

# AN OPERATIONAL INFORMATION SYSTEMS ARCHITECTURE FOR ASSESSING SUSTAINABLE TRANSPORTATION PLANNING: PRINCIPLES AND DESIGN

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## Abstract

This paper offers an integrated information systems framework for the assessment of transportation planning and management. After an introductory exposition, in the first part of the paper, a broad overview of international experiences regarding information systems on transportation is given, focusing in particular on the relationship between transportation system's performance monitoring and the decision-making process, and on the importance of this connection in the evaluation and planning process, in Italian and European cases. Next, the methodological design of an information system (in the form of an *observatory*) to support efficient and sustainable transportation planning and management aiming to integrate inputs from several different data sources, is presented. The resulting framework deploys *modular and integrated* databases which include data stemming from different national or regional data banks and which integrate information belonging to different transportation fields. For this reason, it allows public administrations to account for many strategic elements that influence their decisions regarding transportation, both from a systemic and infrastructural point of view.

Keywords: Monitoring, information system, spatial data infrastructure, assessment, observatory, performance-based planning

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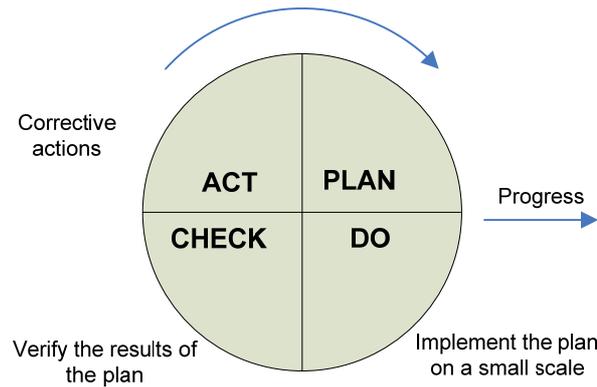
## 1. Setting the Scene of Modern Transportation Planning

Transportation is a natural and dynamic part of any modern space-economy. It offers economic benefits, but it also generates negative externalities at various geographic scales. The transportation sector forms a complex system that mirrors the high degree of mobility, communication and interaction of a modern society. The chain character of transportation embodies many opportunities for economic efficiency and competitiveness, but also leads to many externalities (e.g. accidents, congestion, pollution). For balanced transportation planning, an integrated assessment of all positive and negative impacts of transportation is necessary (Black and Nijkamp, 2001). Clearly, there is a need for the design of sustainable decision support instruments for this complex system. In recent decades, from an international perspective a great interest has emerged in the necessity to coordinate and manage in a unified framework all relevant strategic information related to the planning of a transportation system that originates from different sources (Ballis, 2006). This interest stems from the necessity to programme and manage the transport system in an efficient, sustainable and efficacious way by the organizations in charge of it: both public administrations and private agencies. The programming and managing stakeholders need to trust the reliability of information needed to evaluate action plans and to take decisions and to be able to control the implementation of the planning information strategies by responsible bodies. This calls for smart information systems for evaluation and planning.

An example of the integration of information systems technology in efficient transportation decision making (ETDM) is well described in Bejleri et al. (2006), who designed a powerful technological tool to support the complex transport decision-making process, validated for more than two years of implementation in some real-world situations of the Florida Department of Transportation. In Europe the ETIS (European Transport Policy Information System) framework (Ballis, 2006), finalized at the end of 2005, aimed to address the heterogeneity of information related to a transportation system by using systematic data collecting and archiving processes, together with interoperability and ease of use through the Internet (see ETIS homepage in the references).

One particular efficient decision-making process is the so-called Deming PDCA Cycle (see Figure 1), successfully used in industrial and quality processes. It consists of the following components:

- PLAN: to design or review the components of a process in order to improve the results.
- DO: to implement the plan, preferably on a small scale, and to measure its performance.
- CHECK: to evaluate the measures and to report the results to the decision makers.
- ACT: to take decisions on the necessary adjustments in order to improve the processes and implement them.



**Figure 1.** The Deming PDCA Cycle

In Italy, the current practice in programming and managing transportation systems does not follow these virtuous examples and guidelines. The recent redistribution of competences about this subject as a result of new national and regional laws, has heightened and emphasized the contingency features of decision-making in public administration. Indeed, most problems are dealt with by means of specific studies designed in order to satisfy contingent needs. This has led to a limited vision on emerging problems, for example, in the field of energy consumption, and to outcomes not transferable to other corresponding cases nor applicable in different periods for the same context. At the same time, the very nature of this orientation appears to restrict the communication between decision-making agencies to vertical and non-traceable relationships between programming and management units, while the horizontal connections between programming units of the same level are not always existent. Furthermore, the feedback of tactical actions on strategic planning at a higher level is occasional and does not follow a precise and systematic control process.

