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Abstract

According to PSR (OECD) and DPSIR (EEA) models, Environmental Agencies are in charge of measuring the State and Pressure and evaluate the Impact in order to define the most suitable Responses; this implies data analysis and reporting activities, as one of their core responsibilities. Environmental Information Systems (EIS) support these activities by combining the advantages of first-rate consolidated technology (such as

Business Intelligence and Data Warehouses) to specific technical architectures tailored to environmental management tasks. E2SP (Environmental Enterprise Service Provider) is a online reporting and forecasting platform, providing a cost effective, Internet based EIS and Decision Support System in ASP (Application Service Provider) mode. Tasks such as data integration, data analysis through OLAP (On Line Analytical Processing), impact analysis and forecasts through mathematical models, emission inventories, indices/indicators calculation, reporting, are supplied in an integrated environment as on line services to public authorities and private industries. E2SP project, funded by the eTEN program of the European Commission, allowed to deploy two service centres and to develop the business case study, described in this paper, to verify the viability of the ASP approach to EIS in a trans-national context, starting from the air quality theme.

Keywords: *Environmental Information Systems, Application Service Provider, data analysis, forecasts.*

1. Introduction

The current ASPs, after the dot.com experience in late 90s, are more careful about customer needs and their business trends, and more focused on vertical markets. The wide diffusion of Internet technologies and the increasing number of good practices are contributing to rebuild users' trust on ASPs. Examples of ASPs in Public Administrations, such as the electronic signature, open the way to opportunities to ASPs, such as environment and related applications. This paper describes how the ASP approach to EISs deployment has been developed through business cases, the implemented services, the challenges, the achievements and the still open points.

2. The Environmental Context and the ASP Model

2.1 EIS State of the Art

In 90s environmental stakeholders were focused on measuring the environmental state, by deploying monitoring networks; now they are adopting an integrated approach to environmental management, driven by European and National environmental policies, sustainable operating costs and e-Government directives. This trend is generating an increasing demand of effective environmental management systems, to transform environmental data into information through the availability, also at local level, of powerful decision support systems and tools. EIS is a computer based system performing data collection from heterogeneous data source, such as monitoring networks and laboratories, data analysis and information diffusion. It supports Municipalities, Provinces, Regions and industries (such as power plants, chemical and petrochemical industries, incinerators) in planning activities, in the assessment of environmental policies and in the definition of sustainable development policies. EIS market is basically regulations driven. State-of-the-art EIS architecture follows the multi-tier paradigm, with a clear separation between data management, application logics and user presentation. The physical system architecture relies on clustered servers on a LAN, segmented by a firewall. The software platform is based on Data Warehouse (DW), supporting a processing layer constituted by Business Intelligence technologies for reporting and data analysis, data mining, GIS and scientific models, with the usage of common standards (XML, XSLT, LDAP, SOAP, Java). Data from different domains, such as air quality, emissions, water quality, noise, electromagnetism, waste, traffic, are collected and harmonised into the DW and made available to the processing layer. EIS has relevant deployment barriers: implementation time (2 years), Total Costs of Ownership (TCO) in the range of MEuro, need of highly specialised personnel (from 10 to 20 FTE –Full Time Equivalent- specialists) relevant hardware and software applications maintenance efforts in organisations where ITs are not core business. Models are supplied by research centres and highly specialised SMEs, monitoring networks by system integrators and IT integrators. EIS is a puzzle resulting from their "temporary associations", together with ISV (Independent Software Vendors).

2.2 Environmental ASP as an Integrated Solution

Integration in EIS of monitoring networks and data, data analysis, GIS and modelling tools is a complex activity, requiring multidisciplinary skills. The main approaches to environmental state evaluation are based on direct measures and simulations (APAT [2004]). Monitoring networks are widely diffused, provide high quality measurement, with high installation and maintenance costs; they control a limited number of points, so partly representing the environmental state of the territory. The second approach uses simulation tools, capable to estimate on the whole territory pollutant concentrations deriving from specific scenarios, with good time and space resolution. Also the scientific models present weaknesses: the results uncertainty is often high, due to insufficient data source resolution, the discipline is very complex and requires highly skilled personnel, they request a considerable processing power. Integration of on-site measurement and models is a crucial point to enlarge territory coverage and to reduce model uncertainty.

