Geographic Information System (GIS) tools for aiding development of inland waterways fleet

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ABSTRACT

The information aiding of planning and operation of inland waterways fleet covers many items among which problems associated with analysis of existing waterways are especially important. Such analyses concern mainly their navigability features (from the point of view of elaboration of design assumptions for floating units) as well as planning land-waterborne transport links. Range of input data for the analyses is very broad hence they can be next used for managing the waterways. This paper presents a concept of forming the GIS data model for the purposes of INCOWATRANS project with taking into consideration the existing data and their possible usage by the administration of waterways and their other users.

Keywords : polish waterways, inland shiping, proposal of navigating system

INTRODUCTION

Data bases elaborated for the purposes of INCOWATRANS project are mainly aimed at providing tools and data for spatial analyses covering course and bathymetry of waterways, leading to generation of correct design assumptions for inland waterways fleet. However a preliminary analysis already shows that the structure and content of such data base is so broad that its limitation solely to that aim would be a loss of time and money. The data necessary for realization of the main aim can be successfully applied also to other tasks provided they could fulfill certain requirements. To this end were defined potential additional tasks of such base, its users and resulting requirements first of all concerning its structure which should be made ready for additional data input in the future without their modification and excessive increase of labour outlay for elaboration of the data model itself.

To comply with existing standards is also important in order to make it possible to integrate the data base in question with already existing systems.

DESIGN ASSUMPTIONS FOR THE DATA BASE

The expanded GIS data base can contain many additional functions going beyond analysis of navigability features of waterways shared and maintained by many users simultaneously. The most potentially interested in using such tool can be the following :

- ship owners (operators) – (their land staff and ship crews)
- producers (constructors) – (building and repair companies engaged in building waterway infrastructure)
- supervisors (state and local administration, ship classification institutions, insurance companies, engineering supervision)
- scientific research and didactic institutions
- other commercial and non-commercial users (tourist agencies, forwarding agents etc).

The most important functions of the base desirable from the point of view of the potential users cover the following :

- Inventory control functions
  - Inventory control and aiding the management of waterways infrastructure resources
  - Inventory control of waterways land-surroundings
  - Aiding the financial analyses and rationalization of infrastructure maintenance costs
- Analytical functions
  - Running the spatial analyses associated with ship traffic – – mainly concerning navigability of waterways and resulting requirements for floating units
  - Running the spatial analyses aimed at planning the inland navigation maintenance and development as well as its infrastructure (e.g. disclosing "bottlenecks" and planning modernization)
  - Running the network analyses aimed at optimization of land-waterborne transport.
- Interface functions
  - Integration of existing distributed data
  - Accessing the existing data in internet in a coherent way, with taking into account priorities and access rights of particular users
  - Ensuring a uniform mechanism of access to all necessary data for all interested in waterways usage (including non-GIS data, e.g. technical documentation of hydro-engineering facilities or floating units)
- Navigation functions
  - Improving safety of navigation on waterways by real – – time monitoring current navigation situation to avoid collisions and to support environment protection and emergency management
  - Tracking positions of ships and planning their navigation
  - Accessing information on navigability state resulting from water level state.

From the so defined functions of the base technical requirements also result for the entire system which should definitely ensure :

- Effective data collecting which guarantees access to coherent and updated information.
- Comprehensive analysis of collected data on the basis of which it would be possible to generate knowledge useful for their users.
- Information turn automation which covers a.o. :

- Control of access of particular users to information and permissions to put the data into the base
- Control of data modification and validation level of modification (what to modify itself a user is authorized, about what he is to inform other users, for what and from whom he is to get acceptance)
- Control of propagation of messages on modifications (who should be informed about modification and in which way)

♦ Processing the data of different kinds, covering :
- CAD technical documentation (technical drawings and 3D models)
- GIS documentation (of waterways infrastructure)
- Text documentation (procedures, protocols etc)
- Multi-medial documentation (graphic, audio, film, measurement data files etc)
- Database files (catalogues of products, material properties etc)

ARCHITECTURE OF THE DATA BASE

Two kinds of problems associated with fleet and waterways management, which require different informatics tools to be used, can be distinguished as follows :

✩ Problems associated with object's structure – the domain of Product Lifetime Management (PLM) data bases
✩ Problems associated with dispersion of geographic objects – the domain of Geographic Information Systems (GIS).

