. These operations can be divided into main groups:

- **Filtering** - selection according to attribute or geometry predicate. For instance use just polygons with area larger than some value or select features that overlap the selection shape wholly or partially.
- **Attribute operation** – e.g. renaming, change of data type, change of taxonomy (reclassification etc.) or summarizes the attribute values of the affected feature as a series of statistics or a single calculated value.
- **Geometry operation** - change the spatial representation – creation of new data from input data, e.g. to represent polygon feature as just as point (centroid),
- **Aggregation** - calculation of new feature according to particular predicate with usage based on a specified aggregation strategy (Sum, Min, Max, Mean, or Median), e.g. union of all geometries

according to some attribute, for instance join all features of same kind that are adjacent to each other into one new feature.

5. Conclusion

The collected project data are checked, harmonized and integrated using the reported methods. The outcomes are interoperable spatial and non-spatial data spread all over Central Europe which can be included in geodatabases useful for the forthcoming project activities. In performing the harmonization and integration of the collected very heterogeneous data and information, the BOOSTEE-CE project will consider the needs of providing energy-related datasets and to satisfied large group of potential users (local, regional, national authorities as well as general public) with various requirements and experience as well as many data and information providers with different scope as well as expectations.