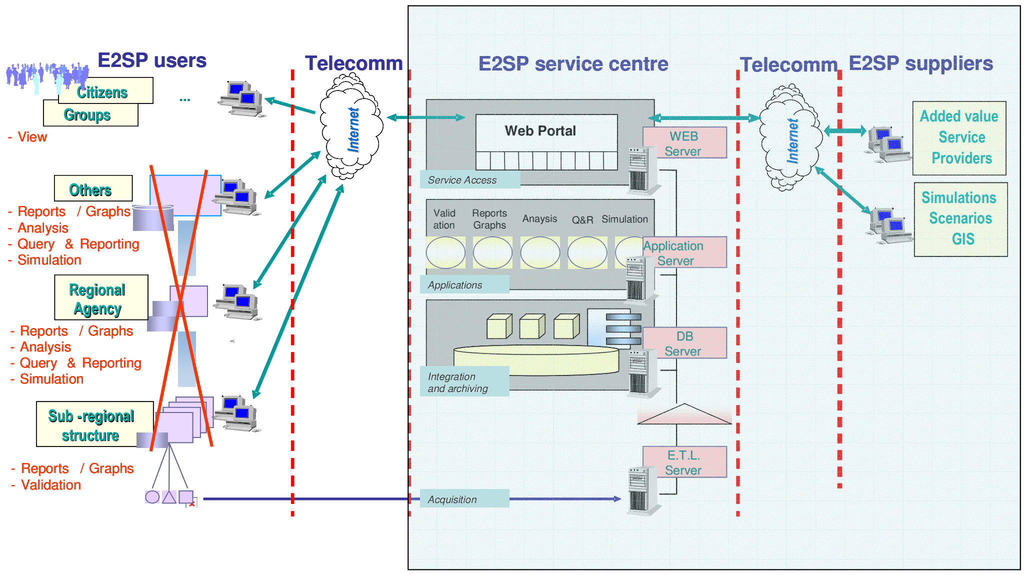


Figure 1: The E2SP service centre architecture and the users

EIS deployment presents relevant challenges: TCO, implementation time, software and skills integration, regulations in continuous evolution. While large Public Administrations with internal IT groups may face these challenges (Daylami et al. [2005]), ASP model is a potential solution for medium and small environmental agencies and for the industries. ASP model (figure 1) offers a single access point to all EIS building blocks and tasks, so giving the possibility to use the full range of EIS functions, independently from user dimension, transforming TCO in a periodic fee ruled by Service Level Agreements (SLA) and giving the ability to access to a broader range of applications and to achieve on-demand scalability while keeping implementation time short and TCO predictable and sustainable.

E2SP is a Value Added, Vertical Market ASP, providing decision support e-services to Environmental Agencies and public bodies engaged in environmental governance, chemical, petrochemical and waste industry, educational and research centres, private firms acting in the environmental assessment sector. E2SP relies on a "Basic Hosting" model, offering “Out-of-the-Box”, partly customised, services to clients. Environmental applications are accessed via Internet through the Service Centres infrastructure, that remotely host and deliver packaged applications to clients from an off-site, centralized location. The clients do not claim ownership of the applications, but instead "rents" them and their technological and functional evolution. Environmental data are only hosted by the ASP, but they remain property of the data supplier, often coincident with the customer. The customers pay a periodic licence fee, increased with the cost of the service management (ASP licence fee) but they save themselves the expense of the HW products, SW developments and maintenance.

3. The Approach to ASP Deployment and the Architecture

3.1 From the Prototype to Service Deployment

E2SP started in 2001 as a research prototype, installed in 2002-2004 in Apulia region (Italy) as the core part of an industrial accident early warning system. While these experiences validated the technical platform, the ASP model in the environmental field was still to be exploited. TCO reduction (typical ratio of 1:10) and QoS (Quality of Services) were necessary, but not sufficient to ensure ASP deployment. Integration capability is a key issue (Seltsikas and Currie [2002], APAT [2004]) and the vision of ASP strategic benefits, in terms greater efficiencies in government information processing, must be clearly given to Public Administrations management. Top management support and attitude toward change are fundamental in innovation adoption (Eder and Igbaria [2001]) and ASP adoption is a strategic decision of the top management that perceive it as a solution to overcome the organisation internal constraints (Kern ed al. [2002]).

