# Road Information System: a Case Study

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## Synopsis

The Italian Road Law urges the Road Agencies to create and upgrade the road cadastre. To form the cadastre, a recent Law (D.M. 1/6/2001) defines a set of geographic data files compliant with the TC287 CEN standard. This is the base of Road Information System (SIS) that should be implemented by local Administrations. The data from all SISs will supply a largest national data base that will be set up at the Central Government's Ministry of Infrastructure and Transportation. The National data base and local SISs can be important tools for the asset management and to improve safety and quality of road networks. A complete SIS must be based on upgraded maps and must have all the data about traffic, incidents, signs, pavements, bridges and tunnels, road yards, financial aids, environmental characteristics.
The Provincial Administration of Teramo, Italy, has implemented a Road Information Systems (SIS). This activity is one of those included in the Pilot Project to increase Road Safety, developed by the local Administration to access to the financial aids forecasted in the National Plan for Road Safety (NPRS) promoted by the Italian Ministry of Public Works (now Ministry of Infrastructure and Transportation).

During the pilot project, the road Cadastre and the data bases of traffic, incidents and road signs have been implemented to form the first SIS configuration. This SIS is represented on a GIS digital map and allows queries using the information coming from all the data bases. In some cases, such as road signs, the data has been integrated with photos.
The other data bases (pavements, bridges and tunnels, road yards, financial aids, environmental characteristics) have been studied and will be implemented in a following step later.

This paper deals with the implementation of Teramo SIS during the phases of the Pilot Project and with the first application of the system to the asset management.

# Road Information System: a Case Study

## INTRODUCTION

In 2000, the Italian Ministry of Public Works (now Ministry of Infrastructures and Transportation) issued the National Plan for Road Safety (NPRS), the first real attempt to face safety problems by the definition of an appropriate, strict, efficient policy to control all the main risk factors.
According to its definition, the NPRS is a system of guidelines and measures to promote and increase plans to improve road safety standards with special regard to infrastructure design, accident prevention and control activities, so to achieve an important EU goal: 50% reduction of deaths or injuries in road accidents.
The NPRS promoted the implementation of "Pilot Projects", in order to plan safe mobility systems and to improve road infrastructure at test sites, proposed by road-owners and management bodies in partnership with local administrations.
The Pilot Projects are tools selected by the Ministry to validate the NPRS guidelines, according to a very strict selection process, since it was expected that such a huge program could be of a wide interest at national level. So, the Pilot Projects' concept was, on one hand, to develop some tests on the most dangerous sites to implement holistic designs to increase the overall safety level and, on the other hand, to partially contribute by funding to the implementation of packages of solutions, whose costs administrations wouldn't be able to afford in short times. Total budget for funding was 11,878,508 Euros for 60 projects.
The most appropriate procedure to start Pilot Projects process was supposed to be a competition among all the bodies that at different level, and according to different tasks, participate to roads management, addressing the call to municipalities, provincial and regional administrations, school and health authorities, practitioners, public transportation operators, pressure groups, private services companies and so on. About 200 design proposals have been presented at the call for competition deadline, in spite of the Ministry's decision to finance only the 60 best proposals.
The protocol for the competition was very strict, since participants had to present an in-depth study on the state of the art of the mobility and of the safety standards of the site worth to be re-designed, reporting data and information on the local economy and social structure, on the road system and the related mobility pattern, statistics on accidents (from 1991 to 1999, when available), as well as an analysis of the risk main causes.
The protocol asked the participants to outline, among various practical information, the proposals objectives at short, mid and long terms, to describe the design contents also by drawings and maps (if necessary), to indicate how results would be monitored, to highlight how partnership among the involved bodies would work, to add a Gantt-chart describing the design and the building phases and eventually a detailed list of costs.
Interventions to be dealt with in the proposals could envisage all the main fields that contribute to make roads safe environments: improvements on road links and intersections design (not only in terms of crossings safety standards, but also in terms of appropriate lighting systems, paving management, system of signs, etc.) vulnerable users safeguards, alignment readability and perception, enforcement, educational and training programs, telematics monitoring, on-board safety devices, first aid and emergency services, awareness and so on.

In December 2001, the Ministry released the list of the 60 awarded Pilot Projects. Teramo Province was located at 30$^{th}$ place of the list.