At a normative level, some steps have been taken in advance in Italy to care at least for the need to promote a new assessment approach to transportation planning and management problems. In 2001, the Italian *Piano Generale dei Trasporti e della Logistica* (General Plan for Transportation and Freight Movements) (Italian Ministry of Transport, 2001) confirmed the need for monitoring, and for planning the design of a national decision support system tool for the implementation of strategic action. This turned out however, to be a model whose input data needed to be updated regularly, but without continuity, though with the benefit of including consistently all national transportation networks (the so-called SNIT network). Unfortunately, after this first national example, neither a legislative nor a practical process has been developed which could transfer over a longer period and with more spatial detail this experience to local public administrations. That is to say, a systemic integration is considered only when making the plan, but it is not guaranteed in the management actions and in the implementation at a lower scale, and therefore there is no feedback on the fulfilment of the plan objectives.

More recently (October 2007), the Guidelines for the General Plan for Mobility in Italy (Ministry of Transport, 2007) aimed to lay the foundations for a new planning tool which addresses – besides the infrastructural and system performance area – mobility in a wider sense, promoting the integration of networks, modes, levels (short/medium/long trips), and land use, and highlighting even more the importance of a monitoring framework and the specification of target values.

In the context of the above observation, this study aims to present and illustrate: (i) the design of an information system for monitoring the transformation processes of transportation systems, able to assess and support transportation planning and management by means of the collection, from different sources, of data which needs to be stored, integrated, elaborated and made available; and (ii) the operational implementation of a technological demonstrator of this assessment system. This so-called Information System for Mobility and Transport (SIMT) is designed here as a validated immaterial data architecture aimed at the implementation of programming and management processes, in order to meet the current needs of public administrations in various ways. The study provides a scientific and practical contribution in order to make up for the lack of integration in Italy between different transportation fields and the lack of communication between the different planning and management levels. It makes a reference to modern performance-based planning.

It is well known that the American experience is well consolidated (see e.g. Cambridge Systematics Inc., 2001; Pickrell and Neumann, 2001) in what is called *performance-based planning*: namely, a system of continuously adapted and corrected planning based on macroscopic indicators, or “target values” of the ongoing transformations, that are broadly recognized, based on the incessant monitoring of the transport system concerned.

At both European and national scales, several efforts have been reported in recent years on the design and use of such information structures, concerning data standards, data access, data interoperability, data security, data integration problems and similar issues (Directive 2007/2/EC). In the Italian context, notwithstanding the presence of a rather clear and consolidated architecture to follow (see Directive 2007/2/EC, and specifically, the above cited General Plan for Transportation (*Piano Generale dei Trasporti*, 2001) or Ministerial Decree of the Ministry of Public Works, 1/6/2001 on the Street Cadastre), many of the various attempts made at a local and national scale – in order to design a monitoring framework for the transportation system – were terminated after the first efforts, and to date it is difficult to recognize or identify the requirements of a unitary national system and the observance of international standards, a situation resulting in an excess of information in some cases and a lack in others.

Our current project, elaborated in the light of international and national standards but also of common formats, protocols and procedures, but not yet codified in the transport sector, has led to the design of the conceptual and technical specifications of a complex and

integrated information system, which constitutes an interesting demonstration of the novel and actual relevance of the principles of ‘performance-based planning’ in the Italian context.

Our contribution is now structured as follows. First, section 2 reviews current tendencies in transportation planning supported with information about various monitoring systems in the Italian and European context. Then, Section 3 discusses the current normative framework and the existing official and de facto standards, while Section 4 describes the methodological steps for the design of the architecture of the SIMT model following the so-called ARTIST<sup>4</sup> guidelines. Section 5 then presents the implementation of a prototype SIMT for the field of road, traffic and safety management. Finally, in Section 6 some conclusions are drawn.

## **2. Transportation Planning and Monitoring**

In the established tradition of transportation modelling (Cascetta, 2001; Ortùzar and Willumsen, 2001), spatio-economic characteristics – both current and future – are synthesized and represented by means of the ‘activity system’: transportation models account for these characteristics rather exclusively by means of exogenous socio-economic spatial variables which, as inputs in behavioural models often based on discrete choice theory (McFadden, 1978; Ben-Akiva and Lerman, 1985), influence the forecasts about current and future transport demand.

Generally, the prediction of these spatial and socio-economic variables which are inputs in transportation systems simulation models is carried out via the definition of future development ‘scenarios’ for the above-mentioned variables, usually obtained by considering various hypotheses deriving from land-use planning choices in the study area concerned: by varying the kind of territorial scenario (considered a fixed component, given the time horizon), different results are obtained concerning the transportation system, in terms of traffic flows and the total mobility in the study area (see Figure 2).