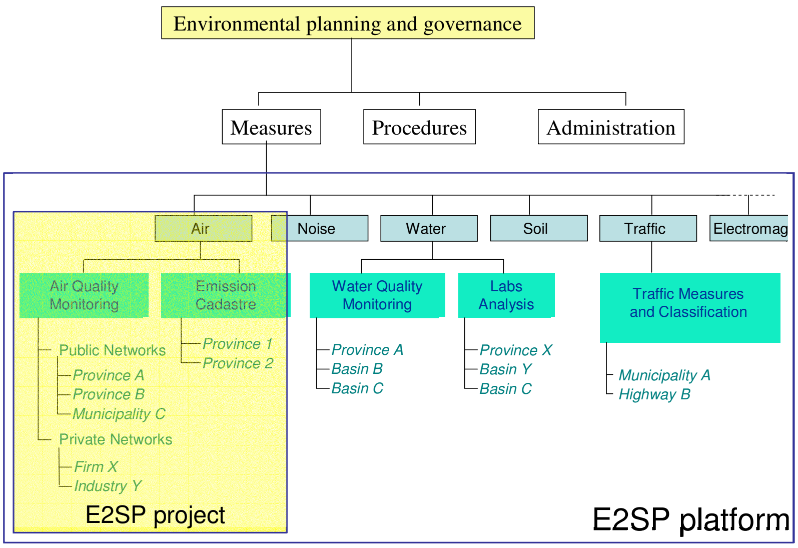


Figure 2: The application areas

The first step has been to define the test domain. DW architecture and DPSIR model allowed to validate the ASP model in air quality domain. The other thematic domains (figure 2) share with air quality similar processes architecture. Air quality has been chosen thanks to the available infrastructures, the investments level, the regulation framework at European level. Public Administrations awareness is good, due to the relevant impact of air quality (traffic limitations, emission abatement) on social and economical activities.

The second step has been the definition of the "reference user" of ASP services. Professional actors in environmental monitoring can be divided in "data producer", managing monitoring networks and/or generating pollution episodes, and "data users", accessing the available environmental data to perform scientific, business and institutional tasks. The "environmental monitoring process architecture" suggests as "reference user" the single physical or virtual monitoring (sub-)network; it may be linked to a department of a regional agency, a municipality, an industry. This made possible to define modules of homogeneous e-services packages (report, data analysis, different packages of models, etc.), compliant with regulations. The business cases have been created starting from these assumptions.

Finally, the eTEN program helped in creating the needed cooperation frame between institutions, scientific world, industries and business consultants.