## TERAMO PROVINCE PILOT PROJECT

The Pilot Project, implemented by the Department of Roads of Teramo Provincial Administration, was born with the cooperation of other Administrations working on road safety, in the same area: the Local Office of the Government, that coordinates several Police Forces and the Consortium of Val Vibrata, a consortium among the municipalities of Val Vibrata, an area of Teramo Province. The scientific coordination has been entrusted to the Department of Hydraulic, Transportation and Roads of University of Rome "La Sapienza". The title of the Pilot Project is: Safety Audit – increase of road Safety in Val Vibrata (CERA, DI MASCIO and VALENTE 2003).

The activities of the Pilot Project are shown in figure 1. They are:

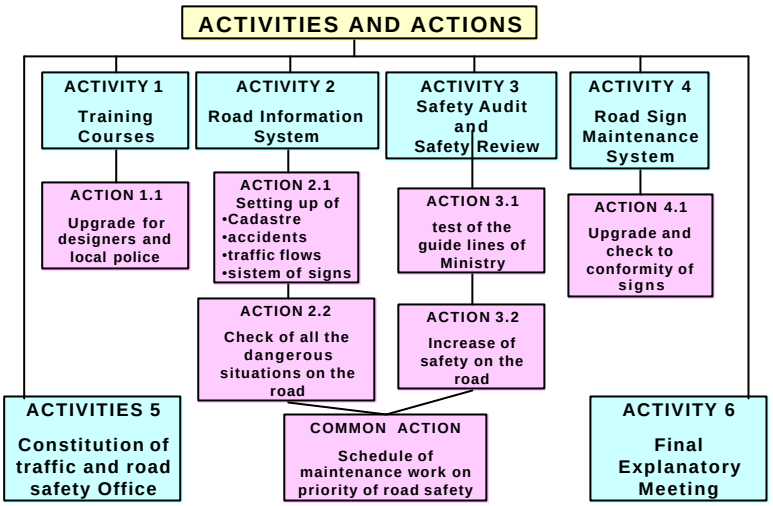


**Figure 1: Actions and activities of Teramo Province Pilot Project**

1. Upgrading Training courses for designers and local Police;
2. Development of the Road Information System of Teramo Province by:
   - setting up the following data-bases:
     - geometric and functional characteristics of road network (road cadastre);
     - road accidents;
     - traffic flows;
     - system of signs.
   - Implementation of routines to make queries to the data-bases. The aim of this step is the study of all the dangerous situations on the road, to give a tool to the Administration for scheduling the maintenance interventions on the priority of road safety.
3. Testing procedure of guide lines on Safety Audit and Safety Review drawn up by the Italian Ministry of Public Works. In Italy these procedure are in testing phase yet, and the Ministry asked to include this action in the Pilot Projects, when possible.
4. Implementation of the Road Signs Maintenance System.
5. Constitution of Traffic and Road Safety Office.
6. Final explanatory meeting.

This paper deals with the activity 2 ”Road Information System” and activity 4 “Road Signs Maintenance System” that are strongly linked to each other.

## THE ROAD INFORMATION SYSTEM OF TERAMO PROVINCE

The Italian Road Code urges the road Administrations to implement and upgrade cartography and cadastre, according to a recent law (D.M. 1/06/2001: Institution and upgrading of road cadastre). The cadastre is a part of a largest data-base: the Road Information System. This is the tool for collecting, processing and representing data regarding different roads, coming from different sources (police, municipalities, territorial agencies) and that can be used by the administration with different aims (maintenance, safety analysis, etc.). All the data collected by every Administration will be gathered in the National Road Data-base, that will be formed at the Ministry of Infrastructure and Transportation.
The National Road Data-base is composed of the following sections:

a. List of the roads, identified by the classification settled by the road code;
b. Traffic data
c. Accident data
d. Practicability for working machines
e. Pollution data

The Italian Road Administrations are starting the implementation of the system and Teramo Province has tested the construction of the cadastre and the Road Information System in the Pilot Project. Cadastre, traffic, accident and system of signs data-bases have been developed as activities of this project (figure 2). The other data-bases (pavement, bridge and tunnel, work yards, economic, pollution data) will be implemented after the end of the Pilot Project as activities of the new Traffic and Road Safety Office.