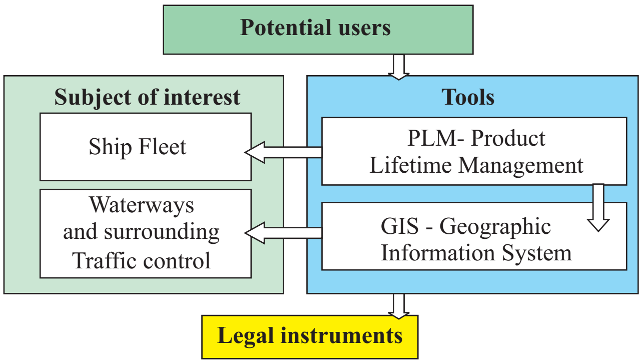

***Fig. 1.** Structure of issues covered by data base .*

The data base for INCOWATRANS project connects both approaches by means of integration of GIS and PLM tools into one coherent system ensuring user access to all data in a way which best corresponds with their character.

The next important issue, the first element of data base structure is a mode of access to data. In order to ensure up-to-date information the distributed structure was chosen. It is characterized by uniform access to data on logic level though their physical location may be different, and by avoiding redundancy of data.

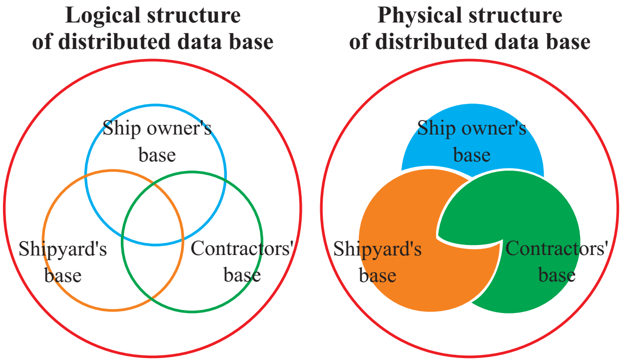

***Fig. 2.** Structure of distributed data base .*

GIS DATA

From the very beginning it was assumed that the base in question will be built on the official data accessible in official data bases and enabled for research purposes at no charge or preferential conditions. Hence selection of data is crucial for GIS model structure. Models and data quality of a few bases were preliminarily analyzed and as a result the base of Map of Hydrographic Division of Poland (MPHP) and the base of General Geographic Data (BDO) were selected as those potentially most useful.

MODEL ANALYSIS

Model analysis of the selected data bases is aimed at answering the question whether they are conceptually coherent and may be used to build an integrated GIS covering shipping problems and which elements of both the bases may and should be used to this end.

The MPHP base contains the data on surface waters in Poland, having the accuracy equivalent to a map in 1 : 50 000 scale. Such accuracy of data makes their using for navigation purposes possible. Next, their structure enables to conduct network analyses (all water-courses have defined axes and nodes in junctions). A drawback of the MPHP data is the lack of attributes determining navigability of water-courses.

The BDO base was elaborated with the accuracy corresponding with a map in 1:250 000 scale. Hence it is less precise, however apart from layers describing waters it contains several layers of the so called "background" which describes land surrounding waterways. Additionally, the water-courses have defined attributes describing their navigability however in the way not complying with the Act on Inland Navigation. In Tab.1. the most important criteria of the model in question and BDO and MPHP bases are compared.

***Tab. 1.** Comparison of content of BDO and MPHP base .*

Content	INCOWATRANS base	MPHP base	BDO base
Waterways	Yes	Yes	Yes
Water-course network	Yes	Yes	Yes
Land - water - course network	Yes	No	Yes
Navigability	Yes	No	Yes
Compatibility with UZS	Yes	No	Yes
Roads	Yes	No	Yes
Railways	Yes	No	Yes
Ports	Yes	No	Yes
Hydro-engineering objects	Yes	No	Partial
Navigation obstacles	Yes	No	Partial
Compatibility with TBD	Partial	No	Partial
Compatibility with RDW	Partial	No	No
Scale	1 : 50 000	1 : 50 000	1 : 250 000
Coordinate frame	WGS84	WGS84	WGS84

The optimum solution seems to be connection of the MPHP layers describing water-courses and reservoirs and the BDO "background" layers. For such data integration speaks the fact that both the bases were elaborated with the use of the same frame of geographic coordinates, namely WGS84.