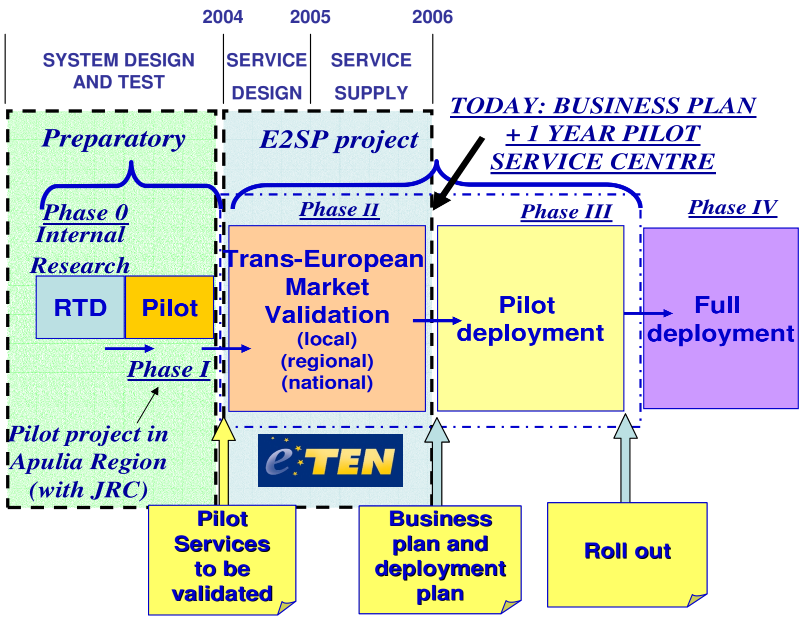


Figure 3: The business case story

The "E2SP project" (figure 3) started in March 2005 with the objectives to transfer to environmental stakeholders the right vision about the ASP strategic benefits, to define a consistent service proposal and to run a pilot on-line service delivery with all relevant actors. The E2SP service centres, activated in June 2005, have been used support trials performed by a relevant "panel" of operators:

- Environmental Agencies: Regional Inspectorate of Upper Silesia, WIOS (Poland), Municipality of Bari (Italy);

- research and educational: University of Bari, (Italy), the Polish Academy of Science, IPIS-PAN (Poland);
- industrial partners (monitoring networks, environmental software and models): Project Automation (Italy), ESAPROJEKT (Poland), Aria Technologies (France);

and business partners (Sineura (Italy), GL2006 (UK)). Two business cases, covering different environmental scenarios have been developed:

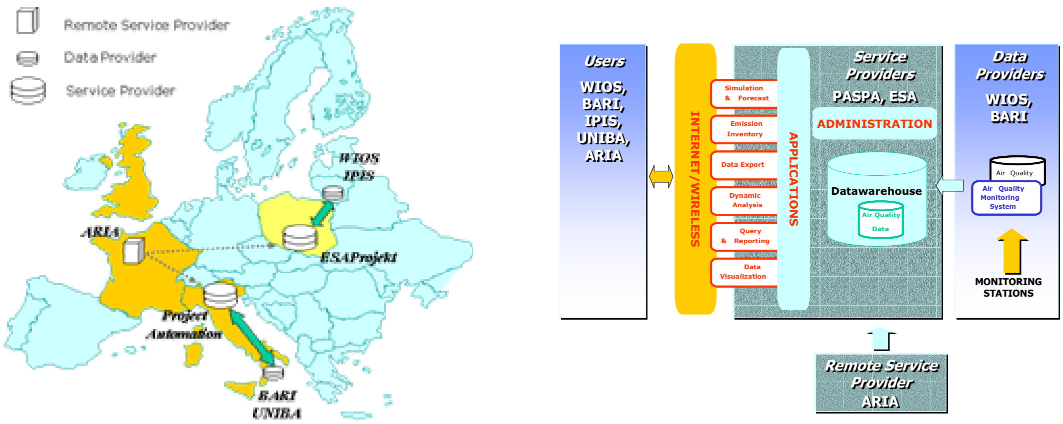
- **Traffic and photochemical pollution in Bari (Italy).** It is a sunny area, delimited by the Adriatic sea coast, with traffic pollution, production of secondary pollutants, and limited industrial settlements. Data analysis, O_3, NO_2, CO, PM_{10}, wind fields and temperatures measures and forecasts are supplied on daily basis. Bari is a Public Customer at Municipal level.
- **Industrial pollution at Regional level: Upper Silesia agglomeration (Poland)**. It has one of the highest industrial settlements density in Europe, with a relevant number of industrial point sources emissions (Klejnowski et al. [2002]). Data analysis, SO_2 and NO_x deposition forecasts due to point sources, wind fields and temperatures are daily supplied. WIOS is a Public Customer at Regional level. This case is relevant also for data privacy issues, related to industrial emissions.

Each test case involved a user group, composed by the environmental agency and the scientific advisors, and the business group, composed by the service providers and the business consultants. Users groups performed service evaluation. The service providers analysed the technical elements (bandwidth, data transfer, data storage, demand for processing resources) connected to service delivery. The business consultant supported the definition of the business plan.