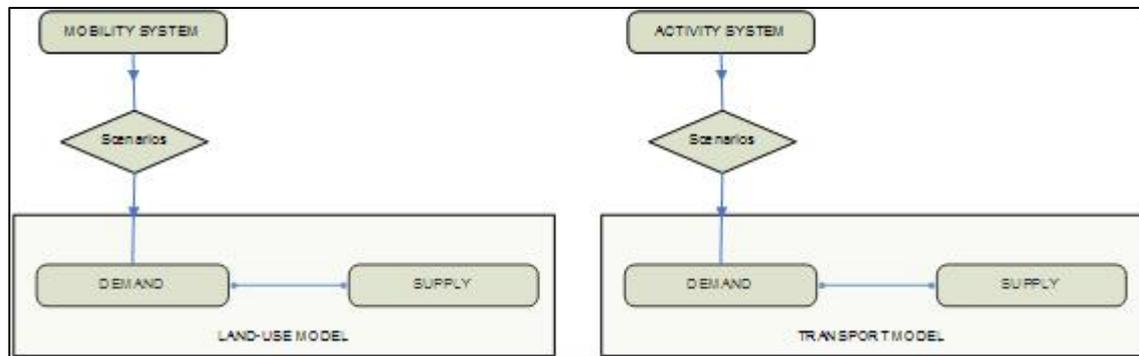
The same approach is adopted in evaluating land-use and environmental planning, where choices are made notwithstanding the emerging – often rising – mobility needs, and transportation planning adapts itself to the choices made about land use and the environment.

Actually, given the complex relationships existing between the transportation and the land-use system, it is probably not conceivable to consider the latter only as an independent substrate on which the transportation system is superimposed with all its actors, but it is important to consider it as a system which, in turn, transforms itself in the long run, depending not only on land-use planning choices, but also on transportation interventions as well. It is increasingly recognized that the integration between the two systems leads to a system which is *complex* (characterized by a great number of relationships between its

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elements) and *dynamic* (continuously evolving, with a mutual dependence of the transportation and the land use system) and, as with evolving every physical and economic system, may lead towards a varying steady state.



**Figure 2.** The traditional approach: scenario analysis

In this section, we focus on the growing need in transportation planning to study how these complex relationships are considered and managed. It is well known in the international scientific community (Ortùzar and Willumsen, 2001; Black and Nijkamp, 2001) that the classical planning approach – in particular regarding transportation, that consists of concentrating planning efforts in a limited time period, but whose follow-up only marginally achieves the effective fulfilment of the chosen interventions – is often not the most suitable one in order to deal with a real-world system in continuous evolution. There is a clear need to regularly check the strategic plans, assessing the system’s performance by systematic data monitoring, so that it is possible to judge the development of the transportation system and to orient future transformations. The monitoring task (Cascetta, 2001) is intended to be “*the systematic checking of the main state variables of the transportation system and the use of these checks for the identification of new problems and the a posteriori evaluation of project impacts*”.

In Italy, in recent years transportation planning has enjoyed the benefits of a wider and shared participation amongst different authorities, after updates from a normative point of view. Unfortunately, however, there are no clear differences compared to the actual usually applied planning process, which is based on the analysis of simulated scenarios and on the identification of the needs deriving from the articulation of objectives and constraints. The objectives are connected with the contingent requirements of various stakeholders, and with national and European policies, while the constraints are substantially linked to the current norms (Russo and Rindone, 2006a). However, at the same time, in the planning process the role of monitoring is considered essential for the evaluation of the effective fulfilment of quantitative and qualitative objectives pursued by means of planning choices (Russo and

Rindone, 2006b). The difficulty is mostly associated with the definition and the explication of such objectives which should be based on the effective execution of the projects and in turn depends on the land-use context in which the project is implemented.

This difficulty to assess the transportation system's performance, which needs to be monitored in order to check the trend of the planning choices, has been widely recognized, including in the application of what is known as the 'performance-based planning' approach in various contexts, such as the American one.

In the USA, a number of Departments of Transportation (e.g., in Oregon, Virginia, Minnesota) are experimenting with new solutions by means of stakeholder consulting processes and by paying major attention to user needs by fixing 'objective performances' and by introducing adequate performance measuring systems in order to evaluate the success of the policies implemented. In 2003, the NCHRP (National Cooperative Highway Research Program) presented the Report 446 on the 'Guidebook for Performance-Based Transportation Planning'. The aim was to provide public authorities with a reference data structure in which systematic procedures are suggested, to be used for monitoring, evaluation, and reporting on the transportation infrastructure, in order to offer a valid support for planning decisions.

*Performance-based planning* is a systematic and analytical process, which involves: the rigorous expression of policies in terms of quantitative objectives; explicit measures of the system's performance; analytical methods to forecast the impacts of different types of intervention on the system's performance; the creation of a decision support system for the assessment of a series of interventions in a transportation network; and the definition of models for the periodic monitoring of the system in order to orientate performance measures to a feedback mechanism, to evaluate the temporal trend of performance measures and to identify the required corrections in investment priorities (Pickrell and Neumann, 2001; Neumann and Markow, 2004).

Even this kind of planning process considers strategies and policy tendencies at a national and international level, and aims to include and quantify in programmatic objectives the demand for sustainable development, economic growth, and so forth. Performance-based planning also includes the definition of political aims (for example, ensuring road safety or environmental conservation) corresponding to real and definitely non-ambiguous objectives (in numerical or strategic terms) which are pursued by the planning process itself (Neumann and Markow, 2004). The system performance measures to be monitored are chosen in correspondence with the objectives and the strategies identified in the first phase. Once the current values of the system performance measures are assessed, it is possible to make use of analytical methods and diverse evaluation techniques of alternative strategies in order to improve the system performance measures. Such methods can be made available to agencies and public authorities. Great importance is given to (i) the monitoring process and to the subsequent feedback, which allows the regulation of trends in the planning process, and, at the same time, the documentation of the results to be shown to the stakeholders, who have to

share information and participate in decisions; and (ii) the role which the availability of data banks (systematically updated) plays in a clear and rapid application of the analytical instruments useful for evaluation and the decision support (Neumann and Markow, 2004).