ANALYSIS OF DATA QUALITY

Assessment of data quality is usually very important for estimation of labour consumption for their implementation, and it covers several aspects :

- Correctness of geometrical and attribute data
- Completeness of geometrical and attribute data
- Topological coherence of water network and land-water network within a given data base as well as at the points of contact of the bases to be integrated.

To ensure an efficient and reliable assessment a few procedures and techniques of quality control were applied. Some of them were of organizational character, another were based on available informatics tools. The most important are the following :

- Automated control realized by means of the tools available within GIS software (e.g. coherence control of topological network)
- Automated analysis of data base content (e.g. searching for nonsense quantities : odd values, exceeding limits, control whether all attributes are determined, whether appropriate error codes are introduced for those not determined etc)
- Manual control of the GIS on the basis of spot check of well documented areas (e.g. basins of ports of Gdańsk and Szczecin)
- A part of metadata attributes was shifted from the level of class description to that of records (e.g. date of input, date of approval, putting-in person). Due to this a better control over quality of input/ modified data was achieved.

Correctness assessment of geometrical data was performed only for water-courses and reservoirs. It consisted in simultaneous displaying the hydrological layers of BDO and MPHP bases and their visual comparison. The observed differences resulted from the different scales of the bases and consisted in simplification of shoreline on BDO layers against that on MPHP layers, which seem unimportant however. The maximum shifts of characteristics points did not exceed 10 m. As in both the cases the data were introduced independently the mutual coherence of water-courses and shorelines demonstrate that the data stored in both bases are correct.

Assessment of completeness of the data covers only those connected with water-course navigability. The assessment was performed by means of :

- Comparison of content of the data bases with maps of Gdańsk area (the lack of about 20 landing stages and 10 other hydro-engineering objects was stated)
- Analysis of data base content as regards filling base records with all attributes (the common lack of many important attributes, e.g. name of port/landing stage is observed only for a few biggest port facilities, also an error code description is lacking in the case of a lacking value of attribute)
- Analysis of base structure completeness and possibility of its supplementing by means of existing data. The lack of objects of the type "MOST" in the BDO base may be given as an example. Such objects can be indicated by pointing out sections of roads and railways having the attribute "PRZEBIEG" of the value "PO MOŚCIE".
- Analysis of completeness of definitions of particular classes of objects against demands of the elaborated model and possibility of their extending. As an example the height above water level for bridges and electric transmission lines crossing water-courses, and current speed for selected river sections can be given. Many lacks were here revealed and their detail description is contained in the report on the modified data model.

In the case of the topological coherence control the following was assessed :

- Topological coherence of water-course networks within MPHP and BDO bases.
- Topological coherence of water-course network and land-water-course nodes and land junction network within BDO base (in MPHP base there is no land objects).
- Topological coherence of water-course network of MPHP base as well as land- water-course nodes and land junction network within BDO base.

The topological coherence was investigated by means of relevant tools contained in GIS GeoMedia system. Sporadic lacks were revealed in junctions between water-courses covered by MPHP base (Fig.3) as well as lacks of junctions of the type of water-course/port, port/road as well as port/railway,which can be deemed typical for BDO base (Fig.4). Therefore without any further control was assumed the lack of coherence between the water-course network of MPHP base and the land network of BDO base. Additionally, to include sea ports into network analyses some artificial sections of sea waterways to connect the ports with inland waterways network, should be added.

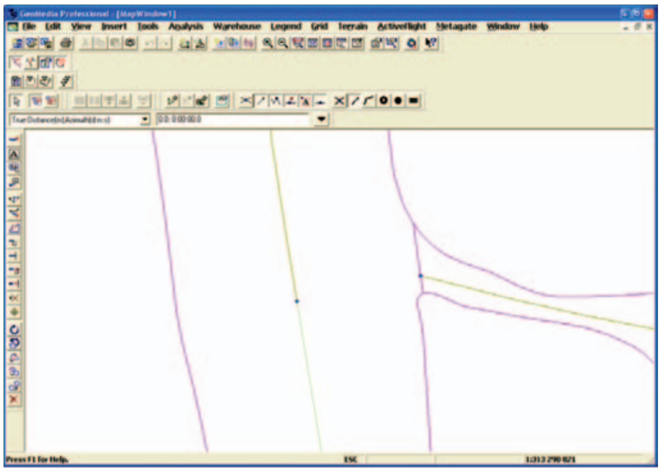

Fig. 3. An example of lack of junction between water-courses represented in MPHP base .