A Users satisfaction survey has been conducted in order to measure QoS in terms of usability, reliability, completeness, user needs fitting, through questionnaires and interviews. The sampling population and the number of the interviews have been defined so that the NSI (Net Satisfaction Index) of people not interviewed had 90% of probability to be the equal to people interviewed. The SUMI (Software Usability Measurement Inventory) method has been used to develop questionnaires and interviews for measuring software quality from the end user's point of view. Users' expertise allowed to evaluate service completeness, and their compliance with environmental regulations. According to the outcomes of these activities, a business plan has been defined; FTE, infrastructure and operational costs, service catalogue have been defined.

3.2 The Service Centres and the Service Architecture

Two service centres (figure 4) have been started in July 2005, one in Italy, the second in Poland, and a remote "back office" modelling service centre has been started in France. In the air quality area, the most relevant services that have been individuated with the users are reporting, data analysis, meteo and pollution short term forecasts, with geo-referenced representation. The pilot service centres offer Internet-based user interfaces (figure 4) for:



(a) **(b)**

Figure 4: (a) the service centres and (b) the services architecture

- Configurable query & reporting.
- Air quality, traffic and noise data analysis and validation.
- Data export in XML format.
- Modelling, meteorological and air pollution forecasts.
- Geo-referenced and thematic representation.
- Environmental portal.

Through ETL (Extract, Transform and Load) procedures running on remote data sources, data from Bari and Upper Silesia air pollution monitoring networks and laboratories are extracted and stored on daily basis in the service centres datawarehouses and made available for online data analysis. Collected data are typically hourly average values. These data are sent in XML format to the remote service provider in Paris (Aria), that uses them with meteorological inputs from MM5 model, to generate pollution and deposition forecasts for the next 48 hours, through dispersion models running on the remote model servers.

Simulation results are sent to E2SP systems via Internet, and integrated in their DWs and presentation layers. The environmental operators remotely access E2SP portal and related environmental decision support functions via Internet, using a common modem/ADSL data connection.

4. The Services

4.1 Air Quality On-Line Reporting and Data Analysis

Reporting and data analysis services on collected data (Cislaghi et al. [2005]), including the virtual sensors from the models, are based on Business Intelligence applications on top of thematic datamarts. They are accessible via Internet through the online OLAP module, capable to supply tools for fulfilling the legislative frameworks and to perform advanced environmental data analyses for:

- creation new combinations of environmental indicators and indices, according to various space-time aggregation criteria,

- investigation data according to “free” and personalized analytical paths,
- dynamically view, build and consult reports in graphic and/or table format.

The OLAP module generates "standard" reports, required by the regulations, and "ad hoc" reports created according to users' specific needs, with simple drag and drop operations.

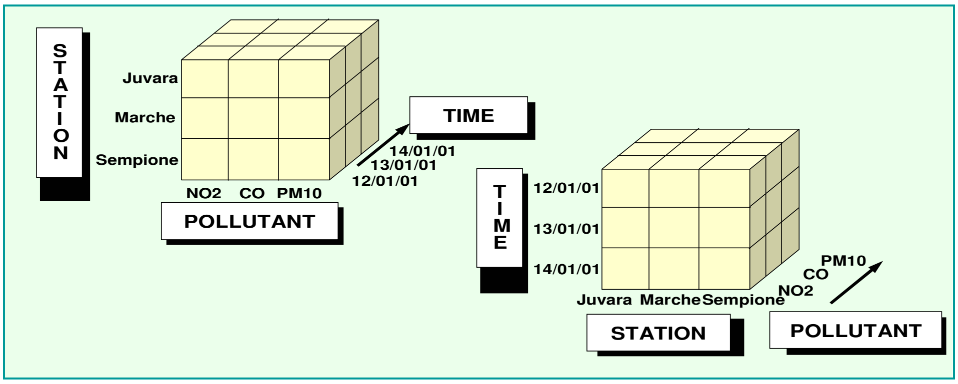


Figure 5: Multidimensional data analysis

There is no need for programming, only environmental expertise is needed, and the standard and customised analysis are stored in the ASP systems. Compared with usual reporting tools, E2SP-OLAP supports the capability of viewing data according to analytical paths which may follow different aggregation criteria (geography, time, type of pollutant, name of monitoring station etc.). The user can choose free analytical paths by changing the analysis dimension at every step (for example, starting from geographical aggregations and after focusing on time dimension etc.). The module supports dynamic exploration of the information through "drill down" and "roll up" capabilities, with fast data aggregations and disaggregating. By intuitively interacting with report objects (tables, graphs, etc.), it is possible to perform detailed analysis or new groupings and correlations, such as analytical "zooms" to display detailed data (e.g. average monthly or daily concentration of a pollutant) starting from extremely synthetic data (e.g. average yearly concentration).