Performance-based planning has been also applied in wider contexts than the USA: in Meyer (2005) an interesting comparison of Australian, Japanese and New-Zealand cases is presented, highlighting the utilization of a common structure for measuring the system's performance, the importance of collaboration between different authorities all interested in a single strategic area, the use of performance measures at different choice levels, the vertical integration of information flows in the agencies, the distinction between 'result' and 'output', the importance of the capability to collect data, and the use of Information Technology as a means to provide more visibility to the public. The contribution brings to light that, in each case study, a common structure exists as a basis for performance-based planning, which is mostly founded on the collaboration between different interested authorities involved in the evaluation of the performance of the transportation system at different levels of the decision process, starting from the strategic level to the application level. The best results in all four case studies are found in the field of road safety, with an impressive reduction of accident rates. In all cases, much importance was given to user-satisfaction indices, paying attention to sustainability and equity issues. In some applications an *ex-post* analysis was carried out on a certain percentage of the planned projects, in order to evaluate not only the efficiency of the *ex-ante* analysis but also the transformation trend itself. The best outcomes were found in the structure which was able to benefit from large amounts of historical and updated data, following well-defined strategies. In addition, in all case-studies there was widespread use of modern Information Technology for the monitoring. Even when the transportation agencies originally justified the utility of performance-based planning as a means to increase visibility and public responsibility, in fact one of the positive sides of the application of performance-based planning is considered to be the education of decision makers and of the general public, concerning the role of transportation in society. It should be noted however, that the case studies analysed concern decision-making processes at a national, and not on a regional or local scale.

In this short review, the above-mentioned issues are sufficiently covered, by focusing on the need to select performance indicators for appropriate planning decisions and on the role played by data collection and monitoring, the storing and the subsequent elaboration by means of specific information systems in the application of such a planning process. After an overview of the norms and the protocols in force in Italy, the design of an information system for mobility and transportation intended for public authorities will be presented. The monitoring system makes it possible to identify the critical aspects and the differences from the desired state, while moreover, the acquired information can be used for improving and correcting the planning criteria used.

### **3. Information Systems for Transportation Policy: A Normative Framework**

Despite many appealing features, at the administrative and decision-making levels, the performance-based planning philosophy is not yet spreading rapidly, neither in Italy nor in the rest of Europe. However, from a scientific viewpoint the need to systematically monitor the state variables of the system has been highlighted, proposing monitoring functions which allow structural transformations to be identified and to orient and use them for the subsequent decision processes.

A glance at the existing norms and standards in the international and national contexts indicates the necessity to build codified spatial data infrastructures (SDI) which are able to integrate and harmonize existing data banks coming from different sources and with various scopes. Recently, the so-called EC Inspire Directive (Directive 2007/2/EC (2007)) has been approved, which identifies guidelines for the SDI. It provides a definition of spatial data as any type of data with a direct or indirect connection to a specified locality or geographical area; stresses the need to create meta-data, which represent information describing spatial data collections to enable their archiving, consultation and use; suggests effective implementation according to codified standards which ensure interoperability; and calls for measures for data sharing between public authorities, which, amongst others, are indicated as the main actors of the Directive. At the same time, it invites the Member States to create a network of services for access to the SDI via the web, for data consulting and downloading.

The SDI clearly refers to various thematic sectors, ranging from geology to urban planning or hydrology. Among the themes considered by the Directive, ‘Transport Networks’ is one of those for which every Member State must provide an SDI by the year 2009, with the mandatory task to identify every three years – at least from 2013 onwards – the trend of the initiatives in their territory, at a national, regional and local level.

The Inspire Directive proposes guidelines on the composition and structuring of the national and local SDIs for each Member State. Therefore, it is obviously necessary to consider norms and protocols at a national level to facilitate the use and the interoperability of the SDI that is built.