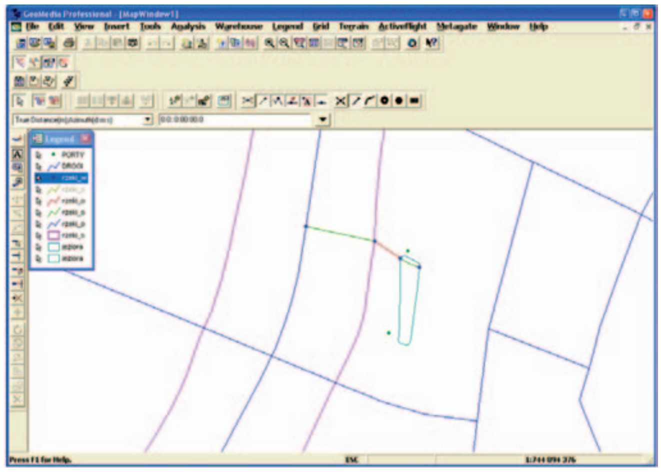

Fig. 4. An example of lack of coherence between water-course network and road network represented in BDO base .

DESCRIPTION OF GIS MODEL

For elaborating the GIS data model were established several principles and guidelines resulting from provisions of Polish legal acts {Act on Inland Navigation (UŻŚ), Topographic Data Base (TBD)} and European ones {General Outline Water

Directive (RDW)} as well as from structures of the existing data bases whose data have to be used in building INCOWATRANS data base.

The most important are the following :

- ★ All types of objects of the same functional features (i.e. those described by the same attributes) are located in one class but other layers. For instance the class ”Pipeline” covers the layers : “Water pipeline”, Gas pipeline”, “Oil pipeline”.
- ★ A part of attributes resulting from location of an object on a map is duplicated within the base structure. It results from possible inaccuracies or ambiguities e.g. in which way should be territorial membership of an object located on the border of two administrative regions qualified ?
- ★ Water-courses are divided into sections of constant features. Additional division points are assumed in the points where nodes are located even if the water-courses in question do not there change their properties.
- ★ As use is mainly made of existing data (MPHP, BDO) and easy integration of the elaborated base is aimed at, only new classes of objects are defined (not included in MPHP and BDO) or the definitions of existing classes are extended by navigability features (without any changes of the existing ones even at the expense of redundancy of some attributes).

Model class hierarchy can be defined on the basis of a kind of geometrical representation of objects (Fig.5) or their functions. The presented scheme of the model contains only the classes introduced to be used solely in shipping model, and not defined in the MPHP.

DESCRIPTION OF PLM MODEL

PLM base serves for effective collection of data on infrastructure objects of waterways (and ships) in the way which is not possible in GI- systems which impose some limitations on the depth of hierarchy of classes and types of objects (limited to simple 2D geometrical objects). In PLM system an arbitrary object structure of an arbitrary depth of class nesting in model hierarchy can be modeled. In the current stage of implementation of the system the PLM structure limited only to floating units was elaborated. It results from the classification of ships adopted by most ship classification institutions, shipyards and authors of CAD software for shipbuilding industry.

Important is that in the same way the data base for ships and that for hydro-engineering objects can be built.

In Fig. 6. the hierarchy of PLM model classes is presented. It can contain an arbitrary number of nested levels of subsystem and subpart classes. The main ship systems cover the following :

✦ Hull ✦ Piping ✦ Cabling
✦ HVAC ✦ Machinery ✦ Equipment.

The example structure of one of the systems (Hull) shown in Fig.4, contains several subsystems :

⅄ Geometry ⅄ Structure ⅄ Material.