4.2 Online Forecasts

E2SP provides model services (De Gennaro [2006], C.Derognat et al. [2005]) for: evaluation of: traffic pollutants concentration (CO, PM, benzene) in urban areas and close to main roads; photochemical pollution on relatively wide areas: and pollutant concentrations due to industrial settlements or large combustion plants such as energy production plants and incinerators (area and point sources).

The models chain runs in Paris. The simulation results include daily supply of 48 hours meteo and pollution forecasts, with 2D/3D graphic presentations, time series, altitude profiles, virtual sensors and scenarios. They must be available to users within 7 a.m. and, consequently, data collection from E2SP datawarehouses takes place during night time. The results are available at E2SP portal at 4 a.m., thanks to an accurate dimensioning of data processing times. The data transferred to E2SP systems are about 30 Mbytes large and data exchange is ftp based.

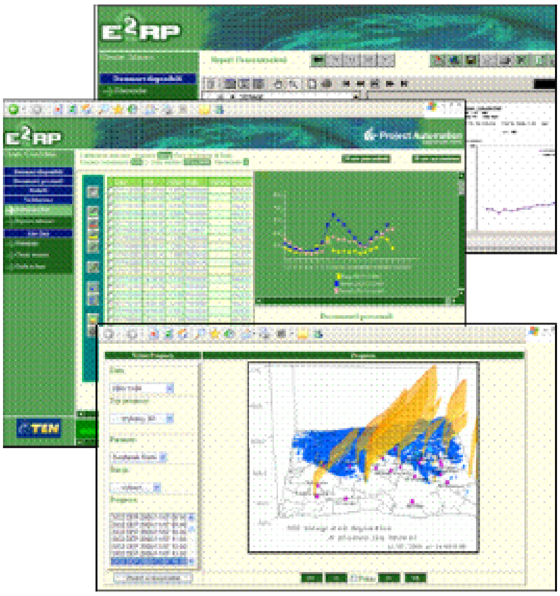


Figure 6: E2SP integrated user interface

The steps performed to produce daily forecasts are:

- reception of global scale meteorological forecasts (NCEP);
- reception of air pollution and meteorology data from the E2SP servers;
- daily operation of a refined regional scale weather forecast for the sites in Italy and Poland, based on the MM5 model;
- daily forecasts, based on CHIMERE, SPRAY and FARM dispersion models;
- Transfer via ftp to the E2SP servers of tabular and graphical results.

Evaluations are performed considering the emission scenario supplied by the users (point source cadastre, regional scale emission inventory with CORINAIR methodology - EEA [2005]-). The system uses DTM territorial data and land-use data. The MM5 meteorological model drives different dispersion models: the multi-scale chemistry-transport models CHIMERE (Derognat et al. [2005]) and FARM (Silibello [2003]) gridded Eulerian model, and the Lagrangian Particle model SPRAY. The CHIMERE dispersion model runs over the three nested following domains: Large Scale domain (LaS_EU), Polish Regional Scale domain (RS_PL) and Italian Regional Scale domain (RS_IT).

The Large Scale domain takes into account, over the two regional areas, of European emissions and main continental meteorological features (e.g. West to East main flow, etc.), while the two regional scale domains (RS_PL/RS_IT, 600x600 Km) take into account the recirculation of air masses (e.g. link to the sea/land breezes) and the ratio of 3 between large and regional MM5 nested grids. FARM and SPRAY models run on the target Local Scale domain that cover an area of 150x150 km^2 centred on the target cities of Bari (LcS_BA) and Katowice (LcS_KA). MM5 and CHIMERE runs over the Regional Scale domains (RS_xx) are used to provide to local scale domains, initial/boundary conditions and meteorological fields (wind, temperature, humidity, pressure, precipitation, clouds data). SURFPRO micrometeorological postprocessor derives, from MM5 2D/3D fields, further information needed by FARM (horizontal/vertical diffusivities, dry deposition velocities, etc.).