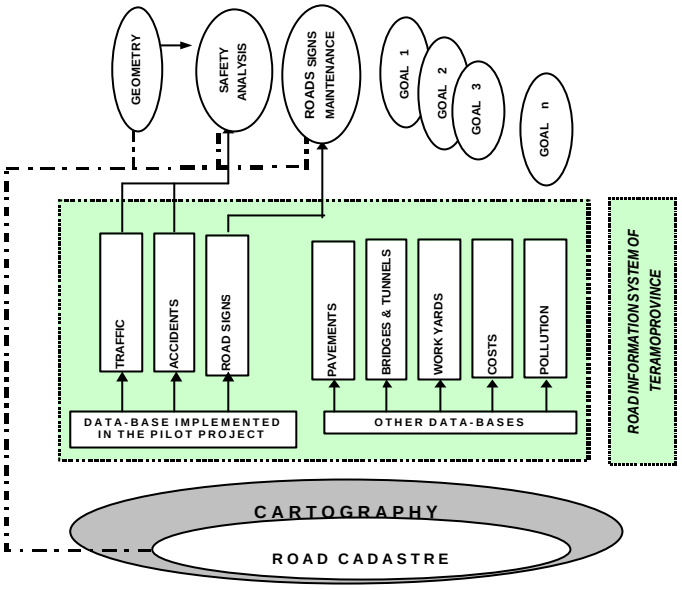


**Figure 2: Road Information System of Teramo Province**

## The Road Cadastre

The Italian road surveyors and GIS makers are nowadays paying a great attention to the so-called "Road Cadastre". It is a set of basic digital road maps, which in a few years will be applied to the whole Italian road network. The "Road Cadastre" introduces the GDF (Geographic Data Files, version 3.0, 1995) European standard in the representation of the road network and the road related informations. In this way, it represents a challenge to the GIS and RTTT (Road Transport and Traffic Telematics) applications makers, because of the induced standardization process. It represents also a challenge to surveyors, because very productive and accurate techniques are required to meet his completeness, up-to-dateness and accuracy requirements.

GDF is an European standard (upon studies of the Comité Européen de Normalisation – Technical Committee 287), that is used to describe and transfer road networks and road related data. It is much more than a generic GIS standard and an exchange format, because GDF gives rules how to capture the data, how the features, attributes and relations have been defined. A GDF map has no scale, but contains accuracy. The scale depends on the application where it is used.

A GDF database will never be used as such. The first thing that a user will do, is to transform it into their system. This could be a GIS, or any other application: the GDF standard is application independent.

GDF uses a three level structure in the world representation:

1. Level-0: Topology. This is a common GIS topology description. Everything is described by Nodes, Edges and Faces.
2. Level-1: Features. Level 1 is the most used level of GDF. It contains simple features like "Road Elements", "Road Junctions", "Traffic Areas". Features have attributes (i.e. road width, number of lanes). Features can also have relations (i.e. "Forbidden turn from Road Element #1 to Road Element #2" or "Road Element #1 has priority over Road Element #2").
3. Level-2: Complex Features. At this level the simple features are aggregated to a higher level of generalization. For instance a "Road Intersection" is a group of "Road Elements" and "Road Junctions" at the Level-1, while at the Level-2 it is just a Point Feature. Level-2 is mostly used when a simplified description of the road network is sufficient.

The Italian "Road Cadastre" Specifications are a GDF implementation. These contain:

- Level-1 features definition. The only defined features are: "Road Junction" (simple point feature), "Road Element" (simple line feature), "Enclosed Traffic Area" (simple area feature). There exist a huge number of segmented attributes definitions.
- Accuracy requirements. Accuracy is defined for the point coordinates needed for the Level-0 representation. Plane coordinates must have 1-metre accuracy in the global frame. Accuracy is also defined for some segmented attributes: the road width must have 1-decimetre accuracy and the slope data must have 1% accuracy.
- Survey guidelines for the identification of features and road axis measurements process. Briefly, 1. the axis topography must be obtained by a least-squares process from a "seed" of measured points and 2.

the junction features, which represent the start- and end-point of road elements, must be obtained by a road axis functional intersection.

- No Relationships definition exists.

Thus, the "Road Cadastre" aims to be a only a basic Level-1 GDF digital road map. His Level-0 representation meets the accuracy standards of the Italian national technical cartography. In this way, it is open to a wide range of applications, because each application may define his requirements, relationships and data structure extensions. Furthermore, accuracy requirements are adequate for a wide range of application fields. Finally, all the road applications will be virtually compatible because of the standardization process.