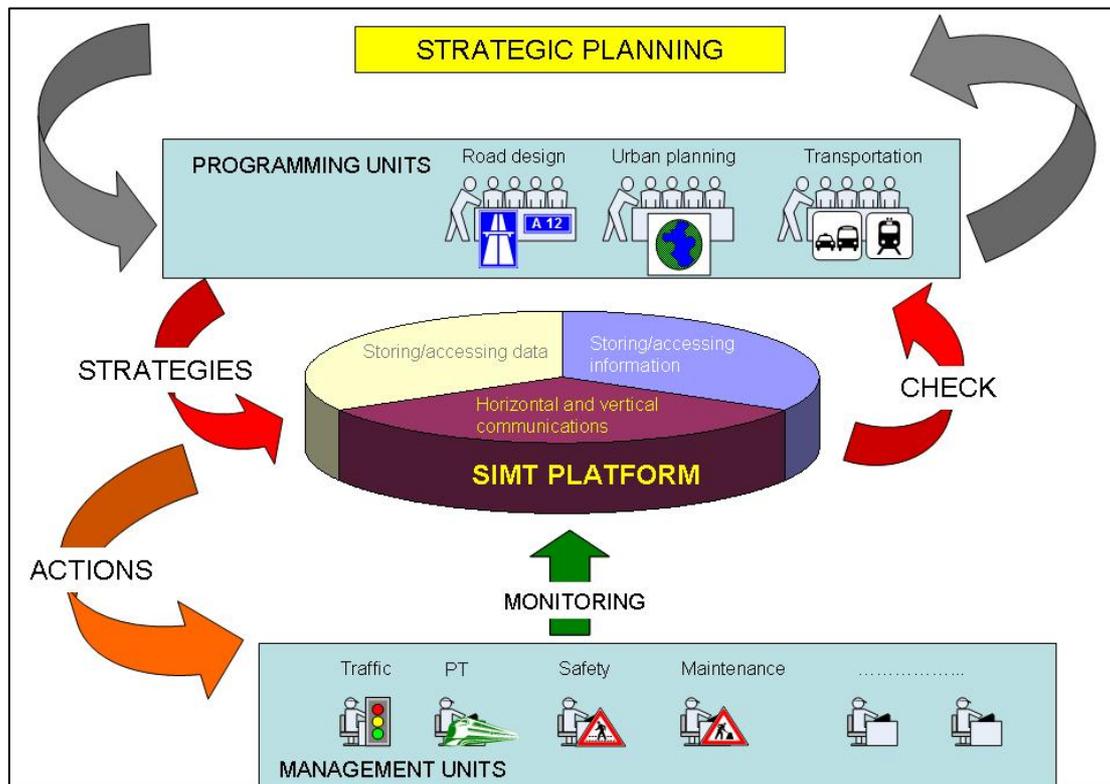
In Italy, the General Plan for Transport and Freight Movements has advocated the importance of monitoring, of ITS (Intelligent Transportation Systems), and of innovation in order to reach sustainable mobility at a wide and local scale, in order to recognize the necessity of a unitary framework: namely, a target architecture which identifies the functions, services, technological systems involved, actors and norms. The above-mentioned ARTIST system, incorporating all these needs, is designed as a target structure able to integrate different technologies belonging to different sectors, used by different actors.

From a practical point of view, its main objective is to provide a tool for the implementation of information frameworks for transportation systems, providing the satisfaction of user-requirements, an independent guide to technological platforms, the design of an integrated system, information consistency and a common terminology for the different stakeholders. In the following section, the phases to design an information system according to the ARTIST methodology are explained. Here, we briefly recall that ARTIST's special feature is its integration within the European context, because it is compatible with European standards by means of the network FRAME-NET, which is also connected with the similar French information architecture ACTIF. The SIMT architecture includes the definition of the databases related to the fields of transportation planning. In Italy, standards and norms regarding the design and the building of spatial databases already exist, and these will be examined in detail when describing the design phase of SIMT.

#### **4. The Role of Information Systems for Mobility and Transport (SIMT)**

The scientific assumptions discussed in the previous sections provide the theoretical and practical tools for the formulation of the need to obtain an information tool to support the programming decisions of public administrations. As exemplified in Figure 3, the role of the SIMT platform is central, because it enables different programming and implementation levels able to communicate and obtain understandable information. At the inner level, the direction of flows in Figure 3 is in anti-clockwise direction: the strategies of the programming units whose target values are archived in the platform become strategic guides for the action of the management units of the system in various fields of application. The bodies responsible for the implementation of the planning actions are also responsible for monitoring the data acquired and the direction of the actions or the immediate effects of interventions. Such data are stored in the SIMT platform after having been checked, validated and codified. After the data acquisition is performed following the existing standards and norms, SIMT plays a central role and facilitates effective communication and strategic decision support: raw data, acquired and archived with consistency and integrity criteria, are stored and protected in the platform, but at the same time can be elaborated according to specific needs following codified and traceable elaboration procedures. Both data and information can be accessed and queried from different competence levels, and at different aggregation levels in a safe (tracking users) and protected (ensuring the non-manipulation of the data and the validated information) environment. In particular, because of the data access and the communication, programming units are able to check if the implementation of the interventions reaches the desired target values of the plans, according to the constraints and the criteria imposed not only by the single disciplinary field concerned but in a way that can integrate competences from various fields. The checking procedure allows for varying strategies depending on the data values. The external cycle covers a broad time and spatial scale, and concerns the

incorporation of strategic planning instructions coming from higher levels, but also the updating of the latter with the practical results of short/mid-term programming. In such a way, SIMT carries out not only the data and information archive and access, but also enables communication between different strategic levels, in both a horizontal and vertical sense.