SUMMARY

- ❍ The structure of GIS model coherent with description of features of navigable inland waterways was presented together with the premises laid down during its elaboration. All efforts were made to achieve the elaborated structure complying with formal and practical standards being in force in the domain of GIS modelling, especially in water economy.
- ❍ The range of elaborations which have been so far worked out within the frame of building the GIS base intended for INCOWATRANS project, contains main conceptual investigations associated with the elaboration of the data model and its implementation. They contain the following items :
  - ⌘ Control of inventory and analysis of legal acts with a view to building GIS model.
  - ⌘ Elaboration of the preliminary GIS data model covering various functions of the model such as :
    - ⅄ analytical
    - ⅄ inventory
    - ⅄ interface
    - ⅄ navigation.
  - ⌘ Acquisition of the existing data (BDO, MPHP).
  - ⌘ Conversion of the data into an editable form which makes their extension by means the available GIS tools (GeoMedia 5.1) possible, as well as split of the data which makes their handling easier and processing within the network also possible.
  - ⌘ Consultations of the data base design assumptions with its potential users (Water Economy Office inWarszawa, RZGW in Gdańsk, Institute of Meteorology and Water Economy (IMGW), CODGiK, Port of Szczecin).
  - ⌘ Test implementation of the model and conformity tests of software, data and the assumed model of usage of the data base (the distributed data base model).