The experimental cadastre of Teramo Province is generated upon mobile mapping measurements. A mobile mapping system is substantially a van-mounted trajectographic subsystem with high performances, whose positional solutions are synchronized with the data collected from the so-called "mapping sensors", such as digital cameras, laser scanners and so on. The data obtained from the mms are subsequently post-processed in order to obtain an ordered set of point coordinates records - the so-called "point seed" - provided with the curvimetric distance along the road axis and a set of "segmented attribute" values geo-referenced in the curvimetric frame which geometrically and functionally describes the given road. The process of the GDF road network definition starts with the identification of the "Road Junctions", as intersection points of road axis. Subsequently, the "point seed" is clustered obtaining a set of "Road Elements", each starting and ending at a "Road Junction" and, finally, the segmented attributes curvimetric references are reported to each "Road Element". In the figures 3 and 4 we can see the interface of the photogrammetric process, specifically developed for this project, and a snapshot of the final result imported into the Intergraph GDF Viewer which assures the GDF 3.0 compliance.

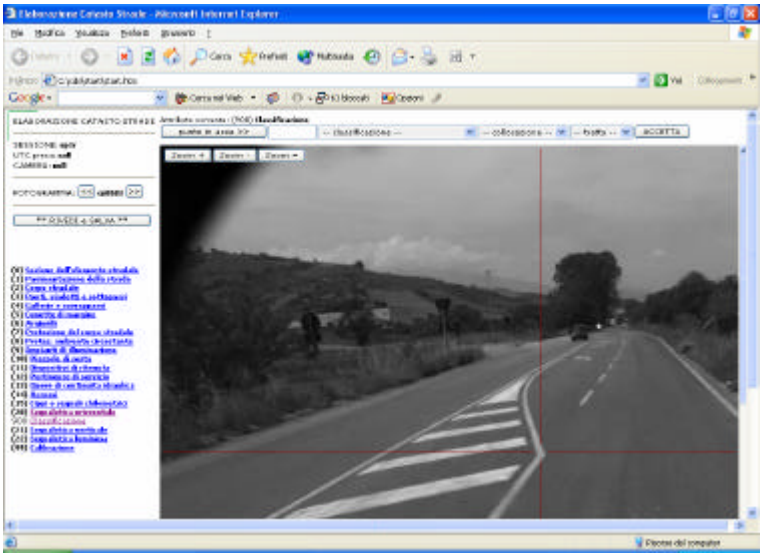

**Figure3: The main interface of the MMS photo observation process**

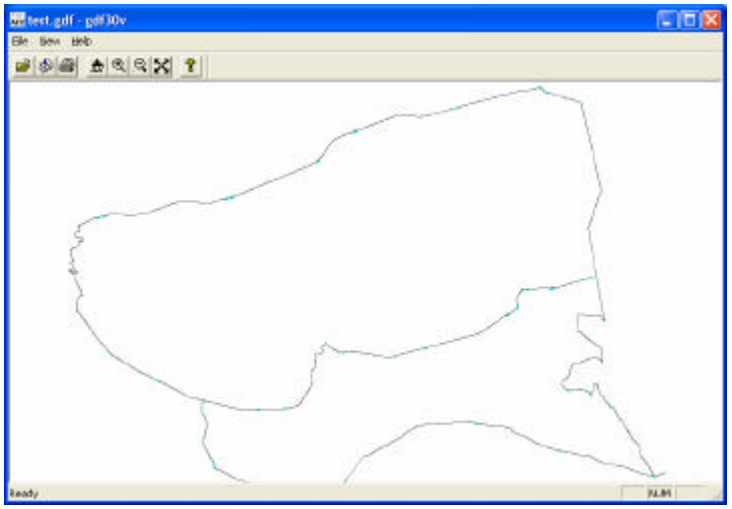

**Figure4: The experimental road network database opened by the Integraph GDF viewer**

The mms accuracies, certified by the Trieste University, are compliant with the ADAS (Advanced Driver Assistance Systems) requirements, as specified in the Nextmap project of the European ITS Research Organisation.

## The Road Cadastre assessment

The experimental approach is also applied to the final phase of the work, concerning the assessment of the produced "Road Cadastre". The technical specifications of the Ministry only requires the cartographic correctness of the road network graph.