**Figure 3.** The role of SIMT

The reference framework that forms the context which generated the need to develop our Information System for Mobility and Planning has been extensively described in the previous sections. After various interfaces with Italian public authorities responsible for the maintenance, management and planning of the national and regional transport system, who want to promote the implementation of such an Information System, our analysis has concluded that its aspirations could be synthesized as follows:

– Archiving of strategic information:

- road network data, for the building of a Street Cadastre that is in conformity with the norms and standards;
- data from traffic surveys for the elaboration and evaluation of indicators characterizing network performances;
- data concerning the state of road pavement;
- data from incident surveys;
- data on the Public Transport exercise and users in order to analyse the services required by national norms (D. L. 422/1997 and regional laws);

- the use of GIS support in order to visualize all data on maps and to easily locate elements, by means of georeferencing;
- allowing the integration and the elaboration of collected data by means of transport systems' impact models and related statistical techniques, in order to support planning decisions;
- providing automatically data and elaboration for public authorities;
- providing aggregate information for common and specialized users, by means of web-mapping;
- providing support for the automatic management of road maintenance and for the generation of internal reports;
- allowing safe and easy data sharing;
- allowing data back-up and recovery, without danger of losing data.

Spatial and non-spatial data archiving is made possible in our SIMT infrastructure by means of specifically designed import interfaces, for data systematically collected by institutional data banks, or organised “on the fly” for data collected once in a while. The elaboration of such data is provided by means of internal tools, which include statistical techniques, spatial and network analysis, or external tools, such as specific transportation models: data export is made possible by means of specific interfaces even in this case.

Various automated and systematic elaborations to the benefit of public authorities' functions can directly be realized, after aggregation, in order to serve common and specialized users which can access the system through the Internet, by means of web applications. The protection and safety of data is ensured by the use of reliable software for database management. All these elements will lead to a systematic data structure design, evaluation and use, as will be explained in the next section.

## **5. SIMT Architecture Design**

SIMT is an “observatory“ of the transportation system which combines the need for data and information codification by characterizing the information systems in general with the need for detail and transparency for public authorities and the research community, in order to support activities such as road maintenance, incident monitoring, mobility system's planning, or investment planning.

This objective is pursued not only just by means of a list of data requirements, but also with the systematic organic collection of data articulated thematically and shared by different disciplinary sectors in a dynamic and integrated information system in conformity with national and international standards, able to provide an appropriate input that is easily usable for the elaboration of complex information by means of advanced modelling and engineering techniques.

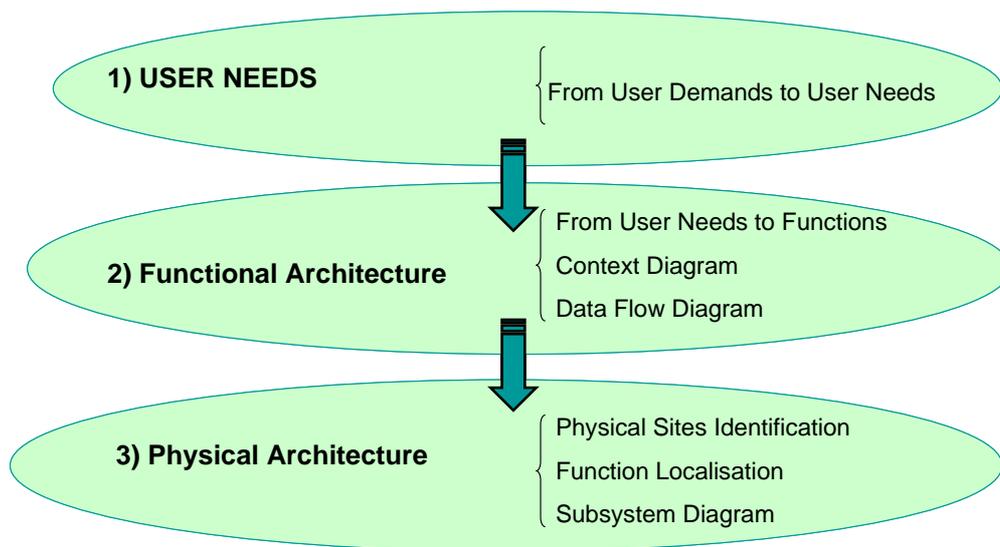
The target of our study is, therefore, to design and realize an operational information system for assessment in mobility and transportation planning with the characteristics of unity, conformity with standards and universal codification, which covers multiple fields ranging from network representation to incident analysis. Clearly, it should not ignore the presence of already systematically acquired data, so that it is possible to update the system periodically with minimum effort.

The main benefit of our system is the possibility (e.g., by designing systematic surveys and by using a geo-referenced database, up-to-date data, and elaborated information according to specific needs) to support planning and programming decisions. The system is therefore configured as a decision support system (DSS) able to meet the public authorities' needs for reliable, flexible and easily accessible information, the requirements for national and international standards, and the scientific community's need for monitoring structures on which to perform actions.