4.3 Traffic and Noise Online Reporting and Data Analysis

Monitoring networks may include traffic and noise measurements. They are geo-localised traffic flows (vehicle counting, classification, vehicle average speeds, lanes occupancy) and noise measures (LEQ, LNA). These data, normalised to hourly data by the ETL procedures, can be processed through the online OLAP module, so allowing cross-theme analysis with air quality and emissions.

5. Functional and Non Functional Requirements

Data security and privacy, accessibility, usability, interoperability are key issues of e-Government guidelines, that complement the environmental regulations with non-functional requirements (Larsen [2004]). E2SP "business group" developed a qualitative reticular model (figure 7) in order to assess the positioning on the market vs. users' requirements and potential competitors. This model was used in developing the service catalogue and defining the Service Level Agreements (SLA), the "core part" of an ASP contract. The 3D model represents the real value added of environmental ASP services, with the following metrics:

- SLA as Web availability (from no web interface, up to high security, full support for interoperability, high availability "24x7").
- Data elaboration (from standard Reporting to User configurable Data Analysis and OLAP toolsets).
- Models (no models, simple Gaussian, up to a full set of models).

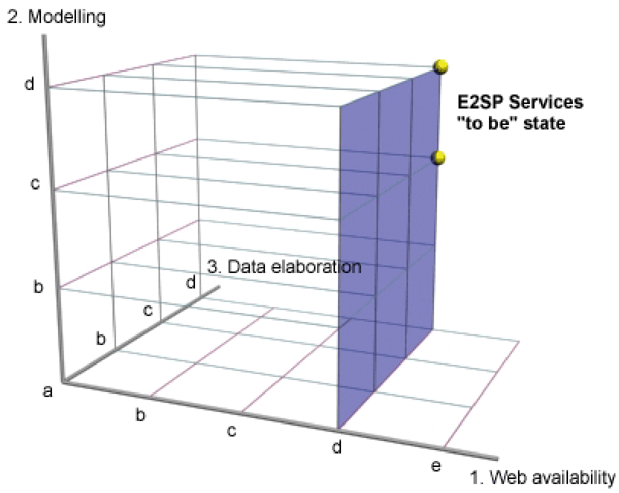


Figure 7: Environmental services positioning model

Guidelines from ISO27001, EEA and National Agencies have been used to define the qualitative scale on the axis. Very high availability (>99,99%, 24x7) brings to unsustainable service costs. An availability adapted to prevailing user demand (average 98,5%, peak 99,5%), joint with the data security operations compliant with ISO 27001:2005, is the basis for a viable environmental ASP model. Service centres architecture has been accordingly defined: three tiers levels architecture, with Quad-processors Intel DB and application servers in cluster, Storage Area Network, web servers with Network Load Balance and broadband connection with Internet provider. SLA must cover system technical availability and

- Local support via call centre.
- Time to recover in case of ETL procedure failure on remote data source. This introduces the need for a technical assistance network.
- Activation time for new and extended services.
- Time to compliance with new European and National regulations: 90 days.

On the functional point of view, E2SP business cases showed that:

- Integration between monitoring networks and widely accepted models (such as MM5, CHIMERE, FARM, SPRAY) is a key point.
- Monitoring networks are “living” infrastructures; instruments and stations are added, moved and removed, campaigns are performed. ASP provider must dynamically follow networks evolution.
- Services have to be gradually extended to water, noise, traffic.
- Data analysis must be cross-thematic.