Some problems then arises:

1. the road network graph is an abstract entity;
2. the road axis is not accurately defined by the Ministry specifications (see Figure 5);

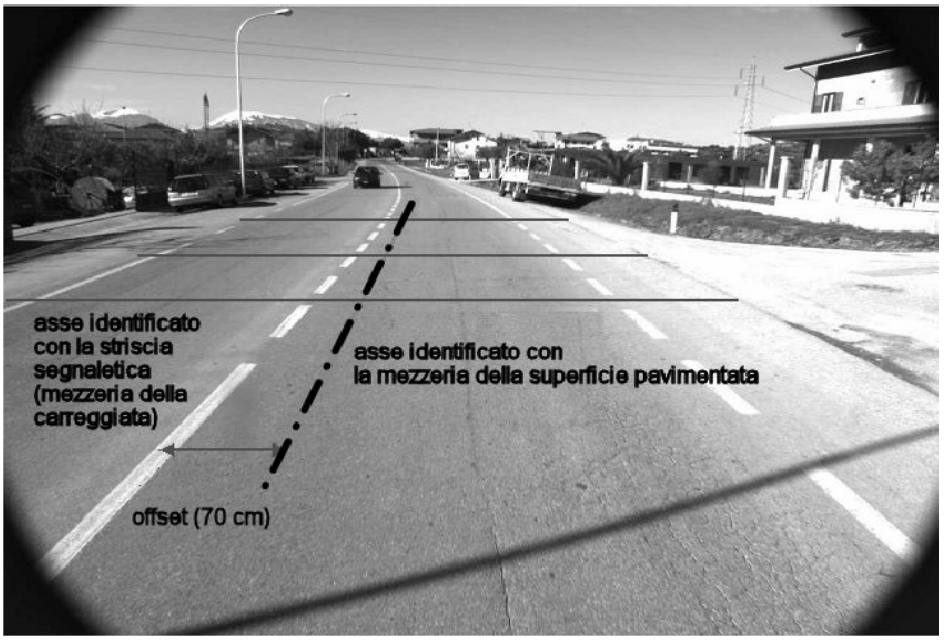


**Figure 5: The road axis uncertainty**

3. the junction individuation is not an exact process, but relies on some "functional" and extremely arbitrary criteria;
4. the materialization of the "point seed" is not required (and not feasable, obviously); the only road reference system materialization is achievable by double georeferencing the milestones (the so-called "cippi chilometrici") in the cartographic reference and in the road curvimetric reference system (e.g. by the mean of the curvimetric distance and the axis offset, altough the Ministry specifications does not contains any offset request ...);
5. no suggestions are made to evaluate the acceptability of the road lane and the values of the other segmented attributes;
6. the requested accuracy of 10 cm of the lane width is very difficult to achieve; often the road lateral mark are missed and the pavement edge is not regular or unidentifiable (e.g. because of the presence of grass and so forth); furthermore, when the assessment is made, the pavement maintenance activities can change the original measure;
7. no suggestions are made to evaluate the consistency an completeness of the final data base.

Our approach to the "Road Cadastre" assessment is the following:

a) we have measured several little segments on the road axis and the road pavement edges, opportunely distributed along the graph (see Figure 6); the team, the tools and the tecniques employed in this phase (kinematic GPS survey, see Figure 7, left) are not the same employed in the main campaign; this way, we can test the repeteability of measures and the intepretation of the Ministry specifications;
b) the data obtained for the road axis are then projected and compared with the main graph; the result shows only some minor problems in the planimetric coordinates of road axis (see Figure 7, right: in blue the main point seed, in red the assessment data);
c) to evaluate the road width measures of the "Road Cadastre" we consider an acceptable precision of 50 cm (because of the un-exactness of the road edge identification process, as depicted in the point

6 above; this assumption respects anyway the requirements of the Ertico-NextMap EU project for ADAS applications); the result shows only some minor problems in curves and intersections;