The information system architecture is designed by following the above-mentioned ARTIST guidelines and simulating the service demand from a public authority according to the following phases (Figure 4):

- Scenario definition, that is, design of the context which generates the need to operationalize an information system like SIMT;
- Logical/functional architecture definition, which enables the formalization, at a high level, of processes, functionalities and data flows, needed to provide services oriented towards user requirements:
  - articulation of customer requirements, by considering the preferences of public administrations, responsible for the management, maintenance and programming services for road and public transport networks, combined with the study of the current tendencies in this field;
  - user needs and function selection corresponding to the identified requirements;
  - demarcation of the system by means of the choice of 'terminators': namely, a set of external systems, variables and databases, but interacting with or influencing the system's context;
  - representation of the context diagram of the system and its relationships with the outside world;
  - Data Flow Diagram (DFD) to be built for each relevant field and for its related functions and subfunctions: DFD allows the explanation of functional data flows shared amongst different logistic sectors;
  - identification of subfunctions and data stores involved;
- Physical architecture definition:
  - identification of physical sites and of the corresponding subsystems: the system is effectively realized in physical sites where the related functions are developed;

- allocation of functions in the physical sites;
- analysis and description of the functional data flows shared between each pair of subsystems;
- functional data flows grouped in macro-sets of physical data flows;
- subsystem diagrams, schematically representing the subsystems created and the relationships between them and the terminators;



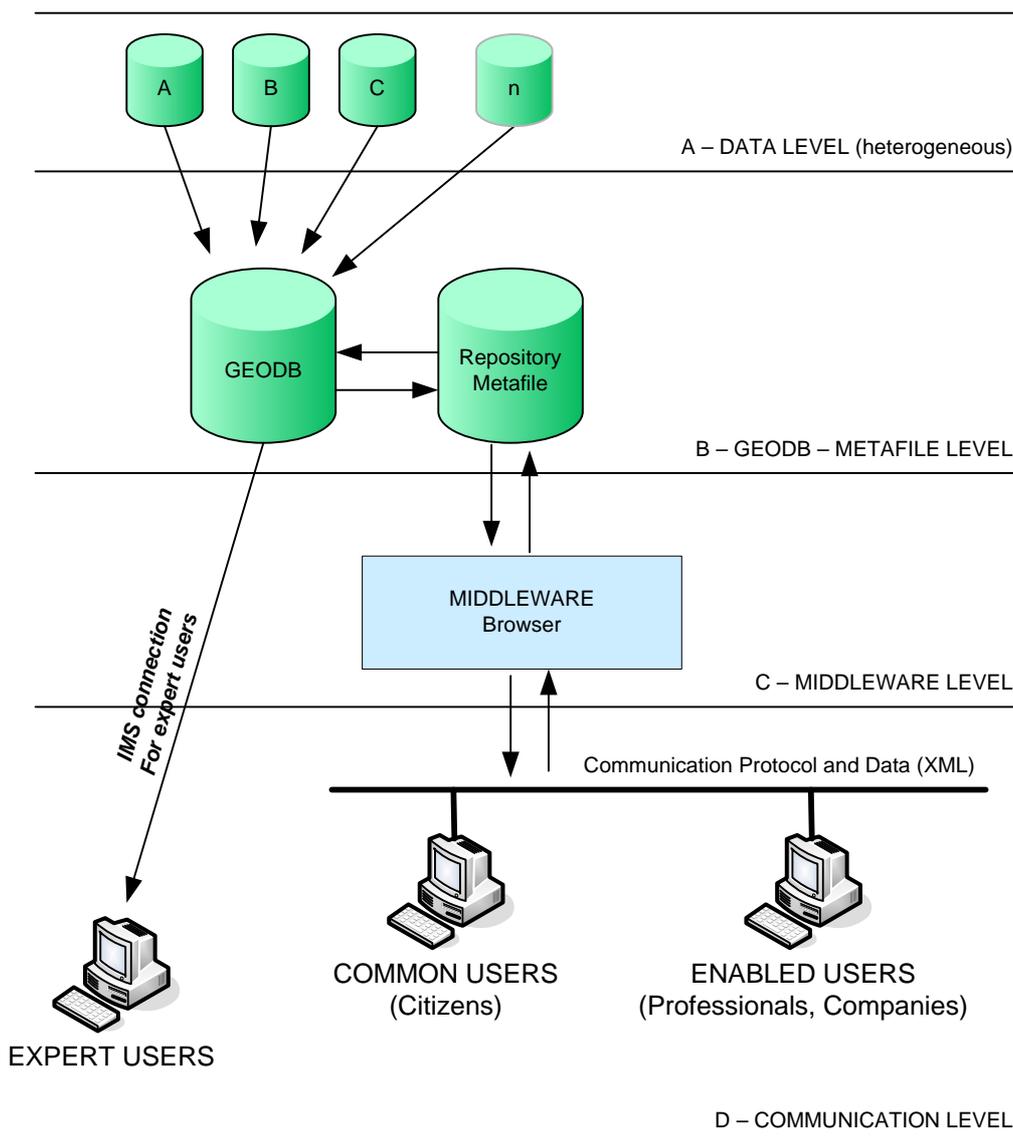
**Figure 4.** The ARTIST design process

The general architecture of the SIMT platform is described in Figure 5: at level A heterogeneous data are collected, and then stored and protected in a geo-database at level B, while at level C and D the communication between the geo-database and various kind of users can be taken care of.