6. Conclusions

Environmental market is regulations driven and fragmented. Users cover different geographical areas: Regions, Provinces, Districts, Municipalities, industries, with different environmental obligations and problems (photochemical smog, traffic pollution, industrial pollution and its impact) at different geographical scale. The ASP must supply high quality, cost effective services, fully compliant with environmental regulations and e-Government guidelines; but not all users need to access to the full EIS functions range. Bari area had no need about models for industrial pollution; Silesia Region had the opposite problem. Municipalities need integrated pollution, noise and traffic data analysis; many industrial settlements need to integrate meteorological instruments with simple impact assessment models; environmental agencies use all EIS functions. The services must be modular, covering customers with budget ranging from few thousands euro per year (small/medium industry) up to large public administrations. Table 1 shows a comparison between EIS system and EIS in ASP.

Table 1: ASP vs. traditional system approach.

	SYSTEM PURCHASE	SERVICES IN ASP MODE
EIS functions Availability	EIS functions need the support platform and its purchase costs make it unavailable to many users, both in daily operation or in case of specific monitoring campaigns.	ASP can supply the full range of EIS functions as e-services, clustered in service packages capable to reach also the low end market.
	Compliance to security and privacy regulation request to a single end user relevant organisational and structural efforts.	ASP is in charge to guarantee the needed level data security and privacy
	Different themes are often managed by different administrative units, with different technological platforms.	ASP is capable to support cross theme analysis and trans-boundary (including administrative ones) analysis.
Service availability	Supply of high availability services (up to 24x7) request to a single end user relevant organisational and structural efforts.	ASP has already internal organisation and structures capable to guarantee high service availability (up to 24x7).
	The need for specialised personnel for models run (usually during night time) and maintenance represents a considerable cost.	ASP guarantee through internal expertise or "back office" providers, the models results availability.
Time to market	High, because planning, implementation and configuration of an IT system require qualified resources and complex processes. In public administration separate tenders may be needed.	Short, because ASP already has the infrastructures, the competence and the instruments needed to guarantee a quick services supply.
Infrastructure update	Systems (hardware and software) need of continuous and costly updates, in particular that are totally sustained by the End User.	ASP is in charge of upgrading and updating the applications at reduced costs.
Start up investments.	Very high, because EIS implementation obliges the Agencies and the industries to massive initial investment in hardware and software technologies in the MEuro range.	The payment of a fee allows transforming IT investments into fixed, predictable and time diluted costs.
Flexibility and scalability	Infrastructures undergo quickly to obsolescence and under dimensioning, so generating the need for new investments.	ASP guarantee state of the art solutions and the proper infrastructure dimensioning.
	The user must implement new functions integrated in existing EIS in case of new functional needs, totally in charge to end users	ASP covers the full range of EIS functions, the user has to rent a new service package and its activation.
Maintenance and support costs	High, because an IT system needs dedicated resources and personnel to guarantee a continuous and effective maintenance, in particular for technological updating and for compliance with new regulations	Hardware e software maintenance and related problem solving is totally in charge to ASP provider, and these activities are managed by qualified and updated personnel.

The main reason for ASP adoption is the quick availability of integrated decision support tools (reporting and indicators calculation, data analysis, models) independently from users dimension. Customers will evaluate Environmental ASP on the basis of their partnerships with the key players; the provided SLA; the range and quality of web enabled applications; and their financial soundness. TCO reduction is important, but not sufficient. ASPs must offer support for interoperability, multi-lingual interfaces, data security. High quality contents and cross-theme elaboration capability, domain expertise, customer support, must be available. The offered services must integrate simulations and monitoring networks, be modular, complementary to already running software at customer premises (ERP software, models, etc.), and capable to integrate software from different ISVs (Independent Software Vendors), in particular models. Datawarehouse organisation into datamarts (such as air, traffic, noise) and the consequent possibility to offer scalable service packages is a starting point to reach high end customers (regions, large agencies, large industries), middle and low end market.

Services must target the full range of environmental actors, and be deployed in a trans-national context, in order to reach the critical mass needed for their economical viability. Services with the fastest deployment potential are related to air quality, but in a mid-long term perspective E2SP has to extend the thematic coverage to other domains (water, noise, waste, cadastres, mobility related issues) in order supply a set of services fully covering the management of territory.

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Pennsylvania State University / National Centre for Atmospheric Research numerical model home page http://www.mmm.ucar.edu/mm5/