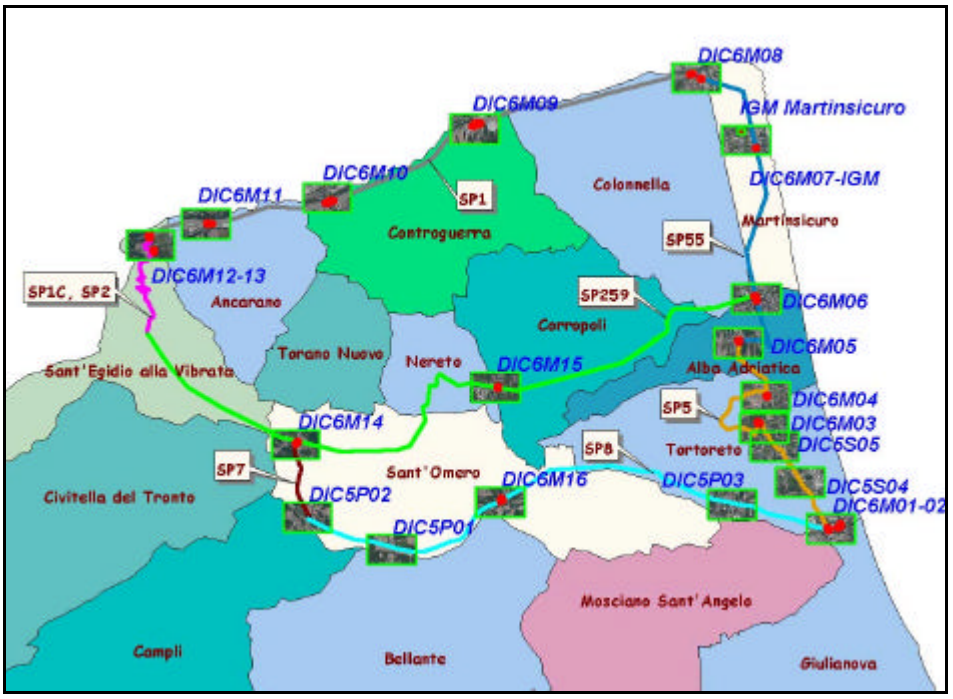


**Figure 6: The test sites in the assessment phase**

d) to evaluate the completeness and consistency of the final database, we make some a-spatial queries to identify the "orphan" entities and geometries and some spatial query to evaluate the correctness of the dynamic segmentation, because of no constraints exists on the database structure; this activity also shows only some minor problems;
e) no evaluations are possible for the junctions and intersections, as depicted in the point 3 above; the only activity is the collection of the documents explaining the adopted functional criteria.

Definitively, some aspects of the "Road Cadastre" need more investigation:

1. What is the main goal of the "Road Cadastre"? In the Ministry specification it seems to be an "inventory", but the usefulness and functionality are not indicated. We assume that the main goal of the "Road Cadastre" is the support for several information systems and applications such as traffic, fleets, accidents, routing, signs, pavement management and ADAS applications. This assumption requests a good repeatability (and, definitively, a more exact specification) of the junctions and axis identification process; conversely, a less-restrictive precision on the road width measures is possible, because of the high cost and useless of the actual one;
2. The requested accuracy of the segmented attributes makes in some cases a non-sense if compared with the achievable accuracy in curvimetric coordinates.


**Figure 7: The road axis repeatability. Left: survey process; Right: evaluation**

## Accidents data-base

Accidents data will be supplied by the Local Office of the Governement, that collects data from Police and Carabinieri, and by the Consortium of municipalities of Val Vibrata, that collects data from Municipalities.
The agreement with the Local Office of the Governement set that Teramo Province will automatically acquire data from informatic network. The old accidents data will be supplied by ISTAT (the Italian Statistical Institute) and they will be input by manual procedure.

## Traffic flow data-base

Eighteen traffic survey stations are located on the road network, as in figure 4. Every station is equipped with two coils and a fixed link with the survey equipment. The latter can record the traffic flow for every class of vehicles, the transit speed and the type of vehicle.

## The Road Sign Data-base

The development of data-base follows two phases:

1. START: the quickest tool actually available to create a data-base is the automatic continuous survey by means of the mobile mapping system (mms). In the Pilot Project of Teramo Province this phase has been performed at the same time of the survey for the road cadastre. The coordinates and the kinds of all the signs (pavements markings, roads signs and traffic lights) on the road network has been recorded. So all the signs are geo-referenced.

2. DATABASE UPDATING: the mms could be used to upgrade the data-base of signs. Alternatively, especially when the survey is limited to few data, the following procedure can be used:
    1. manual survey of technical characteristics and the conditions of the signs with a survey paper form.
       According to Italian law, every sign must have written on the back:
        - the name of manufacturer and supplier of the sign
        - the year of manufacture
        - the owner of the road
        - the reference of the decree of apposition (for regulatory signs only).

       All these information must be surveyed and recorded.
       In addition, it is important to have information on visibility, readability and conditions of maintenance for every sign, according to the standard of Italian Road Code.
    2. photographic survey of the signs with a geo-referenced digital camera;
    3. input of gathered data and photos on computer.

The road sign data-base is composed by:
- a road network description based upon the set of Road Cadastre's entities, compliant with the GDF 3.0 theme "Road and Ferries"
- a road sign description based upon a set entities included in the GDF 3.0 theme "Road Furniture".