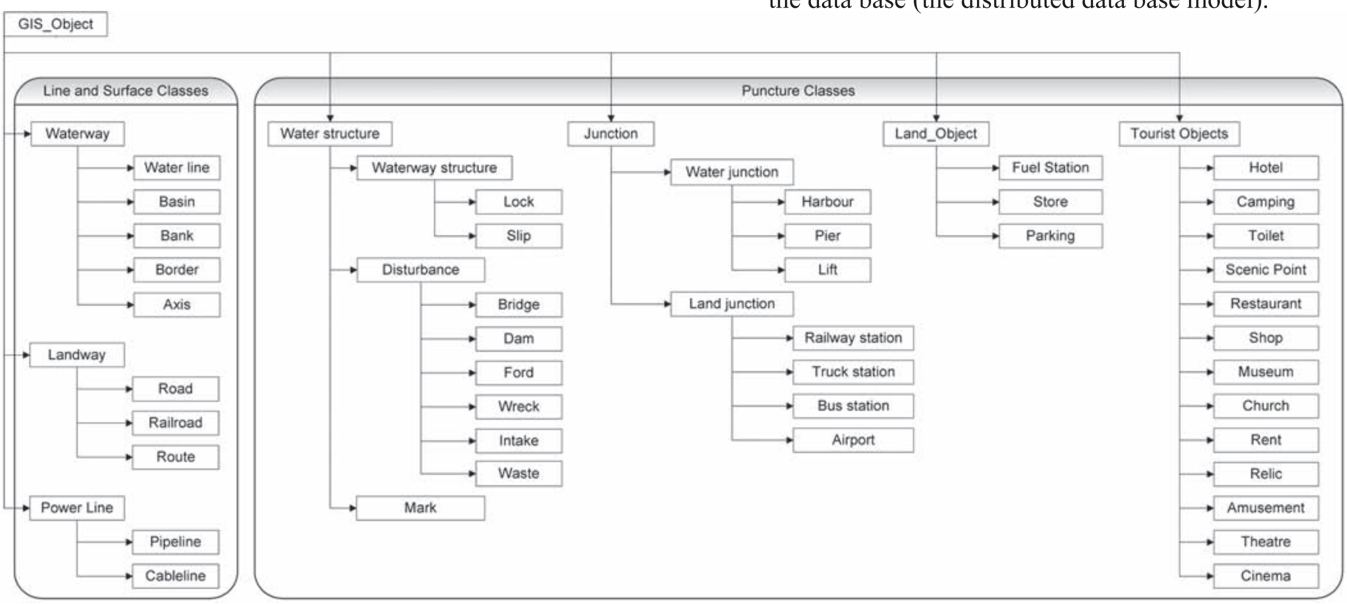

Fig. 5. *Hierarchy of classes of the assumed GIS model .*

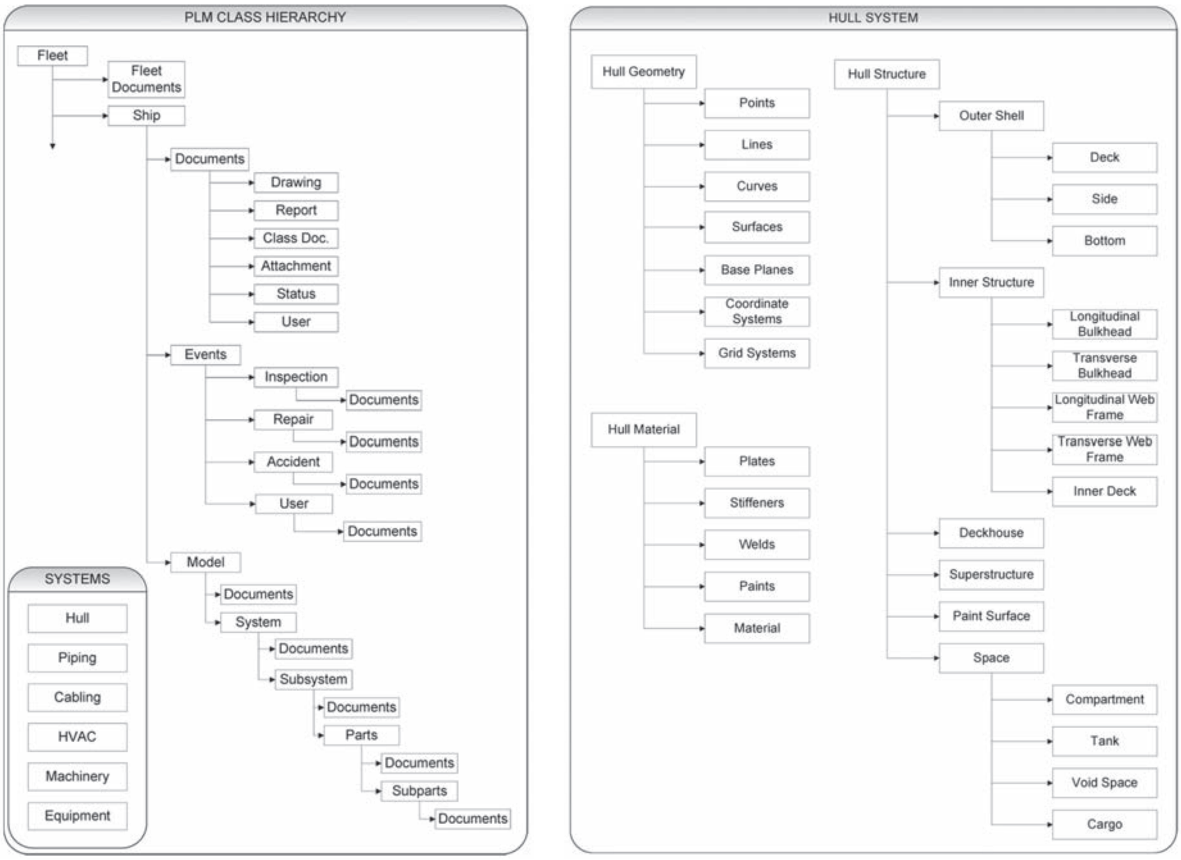

Fig. 6. Hierarchy of classes of PLM system model for ships. Hierarchy of classes of HULL system .

- Amendment of the design assumptions and the model on the basis of the two preceding points so as :
  - to make use - at the possible greatest extent - of the existing data of the MPHP and BDO,
  - to maintain the present structure of data, which – after removal of introduced extensions - will facilitate integration of the new data and corrected ones taken from the BDO and MPHP,
- Elaboration of an application program for automatic acquisition of data on water-level indications from IMGW internet portal, as well as elaboration of a simple interpolation model of water levels at particular sections of rivers.
- Digitalization of selected documents of water objects to implement PLM base and test the interface function of GIS base.
- Elaboration of “taken from nature” documentation for selected sections and objects,
- Elaboration of inventory control of the internet data sources together with their storage in a local server.

Full implementation of the model in question necessitates to realize several additional tasks as follows :

- Harmonization of the data stored in the BDO and MPHP in the range of roads and water- engineering objects (e. g. shifting the ports up to the water-course nodes, extending the roads up to the ports etc)
- Comprehensive verification and correction of the BDO and MPHP data in order :
  - to remove errors from BDO in the range of attributes and location of water -engineering objects
  - to add several water - engineering objects on the basis of maps and aerial and satellite photographs.
- Acquisition of shipping and bathymetric data and their addition to the bases.
- Elaboration and implementation of procedures for data input and update (e.g. by means of reporting errors by users via internet).
- Solution of formal and legal problems associated with making available to third parties the data acquired for the project’s purposes.

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