The operational design of this system has thus far been implemented for the fields of road management, road safety and traffic monitoring. A general prototype of the SIMT was implemented by creating in detail the databases, in particular for the fields related to traffic, road and safety management. The implementation phases have addressed in particular the design and implementation of the databases involved, and the definition of the information architecture of the SIMT platform. In particular, the following databases have been developed:

- Traffic & Strategies Data Storage: stores data from traffic surveys, classified in seasonal, continuous or short surveys. Collected data include hourly traffic flows, classified by type of vehicle and speed. Elaborations take into account histograms of hourly traffic flows, average speed, annual average daily traffic, and assessment of levels of service for the road sections surveyed.
- Road Static Data Storage: stores data of the Road Cadastre of the public administration, according to the Ministerial Decree 3042 (1 June, 2001). The spatial

data of these data store are the base for the entire prototype, and include junctions, road segments and traffic areas, together with their attributes. For the road network features a dynamic segmentation has been adopted, so that all attributes may be classified as global attributes, if the properties relates to the entire spatial entity, or segmented attributes, if they relate to properties which can vary over the spatial entity at hand. Attributes stored in these database are, e.g. for the road network, name, administrative and functional classification, length, flow direction, width, lighting, presence of bridges, tunnels and so on.



**Figure 5.** The general architecture of SIMT platform

Thus, ingredients of SIMT may relate to:

- Incident Data Storage: stores accident data from surveys in situ by means of survey forms from ISTAT (the Italian official statistical organization), which reports date,

place, localisation, nature and causes of the accident, involved persons, accident effects on vehicles and persons.

- Demand Data Storage: stores socio-economic data and data concerning mobility demand originating from external data banks that are useful as inputs in forecasting models or in order to estimate the O-D (origin-destination) matrix.
- Maintenance Data Storage: stores data regarding pavement and road conditions, useful for the elaboration of specific indicators for the assessment of pavement situation .

A SIMT prototype for Italy has recently been developed by building an enterprise geodatabase (by means of ESRI ArcGIS products) in which the responsibility for the management of geographic data sets is shared between the DBMS software (Database Management System, Oracle), which is in charge of the storage, of the attribute type definition, and of the elaboration of queries and of multi-use transactions, and the GIS application, ArcSDE (Spatial Data Engine), which defines the scheme that the DBMS has to use in order to represent the geographic data sets and the logic of domain management. The conceptual and logical design has been carried out for the databases, while the physical design has been carried out for the databases concerning traffic, roads and incidents.

## **6. Conclusions**

This study presents the design and implementation of a prototype of an information system for monitoring and evaluating a mobility and transport system (SIMT), in order to support the technical/administrative competences in the field of transportation programming and management of a public administration.

The implementation of the complete system calls for competences not only linked to transportation engineering but also including system informatics, software development for the communication and database management, public administration management and cooperation. In particular, the study has emphasized the link between the system's monitoring and the transportation system's management and programming.

As the literature confirms this need (see Section 2), it is also true that it is reflected in the norms and standards, and in the needs of public administrations which aim to comply adequately with such norms. This adaptation depends on the availability of decision support systems able to provide quantitative elements for the evaluation and the choice of the intervention alternatives. Illustrative applications carried out so far in Italy show that information systems that just are limited to the land-use system or to specific branches of the transportation system are, in some cases, not in compliance with existing standards and norms, or not specifically designed for public administrations.

In this study – starting from the needs found amongst public administrations, and deepened and systematized by means of the analysis of the current problems of transportation system management – we have presented the design of an information system, based on performance-based planning, and at the same time modular and integrated. Indeed, the SIMT combines the recognition of the transportation system in its complexity with the plurality of its modules (e.g. traffic, safety, road management, public transport) for which it integrates data and cases, with the possibility of implementing in an immediate and systematic way either the whole system or only a section, without losing coherence and the opportunity to integrate different modules at different times, while avoiding redundancy and waste. The definition of the physical architecture will allow the implementation of the system notwithstanding the technological constraints and the normative framework, because existing standards and norms in the European context have been considered during the design process.

The compliance with existing standards and the possibility of elaborating quantitative indicators, but also the availability of reports and documents useful for public administration activities, and the possibility of providing statistical information to users by means of web services and aggregate on-line information provision make the SIMT a useful and competitive information system in the planning of the Italian transport systems.

The SIMT archives provide the following quality conditions for the stored data:

- Validation, on the basis of data whose design and collection methodology is known;
- Protection, with the provided back-up and recovery procedures;
- Continuous updating;
- Interoperability, which is recognized in the possibility of sharing data by means of common formats.

In turn, the stored information has the advantage of traceability – because the elaboration procedure is codified – and transparency – because data will be more easily accessible without expensive conversions or interpretations.

From a scientific point of view, SIMT is a useful tool for the analysis, evaluation and monitoring of developments in the transportation system and for the study of its relationships with other interacting systems such as land use, environment, or economic development. The availability of reliable, consistent, standardized and up-to-date data and information is the key for a systematic analysis of the (sub)systems directly or indirectly related to the transportation sector, with the aim to derive systematic and proper indicators that better represent the complex behaviour of transportation systems.

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