## The dangerous situation analysis

The main goal to reach with the Road Information System is the D*angerous Situation Analysis* on the road network of Teramo province (see figure2). This analysis is by the following phases:

1. implementation and updating of cadastre, accidents and traffic flows data-bases;
2. definition of road sections with similar geometric and traffic characteristics;
3. aggregate accident analysis to define the most dangerous sections and intersections. In this phase the analyser can choose among different accident indicators, that he can defines in the analysis software;
4. desegregated accident analysis to identify the main causes of accidents and to study the possible solutions to the problem.

By means of this analysis, the technicians of the administration can identify the priority of maintenance works. It is clear that this procedure is efficient only if the data-bases are always updated and the data-base management software can make queries that can clearly highlight the causes of a repetitive accident.

The comparison between the results of the *Dangerous Situation Analysis* and the results of the *Safety Review* can be very useful, because it can link the accident causes to the geometric and organisation defects of the examined road. This means that the Safety Review has two functions:

- to be a support of the desegregate analysis to identify and to remove the accident causes linked to the road;
- to identify the road defects that could cause accidents. However, in many cases, these defects are not a real cause of accident because, if the users know the road and its dangers, they generally have a careful behaviour.

At the moment the software for the dangerous situation analysis is in progress and it will be available for the end of this year with the name of ASPES (Analisi delle Situazioni di Pericolo per la Sicurezza).
Instead it is already available (and operating in the Office of Teramo Province), the section of the software for the road sign management system (see next paragraph).

## The Road Sign Maintenance System

The software is composed by the following subroutines:
UPDATING SUBROUTINE (with restricted access): it allows

- maintenance and updating of data with accuracy requirements (as the coordinates of the road). The access to these subroutines is restricted to the company that manage the software;
- maintenance and update of data without accuracy requirements that can be often variable during the time (as conditions of road signs). The access to these subroutines is restricted to Administration technicians.

QUERING SUBROUTINE: all the technicians of the Administration can make queries on the database. Two kinds of queries are possible:

- maintenance queries: i.e. queries on the physical condition of the signs; for example, how many and which signs must be changed until a defined date;
- design queries: i.e. queries on the location of the different kinds of signs for different roads. This subroutine allows to see the signs and the traffic light phases on the screen.

Some outputs of the software are shown in the following figures to better explain the data-base.
It is possible to choose a single road of the network (Theme “Road and Ferry”) on the menu or on the map on the screen (for example “strada provinciale n.259 – provincial road n.259” in figure 8).

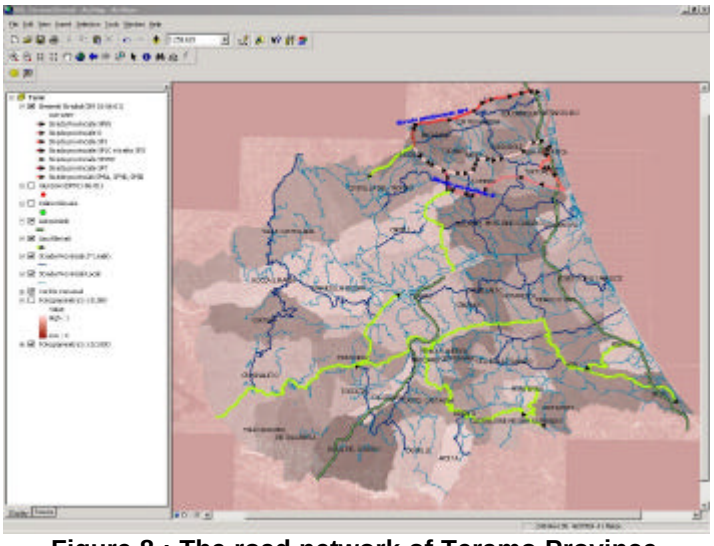

**Figure 8 : The road network of Teramo Province**

The surveyed signposts are shown with a green dot on the map (figure9) and selecting one of these by the mouse you can have all the information about it.
The length of the selected road element, the progressive of the signpost in the road element, the progressive in the whole road are shown. The geometric characteristics of the road close to the signpost are shown in a pop-up window “Geometry” (Catalogue of Relations): longitudinal slope, vertical radius, horizontal radius, cross slope.

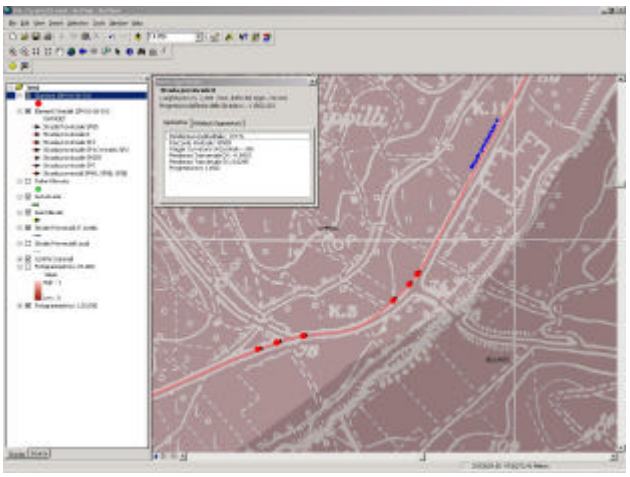

**Figure 9 : The geometric characteristics of the road close to the signpost**

Another window with two menus is available for the signpost (figure10): “General Data” where the direction and the side of the road where the signpost is installed, the material, the type and the co-ordinate of the signpost are listed (figure10), and “Conditions” where the condition, the name of the installer and the date of installation are recorded. Three menus are available for every sign on the same signpost (figure11): “General Data”, “Refracting film” and “Maintenance”.

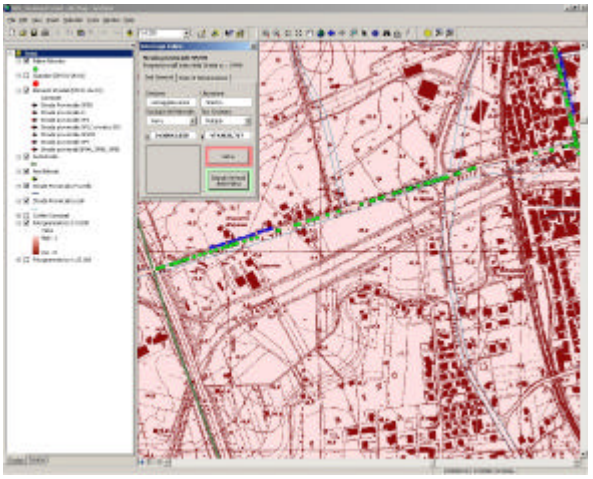

**Figure 10 : Data on the signpost**

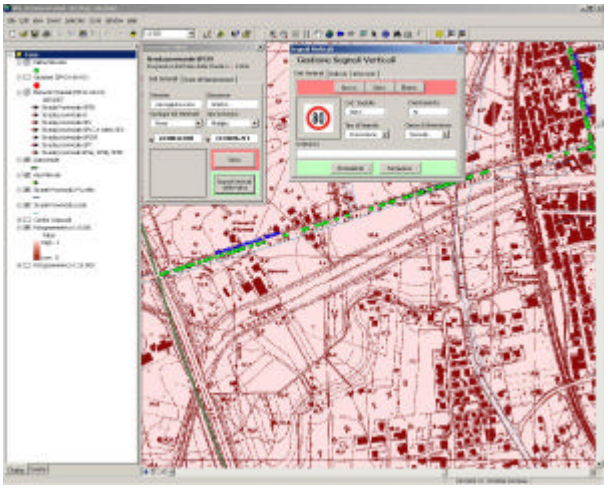

**Figure 11 : The data on the sign**

Symbol, identifier code, orientation, type of sign, dimensional class and decree of apposition (for regulatory signs) are in “General data”. The condition of the refracting film, the refracting class, the expiry date and the installation date are listed in “Refracting film”. The past maintenance works are listed in “Maintenance”. Queries on all the items in the menus can be made.

## CONCLUSION

The Provincial Administration of Teramo, Italy, has implemented a Road Information System as an important part of the Pilot Project to increase Road Safety. The project was developed by the Administration to access to the financial aids from the National Plan for Road Safety (NPRS), promoted by the Italian Ministry of Public Works (now Ministry of Infrastructure and Transportation).
The Road Information System is linked to the data-bases of cadastre, traffic, accidents and road signs implemented in the pilot project. The data-bases are managed by a software composed by two kinds of subroutines: to upgrade the data and to make queries.
The system could be very useful for the Administration if the database will be updated constantly and if the other local Administrations (as municipalities) could consult it to have a homogeneous and integrated system of asset maintenance in the whole province.

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